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FORMAL RULES AND NETWORKS FOR TECHNOLOGY DIFFUSION IN THE CONTEXT OF PLANT DISEASE EPIDEMICS:

THE CASE OF SMALL-SCALE PRODUCERS OF OIL PALM IN COLOMBIA

PALOMA BERNAL HERNÁNDEZ

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE UNIVERSITY OF SUSSEX FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN SCIENCE AND TECHNOLOGY POLICY STUDIES

BRIGHTON UK, MAY 2019

DECLARATION

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature: …….

Paloma Bernal Hernández

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UNIVERSITY OF SUSSEX

Paloma Bernal Hernández

THESIS TITLE

Formal rules and networks for technology diffusion in the context of plant disease epidemics: The case of small-scale producers of oil palm in Colombia

SUMMARY

In this research we specifically look at how top-down diffusion strategies are essential for producers to deal with these stress situations. The research investigates the diffusion of strategies introduced by technical experts through network relationships prompted by a plant disease epidemic in the Colombian oil palm agribusiness.

The thesis discusses how different pathways of technology diffusion emerge and are practiced in the context of top-down agricultural governance systems, and what the impacts of these pathways are in terms of the technology adoption of small-scale producers in developing agricultural clusters. The framework of this thesis draws upon three main bodies of literature: innovation diffusion, social capital and contract farming arrangements.

The main argument of the research is that despite high levels of top-down control, there is more than one way in which diffusion of codified practices occurs. Using three case studies in the Colombian oil palm agribusiness, the main findings are, first, that formal rules are a critical factor in the creation of two scenarios of diffusion: a *diffusion pathway of governance dictated by dominant change agent control*, and a *diffusion pathway of governance dictated by change agent control and user participation*. Second, short-term practices are introduced, regardless of the type of model, mainly through network links between agro-industrial firms and producers that underpin non-formal systems of relationships. Third, successful adoption of long-term practices occurs in scenarios with a broad distribution of functions among multiple key actors and producers. The adoption of long-term measurements is also significantly related to the following factors: the long-

term vision, the attachment to land and the engagement in collective action of rural farmers, and the long-term sustainability vision of agro-industrial firms regarding the integration of smallholders into agribusiness.

This thesis contributes to the innovation-diffusion literature by:

- extending the view that the current literature offers on centralised-diffusion systems;
- considering the influence of formal rules in the creation of multiple scenarios of diffusion and the effect of these rules, the nature of users and the interest of change agents in the adoption of short-term and long-term practices;
- highlighting the role of informal relationships in top-down relationships; and
- recognising the potential of network methods as an instrumental way to reflect types of governance centralised-diffusion systems.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

CFA – Contract farming Arrangement

CENIPALMA - Colombian Oil Palm Research Centre

FEDEPALMA - National Federation of Oil Palm Growers of Colombia

FFB - Fresh Fruit Bunches

ha. – Hectares

ICA – Colombian Agriculture and Livestock Institute

NES – Nucleus Estate Scheme

PC – Bud Rot disease

SENA - Colombian Vocational Training Agency

SNA – Social Network Analysis

UAATAS – Technical, Environmental and Social Audit Units

CHAPTER 1

INTRODUCTION

The introductory chapter is organised into five sections. The first section explains the motivation of this thesis. The second section discusses the research problem addressed in this research. Section 1.3 presents the research questions, a theoretical framework positioning this work within the context of the existing literature, and a quick review of the research method and data collection. The fourth section explains the arguments and contributions, and the final section outlines the structure of this thesis.

1.1 Motivation of this research

The motivation of this research is to understand technological diffusion in a developmental context, and the impact that different diffusion processes can have on the technology adoption of small-scale producers. This research aims to explain the different ways that agricultural technologies, developed by technical experts, can be transferred to smallholders in a context of predominantly top-down governance. The central topic of this thesis is **how different pathways of technology diffusion emerge in the context of top-down governance, and what the impacts of these pathways are in terms of the technology adoption of small-scale producers**.

The context of the study is the introduction of agricultural practices in the agribusiness sector. We look at the diffusion and technology adoption of *preventive* practices (pre-emptive practices) and *shock* practices (reactive practices) from 2013 to 2015 to deal with the plant disease epidemic of oil palm *Bud Rot,* referred to in Spanish as 'Pudrición de Cogollo' (PC), in a number of oil palm clusters in Colombia. Since the late 1980s, this epidemic has caused important agricultural and economic losses for small-scale producers and has triggered socio-economic crises in the affected areas.

The oil palm sector is an example of the rapid expansion of agribusiness in a developing country and the increasing incorporation of producers in formal processes of commodity production (Rangel et al., 2009; Sanz, 2014). Unlike processes of technology diffusion in other agricultural sectors, the process in agribusiness sectors involves the transfer of technologies that incorporate high levels of complexity (Minh et al., 2011). In situations such as agricultural epidemics, the complexity of technological practices increases due to the difficulty in designing effective management strategies and the challenges that these strategies deal with.

This thesis addresses three case studies related to three agricultural clusters from the same region. In these cases, diffusion processes and the adoption of technologies for plant disease management occur with differing underlying characteristics. Since these characteristics vary between clusters, regions and sectors, lessons about the theory of innovation-diffusion can be learned from the contrasting case studies. Furthermore, analysis of the diffusion processes can be applied within the context of dominant top-down approaches.

1.2 Context and research problem: The Colombian oil palm sector and the plant disease epidemics of *Bud Rot* (PC)

The basic configuration of clusters, or nuclei, in the oil palm Colombian sector, is made by *anchor* companies and surrounding plantations or growers in other areas that sell their produce to these firms. Anchor companies are in charge of purchasing the oil palm fruit, and as such they can be either large-scale growers that own a processing mill or the processing mills themselves. The formation of these clusters and the commercial and technical relationships between *anchor companies* and small-scale producers arise mainly from economic interests. On the firm side, the restrictions on the extension of land ownership and the necessity of using all their installed capacity, encourages anchor companies to incorporate small-scale producers to the agribusiness. On the producer side, the profitability of the agribusiness, based on a minimum distance from plantations to processing mills and a long-term commitment for the sale of the oil palm production, encourages producers to join oil palm clusters. In order to orchestrate both oil palm mills and producers' interests, these actors usually negotiate commercial and technical agreements underpinning the formation of clusters.

In the oil palm sector, it is possible to distinguish two types of configuration of clusters for the agricultural production: isolated producers and grouped producers. In the first case, small-scale growers carry out the agricultural production individually, with or without the economic and/or technical support of oil palm mills. In the second case, many small-scale producers grow in managed smallholder schemes (e.g. Nucleus Estate Schemes (NES), contract farming, joint venture schemes and associations) rather than independently. These schemes facilitate cultivation, give bargaining power, reduce production costs, and enable access to credit and technical support.

In Colombia, oil palm clusters and processes of diffusion within these clusters are influenced by actors who have participation or control in research and development (R&D), transfer (extension services, technical support and training) and final adoption of agricultural practices. One of the most important actors in the oil palm sector is the National Federation of Oil Palm Growers of Colombia (Fedepalma for its Spanish acronym), which defends the oil palm growers' interests. Fedepalma has implemented different strategies to facilitate R&D and innovation in the sector. For example, this federation sponsors the Colombian Oil Palm Research Center (Cenipalma for its Spanish acronym), who produces, adapts and transfers technology packages for cultivation and fruit processing. Also, the federation has implemented and strengthened Technical, Environmental and Social Audit Units (UATAAS), which are located in numerous anchor companies assisting phytosanitary and technical problems during oil palm production (Fedepalma, 2009). This sectoral entity has institutionalised a dependent relationship in terms of diffusion of agricultural practices and market power between anchor companies, and small-scale producer neighbours.

Marketing organisations, academic institutions, international organisations, local authorities, social organisations and government institutions, are other actors that are linked to small-scale producers and anchor companies; they also participate in technology transfer. The support of the Colombian government has been crucial for the participation of small-scale growers in the production chain, for example, with the promotion of productive alliances, provision of credit and subsidies, and tax exceptions (Conpes et al., 2008).

In the oil palm sector, multiple actors support the diffusion of agricultural practices to smallholders, but technical decisions are highly centralised to just a few entities. Large growers, anchor companies and the national federation mostly lead a top-down strategy within oil palm clusters, where they are in charge of decision-making processes and the transfer of agricultural practices to small-scale producers. This is also the case in the planning of strategies and management of protocols to deal with the agricultural epidemic crisis of PC disease in Colombia.

The principal questions of this thesis arise from the examination of technology-diffusion processes of three nuclei in the north-east of Colombia at the time of the PC epidemics. This analysis requires the consideration of both formal agreements and technical relationships within clusters. The period covered in this thesis begins in 2013, when the Colombian Agriculture and Livestock Institute (ICA for its Spanish acronym) announced the official declaration of an epidemic emergency in the north-east of Colombia, until 2015, when results in terms of technology adoption were evidenced. The analysis of this research takes into account:

- local agreements and technical relationships between anchor companies and small-scale producers;

- the technical support and participation of anchor companies, small-scale producers, grower associations, sectoral agencies, governmental entities and social organisations in PC management; and
- the variation of these aspects between clusters.

1.2.1 Agricultural epidemic crisis in the Colombian oil palm sector

With the rapid expansion of agribusiness crops such as oil palm, there is a growing exposure of producers to greater risks and vulnerabilities, such as environmental change and agricultural pests and diseases. Agricultural diseases are especially critical in monoculture since pathogens spread more rapidly when crops are genetically uniform (Mead and Evans, 2001). Therefore, these situations require fast and effective responses before disease outbreaks become epidemics and threaten the long-term sustainability of producers.

Since 2006, the Colombian oil palm agroindustry has experienced one of the worst plant disease epidemics in its history. The PC disease can attack plantations, cause the death of oil palm trees and spread quickly to the remaining plantations in the region. This disease has affected entire plantations in Colombia and caused the eradication of 70,000 hectares of oil palm crops (out of a total of 520,000 hectares). The economic losses of this disease were about US$5,681 per hectare out of US$35,815 average net profits in 2012 (Mosquera et al., 2012).

Cenipalma, anchor companies and the government were crucial actors in the development and implementation of agricultural management practices (planning, monitoring and adoption), since the beginning of the epidemic. Cenipalma developed official protocols for the treatment of PC disease and researched technological practices for prevention and treatment. This is what the oil palm sector calls 'the Cenipalma protocols'. It also gave technical support to oil palm growers through UAATAS or technical departments of the anchor companies. The anchor companies had direct communication with small-scale producers and transferred agricultural practices for prevention and treatment of PC disease through technical, and sometimes economic, support. The government enforced the adoption of the Cenipalma protocols and provided subsidies for the eradication of affected crops and cultivation of oil palm with resistant plant varieties.

Local agreements between small-scale producers and anchor companies played a prominent role during the epidemic. Since the configuration of clusters, anchor companies and producers had defined rules for the selection criteria of members, commercial contracts and responsibilities for technical and financial assistance. These agreements also indicated the level of participation of anchor companies and producers in decision-making processes, provision of inputs and technologies, and adoption of practices for crop management, including diseases and pest management.

When referring to PC disease, the technical assistance and disease management mainly consisted of two types of practices. The first type of practice was preventive practices, which refer to agricultural technologies that were intended to guarantee the long-term development of a crop whilst preventing plant pests and diseases. The second type referred to shock practices that treated infected plants and whose results could be observed in the short term. The adoption levels of these two types of practice highly depended on conditions of agreements for technical assistance. For preventive practices, anchor companies agreed varying degrees of technical and financial support to producers, and producers adopted these technologies voluntarily. Regarding shock practices, the risk of the fast spread of PC disease led anchor companies to assume a strong leading role in the management of these technologies, and producers were committed to adopting these practices.

The diffusion process of techniques for PC management that were promoted by technical experts highlighted some problems that affected the final adoption of agricultural practices in affected areas of Colombia. First, small-scale producers stopped relying on Cenipalma protocols and other methods promoted by technical experts. At the same time, producers started relying on actors within their local communities bringing treatments that were not officially approved. Second, there was low awareness amongst producers about the severity and speed of spread of the PC disease.

1.3 Research questions, theoretical framework and research design

This research analyses processes of technology diffusion and final adoption of practices as a result of local agreements of clusters and network structures of technical relationships within a top-down governance context. Three main questions are addressed by this research within this context:

1. How do different types of formal rules lead to different pathways of technology diffusion?
2. What is the influence of network structures, affected by different types of formal rules, on technology diffusion?
3. How does technology adoption vary with the different pathways of diffusion, and how do these variations impact the adoption of long-term and short-term practices separately?

An overarching argument is that, within the context of top-down governance, there is more than one way in which the diffusion of codified practices occurs. 'Centralised-diffusion systems' (i.e. systems in which strategies are diffused under a top-down direction) are described by Röling (2004), Knickel et al. (2009), and Rogers (2010) as 'linear models' or 'one-way models of communication' that do not seem to exhibit possible variations. This research considers 'formal rules', or local agreements, as the rules that define the distribution of technical responsibilities for crop management, the selection criteria by which members of a cluster are chosen, and the social values underpinning mutual commitments.

This work argues that formal rules are one of the critical factors in these centralised-diffusion systems that are not taken into account in the literature. The theoretical framework in this work draws upon the literature of 'innovation diffusion' (Monge et al., 2008; Rogers, 2010), 'social capital' (Woolcock, 1998; Adler and Kwon, 2000, 2002; Burt, 2005), and 'contract farming arrangements' (CFAs) (Key and Runsten, 1999; Kirsten and Sartorius, 2002; Barrett et al., 2012). The innovation diffusion literature was chosen to identify roles and functions of central actors and small-scale producers. This literature also identifies general characteristics of the governance of diffusion processes, specifically in top-down diffusion systems. The literature on social capital was chosen to understand the values underpinning formal rules and technical relationships amongst actors, and to explain the occurrence of networks that facilitate the technology transfer between small-scale producers and central actors within top-down diffusion systems. Through the literature on contract farming arrangements it is possible to detect and characterise the different types of formal rules (specifically the technical responsibilities of smallholders and leading agro-industrial firms), the leading roles in decision-making for crop management, and the selected producers participating in these agreements.

The research questions laid out above suggest that pathways of technology diffusion within centralised systems need to be examined in relation to the formal rules of clusters, the network structures that are shaped by these rules, and the responses of these diffusion processes in terms of adoption. The research method is based on three stages, starting from the base of distinct types of formal rules (Stage 1). In Stage 2, these types of rules are linked to characteristics of network structures for diffusion. In Stage 3, resulting pathways are associated to impacts on adoption. The analysis of these stages draws on the literature of innovation diffusion and the perspectives of rules and network relationships that come from the CFAs and social capital literature.

In the first stage, literature on contract farming agreements (CFAs) was used to help in the understanding and comparison of different formal rules within centralised-diffusion systems. We use the perspective of rules by which they regulate the interaction of individuals, their functions and mutual commitments (Ostrom, 2000a). Under the context of agribusiness in developing countries, formal rules can take the form of CFAs. In this work, local agreements and governance structures (distribution of responsibilities and control in decisions of the cluster) for transfer and adoption of agricultural practises were analysed and compared between the three oil palm clusters.

The elements of formal rules that this research established helped in the characterisation of the case studies. These rules were a set of agreements regarding the selection criteria of producers according to socio-economic characteristics, and the assignment of responsibilities and leading roles for technology transfer and governance. With rules, it was possible to represent the degree of centralisation of the decision-making processes and to define functions of actors in crop management (e.g. planning, monitoring and implementation of technological practices). These elements of rules can be understood through the CFA literature that focuses on the distribution of technical responsibilities and control.

In the second stage, this research borrowed the concept of social capital at an 'individual level' (Burt, 2005; Lin, 2002) to try to explain the technology transfer from anchor companies and other central actors to producers, and the values that are embedded in these technical interactions. Furthermore, this research uses the work of Adler and Kwon (2000) within the social capital literature, that considers rules as a factor for shaping networks (based on Salancik, 1995). This framework is used to understand how formal rules can affect network structures and how these structures can affect diffusion of practices for PC management.

From the same literature, we use networks as a way of revealing how pathways of technology diffusion, created by types of formal rules, actually occurred. Three network measures were relevant to analyse relationships that give small-scale producers and other key actors access to resources: *network interactions* based on Lin (2002) and Burt (2005) (reproduction of dense relationships), *central positions* based on Freeman (1978) (popularity of actors in a network), and *brokerage* based on Burt (2005) (sparse networks with brokers connecting different actors with sources of information).

Finally, in the third stage, the outcomes of the diffusion pathways within centralised systems were evaluated in terms of levels of adoption. We used the works of Burt (2005); Darr and Pretzsch (2008); Monge et al. (2008); Spielman et al. (2011) and Díaz-José et al. (2016) to assess the effects of the resulting network structures. This research measured levels of technology adoption as the total number of adopters (technology users) and non-adopters, in the same way as the study of Wyckhuys and O'Neil (2007) and Díaz-José et al. (2016). These studies, however, did not analyse a separate impact on the adoption of long-term and short-term practices, which is common in the innovation-diffusion literature.

This research followed a multi-case study strategy whereby the small-scale producers organised in schemes of production was the main unit of analysis. In relation to this, other units of analysis were employed within each oil palm cluster; these included formal rules, network structures and levels of technology adoption. The evidence was gathered mainly through questionnaires and semi-structured interviews and was complemented with secondary data.

1.4 Argument of the thesis and main contribution to knowledge

This thesis argues that, despite the top-down control in centralised systems, there are in fact different pathways of technology diffusion. The critical factor of formal rules helps to create these pathways. The argument is demonstrated using the case of the Colombian oil palm sector, where a plant disease epidemic prompted the diffusion of agricultural practices developed by technical experts. In these diffusion processes, small-scale producers and agro-industries had different levels of participation in the introduction of shock (short-term) and preventive (long-term) practices and therefore had a different impact on the resulting levels of adoption.

This research contributes primarily to the innovation diffusion literature and, to a lesser extent, to the adoption literature. It extends the diffusion literature by considering more scenarios of technology diffusion within top-down contexts, as opposed to the linear way in which they are described in the literature. It recognises the importance of formal rules in the creation of diffusion pathways combined with other essential factors that may explain the focus placed on the adoption of certain types of practices within each pathway. These factors are the type of technical support that agro-industrial firms and other key actors provide to smallholders and the way producers get involved in crop management, both of them also contributing to the adoption literature. This combination of elements leads this work to argue that a more holistic approach in technology diffusion is necessary when considering the introduction of short-term and long-term practices. We also argue that these elements are important in the future configuration of agricultural clusters that aim to integrate small-scale producers into production processes with predominantly top-down governance.

By examining the relationships between actors in charge of the technology transfer and smallholders, this research makes another contribution to the literature of innovation diffusion. As was presented in Sub-Section 1.2.1, some of the problems of diffusion were the result of the little trust producers had in practices promoted by technical experts. Therefore, by examining the role of social capital in these relationships, this research contributes to the discussion that links social capital to agricultural systems of top-down governance.

1.5 Structure of the thesis

This thesis is organised into nine chapters, including this introductory Chapter 1. Chapter 2 identifies the theoretical context and challenge of this research, and positions the research questions within the existing literature. The chapter links together the perspectives of rules and networks, under the innovation diffusion literature, social capital and contract farming arrangements. It describes the role of rules and networks in centralised-diffusion systems and, from there, identifies the contribution to the diffusion literature. It then draws on this discussion to propose an analytical framework for the investigation of diffusion processes based on three types of CFAs, which are adapted for the purposes of this research. These agreements are:

- *governance dictated by the high control of change agents;*
- *governance dictated by the partial control of change agents;* and
- *governance dictated by little control of change agents.*

After analysing responses of these different scenarios in terms of adoption, this research argues that the explanation of contrasting diffusion processes within centralised systems may encompass formal rules and network structures that shape their own responses.

Chapter 3 presents the background of the oil palm agribusiness and particularities of the Colombian sector. It also explains the agricultural epidemic crisis caused by PC disease and the roles and diffusion strategies of different actors to face this stress.

Chapter 4 delineates the research design and methodology employed in this research. This chapter explains the choice of the multi-case study as the methodology for this work, the selection of three case studies, and defends the possible validity of generalising from these cases. Furthermore, it presents the research strategy, the operationalisation of the research questions and the theoretical framework, and the methods by which the data and information were collected and analysed.

Chapter 5 is the first empirical chapter. It discusses the process of technology diffusion in Nucleus A, which is characterised by having semi-autonomous small-scale producers. The analysis is based on the core elements of the theoretical framework (i.e. formal rules, networks and technology adoption) and the particularities for this case. To do this, it studies the configuration of the cluster and characteristics of producers, the formal rules allocating technical responsibilities and roles in the cluster, the values embedded in these formal rules and technical relationships, the resulting network structures, and the outcomes in terms of adoption of short-term and long-term practices for PC management.

Chapter 6 is the second empirical chapter. It elaborates on the process of technology diffusion for Nucleus B, where an agro-industrial company had high control of the crop management of producers. It follows the same structure as Chapter 5 but includes specific emphasis on the problems encountered amongst participants of the agreements and their impact on the diffusion process.

Chapter 7 is the third and final empirical chapter. It discusses the process of technology diffusion in Nucleus C, in which poor smallholders are organised in a farmer association and share control of the crop management with an anchor company. It also follows the structure of Chapter 5, highlighting the distribution of functions for technology diffusion between smallholders and leading actors.

Chapter 8 presents the discussion of the three aforementioned case studies. It applies a comparative analysis amongst the three studies based on the core elements of the theoretical framework. It answers the research questions by highlighting these contrasting results.

Chapter 9 is the concluding chapter of this thesis. It revises the motivation and explains the theoretical and methodological contributions to knowledge. It also makes some policy and practitioner suggestions and outlines some limitations of this work.

CHAPTER 2

LINKING FORMAL RULES AND NETWORKS TO DIFFUSION OF INNOVATION

Previous research concerning agricultural sectors in developing countries shows that small-scale, resource-poor farmers are highly dependent on social networks to access information and gain knowledge for the adoption of technologies (Conley and Udry, 2001; Bandiera and Rasul, 2006; Darr and Pretzsch, 2006; Monge et al., 2008; Spielman et al., 2011; Wossen et al., 2013; Díaz-José et al., 2016). In the processes of commodity production, these network connections provide channels of communication through which extension agents and agro-industrial firms may transfer technologies, introduce new agricultural practices and provide technical support to smallholders. Technology diffusion in these sectors tends to be characterised by the use of hierarchical or top-down networks whose interactions and structures are strongly influenced by the negotiation of agreements. These agreements, or formal rules, regulate interactions between actors with agency power and small-scale producers. Both formal rules and network connections support the integration of smallholders to agribusiness sectors in developing countries.

This research aims to contribute to the innovation diffusion literature in highly centralised agribusiness sectors, and is concerned with the role and influence of formal rules in shaping network structures and pathways of technology diffusion. The study explores the different pathways of technology diffusion within a top-down context that emerges from the ways in which different types of formal rules affect network structures. We also explore the contrasting outcomes of those pathways on the technology adoption of small-scale producers. This chapter introduces three strands of literature that can contribute to answering these questions: innovation diffusion[1] (Monge et al., 2008; Rogers, 2010), social

[1] In the theory and research of diffusion, Rogers (2010) found that most innovations are investigated as technological innovations, and therefore 'technology' is often used as an equivalent of innovation. This is also the case in the literature on diffusion of agricultural innovations. Different studies in this field (Raini et al., 2005; Monge et al., 2008; Spielman et al., 2011; Díaz-José et al., 2016)) show that adoption of

capital (Woolcock, 1998; Adler and Kwon, 2000, 2002; Burt, 2005), and contract farming arrangements (Key and Runsten, 1999; Kirsten and Sartorius, 2002; Barrett et al., 2012). It suggests that this literature may well provide a rich theoretical lens through which to understand the process of technology diffusion to small agricultural producers in the context of highly centralised models of diffusion.

An essential aspect of this research is concerned with centralised-diffusion systems, which are the types of diffusion mechanism that dominates agribusiness. Literature concerning innovation diffusion of agricultural innovations often characterises centralised models as a single vertical relationship between actors in charge of R&D and technology transfer, and farmers (Röling, 2004; Knickel et al., 2009). This research elaborates on this view and considers that multiple scenarios may emerge within centralised-diffusion systems due to 1) variations in the institutional arrangements underpinning relationships between *change agents* (actors in charge of technology transfer) and smallholders, and 2) differences in network structures. This suggests the need for a deeper understanding of technology-diffusion processes. Within the innovation diffusion literature, the consideration of institutional factors at the local level and the relationship of these factors with networks for diffusion have been identified as an important gap, and the key area of analysis for this research.

This thesis approaches this issue by unpacking specific aspects of institutional and governance arrangements involving small-scale producers and change agents. It also aims to provide an analysis of the effects of formal rules, which is an alternative way of understanding these institutional agreements, on networks and on adoption within centralised systems. To do so, this research aims to integrate the innovation-diffusion literature with both the social capital literature and the contract farming arrangements (CFAs) literature.

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innovations is a synonym of adoption of agricultural technologies or crop management practices; this leads to an understanding of both the processes of technology diffusion and processes of innovation diffusion in an equivalent way.

This chapter is organised into six sections. Each section introduces the key concepts of this thesis and gives a step forward in building up the framework for the centralised-diffusion models that we propose in this research. The first section introduces the topic of innovation diffusion in the agricultural sector and its relationship with technology adoption. The second section explains the theoretical foundations, characteristics and critiques of centralised-diffusion systems in the agricultural sector. The third section studies the role, types, and characteristics of formal rules affecting processes of technology diffusion. It is followed by the fourth section that links formal rules with networks by using elements of the social capital literature, and mainly explains the aspects that will be used to analyse network structures and that may facilitate or limit technology-diffusion processes in centralised systems.

Section 2.5 examines the different processes of technology diffusion and outcomes in terms of technology adoption that may result from particular formal agreements and network structures. In this section, a theoretical framework is presented based on variations of formal rules, network structures, and levels of technology adoption. The final section summarises the chapter.

2.1 Innovation diffusion and technology adoption in agriculture

Before answering the research questions formulated by this thesis, it is necessary to understand the concepts of technology diffusion and adoption as a part of the *Innovation-development process* summarised by Rogers (2010).

2.1.1 Theory of innovation diffusion

Within theories of innovation diffusion, the work of Everett Rogers has become influential in providing conceptual and analytical groundwork. According to his classic definition, '*Diffusion* is the process in which an innovation is communicated through certain channels over time among the members of a social system' (Rogers, 2010, p.5). In other words, it is the flow of new ideas, concepts, information, or practices from a source to a user via communication and influence channels across a social group.

The process of technology diffusion in agriculture can be defined from both the concept of innovation diffusion and the concept of 'technology'. Based on Rogers (2010):

> '*Technology* is a design for instrumental action that reduces the uncertainty in the cause-effect relationship involved in achieving a desired outcome. A technology usually has two components: (1) a *hardware* aspect, consisting of the tool that embodies the technology as a material or physical object, and (2) a *software* aspect, consisting of the information base for the tool' (p.13).

Within the literature on diffusion of agriculture, it is possible to understand technology-diffusion processes as the communication of both hardware and software, specifically, the diffusion of new seeds, sophisticated equipment and inputs as well as skills, experiences, knowledge, information of technologies and practices regarding crop management.

The process of technology diffusion does not happen in an isolated way. According to Rogers (1983, 2010), technology diffusion is one of the stages in the *Innovation-Development process* in which all the activities happen from the occurrence of a problem and recognition of a need, through research and development of the innovation, commercialisation of a technology, diffusion and technology adoption by users, to its consequences (Figure 2.1). This work will focus on the stage of diffusion and the impact of this process on adoption within centralised-diffusion models. The consequences of technology adoption are little studied in this work; this is acknowledged to be one of the limitations of this research.

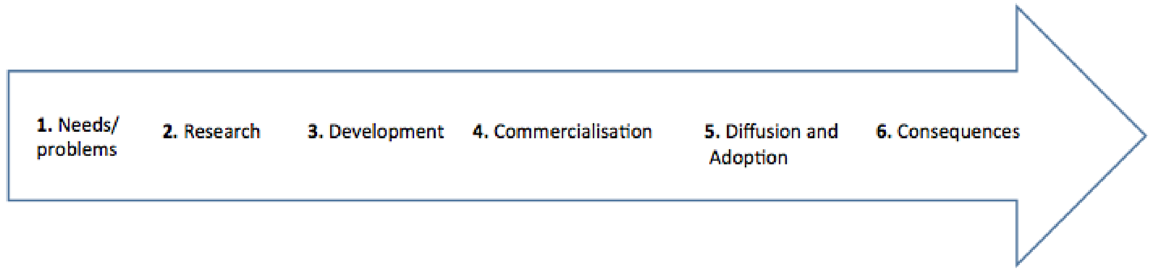

Figure 2.1: Innovation-Development process
Source: Rogers (2010, 1983)

2.1.2 Key drivers of technology diffusion and adoption in agriculture

Within the innovation-development process (see Figure 2.1) and the agricultural sector, we can postulate that technology adoption is a commonly pursued objective of diffusion. Evidence of this can be seen in much of the literature on diffusion of agricultural innovations (Ajayi and Solomon, 2011; Awotide et al., 2016; Choudhary et al., 2013; Díaz-José et al., 2016; Hellin et al., 2009; Lambrecht et al., 2014; Lopes et al., 2015; Monge et al., 2008; Pamuk et al., 2014; Wossen et al., 2013; Wu and Zhang, 2013; Wyckhuys and O'Neil, 2007). A discussion around technology adoption and its determinants, that can also affect the diffusion of agricultural practices, is therefore necessary. This sub-section will review key studies regarding the critical drivers of technology adoption.

Following Rogers (2010), adoption is 'a decision to make full use of an innovation as the best course of action' (p.21) and '*Implementation* occurs when an individual (or other decision-making unit) puts an innovation to use' (p.179). After the process of technology diffusion, actors enter into a phase where they decide to adopt or reject an innovation and finally implement it or not. As with other studies, this research does not differentiate between the concepts of adoption and implementation and uses both concepts indistinctly.

The adoption of agricultural innovations and practices can be influenced by a wide array of key drivers. Due to the considerable number of adoption studies, Table 2.1 summarises these key drivers, their determining factors and their likely relationship with adoption.

Relationships between drivers and adoption can vary amongst studies due to particularities of crops (e.g. food crops, cash crops, subsistence farming, perennial crops), farmers and innovations. Therefore, what we identified in the table was a general tendency of the reviewed studies (Appendix A contains an extended version of Table 2.1 including some research evidence).

Table 2.1: Key drivers of technology diffusion and adoption in agriculture and related studies

Type of determinant	Sub-category	Relationship with adoption based on research studies	Research studies
Farmers' abilities	Household income Financial capital Credits Household assets Accumulated savings Physical capital	High income and access to capital can benefit the adoption of several technologies.	Mills et al. (2017); Feder et al. (1985); Kassie et al. (2015); Marenya and Barrett (2007); Rogers (2010); Wejnert (2002); Mariano et al. (2012)
	Education Training courses Age	Beneficial innovations and application of modern technology tend to be adopted by more educated and trained and/or younger farmers.	Feder et al. (1985); Bjornlund et al. (2009) Kassie et al. (2015); Mariano et al. (2012) Pannell et al. (2006); Aguilar-Gallegos et al. (2013)
	Farm size Labour availability Input availability Dependency on off-farm income sources	Availability of productive factors (land, labour force and inputs) facilitates adoption.	Bjornlund et al. (2009); Feder et al. (1985); Marenya and Barrett (2007); Mariano et al. (2012); Mills et al. (2017)
Farmers' willingness	Values Preferences Personal attitudes (behavioural beliefs) Subjective norms and	Positive beliefs, perceptions and attitudes as well as social acceptation towards a technology can make famers willing to implement it.	Mills et al. (2017); Pannell et al. (2006); Kassie et al. (2015)

	expectations Social norms Ethical standards Perceptions about benefits		
Attributes of innovations and practices	Monetary/non-monetary costs Direct/indirect costs Yields Profits	Expensive technologies or technologies that do not seem to result in increase of profits and yields may reduce the likelihood of adoption.	Pannell et al. (2006); Rogers (2010, 1983) Wejnert (2002); Ghadim et al. (2005)
	Immediacy of reward[1]	Practices or new ideas that people adopt now but whose desired rewards are distant in time have a particularly slow rate of adoption	Rogers (2010, 1983)
	Complexity[2]	High complexity of new technologies can be an important barrier for adoption.	Pannell et al. (2006); Rogers (2010, 1983)
	Compatibility[3]	Farmers tend to adopt technologies that are compatible with their existing technologies, agricultural activities, experiences, beliefs, values and needs.	
	Trialability[4]	Trialling provides information and the opportunity to learn the necessary skills about a practice, increasing in this way the probability of making a correct decision regarding to adoption	

Policy, environmental and market settings	Government policies Supporting programmes Tenure security Price volatility of inputs Biophysical conditions Environmental and climate changes	Governmental regulations and supporting programmes during stress situations and high volatility of markers create better conditions for adoption.	Feder et al. (1985); Marenya and Barrett (2007); Kassie et al. (2015); Mills et al. (2017); Pannell et al. (2006); Wejnert (2002); Deressa et al. (2009); Smit and Skinner (2002)
Social networks	Social relationships Central roles	Networks mainly facilitate the flow of information, knowledge, technologies and inputs between producers to enhance their decision-making processes and accelerate technology adoption.	Bandiera and Rasul (2006); Conley and Udry (2010); Díaz-José et al., (2016); Monge et al. (2008); Oreszczyn et al. (2010); Ramirez (2013); Spielman et al. (2011); Rogers (2010)

1: time lapse in which farmers will receive, or expect to receive, the net benefits of adopting a technology (Rogers, 2010).

2: complexity is ‘the degree to which an innovation is perceived as relatively difficult to understand and use’ (Rogers, 2010: 257).

3: the way an innovation is compatible with 1) farmers’ existing technologies, agricultural activities and experiences, and 2) beliefs, values and needs of growers and their families.

4: how easy it is for a farmer to learn about a practice from a trial and, subsequently, adopt a practice (Pannell et al., 2006).

Source: As shown under the column ‘Research Studies’.

From Table 2.1, and as will be seen in Sections 2.4 and 2.5, three key drivers of adoption will be defining factors in this thesis; namely, environmental context, immediacy of rewards, and social networks. In agriculture, situations of risk and stress caused by agricultural epidemics and crop failures related to environmental changes play a crucial role in farmers' decision-making processes of adoption. The literature of adoption, specifically the works of adaptive capacity and climate change, are useful in studying strategies that help farmers to deal with these extreme circumstances (Smit and Skinner, 2002; Adger et al., 2007; Deressa et al., 2009; Brown et al., 2010). Within these strategies, actors can choose to support and adopt reactive or preventive technologies according to their preference over the immediacy of rewards of these innovations.

Regarding social networks, studies of technology adoption indicate that networks mainly facilitate the flow of information, knowledge and technologies and, in turn, can influence and accelerate farmers' decisions of adoption (Pannell et al., 2006; Conley and Udry, 2010). Social networks, for example, foster a genuine interest and sense of social norms to sustain agro-environmental management and learning amongst producers (Oreszczyn et al., 2010; Mills et al, 2017.

As Table 2.1 shows, Rogers (2010, 1983) made important contributions to the adoption theory within which the author categorised technology users (or adopters) depending on their innovation-decision period. According to this categorisation, the first individuals to adopt an innovation were innovators, followed to a lesser extent by early adopters, early majority, later majority and laggards. However, this typology was critiqued for suggesting that innovativeness was a personal characteristic that was applied accordingly to any condition rather than considering the particular context of individuals. Pannell et al. (2006) argued that:

> '[p]eople who adopt one innovation early are not necessarily early adopters of all innovations. It may be that the innovation in question is particularly attractive in their individual circumstances, whereas the same decision maker when considering

> a different innovation that is less attractive to them than to others may behave as a slow adopter or non-adopter' (p. 1412).

In agriculture, the discussion of technology diffusion and adoption follows different approaches that dominate the thinking of scholars, policy-makers and stakeholders. These models of diffusion imply strategies that set both the way knowledge is created and transferred to farmers for final adoption, and the leadership of actors in decision-making within the innovation-development process. The following section will study the centralised-diffusion models in agriculture, and the different critiques that emerge when comparing these systems with other alternative models. In addition, it will review how central models are understood and what considerations can be taken into account using these models.

2.2 Centralised-diffusion systems in agriculture

According to Rogers (2010), models of innovation diffusion indicate the expected degree of centralisation in decision-making and power amongst members regarding the following activities: planning and development of innovations to be diffused; direction of diffusion; sources of innovations; importance of users' needs in driving the diffusion process; and degrees of adaptation of those innovations to local conditions.

In agriculture, the predominant theoretical models have evolved from being highly centralised to more decentralised or systemic models. Although we will extensively study centralised systems, the importance and contribution of decentralised approaches to address the weaknesses of these systems are not disregarded.

The 'centralised-diffusion systems' or 'linear model' assumes a top-down direction, mainly in decision-making processes where technical experts (research and academic institutes) control formal R&D activities and decide which innovations to diffuse in the system. This was the classical approach of innovation diffusion in agriculture that was first studied by Ryan and Gross (1943) and became popular in the 1970s and early 1980s. It principally aimed to increase the levels of agricultural productivity and establish the principles for diffusion during the 'Green Revolution' (Pray, 1981). The literature on diffusion also relates this approach with 'Transfer of Technology' (TT) models and high extension models sponsored by public administrations (Thompson and Scoones, 1994; Klerkx et al., 2012).

This thesis focuses on two main roles in centralised models of technology diffusion in the agriculture sector: adopters (or users) and change agents[2]. According to Rogers (2010, p.27), adopters are users of technologies and innovations whereas change agents are professionals, located out of users' communities, who facilitate the flow of innovations from a change agency to users; they influence users' innovation decisions in a direction desirable by a change agency. Monge et al. (2008) state that the function of the change agent can be applied to a wider array of actors who promote adoption of specific innovations and/or give producers access to information for adoption. Based on studies of diffusion of agricultural innovations (Valente, 1995; Monge et al., 2008; Lestrelin et al., 2012; Awotide et al., 2016; Díaz-José et al., 2016), farmers can be considered technology users, whilst agricultural extension agents, consultants, and scientific institutions can be considered change agents.

In agriculture, the centralised-diffusion model has been the subject of continuous critiques. First, technical experts in centralised models do not acknowledge the crucial role that the needs, knowledge, values and motivations of farmers play in the diffusion and adoption of technological practices. According to Röling (2004) and Knickel et al. (2009), central models disregard most tacit knowledge and experiences generated by producers who may not feel motivated to implement practices that are not consistent with their needs. Together with this, Chambers et al. (1989), Gilles et al. (2013), and Garb and Friedlander (2014) insist that by not valuing local knowledge, technical experts forfeit valuable innovations and devote resources to inappropriate technologies.

[2] The importance of opinion leaders in processes of technology diffusion is not ignored by this research. However, the influence and the impact that change agents have on farmers is highly recognised in the study of technology diffusion of the agribusiness sector.

Second, centralised models do not grab the complexity of the existing relationships between agricultural producers and extension agents. Since these models reinforce one-way of hierarchical relationships as well as traditional functions in which farmers have a passive role, provision of feedback from producers to experts is difficult. Given these limitations, Leeuwis (2004) suggests that it is necessary to re-invent a conception of extension that includes an exchange of knowledge and experiences, learning, co-design, and negotiation amongst participants of the system.

Third, centralised models focus on the rapid technology transfer and the increase of adoption levels without considering the particularities of every environment. Knickel et al. (2009), Garb and Friedlander (2014) and Wigboldus et al. (2016) critique that these models (and in general the theory of innovation diffusion) assume that the technology is a stable object with fixed characteristics that can be used in different contexts. As stated by Knickel et al. (2009), 'Transfer of innovation (…) means that a tool or a method is 'detached' from a socio-technical configuration and 'reattached' to a different one' (p. 139). Contrary to the assumption of linear models, Kiptot et al. (2007), Gilles et al. (2013), Garb and Friedlander (2014) and Wigboldus et al. (2016) highlight that multiple contextual drivers have an important influence on the transfer of agricultural technologies that may perform differently when implemented in different localities. Most of these drivers were mentioned in the previous section and shown in Table 2.1. Garb and Friedlander (2014) assert that technologies are 'contextual shaped' and, when being transferred from one place to another, 'the technology could very well carry new meanings, advantages, costs, and applications: at the extreme, one might argue that it is no longer the same technology' (Garb and Friedlander, 2014, p. 16).

Another important critique is related to the targets that linear models aim to meet (e.g. high technology adoption) without further expanding the beneficial impacts of agricultural research in accordance with farmers' interests. Particularly, technology transfer does consider the change of commitment around the world. In this case, agricultural policy went from aiming to increase agricultural productivity through technology adoption in the

1970s, to broadening its scope to further technical impacts since the 1980s. After centralised models, the following approaches aimed to improve agrarian reforms, alleviate poverty, build local capacity, generate institutional changes, improve sustainability, increase the resilience of local farming, and impact the livelihoods of rural communities (Leeuwis, 2004; Millar and Connell, 2010; Gilles et al., 2013; Wigboldus et al., 2016).

In order to address some of the weaknesses of centralised models, other approaches became popular. Studied under the umbrella of 'decentralised systems of innovation' (Rogers, 2010) or 'systems-orientated approaches' (Schut et al., 2014)[3], these approaches were sympathetic to farmers' needs and acknowledged the valuable contribution of all stakeholders. One of these approaches is known by the use of bottom-up strategies (e.g. farmer-to-farmer technology transfer model[4] [Grisley, 1994] and farmer organisations) and the development and transfer of technologies by users (Chambers et al., 1989). Other perspectives introduce innovation system perspectives such as Agricultural Knowledge Innovation Systems (AKIS) (Röling, 2004), and Agricultural Innovation Systems (AIS) (Spielman et al., 2008). The AKIS models highlight the interaction of farmers with other peers as well as with other stakeholders through networking, and the importance of joint learning and 'concerted action' for the co-production of knowledge (Röling, 2004). For their part, AIS models consider that networks of stakeholders and institutional, as well as political, changes are key elements in the diffusion of agricultural practices (Lundvall et al., 2009; Spielman et al., 2011, 2008). As can be seen, both models gave an active role to farmers, prioritised farmer participation, local knowledge and needs, and allowed a wide sharing of power among members in decision-making processes.

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[3] For a better overview of the 'system-orientated approaches', see the work of Klerkx et al. (2012) and Schut et al. (2014).

[4] According to Grisley (1994), the model of farmer-to-farmer technology points out that farmers can learn from their more innovative fellow farmers, even when they can access alternative sources of information such as extension agents and agricultural researchers.

When comparing the way that some studies characterise both centralised and decentralised models of diffusion, it is possible to notice that several of these works tend to split between these two approaches and leave out the 'grey areas' in the middle that could be further exploited. It is common to find that advocates of systemic approaches, such as Spielman et al. (2008), Knickel et al. (2009), Röling (2004), Minh et al. (2011), Nordin et al. (2014), Obi and Nwakaire (2014) and Kuijpers and Swinnen (2016), characterise centralised models in a very linear way without considering their possible variations. For example, one of the advocates of systemic approaches, Röling (2004), affirms that according to centralised models:

> 'Science ensures progress. Extension *delivers* these ideas to users […] If farmers do not adopt the scientists' ideas, chances are that they are backward and don't know what is good for them […] Transfer of Technology assumes one-way and uninterrupted flow of technologies from fundamental scientists, to ultimate users via various intermediaries and delivery mechanisms' (pp.12-13).

This characterisation is also seen in Roger (2010) who argues that in centralised models, technical experts generate innovations that are distributed later by *change agents* (actors in charge of linking R&D systems with user systems), to *opinion leaders* (actors able to influence other individuals' attitudes and behaviours), and from them to *users*.

Few authors in the literature of diffusion such as Rogers (2010), Schut et al. (2014), and Díaz-José et al. (2016) recognise that a combination of characteristics from both centralised and decentralised models of diffusion can be used in way that is not mutually exclusive. In fact, Rogers (2010) suggests that the single use of one model is not realistic and the use of *hybrid systems* (or the combination of elements from centralised and decentralised diffusion systems) can be considered to fit a particular situation. In the same way, Schut et al. (2014) synthesised four approaches to agriculture innovation and diffusion while acknowledging that, '[t]he approaches are not mutually exclusive. Elements of, for example, the technology-oriented approach can form part of the different systems-oriented approaches' (p. 99). Despite these works, the study of 'grey areas' between models could have been explored further.

Table 2.2 adapts the characterisation of the centralised and decentralised models made by Rogers (2010), which he himself considers an oversimplification of the system, to the agricultural sector. The oversimplification of the centralised-diffusion systems made within the literature on diffusion is critiqued in this thesis and sets the basis of this research aim, which is to explain how different ways agricultural technologies, introduced by technical experts, can be diffused to smallholders in a context of predominantly top-down governance (see p. 1).

Table 2.2: Characteristics of Centralised and Decentralised diffusion systems in agriculture

Characteristics of diffusion systems	Centralised-Diffusion Systems	Decentralised-Diffusion Systems
Degree of centralisation in decision-making and power	Control of decision by extension agents, consultants, scientific institutions and commercial entities.	Wide sharing of power and control among members of the diffusion systems; much diffusion is spontaneous and unplanned
Direction of diffusion	Vertical or centralised diffusion: top-down diffusion from experts to farmers	Horizontal networks: peer diffusion of innovations amongst farmers through horizontal networks
Sources of innovation	Formal R&D conducted by subject-matter experts	Innovations come from experimentation by farmers on bottom-up basis
Decision-makers of diffusion	Extension agents, consultants, and scientific institutions decide which innovations should be diffused on the basis of their technical evaluation	Farmers decide which innovations should be diffused on the basis of their evaluation of innovations
Importance of farmers'	Emphasis of needs	Emphasis of needs based on

needs in driving the diffusion process	created by the availability of agricultural technologies	the local perceived needs and problems
Desirable adoption	Farmers adopt technologies developed by experts	Farmers adopt technologies developed by themselves
Adaptation of farmers to agricultural technologies	Low degree of local adaption as agricultural technologies diffuse among farmers	High degree of local adaptation as agricultural technologies diffuse among farmers

Source: Own elaboration adapted from Chambers et al (1989), Röling (2004), Rogers (2010).

2.2.1 Dominance centralised-diffusion models in agribusiness

Despite the popularity of decentralised models of innovation diffusion in agriculture, the use of centralised models continues to dominate in agribusiness sectors of developing countries. Darr and Pretzsch (2006, 2008) and Pamuk et al. (2014) found that top-down strategies were frequent in several African countries. For example, empirical evidence in Semi-Arid Eastern Africa showed that, although there was more innovative potential within cohesive groups of farmers in agroforestry, dependence on extension services prevailed for technological transfer (Darr and Pretzsch, 2006). Since the use of centralised-diffusion systems is predominant in agribusiness sectors, this thesis focuses on the study of these systems without ignoring the importance of decentralised diffusion for agriculture.

Agribusiness' corporation strategies promote the integration of smallholders into processes of commodity production through top-down strategies for technology diffusion. The justification includes, first, that smallholders have limited access to productive assets (e.g. land and labour); limited access to production technologies that are appropriate to their conditions; institutional constraints to credit and insurance; insecure land rights; and uncertainty associated to market instability and natural risks (Glover, 1987; Key and Runsten, 1999; Barrett, 2010; McCarthy, 2010; Abebe et al., 2013; Minh and Hjortsø, 2015). By contrast, large landowners, processors, agro-industrial firms or so-called technical experts (e.g. agricultural extension agents, scientific research institutes, government institutions, NGOs, practitioners of science) usually have (or are alleged to have) the technical and economic capacity to support the innovation process of smallholders in agribusiness sectors and to transfer this knowledge.

Second, it is sometimes asserted that agribusiness sectors require higher levels of innovation, intensification and technology specialisation compared with other agricultural sectors (Key and Runsten, 1999). Evidence can be seen in the oil palm sector in Sumatra, Indonesia, where the growing of oil palm involves technological innovations and capital-intensive investment (McCarthy, 2010). Another example can be seen in the work developed by Minh et al. (2011) regarding the difficulties that farmers face when growing *Acacia* crops in Vietnam's North-western Uplands. This work pointed out that *modern technologies* were needed in silviculture[5] to grow forest plantations with exotic species.

In this way, agribusiness sectors not only exhibit special conditions but also technological complexities that may require the use of centralised systems of diffusion. These models are argued to be appropriate in the support and transfer of technological and economic resources that smallholders in developing countries cannot afford by themselves. This is consistent with Rogers' (2010) suggestion regarding the convenience of using centralised models when sophisticated levels of technology and high levels of technical expertise are required. In these cases, scientific research institutions have the technical and economic resources to lead innovation development and diffusion, which users do not have.

The way that large-scale industrial actors, technical experts and processors facilitate the downward transfer of information, knowledge and technologies to smallholders in

[5] Silviculture is the growing and cultivation of trees.

commodity production has been attested in multiple studies. Choudhary et al. (2013), for example, shows that there was an effective transfer of sustainable production nutrient technologies in the agribusiness of potato–*Kharif* onion, tomato–blackgram, green pea–okra, and potato–okra, in Balh Valley, India, under top-down strategies led by extension organisations (e.g. field demonstrations, method demonstrations and farmers' training). Another example can be seen in the high adoption levels of unified recommendations, or 'fixed packages' of innovations, by Vietnamese north-western farmers, especially in very remote villages. These packages were promoted by public organisations in growing mulberry in upland fields and cultivating *colza*[6] in rice fields (Minh et al., 2011).

Important evidence indicates that top-down mechanisms often take place in a *planned* way. A critical feature of technology transfer in agribusiness is the mediation by agreements or contracts established between change agents and small-scale producers. For instance, a case study of fresh fruit production in Eastern Cape, South Africa, indicated that through the contract between agro-industrial firms and farmers, top-down strategies were used to transfer expertise that ensured the alignment of emerging farmers' products with the requirements of global demand (Bitzer and Bijman, 2014). In order to do this, formal arrangements established different mechanisms to improve smallholders' skills for crop management, for instance, standardised training courses. In the agribusiness sector of the developing world, several studies regarding formal agreements reveal the use of centralised-diffusion systems for transfer of technologies to smallholders (Key and Runsten, 1999; Hall et al., 2001; Kirsten and Sartorius, 2002; McCarthy, 2010; Barrett et al., 2012).

In addition to a contract, formal agreements establish a fundamental relationship between change agents and farmers, one that goes beyond the determination of transaction costs for their commitments. More importantly, these agreements are supposed to create a long-term relationship, underpinning mutual expectations and

[6] Winter crop.

values of trust and friendship tying these actors together. And yet, formal agreements embedding these values, and therefore re-interpreted as formal rules, have been little studied within the theory of innovation diffusion, particularly within the centralised-diffusion systems. The next section will deepen the understanding of the role of these formal rules within these systems.

2.3 Formal rules and contract farming arrangements within centralised-diffusion models

This section discusses how different types of formal rules lead to different pathways of technology diffusion (first research question). In order to do this, we first use the literature on social capital to understand the values underpinning rules. We also identify the influence of rules on technical relationships as vehicles for the transfer of technical knowledge and information in centralised-diffusion systems. Second, this section uses the contract farming arrangement (CFA) literature to understand how rules can become formal in innovation-diffusion processes. In the following sub-sections we discuss three types of formal rules and the types of technology users that may be found in the context of agribusiness and that can be adapted to this research. We show how these different characteristics may impact the technology diffusion processes.

2.3.1 Formal rules for technology diffusion

Formal rules can be studied under the social capital literature; social capital has been used by Bourdieu (1986), Coleman (1988), Burt (1992), Lin (1999) and Putnam (2001) to refer to a set of relationships and benefits that result from social interactions among individuals. Based on this literature, Adler and Kwon (2000) group the *sources of social capital* in norms, beliefs, networks, rules and formal institutions. This thesis focuses on the institutional sources (i.e. rules) and, in Section 2.4, on structural sources (i.e. networks) as factors that facilitate processes of technology diffusion to support smallholders. Therefore, it is necessary to increase the understanding of these factors in the literature on diffusion of agricultural innovations, particularly within centralised models.

As a potential source of social capital, rules:

> 'define how this activity [to work better together] will be carried out repeatedly over time and how commitments will be monitored and sanctions imposed for non-performance (...) [rules will be used to] allocate benefits derived from an organizational activity and to assign responsibility for paying costs' (Ostrom, 2000, pp. 176-178).

Essentially, rules refer to instruments that regulate the interaction of individuals, their functions and mutual commitments. This is what Lin (2002) refers to as 'organising principles for action and interaction' (p. 186). This interpretation of social capital theory is used here to study formal agreements, not from a macro perspective of governmental institutions and laws, as can be seen in the works of Woolcock (1998) and Putnam (2001), but from a micro or local perspective, by which actors establish formal arrangements to regulate behaviours and relationships. These arrangements can serve to formalise the relationship of technological diffusion between change actors and farmers, and regulate actors' functions and commitments within agricultural clusters using top-down strategies. Centralised models of diffusion in agribusiness show that formal agreements, such as contract farming arrangements, are essential to regulate the technology transfer between agro-industrial firms and smallholders.

Building on the conceptualisation that the social capital literature does on rules, this thesis defines 'formal rules' as local agreements with embedded values and expectations between participants. We argue that these formal rules are not properly considered within the theorisation of innovation diffusion, and more specifically within centralised models for diffusion of agriculture innovations. Contributors to theories of innovation diffusion (Valente, 1995; Burt, 2005, 1987; Rogers, 2010) do not mention formal rules in the way this research does for the characterisation of diffusion processes. To the best of the author's knowledge, the study of Wejnert (2002) is the only work that considers formal rules in the form of institutions within the theory of innovation diffusion. If formal rules are overlooked, a determinant institutional aspect that regulates the interactions and commitments of individuals may also be neglected within the diffusion processes.

At the micro level, the institution factors that encompass formal rules are also insufficiently addressed in the literature on diffusion of agricultural innovations. Lee (2005), for example, pointed out that an important influence on diffusion of sustainable agriculture in developing countries came from macro-level policies supporting outreach programmes and collaboration amongst public and private organisations. Nevertheless, their emphasis is on macro-instruments, such as governmental programmes and constitutional laws, potentially neglecting the use of mutual agreements and contracts.

In a context of agribusiness where market relationships are at the core, rules are necessary to reduce uncertainty between individuals' market interactions[7]. These agreements are considered here in terms of the types of rules that Williamson (2000) calls 'institutions of governance'. He asserts that 'governance is an effort to craft *order*, thereby to mitigate conflict and realize mutual *gains*' (Williamson, 2000, p. 599). This level deals with contract management between parties through private transactions. According to Williamson (2000), contracting is a vehicle to overcome factors that generate high transaction costs, such as asymmetric information.

Here, the concept of contracting is used in an alternative way. It is argued that these arrangements initially emerge in a scenario of market relationships where small-scale producers (commodity suppliers) and agro-industrial firms have overlapping economic interests. However, both parties commit to each other under rules of expectation and trust regarding other issues, in this case, technology transfer and technical support. Although not a defining concept of this thesis, trust is a crucial part of the discussion of

[7] This is what Douglas North calls the 'rules of the game' (North, 1990).

centralised models due to the effect this value can have on formal rules. According to Ribstein (2001), trust is defined:

> 'as a *decision* by one person to give power over his person or property to another in exchange of a return promise. Niklas Luhman says that this decision is significant regardless of the reason for it, because it encourages people to deal with each other' (Ribstein, 2001, p.556).

Therefore, these arrangements do not only cover transaction costs but a contested relationship whose interpretation of parties' commitments differ from the principles of contracting referred to by Williamson (2000).

This sub-section argued that formal rules are an alternative way of understanding formal agreements in centralised-diffusion systems. This thesis suggests that formal rules can take the form of CFAs in agribusiness sectors of developing countries whilst regulating and creating mutual commitments that underpin values of trust and friendship. CFAs formalise the emergence of centralised-diffusion systems and the vertical relationships for technology transfer between small-scale growers and change agents. As change agents control the content of the practices and the sources of technologies, diffusion occurs under a top-down context. To understand this, the role of CFAs in technology diffusion is explained in the following sub-section.

2.3.2 Contract farming arrangements as formalisation of rules

According to Eaton and Shepherd (2001):

> 'Contract farming [CFAs] can be defined as an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices. The arrangement also invariably involves the purchaser in providing a degree of production support through, for example, the supply of inputs and the provision of technical advice' (p. 2).

Kirsten and Sartorius (2002) assert that '[CFAs have] considerable potential for providing a way to integrate small-scale farmers in developing countries into export and processing markets and into the modern economy' (p. 505). This research focuses on technology-diffusion processes that CFAs involve in the agribusiness sector.

CFAs can influence the extent to which new technologies are delivered through channels of communication and adopted as a result of this transfer (Key and Runsten, 1999; Barrett et al., 2012). Contract farming systems have provided technologies as well as information and economic resources, such as optimal cultivation techniques, specialised planting, sophisticated irrigation and seed varieties, to participants in the production of cash crops in African, Latin American and Asian countries (Key and Runsten, 1999; Kirsten and Sartorius, 2002; McCarthy, 2010; Barrett et al., 2012; Abebe et al., 2013).

Without these contracts, farmers face difficulties in obtaining access to capital, inputs (e.g. planting material and fertilisers), and marketing networks in agribusiness sectors. According to Key and Runsten (1999) and Minh et al. (2011), since agricultural commodity production is focused on increasing productivity levels, specialised inputs (e.g. agrochemicals and seeds), knowledge and information (e.g. use of agrochemicals and complex technologies, and cultivation techniques), and sophisticated equipment are usually required for obtaining large-scale productions. In the study developed by McCarthy (2010) in Indonesia, the author showed that large investment of economic resources in quality seedlings and careful husbandry were required conditions for the cultivation of oil palm. In that case, oil palm farmers, who develop their plots independently without outside support, found it difficult to sustain their agribusiness. Amongst other production schemes, CFAs allowed smallholders in developing countries to access these technologies and information and, therefore, played a fundamental role in the diffusion of agricultural innovations.

Technically speaking, CFAs typically involve commitments that firms have assumed to facilitate support, and thus enable small-scale producers to adopt agricultural practices. In these schemes, farmers from developing countries can gain access to information and technology (e.g. information related to agricultural production, certifications and quality control), managerial skills, technical expertise, and technical inputs for the implementation of agricultural practices (Glover, 1987; Key and Runsten, 1999; McCarthy, 2010; Barrett et al., 2012; Abebe et al., 2013; Bitzer and Bijman, 2014). A case study of frozen vegetable contracting in Aguascalientes, Mexico, showed that smallholders often obtained inputs, capital and extension assistance from agro-industrial firms (Key and Runsten, 1999). In this way, CFAs can help to involve farmers in technological dynamics of crops, overcoming the impediments (e.g. lack of information and technical resources) in the 'imperfect markets' of agribusiness (Key and Runsten, 1999; Kirsten and Sartorius, 2002).

The following table is a summary of market imperfections in terms of technical requirements and the mechanisms to solve these imperfections. It is important to mention that the provision of services may be charged, or not, by agro-industrial firms according to the negotiated arrangement.

Table 2.3: Contract farming solutions for market imperfections

Type of market imperfection	Market imperfection	Contract farming solution
Information access	Lack of information resources about optimal cultivation techniques, complex technologies and quality of seeds Lack of information sources about technical and chemical requirements of production for marketing or exportation Lack of supervision of labours and technology adoption	Agro-industrial firm that efficiently communicates information via: production management contracts; internalisation of production process; and firm-employed extension agents in charge of monitoring, information transfer and regulation for chemical use Agro-industrial firm that supervises labour via firm-employed supervision agents for monitoring
Provision of technical factors of production	Unavailability of specialised inputs and equipment High costs of sophisticated equipment	Agro-industrial firm facilitates specialised inputs, specialised knowledge (extension services), sophisticated equipment, or specialised agrochemicals and seeds Agro-industrial firm lends or acts as intermediary for credits to smallholders

Source: Own elaboration adapted from Key and Runsten (1999), Barrett et al. (2012) and Abebe et al. (2013).

It is possible to say from the technical characteristics of CFAs that, within contexts of commodity production, these arrangements can favour a hierarchical relationship between farmers, acting as technology users, and agro-industrial firms, acting as change agents. In this vertical relationship, agro-industrial firms provide technical and financial support to small-scale producers, so that farmers are able to acquire specialised inputs and complex technologies. For their part, farmers are expected to obey technical instructions in accordance with the agreements and to supply the commodity to agro-industrial firms at an agreed price. This shows a clear use of top-down mechanisms for the technology diffusion agribusiness and is consistent with the view of Rogers (2010) regarding the appropriate use of centralised models (see p. 31).

The CFA literature evidenced that different contracts can be negotiated in multiple contexts and sectors, and assign specific responsibilities to different types of smallholder actors; therefore these arrangements cannot be standardised in a simple typology. The Colombian oil palm sector is a clear example of this heterogeneity, as will be discussed in the case studies. These cases will show that differences in contract obligations and in characteristics of the selected smallholders can influence how rules are defined, interpreted and implemented in the process of technology diffusion. Due to this variety, a framework to analyse these different agreements and their effects on technology diffusion is needed. These variations will be discussed in Sub-Sections 2.3.3 and 2.3.4.

2.3.3 Types of governance introducing variations in contract farming arrangements

Based on the CFA literature, and the close link of this literature with Global Value Chain (GVC) studies, this sub-section will identify three categories of CFAs that entail particular commitments and responsibilities regarding technology transfer (e.g. technical supervision, information transfer, and provision of inputs and equipment) and implementation of crop practices. Thus, these categories can introduce variations in technology-diffusion processes.

Up to this point, this thesis has emphasised the crucial importance of the relationship between small-scale producers and agro-industrial firms for technology transfer. This relationship can be understood from a global value chain perspective and, within this approach, a value-chain governance typology.

Global value chains (GVCs) originated from the changing nature and industrial organisation of retailers, industries and commodity producers (Gereffi et al., 2005, p. 79). Under the GVC approach, governance was defined as ‘power relationships that determine how financial, material and human resources are allocated and flow within a chain’

(Gereffi, 1994, p. 97). Adding to this, governance also indicates the type of services that lead firms will deliver to suppliers. Gereffi et al. (2005) explained that variations of these power relationships resulted from the variation of three elements: 1) *complexity* of information and knowledge transfer with respect to product and process specifications; 2) the ability of suppliers to *codify* information and knowledge; and 3) the *capability* of suppliers in relation to the requirements of the transactions. The more difficult it is to codify the required standards and the more complex the product and process specifications are in terms of technological characteristics and adoption, the more coordination and supporting services are needed.

Based on the studies of Schmitz and Humphrey (2000), Sturgeon and Lee (2001), and Sturgeon (2002), and on the different levels of complexity, codification and supplier capabilities, Gereffi et al. (2005) proposed three governance typologies. In a first typology, *market governance*, suppliers were capable to generate products with simple specifications and under little monitoring from buyers.

Within a second typology, *network governance*, three other forms of coordination could be found: modular, relational and captive. Through *modular value chains*, suppliers make customised, and therefore, complex products for buyers. Although suppliers take full responsibility for certain competencies, they receive support from buyers who transfer codified information and exert little coordination. For their part, *relational value chains* are characterised by complex transactions, difficult codification of product standards, high capabilities of suppliers, and explicit coordination. *Captive value chains* occur when both complexity of product specifications and abilities to codify are high but supplier competencies are low. In comparison to the previous governance types, captive suppliers are responsible for a narrow range of tasks whilst the lead firms are confined to complementary but key activities.

A third typology, *hierarchy or vertical integration*, is characterised by high complexity of transactions and products, high difficulty to codify product specifications and low capabilities in the supply-base. As a result, lead firms are in charge of developing and manufacturing products or exerting high explicit coordination.

In agri-food markets and economies of scale, particularly agro-processing and export marketing, the participation of small-scale producers in value chains tended to occur under a governance of high vertical coordination (Humphrey and Memedovic, 2006; Poulton et al., 2010). Through this GVC governance, agro-processors and marketers delivered a range of resources as well as pre- and post-harvest services to help smallholders in meeting the stringent standards of international markets, to transmit best practices to suppliers, to avoid loss of customers, and reputational damage. In the EU, for example, the regulations about controls on pesticide residues have led food business operators to extend information about required levels of pesticides in produce and agricultural practices on supplier farms (Humphrey and Memedovic, 2006). Pre- and post-harvest services (e.g. access to inputs, finance, technical support, training and output services) were essential if smallholders wanted to intensify production and improve their levels of competence (Poulton et al., 2010; Franz et al., 2014).

It is important to note that, within the same GVC governance typology, particular configurations of services serve to different farmers. This can be inferred from the analysis performed by Aguilar-Gallegos et al. (2015) about information networks in the Mexican oil palm sector. The study suggested that those small-scale growers who adopted more new and improved technologies set up better links with extension agents and, to a lesser extent, with agribusiness companies, through which they received agricultural services and information.

In agribusiness sectors, governance and provision of technical assistance and resources in most production schemes tended to occur under a highly vertical coordination exerted, wholly or partially, by agribusiness companies (McCarthy, 2010; Abebe et al., 2013). Agribusiness or agro-industrial companies are firms that own large-scale production units and engage in some (or all) additional activities such as seed supply, washing, cleaning, post-harvesting processing, packaging, storage, distribution and marketing (Barrett et al., 2012; Bitzer and Bijman, 2014; Brenes et al., 2014). In the oil palm sector, agribusiness companies are usually in charge of seed supply, crop production and fruit processing (McCarthy, 2010).

These agro-industrial firms can play an important role in the process of agricultural innovation and technology diffusion within developing countries. The works of Poulton et al. (2010), Barrett et al. (2012), and Bitzer and Bijman (2014) suggested that agribusiness firms owned a significant amount of financial and technical resources (several of them having their own R&D units) as well as strategic linkages with other stakeholders through which firms could develop new cultivation techniques for cropping and processing. By sharing their agricultural and commercial expertise with emerging farmers, these leading change agents can govern the centralised process of diffusion and influence the final adoption of these producers.

Based on Gereffi et al. (2005) and Poulton et al. (2010), this thesis refers to types of governance as the variations in levels of participation and control of agro-industrial firms and smallholders in decision-making processes related to technology transfer and farmers' crop management (i.e. planning and implementation of agricultural practices). As GVC typologies, differences in governance indicate different levels of control of technical activities and provision of inputs and services. These governance typologies are regulated by institutional mechanisms, in this case CFAs that honour commitments regarding service provision and technology diffusion amongst actors. Consistent with the governance typologies identified by Gereffi et al. (2005) and Poulton et al. (2010) (see pp. 41-42), Key and Runsten (1999) and Kirsten and Sartorius (2002) identify three types of CFAs according to the degrees of agro-industrial firm control:

1. *Marketing contract of sell-purchase:* contract where the small-scale producer has full autonomy regarding production decisions and the agreements are merely contracts of sell-purchase.

2. *Partial agro-industrial control:* contract where certain resources are supplied by the agro-industrial firm.

3. *Full agro-industrial control:* contract where there is full control of decisions and provision of inputs and technical services by a company.

Table 2.4 summarises the characteristics of those CFAs. Due to the positioning of this research within the context of centralised-diffusion systems, the CFA of the marketing contract of sell-purchase is not presented in the table. As an alternative, we propose a type of governance that minimises the role of change agents instead of removing their participation, as is indicated by marketing contract sell-purchase. This classification determined the predominant characteristics of agreements for the selection of the case studies (nuclei A, B and C).

Table 2.4: Types of CFAs

Type of governance	Level of control of production management and provision of technical services and inputs	Roles of parties	Case studies of the oil palm sector in Colombia
Low agro-industrial control	Minimum control on farmers' production management and provision of technical inputs by agro-industrial firm	Agro-industrial firms have minimum involvement in supply of crop inputs, technical services and technologies, credits, etc. Small-scale producers have full autonomy regarding their production management and production decisions; they sell their production to agro-industrial firms	Nucleus A
Partial agro-industrial control	Shared control on farmers' production management by agro-industrial firm and small-scale producers	Agro-industrial firms partially supply crop inputs, technical services and technologies, credits, etc. Small-scale producers participate in their production management; they sell their production to agro-industrial firms	Nucleus C
Full agro-industrial control	Full control on farmers' production management and provision of technical inputs by agro-industrial firms	Agro-industrial firms fully supply crop inputs, technical services and technologies, credits, etc., and fully control production management of small-scale producers' cultivation. Small-scale producers sell their production to agro-industrial firms	Nucleus B

Source: own elaboration adapted from Key and Runsten (1999) and Kirsten and Sartorius (2002)

In the Colombian oil palm sector, it is possible to find CFA strategies that can be classified according to the predominant characteristics of their agreements. This classification also applies to the clusters in this thesis. As will be explained, the agro-industrial firm *B* in cluster *B*, for example, has high control on technical assistance and provision of resources to oil palm producers. However, producers in Nuclei *A* and *C* have more autonomy for the production management.

2.3.4 Types of technology users within contract farming arrangements

In addition to defining control and responsibilities of actors, formal agreements also establish criteria for selecting technology users. Based on the CFA literature, smallholders can be characterised by their socio-economic conditions and whether or not they prefer individual or collective actions. The different types of users can affect the technology-diffusion process in agribusiness, as explained below.

It can be interpreted from the CFA literature that most small-scale producers in developing countries are considered poor farmers, with limited financial and technical resources. However, differences within this group of producers may exist and the socio-economic conditions of users can give an indication of their capacity to assume responsibilities related to technical support and adoption. For example, small-scale producers with low socio-economic conditions may require more economic and technical support to access improved inputs, information and technology than better-off producers. Key and Runsten (1999), Bijman (2008) and Barrett et al. (2012) affirm that the limited capacity of smallholders leads to high transaction costs, associated with provision of inputs and services, for contractors or processing companies. On the other hand, contracting with larger-scale and better-off producers may reduce firm transaction costs because of the low number of services that these companies need to provide to growers. These reasons explain the clear preference of agro-industrial firms to contract with larger growers (Key and Runsten, 1999; Bijman, 2008; Barrett et al., 2012).

Users' socio-economic characteristics also indicate the capacity of smallholders to adopt new technological practices, and therefore to meet their contractual obligations. According to studies of technology adoption in agriculture reviewed in Sub-Section 2.1.2, socio-economic conditions are factors with a significant influence on the adoption of farmers. A similar way of considering these characteristics is observed in the innovation-diffusion literature; for example, Rogers (2010) and Wejnert (2002) argued that socio-economic characteristics can influence the likelihood and the stage (early or late) of adoption. Thus, the type of user indicates how likely they are to adopt practices and, based on that, whether they are able to meet contractual obligations related to final implementation.

The above raises an additional issue in the innovation-diffusion literature. To the best of the author's knowledge, it was not possible to find works in this literature where the association of users' socio-economic characteristics to the diffusion process (fourth stage of the innovation-development process[8]) was not taken to be the same as the association of these characteristics to the technology adoption (fifth stage of the innovation-development process).

Another aspect that distinguishes smallholders of different CFAs refers to their participation within an agreement in a collective or individual way. Associations and cooperatives are mechanisms of collective action used by smallholders to negotiate conditions within a CFA, as well as to carry out or share services. By undertaking different responsibilities, farmer organisations may be able to introduce variations in the agreements. In order to favour its members, Sartorius and Kirsten (2007), Darr and Pretzsch (2008), Ton (2008), Barrett et al. (2012), Awotide et al. (2016) argue that these organisations:

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[8] See Figure 2.1.

- improve the contract terms regarding technical support between a processor and smallholders;
- offer guarantees with certainty over product availability to the buyer;
- cost effectively deliver inputs and technical services;
- coordinate the logistics and communication of their members; and
- obtain additional support from external actors to the cluster, for instance NGOs[9]

In this way, farmer organisations not only contribute to ease the flow of information and technologies, but also participate in the decision-making process related to the crop management of their members as well as activities for technology diffusion.

Sub-Section 2.3.3 and this sub-section suggested that both types of governance and types of smallholders in CFAs may give a partial answer to the first research question about improving the understanding of different types of formal rules associated with different pathways of technology diffusion. The type of CFA gives actors a degree of control on technology-diffusion processes, whilst the type of user indicates their potential capacity to access inputs and services for production and for technology adoption. Both of these factors show the conditions under which change agents and users can assume responsibilities in technology diffusion and adoption.

This section builds the first component, formal rules and their possible variables for differentiation of the framework for centralised-diffusion of agricultural technologies (Figure 2.2).

[9] In Ghana, for example, Barrett et al. (2012) found that members of a pineapple farmer cooperative mentioned the increased likelihood of receiving help from the government and NGOs due to the existence of these organisations.

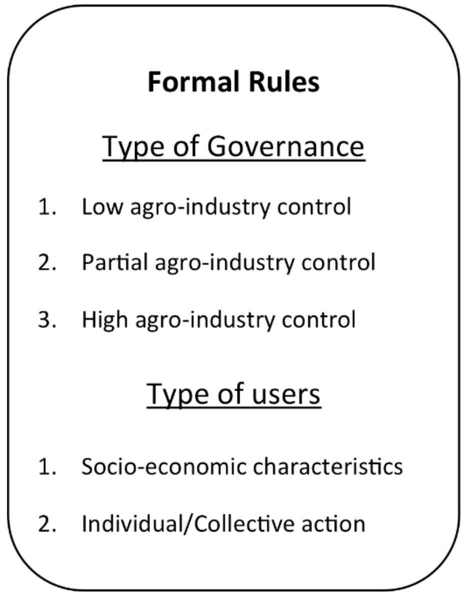


Figure 2.2: Variation of formal rules for centralised-diffusion of agricultural innovations

Source: own elaboration adapted from Key and Runsten (1999), Kirsten and Sartorius (2002) and Barrett et al. (2012).

The next section explores how these types of formal rules may influence technical relationships for diffusion, and therefore network structures. This is a fundamental part of the diffusion process that helps in answering the second research question.

2.4 Networks for diffusion within centralised-diffusion systems

The previous section explained the possible variations of formal rules that were found in the centralised-diffusion of agricultural innovations. This section discusses the resulting network structures that may occur from these different types of formal rules, and the impact of these network structures in technology diffusion (second research question). The relationship between formal rules and networks can be explained on the basis that rules can establish an institutional framework for interactions amongst actors. However, there is a need to consider a more rigorous treatment of the relationship between these two elements within centralised systems that will provide a more complete explanation about different pathways of technology diffusion.

In order to address the second research question, the first part of this section studies the possible relationship between formal rules and networks within centralised-diffusion systems through social capital theory. The second sub-section explains the type of networks that may emerge in centralised-diffusion systems due to formal rules. In the third and fourth parts, we characterise the network structures corresponding to each type of formal rules as well as their effects on diffusion.

2.4.1 Understanding the relationship between formal rules and networks

The relationship between formal rules and networks is not referred to in the diffusion literature because formal rules do not get a key role in the theory of diffusion. This sub-section explains this relationship and uses the theory of social capital to try and illuminate the hierarchical relationships underpinning formal rules amongst actors, as well as the occurrence of vertical networks for the operationalisation of technology diffusion.

Based on Salancik (1995), Adler and Kwon (2000) and Lin (2002), rules and formal institutions regulate interactions and, in turn, shape social networks and the content of the ties. Salancik (1995) explains that:

> 'all interaction occurs in a context of institutions, including rules and roles. Organizational policies impose some of these: Units are explicitly directed to interact with one unit but not others or are instructed to report to one unit rather than another. Others might arise from prejudices or rules in place […]' (pp. 346-347).

Thus, local agreements can inhibit, allow or force interactions with specific actors that could turn into social relationships.

Based on the work developed by Salancik (1995), it is possible to argue that formal agreements can influence the formation, structure and content of social networks. Salancik's discussion of networks is based on a critique of the nature of interactions within organisations that he considers cannot be taken as given. This is because relationships may arise from interactions between people in organisations to achieve, plan, coordinate, or decide on their individual and collective activities. Some of these relationships are mandated in contracts for which they have to interact. In other cases, the absence of relationships results from institutional constraints that inhibit interactions as interpreted from Salancik's quote in the paragraph above.

From the above consideration, CFAs establish an institutional framework under which certain actors participate and play central roles, and other interactions emerge outside these institutional boundaries. For example, one of the case studies developed by Bitzer and Bijman (2014) referred to an agreement in which farmers jointly managed their farms with agribusinesses of citrus production in the Kat River Valley, South Africa. According to the CFA agreed by participants, the agribusiness South African Fruit Exporters (SAFE) was in charge of transferring knowledge and providing services to farmers. Other partners and facilitators, such as the Department of Rural Development and Land Reform (DRDLR) and Eden Packhouse, were involved in the agreement. Unlike other independent farmers in the region who did not negotiate a contract agreement, it may be said that growers in the SAFE and Eden Packhouse partnership built technical relationships with an agro-industrial firm directly. From there a network emerged with at least two types of actors (famers and agro-industrial firms) sharing direct channels of communication for knowledge transfer.

This thesis examines the formal connection between rules and networks, to study the process of diffusion of agricultural practices in centralised models. We argued that most of the network studies within the literature on diffusion of agricultural innovations (Darr and Pretzsch, 2006; Wyckhuys and O'Neil, 2007; Monge et al., 2008; Spielman et al., 2011; Krishnan and Patnam, 2014; Díaz-José et al., 2016) focuses on the effect of relationships on technology adoption and does not link these results with formal agreements underpinning these networks. This link may need to be taken into account because of the way formal agreements are negotiated and characterised, may facilitate or inhibit network relationships, and thus affect outcomes in diffusion systems. This thesis aims to contribute to the innovation diffusion literature by connecting these formal agreements and networks to the final results of pathways of technology diffusion.

2.4.2 Vertical networks in centralised-diffusion systems

As was previously argued in this thesis:

> ‘[CFAs] formalise the emergence of centralised-diffusion systems and the vertical relations for technology transfer between small-scale growers and change agents’ (see above, p. 36).

Although the relationships between change agents and users occur mostly in a hierarchical way in centralised-diffusion systems, informal relationships and values of trust and friendship can be embedded in these vertical relationships. Adler and Kwon (2002), for example, assert that in hierarchical relationships, ‘obedience to authority is exchanged for material and spiritual security’ (p. 18) and that ‘[these] relations give rise to social relations – as is inevitable under conditions of repeated interactions […]’ (p.19). By becoming social relationships, hierarchical interactions can be studied under the umbrella of social capital.

It was said in Section 2.3.1 that social capital referred to ‘a set of relations and benefits that results from social interaction among individuals’ (see above p. 33). Fukuyama (1995) defines social capital as ‘the ability of people to work together for common purposes in groups and organizations’ (p. 10). This definition focuses on ‘bonding’ ties within a collective (e.g. organisation, community, nation, and so forth). This research, however, uses the conceptualisation of social capital at an ‘individual level’ (Burt, 1992; Lin, 1999; Bodin and Crona, 2009), which may help to analyse the hierarchical relationship between change agents and smallholders within centralised-diffusion systems. According to this conceptualisation, social capital refers to the resources that an individual can gain from his/her relationships or ‘bridging’ ties with other actors in order to pursue their own interests. Burt (1992), for example, defines social capital as ‘friends, colleagues and more general contacts through whom you receive opportunities to use your financial and human capital' (p.9). Bodin and Crona (2009) suggest that these links are particularly relevant in leveraging resources and ideas beyond the limits of an actor's community.

Within the 'bridging' ties category, Putnam (2001) found that there is a sub-category of relationships that vertically connect different groups in hierarchical levels of authority. Related to this sub-category, Woolcock (1998) introduced a further conceptual refinement of social capital called 'linking' social capital. Szreter and Woolcock (2004) defined linking social capital as 'norms of respect and networks of trusting relationships between people who are interacting across explicit, formal or institutionalized power or authority gradients in society' (p. 655). This concept arose from the work of Woolcock (1998) in which he argued that, in a developmental context, it is the extent (or lack thereof) of trust-based relationships between poor communities and actors in hierarchical levels that has a major influence on their welfare.

'Linking' social capital highlights the significance of the value of trust in vertical relationships that may exist in the links between agro-industrial firms and smallholders, and thus in the discussion of centralised-diffusion models. In a context of agribusiness, Fafchamps and Minten (2002) assert that trust-based relationships are necessary for continuity and repeated transactions in long-term agreements. Contrary to the CFA literature that discusses the necessity of trust-based relationships between agro-industrial firms and smallholders to avoid breaching of agreements (Kirsten and Sartorius, 2002), values of trust in vertical interactions within centralised-diffusion systems are little discussed in literature on the diffusion of agricultural innovations.

From the discussion above, it can be claimed that technical and interpersonal relationships within centralised-diffusion systems between small-scale producers and agro-industrial firms (or other change agents) can be analysed at an individual level of social capital. These hierarchical relationships allow smallholders to access resources and agro-industrial firms to exert their authority. The aggregate of these hierarchical relationships reveals vertical network structures. Even though other forms of social capital can be found within centralised systems (for example, the participation of users' organisations), the focus of this study will be the individual social capital that actors gain in having linking ties through which shared values and trust are created.

2.4.3 Network for diffusion of agricultural technologies

Sub-Sections 2.4.1 and 2.4.2 put forward the link between formal rules by which these agreements influence network structures of vertical relationships within centralised-diffusion systems. This section explains the network structures that may emerge from the types of formal rules, and subsequently their potential effect on technology diffusion. Before this can be accomplished, however, an understanding of the concept of networks, their possible impact on technology diffusion and their structural characteristics, is required.

Social networks can be considered as groups of actors (individuals, organisations, institutions) that interact in order to transfer resources through communication channels. These channels enable actors to share other valued resources such as knowledge, understanding, norms, rules, trust and expectations (Ostrom, 2000b; Moody and Paxton, 2009).

Since communication channels enable farmers to access information and technologies from other actors, which consequently has a direct impact on their adoption, networks studies are important in understanding the diffusion of agriculture innovations (Ryan and Gross, 1943; Bandiera and Rasul, 2006; Isaac et al., 2007; Wyckhuys and O'Neil, 2007; Monge et al., 2008; Darr and Pretzsch, 2008; Conley and Udry, 2010; Gamboa et al., 2010; Aleke et al., 2011; Spielman et al., 2011; Hermans et al., 2013; Wossen et al., 2013; Wu and Zhang, 2013; Krishnan and Patnam, 2014; Ramirez et al., 2014; Awotide et al., 2016). As with this research, the works of Ramirez et al. (2014), Aguilar-Gallegos et al. (2015), and Ramirez et al (2018) are some of the few studies that contribute to the literature on the diffusion of agricultural innovations concerning the structural particularities of networks for agribusiness sectors. However, in this work, the technical relationships for the provision of services between smallholders and agribusiness companies are emphasised, in order to highlight the benefits of these connections.

Taking the impact that networks may have on diffusion from the literature of social capital (Coleman, 1988; Adler and Kwon, 2000; Lin, 2002; Burt, 2005), this research adapts these concepts to draw conclusions about the impact on centralised-diffusion systems in agriculture where the main participants were smallholders and change agents. Networks are important for diffusion because they facilitate *access of information*, *influence of actors* on other actors, and *access of new information sources*, as will be explained in the following paragraphs.

First, network relationships facilitate the *access of information*. According to Coleman (1988), Lin (2002) and Burt (2005), individuals can access information about opportunities and choices through their connections with other actors. In centralised-diffusion systems, the main aim of change agents is to allow farmers to access information and technology, and thus integrate these growers into processes of commodity production.

Second, change agents can exert important *influence* on the decision-making processes of other individuals. According to Burt (2005) and Lin (2002), strategic locations and positions of some actors give them power to become intermediaries in the transfer of valued resources between disconnected groups and in the control of the type of information that is transferred. In the context of centralised-diffusion systems, agro-industrial companies may become intermediaries between experts and smallholders, and may exert an important influence on smallholders towards technical goals.

And finally, network structures can facilitate or block the access of individual actors to *new information sources*. Burt (2005) asserts that brokers can connect different groups of actors and, in this way, different groups of information. This mostly depends on the network structures (position and distribution of relationships and actors) that facilitate or block the links between these brokers and other individuals. Centralised models of diffusion may favour the transfer and variety of information and agricultural technologies' networks from brokers and intermediaries to smallholders.

2.4.4 Network structures associated with types of formal rules for technology diffusion

As this thesis is interested in the study of technology-diffusion that involves the use of communication channels, it is therefore interested in the analysis of network connections through which actors share and receive technical resources such as information, knowledge, technologies, training, supervision and experiences.

Networks can be analysed and compared by exploring their structures. These structures can help to explain the quantity, role, attributes and positions of actors and connections, which is fundamental to understanding processes of technology diffusion in agriculture. According to Lin (2002), ties in strategic location and/or hierarchical position can provide actors with useful information about opportunities and other choices. Network structures can affect individuals' access to resources and the distribution of these resources amongst these actors. In agriculture, these structures can either facilitate or hinder farmers' access to technical resources that are necessary for the development of their crops.

In order to distinguish and evaluate the network structures that arise from different types of formal rules in centralised-diffusion systems, this thesis adopts three elements of analysis that can help to compare the key roles of actors within these networks. These elements are *size and interactions*, *central positions*, and *brokerage beyond group.* The following discussion explains each of these three structural characteristics, describing how the varying levels of these characteristics are determined by the types of formal rules; it also considers the impact of these characteristics on diffusion.

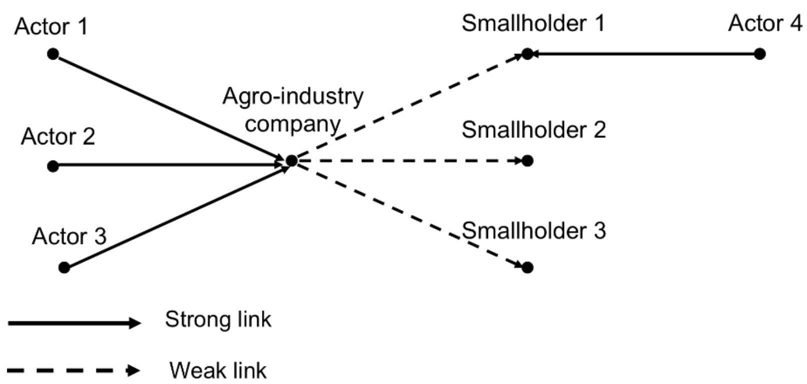
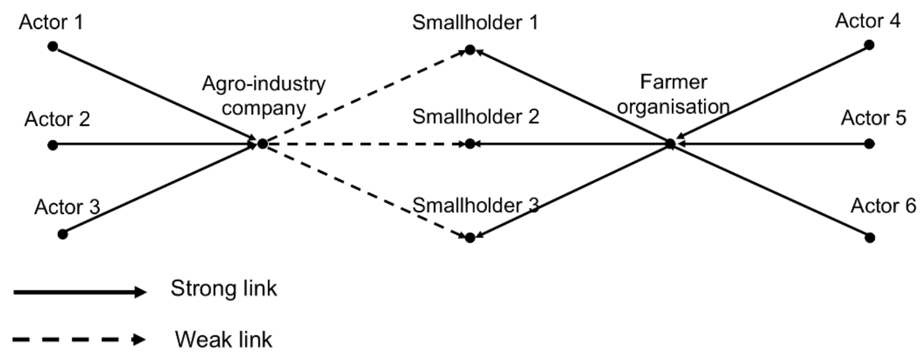
1. Size and interactions

Size and interactions measure the number of actors and technical relationships of networks that originated directly or indirectly from a particular type of formal rules. As was mentioned, formal rules define the type of participants in a CFA and their technical responsibilities, which cause technical relationships. Technical interactions are also observed between participants involved in the negotiation of a CFA and other actors outside the institutional boundaries of this agreement.

Following on from the influence of these networks on technology diffusion (see Sub-Section 2.4.3), one of these impacts is that network relationships allow farmers to access information and technology. Size and individual interactions identify the sources and links available to share information with smallholders. Darr and Pretzsch (2008) show that high interaction favours the access to information. According to these authors, actors of larger networks are more likely to be connected to network peers and different groups of information. Higher interaction amongst farmers allows a considerable diffusion advantage for smallholders with access to similar information. On the other hand, links with leading agro-industrial companies and other change agents enable smallholders to access new information. These conclusions are based on the work of Granovetter (1973) and Hansen (1999) that indicate that 'weak connections' are used in order to provide actors with different information.

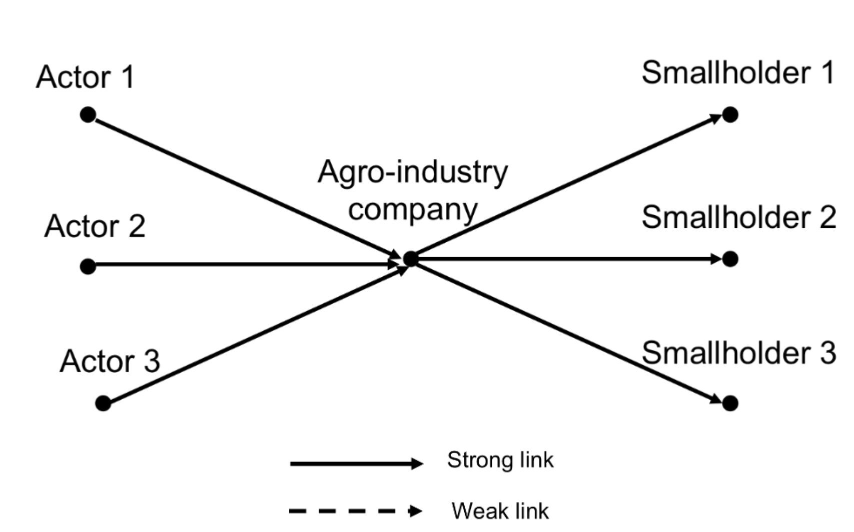
Figure 2.3 presents some simplified examples of network structures that help to identify differences in size and interactions, central positions and brokerage, that are originated from three particular types of formal rules (i.e. low agro-industrial control, partial agro-industrial control and full agro-industrial control). The differences in network structures can be indicated by the numbers of actors, links and brokers, as noted at the bottom of each graph. It is important to clarify that, within these networks, agro-industrial companies, smallholders and farmer organisations are the main participants of the CFAs and clusters, while other actors outside of these institutional boundaries (e.g. Actor 1, Actor 2, Actor 3, etc.) are change agents and additional sources that provide new information. Figure 2.3 also shows the two types of connections (strong and weak links) that help to distinguish the intensity of technical support that producers receive from other actors. We use the definition of Granovetter (1973) about ‘strength’ of interpersonal relationships as ‘a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services that characterize the tie’ (p. 1361).

a) Low agro-industrial control

<table>
<tr><th>Scenario 1</th><th>Scenario 2</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>· Number of change agents: 5
· Total number of links: 7
· Number of strong links connected to smallholders: 1
· Number of weak links connected to smallholders: 3
· Central actors: Agro-industrial company
· Number of brokers: 1</td><td>· Number of change agents: 8
· Total number of links: 12
· Number of strong links connected to smallholders: 3
· Number of weak links connected to smallholders: 3
· Central actors: Agro-industrial company and farmer association
· Number of brokers: 1</td></tr>
</table>

b) Full agro-industrial control (Full or high agro-industrial control)

Scenario 3



- Number of change agents: 4
- Total number of links: 6
- Number of strong links connected to smallholders: 3
- Number of weak links connected to smallholders: 0
- Central actors: Agro-industrial company
- Number of brokers: 1

c) Partial agro-industrial control

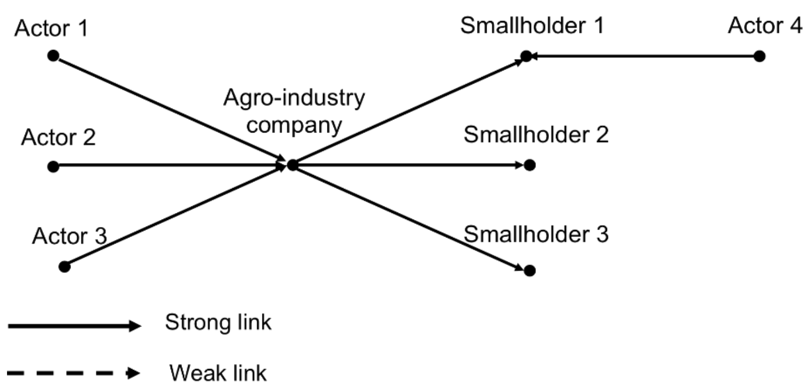
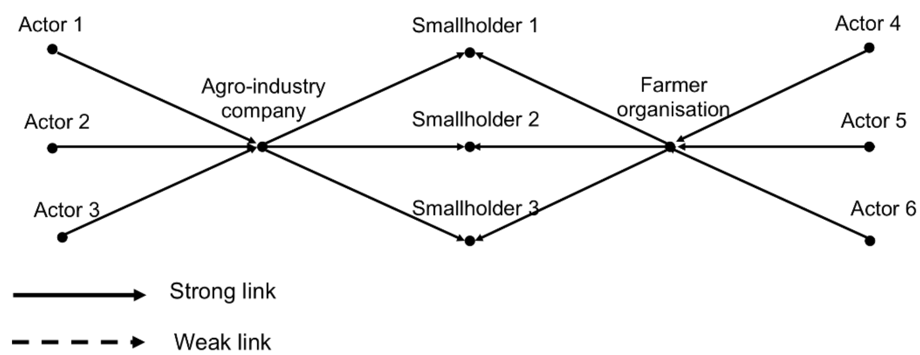
Scenario 4	Scenario 5
	
· Number of change agents: 5 · Total number of links: 7 · Number of strong links connected to smallholders: 4 · Number of weak links connected to smallholders: 0 · Central actors: Agro-industrial company · Number of brokers: 1	· Number of change agents: 8 · Total number of links: 12 · Number of strong links connected to smallholders: 6 · Number of weak links connected to smallholders: 0 · Central actors: Agro-industrial company and farmer organisation · Number of brokers: 2

Figure 2.3 Network structures associated to types of formal rules

Source: Based on author's own experience and fieldwork notes.

When comparing network structures for each type of formal rule, Figures 2.3a, b and c show differences between levels of size and interactions. These levels are affected, firstly, by the number of smallholders, agro-industries and farmer organisations participating in the CFAs and their mutual technical links, and secondly, by the active role of other actors outside the boundary of the CFAs. Since the CFA literature assumes that smallholders have limited economic resources, the scenarios in Figure 2.3 assumed that few producers are connected to other change agents.

Figure 2.3a of low agro-industrial control shows *Scenario 1* where there is poor provision of technical services by an agro-industrial company to smallholders, and therefore ‘weak’ links between these two actors. However, other information sources, some of which may be change actors, provide the total of technical services to both smallholders and the agroindustry, making a total of seven technical links. In the same figure, *Scenario 2* results from adding a farmer organisation to the previous scenario and the links this organisation has with producers and other actors (total number of links: 12). The scenarios in Figure 2.3a contrast with Figure 2.3b under a CFA of full agro-industrial control in which an agro-business company dominates the transfer of technologies to smallholders, and thereby the network technical relationships.

The notable distinction that exists between the scenarios in Figure 2.3a and the networks that result from partial agro-industrial control (Figure 2.3c), is the strength of links between smallholders and agro-industrial companies. In comparison to a scenario of full control, Figure 2.3c shows that smallholders have freedom to search for alternative change agents. Therefore, Figure 2.3c shows scenarios with higher numbers of important links transferring technologies to smallholders (four links in *Scenario 4* and six links in *Scenario 5*). By using these links, smallholders gain more access to technical support than in other scenarios due to the higher number of strong technical relationships. The significant assistance that exists in the networks of Figure 2.3c, in contrast to the other two, might support and, in turn, improve the levels of technology adoption of smallholders.

2. Central positions

Central positions are used to identify key actors within networks that control significant amounts of technical relationships or act as intermediaries. As with the other network elements, differences in central positions reflect differences in the types of formal rules. It was asserted in Sub-Section 2.3.3 that levels of governance determine levels of control in the decision-making processes. These levels of control can confer a leadership position in the network to those actors undertaking important responsibilities in the process of diffusion. Central positions detect these core actors.

As mentioned in Sub-Section 2.4.3, when referring to the impact of networks on technology diffusion, the strategic location of actors can exert important influence on other individuals' decisions. The element of central positions draws on the idea of some actors occupying pivotal positions in networks and taking advantage of that position to exert influence over others. Essentially, they can exploit their significant control over several connections, and their intermediation or brokering role amongst actors.

The concept of central position as intermediation was mainly developed by Freeman (1978) who used betweenness centrality to measure the extent to which a person establishes indirect connections between all other actors in a network. In emerging agribusiness clusters of developing countries, especially in those aiming to integrate smallholders, intermediation is a key function that facilitates the transfer of services and knowledge from relevant actors to producers and supports upgrading processes[10]. In the Peruvian mango sector, Ramirez et al. (2018) found that a public-private entity and a private producer organisation acted as key intermediary agencies that enabled clusters to access opportunities for upgrading. The public-private intermediary improved inter-cluster coordination whilst the producer organisation opened up upgrading strategies in different value chains and helped to build the capabilities of smallholders in export markets.

[10] The capacity of firms to increase production efficiency and added value activities by making sophisticated products and introducing sophisticated processes (Schmitz and Humphrey, 2000).

In addition to upgrading, intermediaries can also support producers' innovation processes. An innovation intermediary:

> 'help[s] to provide information about potential collaborators; broker[s] a transaction between two or more parties; act[s] as a mediator, or go[s]-between, for bodies or organisations that are already collaborating; and help[s] find advice, funding and support for the innovation outcomes of such collaborations' (Howells, 2006, p. 720).

In the developing agricultural context, this role has traditionally been attributed to agricultural extension agencies and, in several cases, to farmer organisations. Both actors establish bilateral or multilateral links between farmers and other key actors of agricultural innovation systems, such as research entities and technical advisors (Poulton et al., 2010; Barrett et al., 2012; Yang et al., 2014).

Additionally, intermediaries can enable roles of vertical coordination for service provision (coordination between smallholders and other actors at different levels in the value chain) and/or horizontal coordination (coordination between smallholders). The Dairy Farmer Business Association (DFBA), for example, was a farmer organisation in Kenya that opened up the clusters in the dairy sector to opportunities for radical changes by simultaneously facilitating both vertical and horizontal coordination (Kilelu et al., 2017). On one hand, this association linked producers to private dairy processing companies. On the other hand, it enabled collective action and linked farmers through horizontal coordination through which producers could access inputs and technical services in peer-to-peer exchanges.

In this research, we particularly highlight the role of intermediaries in supporting information and knowledge transfer. Intermediaries help in the effective production and use of knowledge by:

- articulating the needs and demands of producers regarding knowledge and technology, and voicing these demands to organisations in charge of technical support, research and training;

- supplying information for problem-solving and responding to farmers' needs; and
- engaging farmers and researchers in processes of knowledge co-production (Yang et al., 2014: 116)

In the area of agribusiness clusters, there is a range of studies that have increasingly underlined the roles of intermediation for knowledge transfer (see Poulton et al., 2010; Clarke and Ramirez, 2014; Yang et al., 2014; Mmari, 2015; Kilelu et al., 2017). The case study of Yang et al. (2014) shows the intermediation functions of three farmer organisations in China that aimed at producing high quality standards and introducing technology into farming practices. Funong Vegetable Cooperative organised training with experts from a Dutch company and developed technical regulations for organic greenhouse vegetable production following governmental standards. Tianly Vegetable Cooperative organised training with experts from the public extension agency regarding organic production and certifications. This cooperative also created vegetable bagging technology to improve the safety of greenhouse vegetables and promoted this technology with the support of the county Agricultural Bureau. Finally, Hongmim Farmer Cooperative developed technical regulations with the county Agricultural Bureau regarding non-pollution rice certification. In addition, this organisation organised training with local and regional extension agencies, and linked farmer agronomists in charge of technical support.

The central positions are evaluated in this research through centralisation and centrality measures. Centralisation refers to the degree to which a network revolves around a single actor (Wasserman, 1994) whilst centrality identifies those central actors that control a significant number of relationships (for sharing and/or for receiving information) and/or act as intermediaries between pairs or groups of actors. In other words, whilst centralisation and centrality are related, the former is measured at the network level, whereas the latter is an actor's characteristic.

This research will use the characteristic of central positions to identify those actors who, as a result of a specific type of formal rules, concentrate most information links and/or play an intermediation role between smallholders and other sources. The different scenarios in Figure 2.3 show the different central positions that originate due to different types of CFAs. Because of the hierarchical relationships and the dominant direction of diffusion within agreements (top-down governance) in agribusiness, emergent networks are highly centralised on a few leading actors.

A significant difference is especially noted between scenarios, including the participation of farmer organisations (Scenarios 2 and 5) and the scenario of high agro-industrial control (Figure 2.3.b). From all the scenarios presented, Scenario 5 stands out for its higher number of core actors (two) as well as for the higher influence of these central actors on smallholders through stronger links in comparison to other scenarios.

3. Brokerage beyond the group

The third structural aspect employed in this research and linked to central positions is 'brokerage beyond the group', which is used and explained by Ronald Burt (2005) in the following way. Brokerage has its basis in the theory of *the social capital of structural holes* developed by Ronald Burt (1992, 2000). Accordingly:

> 'holes in social structure – or more simply, structural holes – create a competitive advantage for an individual whose relationships span the holes […] Structural holes are an opportunity to broker the flow of *information* between people, and *control* the projects that bring together people from opposite sides of the hole.[…] Structural holes separate non-redundant sources of information (sources who do not share the same information), sources that are more additive than overlapping' (Burt, 2000, p.353).

Thus, structural holes are a current or potential separation (or weaker connection) between two contacts or subgroups with different characteristics.

While structural holes are the empty spaces between those different groups, 'bridges' are the connections between those groups and 'brokers' are actors spanning these structural holes. Through bridges or weak ties, brokers can increase the variety of knowledge, information and novel ideas because they are able to build effective connections between communities to which they belong (Granovetter, 1973; Burt, 2005; Kimble et al., 2010). On this basis, brokerage beyond the group refers to the brokering roles of actors and how well they create bridging ties between a particular group (e.g. community, family, team or neighbourhood) and other contacts. Referring to the role of brokering, Wenger (1998) asserts that:

> '[this job] is complex. It involves processes of translation, coordination and alignment between perspectives. It requires enough legitimacy to influence the development of a practice (...) it also requires the ability to link practices by facilitating transactions between them and to cause learning by introducing into a practice, elements of another' (p. 109).

An example of network structures with brokers and structural holes can be seen in the work of Spielman et al. (2011), which analysed the innovation process of Ethiopian smallholders. The author showed that NGOs were linked to local public agencies as well as to other actors beyond the immediate locality, for instance, research institutes and universities. These additional bridges were likely to bring new information.

Brokerage beyond the group may help to assess the effectiveness of central actors in connecting different sources of information to the group of smallholders in networks that originated from particular formal rules. The advantage of brokerage beyond smallholders enables farmers to be connected to different and additional sources of technology and information, such as subject-matter experts or input companies that would not otherwise be possible without these bridges. In this way brokers may also exert an important influence on the group of smallholders.

Unlike the studies of Monge et al. (2008) and Kilelu et al. (2017), this work makes a differentiation between intermediation and brokering roles. We consider that whilst brokers bridge the gaps between a pair or different groups of actors having different information and knowledge, intermediaries link a pair or groups of actors who may or may not share the same information. Hence, a broker is always an intermediary, but an intermediary is not always a broker.

Examples of intermediaries acting as brokers can be seen in the studies of Poulton et al. (2010), Yang et al. (2014), Kilelu et al. (2017) and Ramirez et al. (2018). The authors show how farmer organisations and extension agencies can facilitate the technology transfer between smallholders and different sources of knowledge such as technical experts and scientists. The study of Yang et al. (2014) in China (see p. 65) also shows that associated farmers of cooperatives acted as 'internal translators' between expert knowledge and complex farm-level realities, and everyday farming practice due to their rich experience in farming and familiarity with scientific language.

Again with reference to Figure 2.3, each case of formal rules shows a different number of brokers, as in the case of full and partial agro-industrial company control (Figures 2.3b and c, respectively). Unless there is a farmer organisation supporting the technology transfer, CFAs where the agro-industrial company has little control in crop management, it may not have brokers connected by strong links to smallholders (Scenario 1). The presence of two brokers (agro-industrial firm and farmer organisation) in the network of Scenario 5 indicates that smallholders can access different groups of information sources, and thus acquire more technical support in comparison to other scenarios.

Based on the hypothetical scenarios of Figure 2.3 and the impact of these scenarios on technology diffusion, we can say that different pathways of diffusion can be expressed in the form of different network structures. Within the innovation-diffusion literature, it is possible to find studies comparing different networks and drawing conclusions about different diffusion processes of agricultural technologies (see Wyckhuys and O'Neil, 2007; Monge et al., 2008; Spielman et al., 2011). For instance, Spielman et al. (2011) show that in Wemberma, Ethiopian smallholders depended on a small number of key actors to access inputs, credits and information. On the other hand, Ethiopian smallholders in Soro accessed technical and financial resources through a more diverse network that included public services, NGOs and research-oriented actors. Nevertheless, these works do not associate formal rules formalising some of the change agent-farmer interactions with structural patterns of networks.

In order to elaborate on the theoretical framework for centralised diffusion, Figure 2.4 shows the different variations of structural characteristics that a network can present as a result of variations in the component of formal rules.

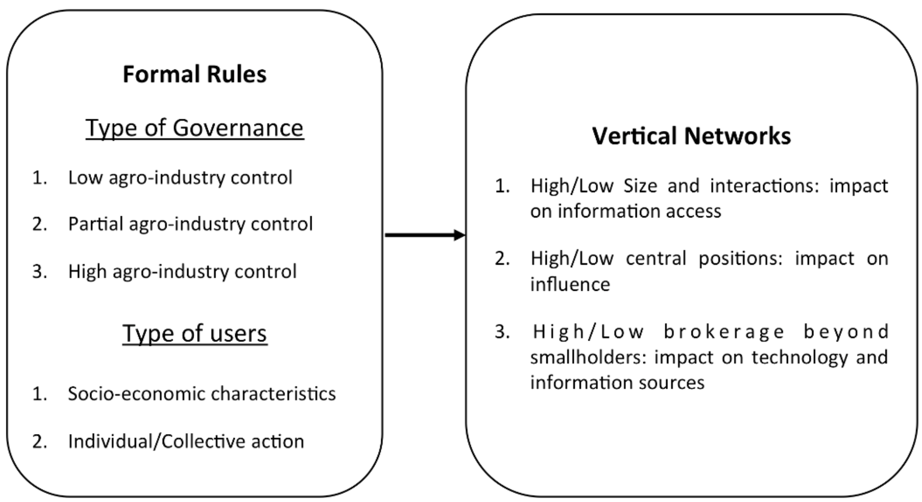


Figure 2.4: Variation of formal rules and vertical networks for centralised-diffusion of agricultural innovations

Source: own elaboration based on Key and Runsten, (1999), Burt (2005), Monge et al. (2008) and Spielman et al. (2011), Barrett et al. (2012).

After presenting the relationship between formal rules and networks, and explaining the structural characteristics to assess the network structures that originated from different types of formal rules, the next section will study which outcomes of technology adoption may result from the different scenarios of technology diffusion.

2.5 Technology adoption for diffusion within centralised-diffusion systems

Sub-Section 2.3.3 analysed the possible types of formal rules, and Sub-Section 2.4.4 explained the different scenarios of diffusion represented in network structures that may result from those agreements (Figures 2.3a, b and c) in centralised-diffusion systems. This section will focus on the way these different scenarios may affect the technology adoption of small-scale producers. It also aims to answer the third research question; how technology adoption can vary with the different pathways of diffusion, and how this impact can be considered separately in terms of long-term and short-term practices. It will be seen that, although the literature of innovation diffusion associates different pathways to levels of technology adoption, this relationship is not commonly studied according to the types or 'attributes' of agricultural practices, such as long-term and short-term practices.

The first part of this section explains the way network structures and technology adoption can be related, and the possible impact of these structures on the levels of adoption. From there, the second part of this section formulates the theoretical framework of this thesis.

2.5.1 Technology adoption within centralised-diffusion systems

Since Sub-Section 2.1.2 already gave a complete characterisation of technology adoption and its determinants, this part discusses adoption as a result of different pathways of the centralised-diffusion process. We use adoption as an *aggregate* term[11] that, according to Feder et al. (1985), 'is measured by the aggregate of a specific new technology within a given geographical a population' (p.256). In this study, as in the works of Wyckhuys and O'Neil (2007) and Díaz-José et al. (2016), levels of technology adoption are measured as the total number of users and non-users for each agricultural practice.

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[11] The other type of adoption that Feder et al. (1985) distinguishes is individual (farm-level) adoption, which they define as 'the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential' (p. 256).

The previous section argued that formal rules have an important impact on network structures (see Figure 2.4), which in turn may significantly influence the technology adoption of smallholders. Before examining the results of adoption that may result from possible scenarios of diffusion (Figure 2.3a, b and c), the way that networks and their structural characteristics are associated to technology adoption needs to be clarified.

Actors can have an influence on farmers' decision-making processes of adoption through network relationships. Rogers (2010) argues that individuals can learn of the existence of an innovation and gain an understanding of how it functions through communication networks. Continuing with this idea, he asserts that before decisions take place, a persuasion phase occurs in which individuals form a favourable or unfavourable attitude towards the use of an innovation. Through network relationships, actors are able to help farmers to become aware of an innovation and to persuade them (in terms of forming and changing attitude) to adopt and implement an agricultural practice.

Since the structures of these networks may be characterised in terms of three patterns, namely size and interactions, central positions, and brokerage, they may also affect the technology adoption of smallholders. Regarding size and interactions, studies from the diffusion literature show a positive association between this structural characteristic and technology adoption. Monge et al. (2008) and Spielman et al. (2011), for instance, show that in case studies of Ethiopia and Bolivia, respectively, the more the actors and interactions influence farmers, the more substantial the influence on farmers' decisions to adopt[12]. Darr and Pretzsch (2008) and Monge et al. (2008) suggest that this is explained by the greater access to information through frequent interaction, and large networks connecting farmers and linking agents with farmers.

As for central positions, well-connected actors can exert a significant influence on farmers' decisions regarding adoption by transferring valued resources from multiple sources.

[12] Exceptions to this positive association can be found in the work of Spielman et al. (2008), which shows that similar users and non-users from Solo (Ethiopia) exhibited similar social networks.

Rogers (2010) asserts that centralised structures are likely to accelerate the pace of diffusion thanks to the action of core actors to transfer information, knowledge or technological innovations. Studies in the literature of diffusion of agriculture show an ambiguous effect of this structural characteristic on adoption. Monge et al. (2008) suggested that if the majority of interactions were centred on a main agent, less noise would be evident in these relationships and adoption levels would be higher.

The study of Spielman et al. (2011) in Ethiopia showed that networks of users were more concentrated around a few core actors than in multiple contacts in networks of non-users. The authors argued that users had greater access to sources of knowledge, information and inputs than non-users, which provided them with greater support for adoption. Unlike this work, the study of Monge et al. (2008) in Bolivia showed that it was rather the multiplicity of contacts that influenced producers' decisions and stimulated adoption.

When examining brokerage beyond the group of smallholders, we can say that improvement in adoption levels was positively associated to high brokerage (multiple brokers linking smallholders and other groups of information and transferring resources to these farmers, see p. 66 for explanation of this term). The case study of Spielman et al. (2011) showed that various actors played a critical role as brokers by making a greater diversity of options in accessing resources available to Ethiopian smallholders.

After elaborating on the relationships between some structural characteristics and technology adoption, it is possible to have an insight into the levels of adoption that may result from some scenarios of diffusion (Figure 2.3a, b and c). Turning to Figure 2.4, it is indicated that at least three types of formal rules (i.e. low control, partial control and high control) can have an influence on three types of structural characteristics, which subsequently impact on smallholders' adoption in different ways. For example, the scenarios in Figure 2.3a showed that unless a central actor intervenes in the provision of inputs and technical services, as occurred in Scenario 2 with the participation of a farmer association, a CFA of low control may have fewer strong interactions (low size and interactions). They may also have fewer central actors (low central positions) and brokers (low brokerage) than scenarios led by other agreements. As a result, there may not be any guarantee that necessary information and technical assistance from central or different sources will become accessible to all smallholders. Following the impact of structural characteristics on technology adoption, it is likely that the poor access of information in this scenario diminishes smallholders' adoption of most agricultural practices.

In the contrasting case of partial control, where both an agro-industrial company and other agents participate in a CFA (Figure 2.3c, Scenario 5), smallholders may gain high technical support in the implementation of most agricultural practices. Figure 2.3c implies that more than one central actor and more than one broker transfer information from other sources to smallholders through their multiple and strong interactions. Unlike Scenario 2, the significant access to information and technical support would entail an increase in adoption levels for most types of agricultural practices.

As was seen in Sub-Section 2.1.2, different agricultural practices may not receive the same technical support and attention during a process of technology diffusion and, thereby, do not have the same levels of adoption. According to the immediacy of rewards, one of the attributes of innovations (see Table 2.1), innovations can be 'preventive' or 'incremental'. Rogers (2010) defines this attribute in the following way:

> 'A *preventative innovation* is a new idea that an individual adopts now in order to lower the probability of some unwanted future event. The desired effect is distant in time […] In contrast, an incremental (that is not preventive) innovation proved a desired outcome in the near-term future' (pp. 233-234).

Following a similar conceptualisation, the types of agricultural innovations can be categorised according to their immediacy of reward, for example, as *short-term practices* and *long-term practices*. The first group of practices refers to agricultural technologies that are implemented after a stress occurs, for instance treatments for pest and disease. The results in this case are generally expected in the short term.

The second group of practices refers to agricultural technologies that are intended to guarantee the long-term development, growth and yield of agricultural crops. These practices are periodically adopted by producers and final results are not usually seen straight away. This category groups the following practices: water management, fertiliser use, crop protection, soil management and prevention practices of pest and disease management. Failure in implementing preventive practices may reduce the 'agricultural sustainability' of the crop in terms of what Hansen (1996) interprets 'as the ability to continue' (p. 119)[13]. Under agricultural sustainability, Conway (1985) asserts that 'Sustainability is the ability of a system to maintain productivity in spite of a major disturbance, such as is caused by intensive stress or a large perturbation' (p. 35). Complementing this concept, Hamblin (1992) argues that:

> 'Agriculture is sustainable when it remains the dominant land use over time and the resource base can continually support production at levels needed for profitability (cash economy) or survival (subsistence economy)' (quoted in Hansen, 1996, p. 119).

This implies a long-term vision and, therefore, the use of long-term practices.

The literature on diffusion of agricultural innovations, and especially network studies, helps to understand the effect of the structural characteristics of networks on adoption. However, except for the works of Wyckhuys and O'Neil (2007) and Díaz-José et al. (2016), this literature does not commonly link the different information sources of farmers with their levels of adoption according to the different attributes of agricultural practices. These studies used SNA measures to evaluate structural characteristics (e.g. interactions and central actors) in the adoption of agriculture practices. The study of Díaz-José et al. (2016), developed in the Mexican maize sector, indicated that although farmers were linked to diverse sources of information, the adoption of most practices was influenced by

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[13] This is one out of the four interpretations of agricultural sustainability identified by Hansen (1996). The other three interpretations are sustainability *as an ideology*, *as a set of strategies* and *as the ability to fulfil a set of goals*.

their communication channels with other peers. The authors show that a few practices, such as the application of bio-fertilisers and use of quality seeds, were significantly influenced by the links farmers had with a research institute and input suppliers, respectively.

Although previous studies related various information sources to different types of practices, they do not classify the adoption according to the attributes of these agricultural practices, such as their immediacy of reward. From this literature, it is difficult to draw conclusions about the tendency of certain structures and central actors to favour the adoption of short-term and long-term practices, which composes the second part of the third research question of this thesis. The next sub-section will build a potential framework that allows this research to explore this gap in the literature.

2.5.2 Theoretical framework for centralised-diffusion systems

Based on the types of formal rules, the characteristics of network structures and the variation in levels of technology adoption that were discussed in this chapter, it is argued that a variety of narratives potentially explaining divergent paths of technology diffusion may emerge in centralised systems. Figure 2.5 displays a potential framework that will help to explore these elements to be considered in centralised systems, as well as its variations and mutual connections. This suggests that the centralised-diffusion systems that are characterised as a linear relationship between experts and farmers, as is found in the literature on diffusion of agricultural innovations (see pp. 28-29), can be critiqued and variations presented.

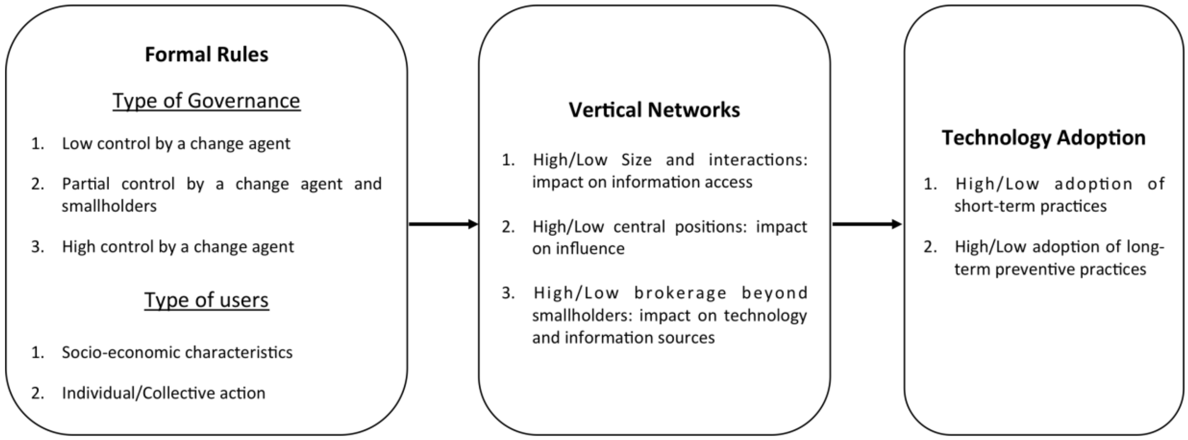

Figure 2.5: Theoretical framework for centralised-diffusion systems in agriculture

Source: Own elaboration based on Key and Runsten, (1999), Burt (2005), Monge et al. (2008), Spielman et al. (2011) and Barrett et al. (2012).

The first element of the theoretical framework is formal rules. From the literature of global value chain (GVC) and contract farming arrangements (CFAs), three possible types of governance establishing the control and participation of actors in the crop management and technology-diffusion process were identified. These types of governance are: *Low control by a change agent*, *partial control by a change agent and smallholders*, and *full/high control by a change agent*. They can introduce significant distinctions between pathways of diffusion. Formal rules may also determine the selection criteria of smallholders participating in these agreements based on their socio-economic characteristics and their way of acting (e.g. individually or collectively).

The three types of formal rules can result in vertical networks with varying levels of size and interactions, central positions and brokerage. Each of these characteristics has a different impact on technology diffusion towards smallholders. With high size and interactions, smallholders gain more access to information and technologies, and *vice versa*. In the case of central positions, the effects are related to the levels of influence that a small number of change agents can exert on smallholders' decisions about crop management. And finally, brokerage beyond the group of smallholders may enable the assessment of the brokering roles of actors and the way these brokers facilitate the access of farmers to information and technical support from different information sources.

These particular network structures are expected to impact on technology adoption, which is the final stage in this framework. As in the cases of formal rules and network structures, variations also exist in the levels of technology adoption of different types of agricultural practices. Based on the attribute relating to the immediacy of reward in agriculture, the framework aims to explore the impacts on both short-term and long-term practices. The theoretical framework will be tested later in the empirical evidence.

2.6 Summary of the Chapter

This research seeks to contribute to the innovation diffusion literature and is concerned with how different diffusion pathways of agricultural practices emerge in the context of predominantly top-down governance. It argues that multiple pathways are possible due to the different types of formal rules and network structures and their impact on technology adoption. The research is guided by three research questions; to help answer them the innovation-diffusion literature is bridged to the literature of social capital and contract farming arrangements (CFAs). In the social capital literature, this research considers that formal rules and social networks are key sources of social capital that are useful for processes of innovation diffusion in centralised-diffusion systems. Particularly, this thesis conceptualises formal rules from the institutional approach of arrangements made by Williamson (2000), where parties agree contracts through a private transaction, and the social capital theory by which these rules underpin mutual expectations and values.

The first research question is related to the way types of formal rules are associated to different pathways of technology diffusion. In the literature on diffusion of agricultural innovations, the importance of formal rules between actors within highly centralised models of diffusion and the effect of variants of these rules on technology-diffusion processes, have been little studied. In order to explain the role of formal rules, this research used the interpretation of social capital by which formal rules are considered a source of social capital that create long-term commitments amongst actors of centralised-diffusion systems.

This research argues that agreements formalise a hierarchical relationship of technological transfer between small-scale producers and leading actors. These formal rules take the form of CFAs between small-scale producers and change agents that are essential for them to work and perpetuate their technical relationships. Three types of formal rules were identified: low agro-industrial control, partial agro-industrial control, and high agro-industrial control.

The second research question is related to the different processes of technology-diffusion that result from network structures affected by the types of formal rules. This chapter employed the works of Adler and Kwon (2000), Lin (1999), and Salancik (1995) in the theory of social capital to explain the fact that formal rules can influence or inhibit technical relationships between the parties of an arrangement and, therefore, shape particular network structures. Structural characteristics, such as network size and interactions, central positions and brokerage, were used to characterise the different network structures corresponding to each type of formal rule.

The third research question is related to the outcomes of multiple diffusion pathways in terms of technology adoption. The different processes of technology-diffusion may have consequences on the levels of technology adoption in aggregate terms and those consequences can have a separate impact on short-term and long-term practices.

In addressing these research questions, a theoretical framework for centralised models of diffusion in agriculture is proposed. This framework features three core elements: formal rules, vertical networks, and technology adoption. By considering the variations of these three elements and the relationships between them, it is possible to build potential pathways of diffusion that need to be tested empirically; this will be seen in Chapters 5, 6 and 7. This contrasts with the narrow assumptions of Knickel et al. (2009), Roeling (2007), and Rogers (2010), whose innovation-diffusion framework constricts the ability to explain diverse outcomes of technology adoption in predominantly centralised settings.

CHAPTER 3

TECHNOLOGY DIFFUSION IN THE COLOMBIAN OIL PALM SECTOR AND IN THE MANAGEMENT OF THE BUD ROT DISEASE (PC)

This chapter outlines the context for the process of technology diffusion in the Colombian oil palm sector during the epidemics of *Bud Rot disease* (PC for its Spanish acronym). The chapter starts by providing an overview of the oil palm agroindustry and its centralised nature. After this, the following section describes the roles of actors in the Colombian oil palm sector and their participation in the transfer of technology to small-scale producers. The third section explains the nature of the PC and reviews the epidemics caused by this disease, mainly in the north-east of Colombia. It also mentions some of the socio-economic consequences of this epidemic for oil palm smallholders. Finally, roles of sectoral actors facilitating diffusion processes during the epidemic are examined, as well as the problems that interfered with these processes.

3.1 Overview of the oil palm agribusiness and roles of actors in diffusion processes

The agricultural phase of the oil palm agribusiness includes the cultivation and fruit processing stages. The description of these stages and smallholder schemes for production help to identify particularities of the technology diffusion as a centralised system in this sector; it also helps to distinguish the main actors that are involved in the process.

The first stage in the agricultural phase of oil palm is the production of fresh fruit bunches (FFB). Oil palm is a perennial crop that provides year-round and predictable yields over a commercial life span of approximately 25 years; there is a long lead-time of 2-4 years between planting and the first productive harvest (Bernal, 2001). Good agricultural practices and technology adoption can accelerate the productive harvest process and increase the levels of productivity further than the average oil palm crop (Arias et al., 2009). FFB of oil palm that is produced in this stage are transported to, and processed in, a mill where the extraction of crude palm oil, the main commodity of this agroindustry, takes place.

The brief description of the agricultural phase of oil palm shows that growers and oil palm processing mills are the main participants in the agro-industrial stage. Growers and processing companies are closely related through a commercial bond for the marketing of FFB. Ideally, this agribusiness needs a minimum cultivated oil palm area within a maximum distance from the plantations to the processing mills in order to: 1) lower transportation costs and achieve economies of scale, and 2) keep the good quality of the palm oil after the harvest[14]. As such, growers are commonly found within a close geographical distance of palm oil mills.

Although the commodity production of oil palm benefits from economies of scale and large areas, small-scale producers are also involved in this agricultural process. The website Rspo.org (2017) defined small-scale producers of oil palm as farmers controlling 50 hectares or less of cultivated area who grow oil palm and other staple crops, whose family provides the majority of labour, and whose farm is the principal source of income. RSPO.org also determined that medium-scale plantations have more than 50 and less than 200 hectares of land, and large-scale plantations have more than 200 hectares of land. This work acknowledges that there is a significant variation of landholdings and that the majority of smallholders control much less than 50 hectares in other agricultural crops. However, we agree with Fernandez-Stark et al. (2012) and Ramirez et al. (2018) that the definition of scale (small, medium and large) varies from one sector and product to another, and producers require different support according to their levels of development. Amongst all the factors that describe small-scale growers in the oil palm sector, this

[14] Processing of FFB produced in growers' plantations should take place within a maximum of 48 hours after harvesting to prevent deterioration of the palm oil quality (Bernal, 2001).

research uses size as the defining aspect of smallholders and, as such, reflects the reality of small-scale producers in Colombia in a much better way.

The participation of smallholders in this agribusiness is hindered by market imperfections. The first and more important requirement in oil palm production is related with high upfront investment for establishing a plantation (planting, clearing and, in some cases, land acquisition and the building up of the infrastructure[15]). For that massive upfront investment, most smallholders´ income does not yield sufficient surplus to provide start-up capital and cover economic costs for the first stages of cropping[16]. In addition to these obstacles, smallholders often have difficult access to credit due to their lack of collateral (FSG Social Impact Advisors, 2010).

Another requirement for oil palm production is the access to information and technical assistance regarding all stages of crop management, pest and disease management, environmental instabilities of the crop, and certification systems. Information is required, for example, to acquire quality planting material for high yielding trees and for careful husbandry during oil palm cultivation (McCarthy, 2010). Gert Vandermissen of Siat, a company involved in strengthening supply chain conditions for oil palm, quoted by FSG Social Impact Advisors in 2017, highlighted how the issue of having quality seeds material is critical and said, 'If you use cheap material, you lose for 25 years' (FSG Social Impact Advisors, 2010, p.11). Technical support is even more fundamental when dealing with pests and diseases, which can be a limitation and a situation of high risk for producers.

The costs associated with obtaining information about the certification requirements, as well as the cost of the certification itself, are also likely to be beyond the means of

[15] In rural areas of developing countries like Colombia, there is poor public investment in road networks; this makes the efficient transportation of FFB to the mills difficult.

[16] Even after the first harvest, production is not sufficient to cover economic costs. According to Arias et al. (2009) and Bernal (2001), producers can reach the equilibrium point of their business (total revenues equal costs) from the seventh to the ninth year. This depends on the adoption of good agricultural practices by producers that allow them to have high yields, pay their financial obligations and make a profit from the agribusiness.

smallholders. The most widespread initiative for oil palm is the RSPO certification that requires the oil palm production to be environmentally sustainable and socially responsible (Rspo.org). This demands high information, additional economic resources to buy expensive inputs (e.g. high-quality seedlings) and equipment (e.g. clearing machines), and a high degree of organisation of smallholders (Potter, 2015). Thus, the activity normally requires large initial investments, which smallholders cannot usually undertake without financial support.

Despite the market imperfections, there are a significant number of smallholders engaged in the sector. Rspo.org (2017) confirms that smallholders account for around 40% of the global palm oil production. In countries like Indonesia and Malaysia, the largest producers of oil palm in the world, smallholders own 42% and 35% of the total oil palm area, respectively (Daemeter Consulting, 2015; Ismail et al., 2015). According to McCarthy (2010), Lizarralde (2012), Beekmans et al. (2014) and Ismail et al. (2015), the considerable participation of smallholders in the world production of oil palm can be explained principally by managed schemes. These schemes are key factors that help small-scale producers deal with market imperfections.

Contrary to independent producers who are free to choose how to develop and manage their plantations, a smallholder scheme refers to small-scale producers that are often structurally bound by a contract to an agro-industrial firm or processing mill company (Rspo.org, 2017). Under these arrangements, agro-industries assume different responsibilities, such as payment of costs for setting up smallholdings, facilitation of credits and loan repayments, and provision of quality inputs and technical assistance during planting and crop management. Despite these benefits, these arrangements involve risks for small-scale producers; for example, they may increase the dependency of smallholders on agro-industrial firms and their services or increase the possible asymmetries with regard to power and knowledge (Bitzer and Bijman, 2014).

With particular arrangements, particular ways of technical assistance and centralised diffusion emerge. Two types of smallholder schemes can be found in oil palm production: Nucleus Estate Schemes (NES) and CFAs. The former is an arrangement between a nucleus estate and smallholders. The nucleus estate is a private or state-owned company with an integrated processing mill that gains access to community land on a leasehold basis and develops the oil palm cultivation for smallholders. Compared to NES, contract agreements do not involve land transfer and reduces the control and responsibilities of agro-industrial firms over the smallholder crop management. NES and CFAs establish a formal relationship between an agro-industrial company and smallholders and a different level of governance between participants, which is consistent with the GVC and CFA typologies presented in Sub-Section 2.3.3. Both schemes enable smallholders to access resources (seedlings and other inputs, knowledge, technical assistance, training and financial resources) and to secure a market for their harvest at a negotiated price (Beekmans et al., 2014).

As can be seen, production schemes are characterised by the significant role that agro-industrial companies play in the technology transfer. Since these companies are essential sources of knowledge and technology, smallholder schemes can be considered as centralised-diffusion systems.

Actors belonging to the organisational and institutional context of the oil palm sector are also complementary sources of information that can support the process of technology diffusion. For example, members of producer associations interviewed during the fieldwork explained that farmer organisations hold certain responsibilities in the agreements (e.g. fruit collection and transportation), help to reduce input costs and, sometimes, provide technical support to their members. Some other actors include farmer cooperatives, research centres, academic institutions, governmental entities, international organisations, social organisations, and agro-input companies. The institutional context is influenced by government policies and sectoral regulations affecting the technology-diffusion process (Mosquera et al., 2009; Bernal-Hernández, 2010; FSG Social Impact Advisors, 2010).

To summarise, this section shows that the market imperfections impeding the participation of smallholders in the oil palm agribusiness can be tackled by adopting different schemes for production. These schemes were characterised as having different levels of control by an agro-industrial company, thereby a different level of centralisation in diffusion processes. The next section explains the schemes for smallholder production and the roles of particular actors contributing to the technology-diffusion processes that exist in the Colombian oil palm sector.

3.2 The process of technology diffusion in the Colombian oil palm sector

This section explains the particularities of the oil palm sector in Colombia, the features of the related technology-diffusion process and the roles of particular actors in this process.

3.2.1 The oil palm agribusiness in Colombia

Colombia is the largest palm oil producer in Latin America and the fourth largest in the world. Despite this high position, Colombia is a considerable distance from the world leaders: Together Malaysia and Indonesia produced 85.3% of the world palm oil in 2015, whilst Colombia only produced 2% (Fedepalma, 2012 and Fedepalma, 2016)

Figure 3.1 shows the regional distribution of the planted area of oil palm in Colombia. The oil palm sector classifies this area in four zones: Southwest zone, Eastern zone, Central zone[17] and Northern zone. The index case is located in the Central zone.

[17] For more geographical accuracy, this zone corresponds to the north-eastern region of Colombia.

Colombia in the world

Central zone

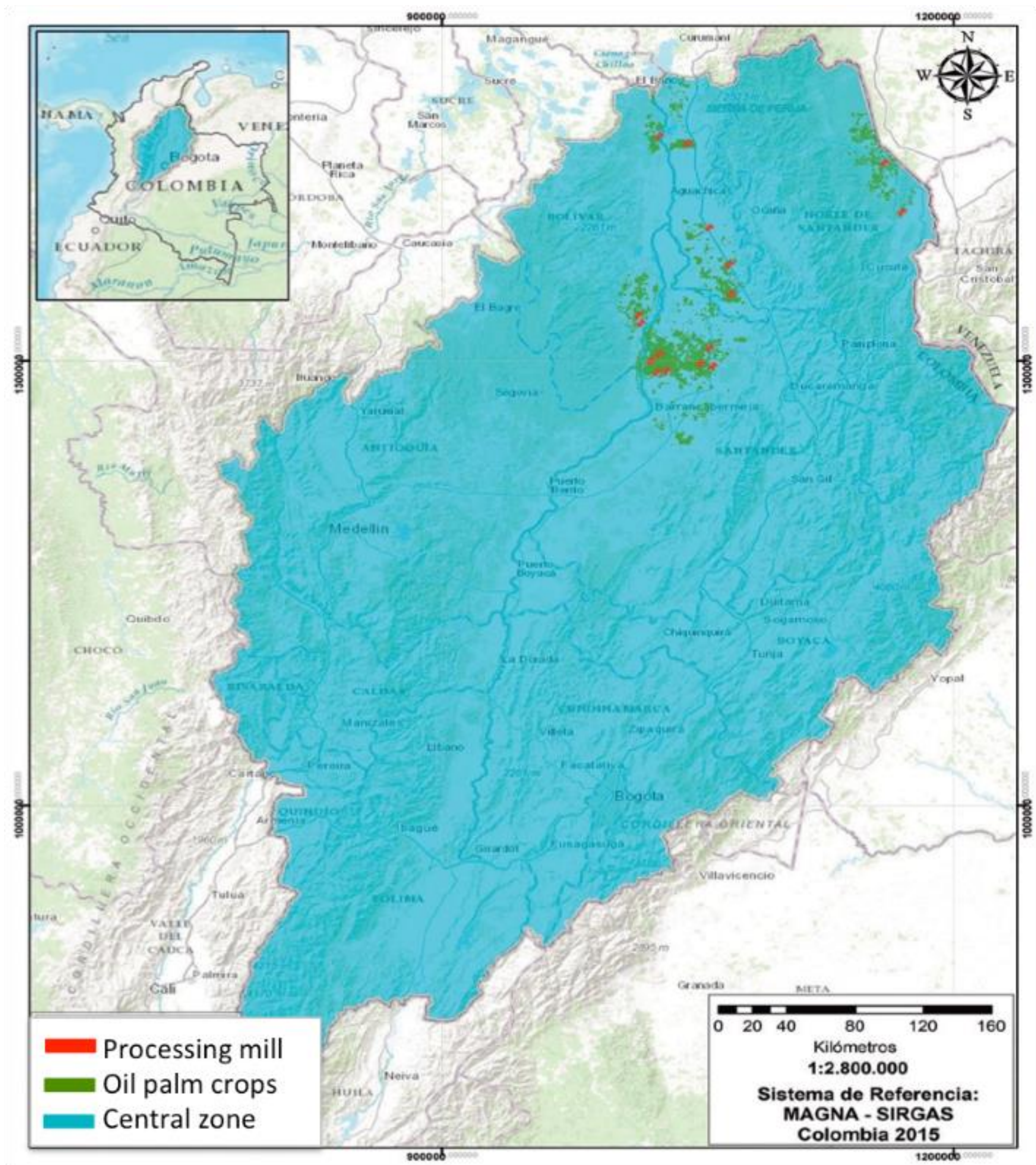

Figure 3.1: Map for geographical localisation of the index case

Source: Commons.wikimedia.org, (2011) and Fedepalma (2016)

With respect to oil palm cultivation in Colombia, Mosquera et al. (2012) reported that the planted area had increased rapidly in the period from 1982 to 2012, at an annual growth rate of 7.2%. Since 2012, the trend changed dramatically and the planted area increased at a yearly growth rate of 3.5% for four years. According to Fedepalma (2016), this is widely attributed to the presence of diseases in south-west and north-eastern regions in Colombia that caused a negative growth of the immature area of oil palm cultivation (-9.5%).

Regarding its economic importance, oil palm production accounted for 4.2% of the agricultural gross domestic product (GDP) in 2016 (Fedepalma, 2017). Although this participation is relatively small, it has increased over time from less than 0.1% in the 1960s to more than 4% in 2016 (Mosquera et al., 2012). This figure does not capture the full economic impact of the agro-industry on the rural communities inhabiting regions of oil palm crops. A general shared view across interviewed producers and representatives of agro-industrial firms was that the development of the oil palm agribusiness was accompanied by the development of the region itself in terms of the creation of employment, the building of infrastructure, and economic dynamism in urban areas.

An important cause of the expansion of the planted area was the integration of smallholders into the process of oil palm production. Although large-scale growers own the major planted areas of oil palm, the area cultivated by smallholders had an important increase over almost 15 years. Table 3.1 shows that the area planted by smallholders increased rapidly from 1997 to 2011, at an average annual growth rate of 4.5%; this was considerably different from the growth of areas planted by medium-scale producers, and is almost four times the growth rate of large producers. In the Central zone where this study took place, 20% of the area was distributed among 2,331 smallholders in 2011, representing 87% of the total producers in the region (Fedepalma, 2011).

Table 3.1: Distribution of planted area of oil palm according to plantation size

Scale range (ha)	Year 1997	Year 2011	Growth rate of planted area (%)
	Area (ha)	Area (ha)	
0 to 50 (small-scale producers)	2,307	51,121	4.5%
51 to 200 (medium-scale producers)	192	57,044	2.7%
More than 200 (large-scale producers)	254	283,022	1.3%
TOTAL	2,753	391,187	--

Source: National Census of Oil Palm in Colombia (Fedepalma, 1997 and 2011)

3.2.2 Participation of small-producers in the Colombian oil palm agribusiness

In Colombia, large, medium and small-scale producers participate in the oil palm agro-industry through a naturally developed ‘nucleus scheme’. Under these schemes, oil palm agro-industrial firms and processing mills, also called ‘anchor companies’, purchase the oil palm fruit from surrounding plantations and facilitate technologies to members of the nucleus (Hinestroza Córdoba, 2010). According to Alcibiades Hinestroza (officer of Fedepalma), and observations from fieldwork, these fruit providers may belong to independent producers, members of ‘productive and strategic alliances’ (also called ‘allied producers’), and members of farmer associations (A. Hinestroza, personal communication, 2 February 2015).

The increasing participation of smallholders has mainly been facilitated through the ‘productive and strategic alliances’ scheme. According to Web.fedepalma.org (2017), these schemes are formal arrangements (or ‘win-win schemes’) that are negotiated between small-scale or medium-scale producers. They are a source of funding, for example agro-industrial firms, in which:

a) agribusiness firms guarantee the purchase of fruit from producers at the international based price of FFB[18], make efficient use of their processing mills by increasing the volume of FFB to be processed, and benefit from subsidies provided to smallholders by the Colombian government, for example, the Rural Capitalisation Incentive (ICR for its Spanish acronym)[19]; and

b) farmers ensure the sale of FFB, acquire technical assistance for crop management and have access to the ICR (FSG Social Impact Advisors, 2010; Minagricultura.gov.co, 2017).

Regarding the technical advantage that strategic alliances offer to small-scale producers, Fedepalma et al. (2010) indicated that in these schemes, anchor companies were committed to sharing knowledge, providing agricultural inputs (e.g. certified seeds and fertilisers) and equipment, and providing sustained technical assistance. Among this assistance, these companies must also promote campaigns of phytosanitary prevention and control of diseases and pests among producers of their nuclei (Fedepalma et al., 2010). Smallholders commit to complying with these technical recommendations and to repaying the costs of the services and technologies with the income from harvest sales.

The high participation of smallholders in alliances and the increase of oil palm crops developed under these productive structures in Colombia illustrate the significant role of this production scheme in the integration of small-scale producers to oil palm sector. Table 3.2 shows that 65% of the total number of smallholders belonged to a productive alliance. This population owned 62% of the total of area planted by small-scale producers. Additionally, alliances experienced an important period of expansion between 2000 and

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[18] Although Colombian agro-industrial firms adhere to the Bursa Malaysia Market and the Argentinian soy market to estimate the FFB price, it is the additional benefits that are offered to smallholders (e.g. a transport subsidy) that determine the differences in value received by producers in different clusters. Subsequently, this has a large impact on smallholders' choice of buyer.

[19] ICR was a government subsidy that covered a percentage of the planting and initial stage of cropping. According to the head of Fundepalma, the ICR paid up to 40% of the cost of agricultural activities during 2002.

2010 when the area planted by these schemes increased from 2,110 to 64,289 hectares; this represented a participation of 1.4% to 15.9% of the total planted area of oil palm in Colombia, respectively (Castro, 2012).

Table 3.2: Participation of smallholders in oil palm alliances in 2011

	Total smallholders	Members of alliance	Non-members of alliance
Population (number)	4,367	2.846	1.521
Distribution (%)	100%	65%	35%
Area planted by smallholders (hectares)	50.726	31.511	19.215
Distribution (%)	100%	62%	38%

Source: National Census of Oil Palm in Colombia (Fedepalma, 2011)

In the Central zone, smallholders participate in the oil palm agribusiness as independent producers, members of farmer associations, or productive alliances. The strategic alliances scheme has significant participation in oil palm cultivation. According to Alcibiades Hinestroza, about 69% of the central zone is planted by members of alliances that include small and medium-scale producers (A. Hinestroza, personal communication, 2 February 2015).

In addition to alliances, NGOs were also involved in structuring associative schemes for oil palm production in this zone. This is the case of the social organisation, Fundepalma, that promotes associative projects for oil palm production with smallholders (Marlin, 2010).

3.2.3 Participants in the technology diffusion process

The process of technology diffusion in the Colombian oil palm sector is mainly facilitated by anchor companies. According to Alcibiades Hinestroza and fieldwork observations, agro-industrial companies or mills, to which farmers often sell the FFB, usually support the majority of these farmers. This occurs whether or not smallholders negotiate a CFA. In the case of independent producers, Hinestroza affirmed that the market relationships between farmers and agro-industrial companies sometimes re-create an organisational condition in which the latter regularly collect basic technical information and provide technical services and credits if required by producers.

Marketing and technical relationships between smallholders and anchor companies are also influenced by a factor that is known in the sector as *loyalty* of fruit provision[20]. This refers to the consistent sale of the oil palm fruit to the same agro-industrial company. This aspect implies more of a trust-based relationship than legal commitment that regulates the side-selling of fruit by smallholders to alternative buyers outside of an official agreement. *Loyal producers*, who do not side-sell the harvest, ensure that the anchor company within the arrangement keep providing them with technical services.

The channels of communication between anchor companies and smallholders, through which the former provided regular technical assistance to the latter, were further exploited by Fedepalma and Cenipalma for technology diffusion. With the aim of building up these channels and improving the technical assistance in nuclei, agro-industrial firms, Fedepalma devoted efforts to strengthen technical units of anchor companies that support smallholders' crop management in the oil palm zones. One of these efforts was the promotion of the Technical Assistance and Auditing, Environmental and Social Units (UAATAS for its Spanish acronym), which are entities responsible for technical support and provision of extension and training services to producers organised in a nucleus scheme. These units were located within anchor companies with the goal of applying one-crop management criteria in their own areas and in the areas of fruit providers. Each UAATAS is established on the basis of particular needs in a nucleus regarding crop management and, primarily, the prevention and control of diseases and pests (Hinestroza Córdoba, 2010).

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[20] A large number of interviewed individuals in the sector (e.g. producers, agro-industrial companies, staff from Fedepalma and Cenipalma, social and farmer organisations) commonly used the term 'loyal producers' during the fieldwork.

Technical units within nucleus schemes help to optimise efforts of technology transfer in the sector. According to several interviewees, such as staff of Cenipalma, Fedepalma and agro-industrial companies, the high volume and geographical dispersion of smallholders require that technical units of anchor companies act as intermediaries of technology transfer between other sectoral actors and smallholders. These units also collect information that enables public and sectoral institutions to make good decisions regarding the smallholders' crop management.

Agro-industrial companies, whilst essential, are not the only actors that contribute to the process of technology diffusion involving smallholders in the Colombian oil palm sector. Farmer organisations, for example, also help smallholders to acquire inputs and equipment as well as to mediate in the technology diffusion. Interviewed members of associations and academic studies indicated that collective action in the Central zone mostly aimed to finance inputs and equipment, to share operational expenses (e.g. fruit harvesting, collection and transportation), and to obtain government subsidies and funding from NGOs (Bernal-Hernández, 2010; Ramirez et al., 2014). A few associations, such as Asopalcentral, Asopepa and Asobenpro, supported training by mediating between relevant entities and smallholders.

Another key actor supporting the processes of technology diffusion is Fedepalma: this federation group represents, and defends oil palm growers' interests (Web.fedepalma.org., 2017a). In terms of technology diffusion, Fedepalma have performed two central functions. First, it created Cenipalma in 1991 for the research and development of technical practices related to oil palm production. Second, it implemented and supported strategies for the promotion, organisation, certification and development of UAATAS (Hinestroza Córdoba, 2010).

Cenipalma is a scientific and technical organisation in charge of the production, adaptation, validation and transfer of technologies for the cultivation and processing of oil palm. Even though this entity has important financial resources[21], it does not have the logistical capacity to reach all smallholders within the regions. Interviewed researchers of Cenipalma stated that in order to reach as many producers as possible, this research centre provided assistance to technical departments and UAATAS, who in turn transfer this knowledge to smallholders within nuclei. In addition, the centre adopts a *producer-to-producer* strategy through which it generates a 'contagious' effect around selected leading producers.

Government entities also contribute to the process of technology diffusion by providing funding, establishing a legal framework and delivering technical training services. Three important government institutions that were often mentioned by interviewees were the Ministry of Agriculture and Rural Development (MADR for its Spanish acronym), the Colombian Agriculture and Livestock Institute (ICA for its Spanish acronym), and the Colombian Vocational Training Agency (SENA for its Spanish acronym).

MADR, for example, establishes regulations for funding and subsidies that address the technical assistance for agricultural producers. Some of the main regulations[22] include the Law 607, 2000 and the Resolution 145, 2015 that help smallholders to acquire high quality services and thus create communication channels between technical agencies and producers (Minagricultura.gov.co, 2000 and 2015).

The ICA supports the prevention of diseases and phytosanitary control in agricultural sectors and develops applied research to manage risks to plant species (Ica.gov.co, 2017). In the Central zone, the ICA established regulations for technical assistance and sanctions related to the enforcement of mandatory procedures for the management of pests and diseases in the oil palm sector (e.g. the *Resolution ICA*, *2009*, and the *Resolution ICA 4170,* 2014) (ICA, 2014 and 2014a).

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[21] This centre is funded with public resources collected from the oil palm sector and other national and international entities (Web.fedepalma.org, 2017b).

[22] Other governmental regulations related to technical assistance are resolutions 140, 217 and 177 of 2007; 026, 303, 336 and 360 in 2008; 406, 208, 161 and 396 in 2009 (Minagricultura.gov.co).

SENA is a public organisation in charge of enhancing the technical capacities of the population (SENA, 2017). According to interviewed smallholders and Cenipalma staff, this entity develops programmes and alliances for vocational training through which actors such as Cenipalma and Fedepalma can transfer knowledge and information.

Other actors supporting the process of technology diffusion are social organisations and input companies. In addition to social projects, some social organisations assist in the development of oil palm production schemes and support smallholder training. This was the case of the organisations Fruto Social de la Palma (FSP) and Fundepalma in the Central zone. Concerning input companies, fieldwork evidence of this research and works developed by Bernal-Hernández (2010) and Ramirez et al. (2014) indicated that these actors inform and train smallholders in the use of their products for technology adoption.

Finally, international entities also help in the diffusion process by sharing technical information and carrying out training sessions with oil palm smallholders. For example, the United States Agency for International Development (USAID) and the Common Fund for Commodities (CFC) implemented projects and programmes addressed particularly to oil palm smallholders. The USAID financed the MIDAS programme[23] through which it adopted the model of Farmer Field Schools (FFS) for participative training. In the case of the CFC, this intergovernmental institution financed the project 'Bridging productivity gaps of small-scale oil palm growers', in which a *producer-to-producer* strategy was implemented (Fedepalma, 2010).

The following figure gives an overview of the main actors having an important influence on the centralised-diffusion process of technologies around smallholders.

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[23] MIDAS was a programme implemented between 2006 and 2009 by USAID. It supported the government project of productive alliances in order to provide technical assistance, ensure the disbursement of credits, enforce producer organisations and support the sustainable development of these alliances. Molano (2008) asserted that, amongst other characteristics, productive strategic alliances had to be articulated with the private sector or social organisations to acquire this support. In this specific case, the leadership of anchor company B was crucial for the nucleus to receive USAID assistance.

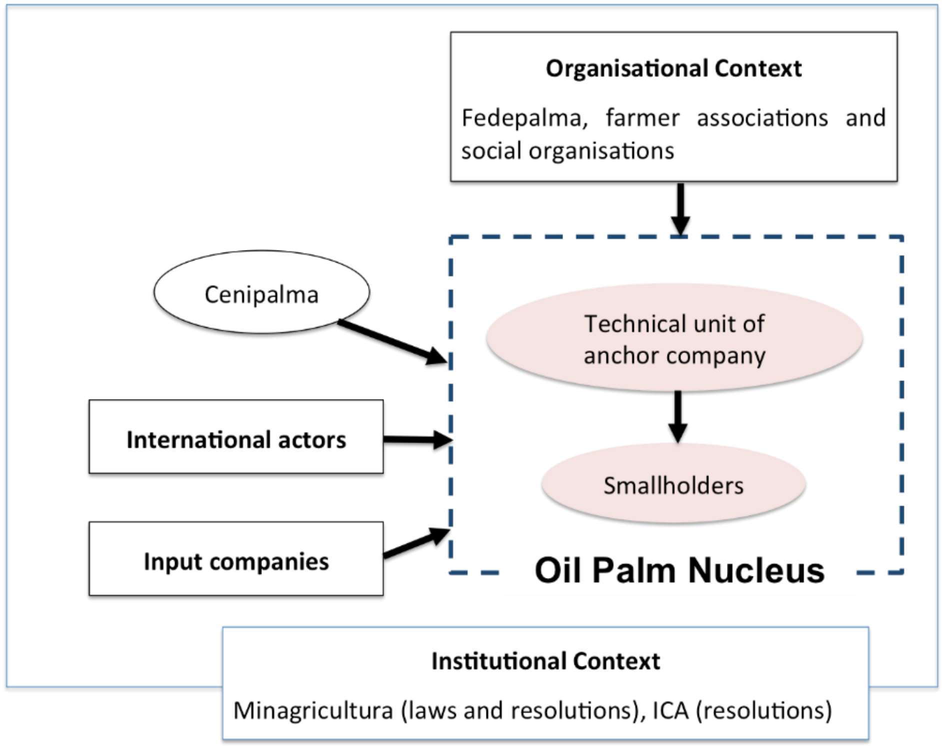

Figure 3.2: Participants in the diffusion of technologies to oil palm smallholders

Source: Own elaboration from collected information

From this section, it was seen that the different ways in which Colombian smallholders participate in an oil palm nucleus were by either acting individually, or by engaging in schemes of productive alliances or farmer associations. Although anchor companies and their units of technical assistance have different levels of control in the crop management of plantations, smallholders often have direct and regular contact with these companies due to their marketing relationships, through which smallholders are more likely to acquire resources and technical services. In addition to agro-industrial firms, there are other actors that contribute to the process of centralised diffusion around smallholders, including Fedepalma and Cenipalma, farmer associations, social organisations, governmental entities, supply companies and international agencies. The role of these actors varies when it comes to the transfer of agricultural practices related to disease and pest management. The next section is concerned with this specific diffusion process.

3.3 Epidemic of Bud Rot Disease (PC) in Central zone

Agricultural diseases are especially critical in perennial crops. In monoculture, pathogens spread more rapidly when crops are generally uniform. Mead and Evans (2001) pointed out that in the case of plantations, the uniformity of species and closeness of trees allow the rapid colonisation and spread of infections. For this reason, producers and sectors face the challenge to act quickly to avoid dreadful results.

When disease or pest outbreaks occur in perennial crops, producers are the most affected actors in the sector. After an epidemic occurs, producers face the challenge of defending their investment in the short and long term for a period of time that cannot be easily predicted (Spreen et al., 2013)[24]. With outbreaks, plants reduce their productive capacity and become more vulnerable to other pests and diseases in the future (Torres et al., 2016). The reduction of crop yields, as well as the increase of production and management costs, the costs of prevention, the treatment and control practices, result in economic losses for producers (Spreen et al., 2013).

Negative effects of a plant disease can also be seen in other stages of the commodity production and other fields of the economy. With the reduction of crop yields, mills lack sufficient raw material to fully cover their processing capacity, resulting in higher production costs and lower profits. In addition, Spreen et al. (2013) asserted that epidemics affect commodity prices (due to the negative impacts in the supply of the raw material), food markets (if local economies depend highly on the threatened crop), and government budget (when public funding is used to help affected growers).

Bud rot is one of the most important diseases affecting oil palm crops in Colombia. It is initially caused by the pathogen *Phytophthora palmivora Butl* (*P. Palmivora*) whose attacks

[24] Spreen et al. (2013) also make an important differentiation between annual and perennial crops that evidences the higher risk that diseases and pests represent for farmers of perennial crops compared to other producers. According to these authors, annual crops are usually destroyed and renovated after the harvesting phase in order to start the next production cycle. In a phytosanitary event, a disease only affects current crops rather than future crops.

make the oil palm trees vulnerable to the attack of other opportunistic fungi and insects (Martínez et al., 2009). According to Torres et al. (2010), PC affects immature tissues of emerging leaves of oil palms and interferes with the creation and maturation of new leaves. As the disease progresses, there is an increase in the number and size of lesions, and decomposition of tissues spreads to the meristem[25], leading to stunting and death of oil palms. At the same time, the tree reduces, and eventually stops, the production of FFB. An added threatening factor results from the attack of opportunistic insects, such as *Rhynchophorus Palmarum*, to diseased and nearby healthy trees (Martínez et al., 2009).

In the last two decades, PC has caused one of the worst plant disease epidemics in the Colombian oil palm sector, and deep economic and social crises in the infected regions. This disease has affected more than 70,000 hectares of oil palm in less than 10 years (between 2006 and 2011), and caused the loss of 14,700 jobs in Tumaco (located in the Western Zone), Puerto Wilches and Cantagallo (located in the Central zone) (Ministerio de Agricultura et al., 2014). The devastation of oil palm crops caused economic losses of more than US$2,910 million for the national economy including, US$129 million for the Central zone (Cenipalma.org, 2018; Fito.portalpalmero.com, 2018).

The PC disease has attacked three out of the four zones in Colombia (Eastern, Western and Central zones), with the Central zone being the most recently affected region in the history of the oil palm sector. PC outbreaks were reported in the late 1980s, when the disease affected 50% of the Eastern zone (Nieto, 1993; Gómez et al., 1995). In this area, the natural recovery of some diseased oil palm trees were observed after the diagnosis of the first symptoms due to the prolonged dry season[26] (Silva and Martínez, 2009; Torres et al., 2016).

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[25] The meristem is the heart of the oil palm tree where new tissue is formed (Torres et al., 2016).
[26] Investigations developed by Martínez et al. (2009) and Silva and Martínez (2009) showed that under drier conditions the disease develops more slowly.

About 10 years after the outbreak in Eastern zone, PC disease attacked plantations and caused epidemics in the Western zone (in 2004 and 2009) and in the Central zone (in 2010 and 2011). In the Central zone, PC disease destroyed around 37,400 hectares (Ministerio de Agricultura et al., 2014). Diseased trees in these regions became completely unproductive and the majority were eradicated during what would have been their productive stage[27]. This caused producers to lose their initial investments and their expected net profits from the next 10 years[28]. The following map shows the levels of PC incidence in the Central zone, where the case studies are located.

[27] The productive stage of oil palm crops is considered to be 15 years after being first cultivated.

[28] Based on data from Cenipalma, Silva and Martínez (2009) asserted that producers in the Western zone lost around 16% of their net potential income in 2006, 39% in 2007, 62% in 2008, and 83% in the first semester of 2009.

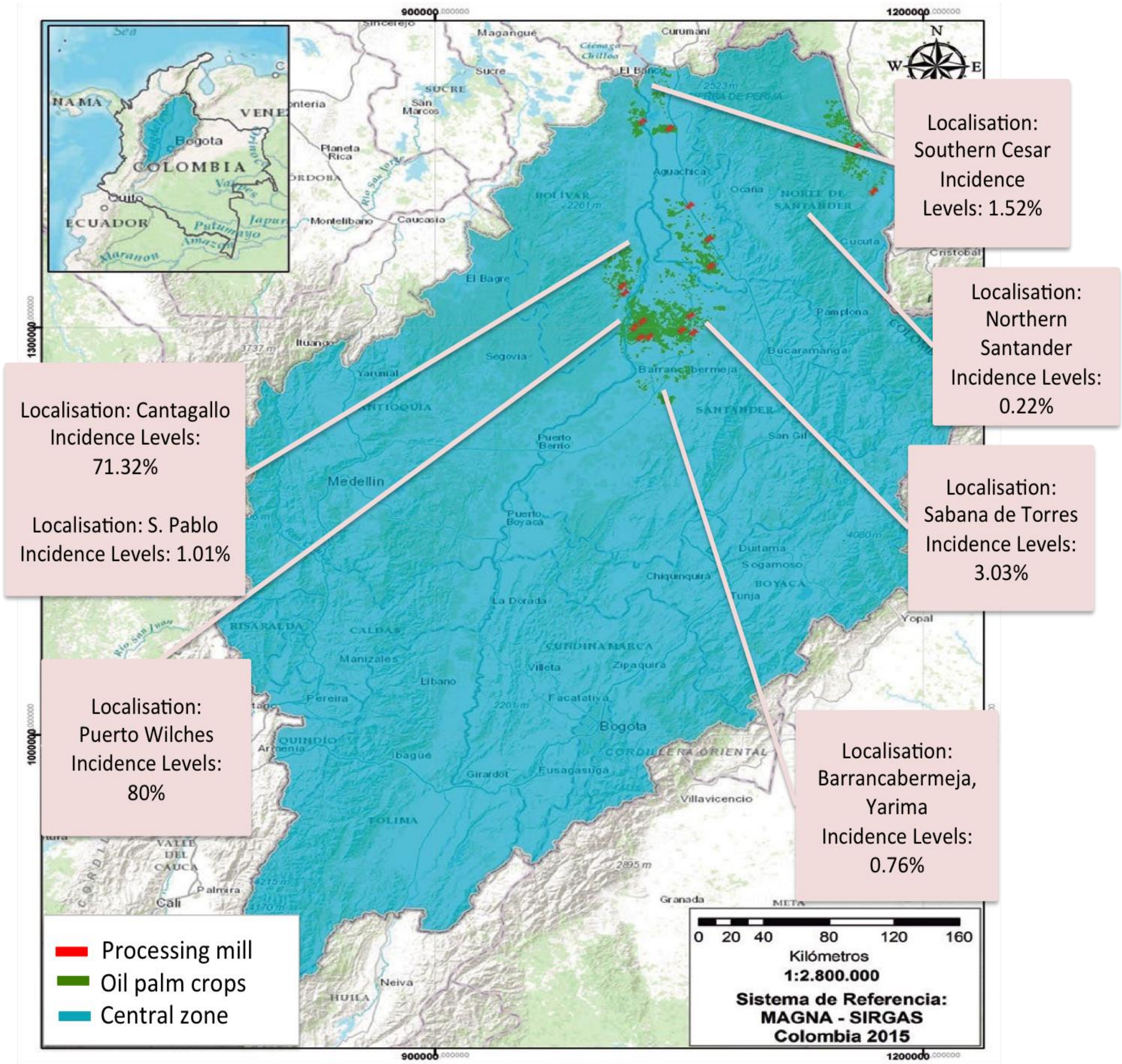

Figure 3.3. Affected areas of PC disease in Central zone during 2015

Source: Own elaboration based on palmasana.org, 2015

Internal and external factors contributed to turning PC outbreaks into epidemics. Amongst the internal factors, Silva and Martínez (2009) identified less tolerant materials, presence of the pathogen *P. Palmivora* and the dissemination of this pathogen via insects. Amongst the external factors, unusually wet weather, conditions of violence and public insecurity, were some of the ideal circumstances for the rapid spread of the disease (Silva and Martínez, 2009; Ministerio de Agricultura et al., 2014).

The epidemic in the Central zone, particularly in Puerto Wilches and Cantagallo, was an example in which mostly external factors contributed to the rapid spread and numerous outbreaks of PC. Some interviewees, including small-scale producers and researchers of Cenipalma, highlighted the increase of rainy periods and flooding, caused by the Sogamoso river, in several plantations during 2010 and 2011. Adding to these environmental conditions, Norberto Galvis and Juan Carlos Jiménez affirmed that conflicts between anchor companies and their labour unions worsened the epidemic situation in the zone (Torres, 2015a). According to these high-level executives, field operations for the management of PC were delayed in clusters of this zone causing a significant increase in diseased oil palm trees in this and neighbouring regions.

An additional factor that particularly affected this zone was the poor attention that producers gave to the control of the PC disease during its early stages, and the lack of clarity about the management of this disease. Julián Becerra, who was the Coordinator of the National Bureau for Phytosanitary Management in 2015, reported that dry conditions in the area led producers to believe that PC was not a problematic disease and that infected trees could recover naturally, as occurred in the Eastern zone (J. Becerra, personal communication, 15 July 2015). Silva and Martínez (2009) pointed out that even though producers recognised the presence of the PC, they did not know the protocol for PC control and treatment.

The PC epidemics grew into a serious socio-economic crisis that also affected smallholders in the zone. Due to the epidemic of PC, Becerra affirmed that around 8,500 people lost their jobs and the local economy collapsed due to the high dependence of local communities (J. Becerra, personal communication, 15 July 2015). Interviewed actors, including Javier Toro (Head of the social organisation FSP) and affected smallholders asserted that the epidemic caused production losses for several small-scale producers, who consequently eradicated a considerable part of their plantations or abandoned the agricultural management of their crops. As a result, a large number of smallholders went bankrupt, sold their lands at a bargain price, had their lands confiscated by banks, or became highly indebted with banks. This resulted in an economic crisis and, in turn, a social crisis (Torres, 2015a). Several interviewed smallholders agreed that these conditions impeded the normal provision of technical assistance to producers.

The economic situation of smallholders further deteriorated with *Resolution 2013 of May of 2013,* through which the governmental entity ICA announced the official declaration of a plant disease epidemic. This declaration indicated that the oil palm crops and nurseries of particular towns of the Central zone[29] had over 70% of PC incidence, which represented a high risk for other areas in the zone (ICA, 2013). A large number of smallholders interviewed during fieldwork pointed out that due to the announcement of the resolution, an important part of the Central zone was considered to be a 'high risk zone' and oil palm production was regarded as a 'high-risk productive activity'. Becerra (2015) stated that 'affected smallholders could not access bank loans and governmental subsidies such as *Phytosanitary ICR*[30] that pay off part of producers´ debt' (p.2)[31].

It is important to highlight that the case studies of this thesis are not located in the towns where the phytosanitary emergency was declared but in the Central zone, where there is still a latent risk because of the proximity of plantations to the region of epidemics. According to Alexandre Cooman (director of Cenipalma) and Gaspar Rueda Plata (officer

[29] These towns were Puerto Wilches, Barrancabermeja, Sabana de Torres and San Vicente de Chucurí (department of Santander), and San Pablo and Cantagallo (department of Bolívar) (ICA, 2013).
[30] Phytosanitary ICR is a subsidy that the government provides to smallholders who decide to renovate their oil palm crops in areas of phytosanitary emergency (Agronet.gov.co, 2015).
[31] This was referred to by several interviewees as 'financial blocking'.

of Extractora Central), the PC disease has been spreading slowly to the north and south of the Central zone (Cooman, 2017; Torres, 2015a).

Since the PC epidemic, sectoral actors have explored and promoted protocols and measurements for treatment and control amongst smallholders. Some of these strategies have proven to be efficient in slowing down the disease's progression, the spread of the PC, and in reducing outbreaks within the regions. The diffusion of these protocols is a key factor for helping smallholders to access technical packages and deal with this phytosanitary problem. The next section studies the roles of different actors in the sector in supporting smallholders for the access and adoption of these strategies.

3.4 Process of technology diffusion during the PC epidemics in the Colombian Central zone

The historical outbreaks and epidemics of PC disease in the three Colombian regions showed that the disease spreads rapidly across plantations, towns and even regions; therefore, individual efforts of growers and agro-industrial companies are not sufficient to tackle this problem. As stated by Rafael Rey Picón (manager of the company Pravia S.A.S), dealing with PC disease requires not only a local but also a regional and national strategy (R. Picón, personal communication, 26 June 2015). This section explains the role that different actors played during the Central zone epidemic in developing and, particularly, in transferring strategies to smallholders for the management of PC disease. The second part of the section discusses some aspects that made the process of technology diffusion difficult.

3.4.1 Roles within technology diffusion for the management of PC

Since the beginning of the PC epidemics, sectoral actors, organisations and institutional entities have fulfilled different functions in the process of technology diffusion. The leading role that Cenipalma, Fedepalma and anchor companies have played in R&D

activities and technology transfer reveals high levels of top-down control of diffusion processes in the context of epidemics. To a lesser extent, farmer organisations, social entities, input suppliers and government actors support these processes.

Cenipalma played a leadership role in the formulation of protocols and transfer of practices for the diagnosis, and PC management. As it will be seen further on, these protocols enjoyed substantial support from both agro-industrial firms and government institutions due to the scientific trajectory of Cenipalma and the necessity of an homogeneous response developed by subject-matter experts in the sector.

Experts in Cenipalma recommended a series of practices for the prevention and treatment of PC disease. Among the first group of preventive practices, Silva and Martinez (2009) and Torres et al. (2010) asserted that the initial selection of disease-tolerant seeds guaranteed to produce plants with resistance to PC attacks. The risk of infection can be reduced with good practices for crop management. According to Munévar and Acosta (2002) and Arias et al. (2014) the implementation of crop management practices such as fertilisation, cultivation of leguminous plants, and construction and maintenance of drainage systems, could protect and even control the spread of PC. Soil and frond analyses were important for producers to know the chemical properties of the soils and the nutrition balance of their plantations. From there, corrective measures could be adopted to strengthen the health status of oil palm trees and to reduce their vulnerability to PC attacks.

Within the practices for treatment, or what this thesis calls *shock practices*, Cenipalma established an official protocol with remedial actions to save affected plants when the disease was detected in the early stages. The set of official procedures was called the *Cenipalma Protocol*. This protocol involved an intervention called *surgery*: that is to say, the removal of diseased tissue to just above the meristem and application of a mixture of fungicides, bactericides and insecticides to the exposed area (Torres et al., 2016) (see Appendix B for more details of this protocol). In addition to this intervention, the eradication of diseased trees with a high degree of severity[32], and renewal of eradicated plantations with seeds tolerant to disease were also required to avoid the rapid spread of the disease between neighbouring palms (Martínez et al., 2009).

One of the most important practices in PC management was the frequent monitoring and systematic registration of pest and disease levels in each plantation; this was called *PC monitoring*. Levels were determined according to the severity scale defined by Cenipalma (see Appendix B and C for more details). Early detection was a key aspect in management of PC since it helped with diagnosis before the levels of severity and incidence became unmanageable. Although monitoring of PC disease helped to prevent the increase and severity of this disease, this thesis considered this as a shock practice and not a preventive practice. Despite the fact that PC monitoring helps to detect the presence of the disease within a plantation, this practice was regularly adopted after the occurrence of the disease and used for the early detection of further diseased trees that could affect other oil palms. Essentially, since the adoption of this practice typically came after the initial discovery of the disease, and when there were high levels PC incidence in the neighbouring areas, it will be considered here as a shock practice. This was the case of the clusters studied in this research.

Although official practices were developed and promoted by Cenipalma, the final protocols for adoption given to producers were the result of consensus decisions between this centre and key actors of the sector. Interviewed actors, such as technical representatives of anchor companies, smallholders, staff of Cenipalma and Fedepalma, explained that these protocols were usually discussed in Regional Agronomic Committees and particularly at the Technical Board of Sabana de Torres (referred to 'Mesa Técnica de

[32] Cenipalma identified different levels of PC incidence, under which producers are able to treat and control the disease in their plantations. According to Arias et al. (2014), if the level of PC incidence in a plantation is lower than 10%, the package for PC management proposed by Cenipalma is likely to be effective. On the other hand, if the incidence is higher than 20% and there is high degree of infection severity, it is said that the grower is dealing with an epidemic and the costs outweigh the potential benefits of the protocol. In this case, the recommended technological practice by researchers is the eradication of affected trees.

Trabajo de Sabana de Torres' in Spanish). In these meetings, Cenipalma shared technical knowledge regarding the diagnosis and treatment of diseased palms and, together with technical assistants, defined criteria for management that was later validated by the centre. Therefore, as Julián Becerra said, 'this protocol should not be named *Cenipalma Protocol*, since it is the product of unified criteria in the region (…) [even though] the scientific knowledge comes from Cenipalma' (J. Becerra, personal communication, July 15, 2015). Only when regional agreement and validation by scientific experts took place were the practices transferred to producers.

The Cenipalma protocol and unified criteria for PC management were mostly transferred to small-scale producers by anchor companies and, particularly, by their UAATAS and technical departments. Due to the close commercial relationships and existing contracts between most agro-industrial firms and smallholders, these relationships often became technical links. Through these connections, agro-industrial firms diffused the criteria of operational procedures for PC management and, in some cases, facilitated purchase inputs for these treatments (Bernal-Hernández, 2010; Ramirez et al., 2014). This support became essential in the adoption of practices by smallholders. For example, interviewed smallholders in Puerto Wilches asserted that the PC epidemics caused most agro-industrial companies in the specific area to become bankrupt, resulting in the discontinuation of technical services and thus, the technology transfer to smallholders from those sources.

The key role of agro-industrial companies and their technical units was recognised by other sectoral entities, for example Cenipalma (see pp. 93-94), that focused their technical support on these companies and used them as intermediaries to reach other producers in an oil palm nucleus. Without these agro-industrial firms, the influence on the final implementation of practices is difficult and likely to be unsuccessful.

In addition to transferring protocols, some anchor companies in the Central zone implemented regional strategies to deal with the epidemic. According to Becerra, the first coordinated action was seen in 2008, when a group of agro-industrial companies and oil palm mills[33] created a joint strategy called 'Mire PC' to monitor PC incidence, benchmarking of best PC-related practices, unifying operational procedures for managing PC, and raising awareness within oil palm clusters (J. Becerra, personal communication, 15 July 2015). Another coordinated action in the Central zone was the creation of the alliance 'Palmeros Unidos'[34]. Consuelo Velasco, leader of this alliance, asserted that in addition to the purposes that 'Mire PC' had, 'Palmeros Unidos' aimed at supporting fruit providers' management of PC in all nuclei of allied anchor companies (C. Velazco, personal communication, 29 July 2015). The technical teams of these agro-industries followed the guidelines of the Cenipalma protocol almost strictly, and regularly verified the adoption of practices, especially in plantations of fruit providers (Torres, 2014).

Together with Cenipalma and agro-industrial companies, Fedepalma also conducted activities supporting the technology transfer of PC-related practices to smallholders. One of these highly recognised actions, according to the researchers of Cenipalma and the majority of smallholders interviewed, was the national extension service provided called 'Sanipalma'. Through this service, a Fedepalma technical team randomly selected smallholders' plantations and demonstrated to them the correct adoption of Cenipalma protocol and the unified criteria of the Regional Agronomic Committees[35] (Pérez Rojas, n.d.).

One of the most important actions of the federation during the epidemic was the creation of the National Bureau for Phytosanitary Management. This unit was in charge of activities related to oil palm diseases and pests management in each Colombian zone. These

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[33] Palmas Oleaginosas Bucarelia, Palma y Trabajo, Palmeras de Puerto Wilches, Palmas Monterrey, Extractora San Fernando and Extractora Central.

[34] This strategy was implemented by four agro-industrial companies: Agroince Ltda., Palmeras del Cesar S.A., Indupalma S.A., and Hacienda La Gloria.

[35] 'Sanipalma' was not only focused on the management of PC disease, but also on the management of other pests and diseases such as *Marchitez Letal* (ML) (translated as Lethal Wilt) and *Marchitez Sopresiva* (MS) (translated as Sudden Wilt) in other Colombian zones.

included the monitoring of oil palm diseases and pests; creation of technical and regional strategies; coordination of actions and efficient solutions; verification of the correct adoption of practices; and reinforcement of the Cenipalma protocols, especially in areas highly affected by disease outbreaks (Web.fedepalma.org, 2017d).

During the PC epidemics, farmer organisations or cooperatives did not have a strong influence on processes of technology diffusion. There was little evidence to suggest that farmer associations of smallholders were directly involved in the diffusion of practices for the management of PC. This was based on the main objectives that associations in the Central zone had set since their formation (see p.93). For example, a head of the association Facasoba explained that the main objective of these organisations had been the negotiation of funding from government entities directed to processes of eradication and technical assistance, for the renewal of smallholders' oil palm plantations (D.J., personal communication, 11 July 2015).

A prominent example is the association of Asopalcentral, one of the biggest associations in the region that was formed during the epidemics. The main objective of this association was to secure economic support from government institutions that smallholders could use to pay financial debts with banking institutions in the area. According to Leonardo Sanchez, head of Asopalcentral, this association occasionally hired agronomic experts with the little financial support provided by the local governorship. This association also received some training and financial support from social organisations (e.g. FSP and Fundepalma), Cenipalma, oil palm companies in the area and government entities (e.g. SENA and Corpoica). It is important to note that Asopalcentral did not support the adoption of the Cenipalma protocol for PC management but alternative methods based on fertilisation programmes for the treatment of diseased trees (L. Sanchez, July 10, 2015). These, and other possible methods that were formulated under a bottom-up approach, while significant, are not discussed in this research, which focuses on the transfer of strategies developed by technical experts.

Except for SENA, whose technical staff worked in alliance with the phytosanitary unit of Cenipalma and conducted workshops with smallholders, government actors were not directly involved in the transfer of PC-related practices. However, these actors influenced this process by establishing an institutional framework and therefore, put pressure on smallholders to adopt official protocols. These protocols were developed and promoted by technical experts such as Cenipalma, regional committees, UAATAS and technical teams of agro-industries.

The most important regulations established by ICA during the PC epidemics were:

- Resolution ICA 507, 2009 by which ICA could quarantine areas with high levels of PC incidence in the Central zone (ICA, 2009);
- Resolution ICA 132, 2012 by which ICA could regulate the production, distribution and commercialisation of seedling plants for oil palm cultivation (ICA, 2012);
- Resolution ICA 716, 2010 and Resolution ICA 2013, 2013 by which ICA could declare a phytosanitary emergency in Puerto Wilches (ICA, 2013 and ICA, 2010);
- Resolution ICA 4170, 2014 by which practices for control and prevention of pests and diseases in oil palm crops were compulsory, including monitoring and registration of PC incidence (ICA, 2014).

The most important governmental institution in charge of prevention and phytosanitary control in Colombia, ICA, verified these regulations and the levels of PC incidence, monitored diseased trees that needed to be eradicated, and inspected nurseries in areas with serious outbreaks (ICA.gov.co, 2013). Through agreements No. 2013387 and No. 20150284, ICA, MADR and Fedepalma provided a total of US$3,066,120 for verification and eradication of areas with high levels of PC incidence during the period 2013 to 2016 (Alarcón Restrepo, 2017).

It was also seen that social organisations had little role in the processes of technology diffusion around smallholders. For instance, Javier Toro explained that the organisation FSP was focused on supporting alternative livelihoods for communities affected by the epidemics in Puerto Wilches (J. Toro, personal communication, 17 July 2015). By contrast, and based on the official protocols, Fundepalma had a more active role in providing technical support to its associative projects. The heads of both organisations affirmed that even though they did not provide technical assistance, they facilitated training and workshops from technical experts such as Cenipalma and SENA (J. Toro, personal communication, 17 July 2015, and J. Perez, personal communication, 7 July 2015).

During the PC epidemics, the presence of other actors, such as input suppliers and private initiatives from local communities, increased substantially in the Central zone, especially in Puerto Wilches. According to interviewed smallholders, Bayer, amongst many other companies, often sold agrochemicals for the treatment of diseased trees. Several interviewees, including officials of Cenipalma, Fedepalma, technical assistants, agro-industries as well as smallholders, also reported that individuals belonging to the local community took advantage of the critical situation and diffused non-scientifically based treatments for PC management. One of these interviewees claimed to have hired these services, as did other smallholders, and later discontinued the use of their products due to the low effectiveness and high costs of these treatments that ultimately led him to bankruptcy.

A summary of actions for technology diffusion is presented in the following table:

Table 3.3: Actors and actions in diffusion processes of PC-related practices of the Central zone

Entity/Actors	Programme/Alliance	Diffusion activities
Anchor companies (agro-industrial companies and processing mills)	Technical departments and UAATAS	Technical assistance, training sessions, workshops, input provision.
	'Mire PC' and 'Palmeros Unidos' alliances	Unification of criteria in Regional Agronomic Committees and Technical Board of Sabana de Torres. Verification and enforcement practices, and technical assistance based on unified criteria. Support to smallholders with high levels of PC incidence.
	Mediation for technical support from other sectoral actors	Training, field trips, demonstration plots by Cenipalma, SENA, technical experts.
Cenipalma	Technology and Validation unit	Distribution of written/illustrated material containing the *Cenipalma protocol*: handbooks, informative pamphlets and posters, technical magazines 'Palmas', 'El palmicultor' and 'PalmaSana'. Training sessions, workshops, technological visits, demonstration plots, promotional campaign 'Palma Sana', radio programme 'Palmeros en Acción'. Visits and recommendations to smallholders with high levels of PC incidence.
	Project 'Bridging productivity gaps of small-scale oil palm growers'	Demonstration plots located in smallholders' plantations.

Fedepalma	Technical service ‘Sanipalma’	Demonstration of technology adoption for PC management in smallholders’ plantations.
	National Bureau for Phytosanitary Management	Creation of technical and regional strategies. Coordination of actions and efficient solutions. Verification of levels of PC incidence. Phytosanitary forums, field days and workshop sessions. Reinforcement of technological practices.
	Strategy ‘De la Mano contra la PC’	Extension services and awareness campaigns.
Farmer organisations	Programmes of local governmental support	Acquisition of economic resources for inputs, equipment and technical assistance.
	Intermediation for technical support from other sectoral actors	Training and financial support from Cenipalma, anchor companies, social organisations and SENA.
SENA	Programmes of training	Training sessions and workshops based on Cenipalma protocols.
ICA	Agreements No. 2013387 and No. 20150284 with MADR and Fedepalma	Verification and eradication of areas with high levels of PC incidence.
	Resolution ICA 507, 2009 Resolution ICA 132, 2012 Resolution ICA 716, 2010 Resolution ICA 2013, 2013 Resolution ICA 417, 2014	Regulations for control and prevention of pests and diseases, monitoring and registration of PC incidence.
Social organisations	Intermediation for technical support from other sectoral actors	Training from Cenipalma and SENA.

Source: Own elaboration from interview and information based on Bernal-Hernández (2010), ICA.gov.co (2013), Ramirez et al. (2014), Torres (2014), ICA (2009, 2010, 2012, 2014), Web.fedepalma.org (2017d), and Pérez Rojas (n.d.).

3.4.2 Problems in the diffusion of technologies to small-scale producers

Evidence gathered during the fieldwork suggests that four factors had a negative impact on processes of technology diffusion to smallholders in the Central zone. These four factors were:

1) the lack of credibility in recommended protocols within affected areas;
2) the influence of local community actors providing non-conventional treatments;
3) the low awareness of smallholders about the severity and speed of spread of the PC disease, and
4) the need to economically exploit the diseased plantations by affected producers and anchor companies.

The first factor was the low trust levels that producers had in protocols developed by technical experts, which did not work effectively under the severe conditions of PC attacks. Interviewed officials of Cenipalma and Fedepalma asserted that with the rapid spread of PC disease, high levels of incidence and severity of PC disease in towns of the Central zone, Cenipalma's recommended actions to control and slow down the disease progression did not always yield positive results[36]. As a consequence, interviewed smallholders affected by the disease and heads of the farmer associations (e.g. Asopalcentral and Facasoba) affirmed that most producers in Puerto Wilches lost faith in these protocols, and in Cenipalma. This situation made it difficult for the institutional action of Cenipalma and Fedepalma to transfer technologies to smallholders in the zone.

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[36] This occurred because the levels of incidence and severity of PC in the most affected towns of the Central zone exceeded the levels at which Cenipalma researchers thought it was possible to properly control the disease. According to works developed by Arias et al. (2014), if the accumulated incidence of the disease is below 10%, it is possible to adopt suggested strategies by Cenipalma to control PC disease. If the accumulated incidence is above 20% with high infection severity, it is not cost efficient for producers to use the management strategy suggested by Cenipalma. The authors asserted that above 20% of PC incidence, growers may be facing a plant disease epidemic, as occurred in Puerto Wilches and Cantagallo where incidence was more than 80%.

The lack of credibility of protocols recommended by experts, and the critical situation in severely affected areas, caused the involvement of local community actors offering practices to treat PC in small-scale plantations. Interviewed smallholders explained that the desperate search for options to cure diseased trees and reduce the rapid spread of PC led affected producers to adopt packages that were not approved by technical experts such as Cenipalma, Fedepalma, agro-industrial firms and regional committees. For example, one of the local individuals offering these types of packages considered himself 'the oil palm shaman' and said that the cure to PC disease was through divine action (M.R, personal communication, 10 July 2015).

Another factor that affected the process of the technology diffusion was the lack of serious attention and awareness about the severity and accelerated rate of infection in the region. Greicy Sarria, researcher of Cenipalma, asserted that the problem with PC management in plantations of the Central zone was not the lack of knowledge, but the lack of awareness among producers about the critical consequences of PC disease (Torres, 2015b: 4). Producers in this area paid little attention to PC outbreaks, since they assumed the weather conditions did not favour the rapid spread of the disease and that the infection could not have catastrophic effects.

A final factor that made technology transfer difficult was the economic crisis; the need of affected producers to generate income from diseased plantations, and the need of anchor companies to buy FFB and fulfil their processing capacity. Javier Toro reported that the lower production of FFB due to the epidemic reduced the income of affected smallholders, as well as the supply of raw material that anchor companies needed for processing. This prompted smallholders to sell their production to the highest bidder rather than to agroindustry firms from which producers had received technical benefits as part of their CFA. Thus, agro-industrial companies in the area became more interested in the purchase of FFB than in the provision of technical assistance to fruit providers. Meanwhile, several producers breached their agreements with agro-industrial companies by side-selling fruit to alternative firms, which resulted in the termination of regular assistance to those producers (J. Toro, personal communication, 17 July 2015). Finally, it was asserted by interviewed producers that affected smallholders were more interested in selling as much fruit as they could from their diseased plantations than adopting crop and PC-related practices and seeking technical assistance.

3.5 Summary of the chapter

The process of oil palm production showed close commercial relationships between growers and agro-industrial companies. This channel of communication was exploited by many of these companies who supported smallholders with technical services and facilitated their integration into the oil palm sector through production models such as Nucleus Estate Schemes and Contract Farming Arrangements. Within these models, agro-industrial companies took a central role in the process of technology diffusion as the main providers of agricultural inputs and technical services. This is the reason why these arrangements can be considered centralised-diffusion systems.

In Colombia, oil palm cultivation had increased rapidly over a period of 30 years. However, that trend fell sharply in 2012 due to the presence of diseases, and particularly the epidemics caused by bud rot disease (PC). The initial trend was principally favoured by the participation of smallholders in the oil palm sector through the schemes of ‘productive and strategic alliances’, which were highly adopted in the Central zone. These schemes, and other commercial agreements between producers and anchor companies, generated technical relationships through which companies supported producers’ crops. Within these companies, technical departments and UAATAS were crucial units with direct and regular contact with smallholders that acted as intermediaries between sectoral actors and producers. Therefore, they had a fundamental role in the technology-diffusion process.

The most recent trend showed a reduction of the planted area of oil palm in Colombia caused by the rapid spread of PC and the situation of epidemics across the regions. This disease directly affected the agricultural phase and had negative consequences on later stages of the agro-industrial production. One of the main effects was the reduction in levels of FFB production, which not only impacted producers' income but also the supply of raw material for processing mills. In some of the towns of the Central zone, PC reached about 70% to 80% of incidence in the plantations and grew into a serious socio-economic crisis. The rapid spread of PC led the national authorities to declare a phytosanitary emergency in the zone. As a result of the declaration and income reductions, producers could not meet their financial obligations and did not have access to credit to continue with their productive activity.

Since the start of the epidemics, Cenipalma has led the R&D processes and formulated official protocols for the management of PC, whilst technical departments and UAATAS of anchor companies have discussed final procedures for PC management in regional committees. Above all, these anchor companies have been in charge of transferring those practices and exerting influence on smallholders for the adoption of controls and treatments.

To a lesser extent, farmer organisations, social entities, input suppliers and government actors supported diffusion processes of technologies related with PC management. The growers' federation, Fedepalma, was in charge of supporting UAATAS and regional strategies, as well as working with government entities to coordinate technical actions and economic resources. The role of associations and social entities in technology diffusion was focused on obtaining subsidies and facilitating the training from other institutions to smallholders. Government actors were involved in the creation of an institutional framework that supported the adoption of official protocols for PC management in the affected areas.

It was concluded that four factors hindered the processes of technology diffusion during the epidemic crisis. These four factors were the lack of reliability of the recommended protocols, the influence of local community actors bringing non-scientifically based treatments, the low awareness of smallholders as to the effects of PC disease, and the exploiting of economically diseased plantations by producers and companies.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

This chapter introduces a research design and methodology intended to examine potential pathways within centralised-diffusion systems. The first part of this chapter recalls the research questions and the main elements of the theoretical framework. Section 4.2 explains the multi-case studies as the chosen research method. Following this, the selection of three case studies in the Colombian oil palm sector and the research design that will be used is discussed in Section 4.3. Section 4.4 explains the possible generalisations from multi-case studies, and Section 4.5 the research strategy and operationalisation of the research questions and theoretical framework. Section 4.6 discusses the sources of data and information, whilst Section 4.7 explains data and information collection. Section 4.8 discusses the data and information analysis, and the final section summarises the chapter.

4.1 Research questions

This research aims to increase the understanding of diffusion pathways and their impacts on technology adoption within the agricultural context of top-down governance. We draw on the processes of technology-diffusion, which is highly dominated by top-down strategies, prompted by a plant disease epidemic in the Colombian oil palm agribusiness during the period 2013-2015. The main research questions, and resulting sub-questions, that this thesis will address are as follows:

Research Question 1. How do different types of formal rules lead to different pathways of technology diffusion?

This question is focused on the study of formal rules, their variations in regard to certain types of governance and characteristics of technology users, and the relationship of these variations with pathways of diffusion. It is hypothesised that the different types of formal agreements, such as the existing CFAs in the Colombian oil palm agribusiness, may define technical functions, participation in decision-making processes, and economic obligations of leading actors and smallholders in the context of highly centralised-diffusion systems, such as the epidemics of PC disease. There are two underlying sub-questions that come from this research question. The first sub-question is: what is the role of formal rules within centralised-diffusion systems? From there, the second sub-question is: how do different types of formal rules impact the technology-diffusion processes?

Research Question 2. What is the influence of network structures, affected by different types of formal rules, on technology diffusion?

This question is focused on the way structural characteristics of networks show variations of formal rules and reflect the process of technology diffusion occurring in each pathway. It is hypothesised that technology-diffusion processes within highly centralised models may result in scenarios with different network structures. These scenarios may allow for different information access for small-scale producers, the influence of leading change agents and other key actors on smallholders, and access to different sources of information. The underlying sub-questions are: which central actors and network structures, in terms of network size and interactions, central positions and brokerage, occur from different types of formal rules? And: how do central actors and networks impact on technology diffusion, in relation to information access, variety of information sources and influence?

Research Question 3. How does technology adoption vary with the different pathways of diffusion, and how do these variations impact the adoption of long-term and short-term practices separately?

This question is focused on the final outcomes, in terms of technology adoption, that resulted from particular diffusion processes, which was a consequence of network structures and certain types of formal rules. We particularly emphasise the differences in adoption regarding long-term and short-term practices. It is hypothesised that levels of technology adoption of different diffusion processes in the Colombian oil palm agribusiness may vary in addition to the levels of the adoption of shock and preventive practices for PC management. The underlying question is: how diffusion processes, resulting from types of network structures and formal rules, impact on technology adoption and how this effect varies when short-term and long-term practices are considered separately?

The research questions posed in this thesis provide a step-by-step approach to examine the technology-diffusion process in centralised systems. From there, three main elements are identified and connected in the theoretical framework: 1) formal rules, 2) vertical networks, and 3) technology adoption. Figure 4.1 is a visualisation of the theoretical framework and the organisation of the research strategy, which will be discussed in Section 4.5.

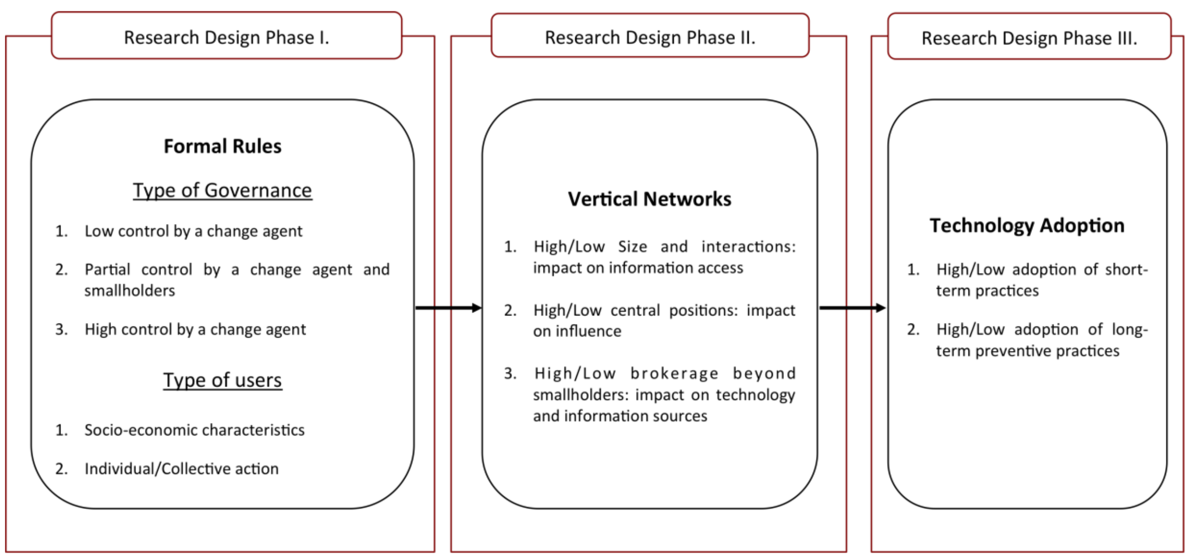

Figure 4.1: Research strategy

Source: Own elaboration based on Barrett et al. (2012), Burt (2005), Key and Runsten (1999), Monge et al. (2008), and Spielman et al. (2011)

4.2 A Multi-case study as a research method and other combined methods

A multi-case study is the general method used to analyse the main research interest of this thesis. As was seen in the last section, three key questions stem from this leading query; therefore, additional research methods will be used for the collection and analysis of the data.

In order to identify the most suitable method to answer the main research question, Yin (2013) suggests that two aspects are taken into account: the degree of control over conditions, and the type of phenomenon studied. First, a reflection on the degree of control the researcher has over the conditions and environment in which events occur is necessary. In situations where the phenomenon can be controlled, experiments are a more appropriate research method than histories or case studies in which conditions cannot be controlled. Since the conditions of centralised-diffusion processes could not be controlled in this research, the options of research methods available were narrowed down to histories and case studies.

Second, Yin recommends that the researcher considers whether the phenomenon is a contemporary or an historical event. If the researcher has direct access to the events by taking an active role in observations and interviews of the participants, the phenomenon is contemporary and case studies are more suitable. This is the scenario here, in which the contemporary phenomenon of technology-diffusion processes was studied and it was possible to have direct access to the events and participants related to that phenomenon.

This thesis employed a multi-case study approach. According to Gerring (2004), case studies are methods of analysis that 'focuses [their] attention on a single example of a broader phenomenon' (p.3420). Multi-case studies enable one to contrast results and draw 'cross-case' conclusions of similar phenomena under various conditions (Stake, 2013). They address some of the challenges of single-case studies in terms of examining theoretical propositions. Stake (2013) claims that by including more than one case study, the researcher can add robustness of research findings and help to understand the way units and programmes function in different circumstances.

Under this approach, three oil palm nuclei in Colombia were selected, within which different centralised-diffusion processes took place. Although the region, stress conditions and period were similar for the cases, the selection was purposely made to reflect differences in their diffusion processes. The three cases aimed to expand the foundations of the theory of innovation diffusion.

To answer the three key questions and their related sub-questions, a combination of research methods was required[37]. Following Bryman (2015), there were two main reasons for the decision of combining both quantitative and qualitative research methods; 1) to answer different sub-questions that need either qualitative or quantitative questions, and 2) to complete the answer that was achieved by using one of these methods and to give a more complete answer. Generally, this research tends to make greater use of qualitative methods, and quantitative methods are used for description and comparative analysis.

Through the qualitative methods it was possible to:

- describe and analyse types of formal rules (related to Research Question 1);
- identify values embedded in these formal rules and subsequent technical relationships, and their impact on processes of centralised-diffusion (related to Research Question 1);
- describe additional information transferred through technical relationships (related to Research Question 2); and

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[37] Note that the use of both qualitative and quantitative methods in this research could be mistaken for 'mixed methods'. According to Yin (2013), 'mixed methods force the methods to share the same research question, to collect complementary data, and to conduct counterparts analyses' (p.32). This research uses each method to answer different sub-questions for the same overarching research question.

- associate adoption levels with the results of technology diffusion caused by network structures and formal rules (related to Research Question 3).

Quantitative methods were employed to:

- compare and analyse central roles and network structures in centralised systems and particular information that transferred through interactions (related to Research Question 2); and
- analyse variations in technology adoption for the different pathways (related to Research Question 3).

4.3 Selection of case studies and research design

Yin (2013) pointed out that the criterion for the selection of cases studies is to confirm, to challenge or to extend a theory. Based on the literature review, this thesis hypothesises that the narrow assumptions of innovation-diffusion theory restricts the ability to explain diverse outcomes of technology adoption in centralised systems. Therefore, the criteria for looking at, and interpreting, the findings of this research follows the need to go further by comparing and contrasting scenarios of centralised-diffusion processes in agricultural developing contexts.

Suitable to this context, the technology-diffusion processes of three oil palm nuclei during the epidemics of PC disease were identified and selected to test the theoretical framework. This selection was guided by the following rationales:

1. The Colombian oil palm sector provided an opportunity to study different centralised-diffusion processes corresponding to each of the three types of formal rules: full/high, partial and low control of the crop management by a leading change agent. These arrangements laid the initial foundations for multiple scenarios in the theoretical framework.

2. Cash crop sectors and shocks stress situations of agricultural pests and diseases were conditions that favour contexts dominated by the use of top-down diffusion strategies. In sub-section 2.2.1 it was explained how the complex nature of agribusiness, for which this activity is produced in imperfect markets of developing countries, favours the leadership of change agents in technology transfer. In environmental stresses, such as outbreaks of pests and diseases, intensive expert assistance is required to obtain homogeneous responses. The Colombian oil palm sector during the epidemics of PC was a clear example of the predominant use of top-down strategies for technology transfer.

3. The analysis of different processes of technology diffusion in the Colombian oil palm sector is a cross-sectional study. The research organises the empirical context in three parts, following and analysing the three elements of the theoretical framework for the three selected nuclei at a specific point in time (see Figure 4.1).

4. This study applies an embedded multi-case design. According to Creswell (2013) and Yin (2013), this type of design involves units of analysis at more than one level within different case studies: the unit of analysis is identified from the main questions and sub-questions. For this research, the main unit of analysis is the small-scale producers organised in schemes for production. In relation with this unit, other units of analysis, such as formal rules, network structures and roles of central actors, and technology adoption by smallholders are used.

The three nuclei of this research were located in the Central zone of Colombia, in which the last epidemics of PC occurred (see Figure 3.3), but without high levels of incidence, as occurred in Puerto Wilches and Cantagallo. Yet, within these nuclei, smallholders still invested economic resources for the development of their plantations and received technical support from other actors[38].

The selection of the three clusters in this study was the first and most fundamental step before starting the data and information collection. The dominant characteristics of each type of formal rule in the theoretical framework (i.e. low, high and partial control by a change agent; see Figure 4.1) guided the selection of each nucleus. Based on these requirements of governance, researchers from Cenipalma and actors in the Central zone helped to identify three suitable cases that strongly represented each type of agreement. These cases corresponded to oil palm agro-industry companies that, as compared with other nuclei in the area, had a well-known trajectory and experience, and provided technical support to small-scale producers, particularly during the context of plant disease epidemics.

This research maintains the anonymity of each anchor company and nuclei by using letters as requested by the companies. The following nuclei were the case studies selected:

- **Nucleus A:** under low level of control by a leading change agent. In this case Anchor Company A provided low levels of technical assistance, and small-scale producers were semi-autonomous in their crop management.

- **Nucleus B:** under high level of control by a leading change agent. In this case, Anchor Company B led the crop management of small-scale producers' plantations.

- **Nucleus C:** under partial control by a leading change agent and smallholders. In this case, smallholders set up a farmer organisation, shared responsibilities for crop management, and received important technical support from the Anchor Company C and other sources.

[38] Nuclei that registered high levels of PC incidence and had devastating impacts were discarded from the selection because, according to some of the interviewed producers, most smallholders in those areas stopped being interested in the development of their plantations and therefore took no action to deal with the stress.

This research reflects the outcomes of the technology-diffusion process at a single point in time, 2015, which can be appropriate for the study of innovation diffusion. Classic works in the innovation-diffusion literature suggest that an extended period of time is required to evaluate the process of diffusion from the start to the final decision adoption (Coleman et al., 1957; Rogers, 2010; Valente, 1995). Although less accurate, Rogers (2010) states that good conclusions can still be drawn from studies developed at one point in time.

In an effort to overcome the limitations on the accuracy of this research, the information and data collected investigate the elements of the technology-diffusion process from different points in time. For example, agreements were negotiated in each nucleus around or before 2010; therefore the information collected refers to this period. In another example, network relationships were built based on information about technical relationships that actors confirmed to have had in the last three years (2013 to 2015). This is more fully explained in the section on data collection.

4.4 Generalisation from multi-case studies

The use of case studies within qualitative research can facilitate drawing inferences and generalising results to wider contexts (Lewis and Ritchie, 2003). In comparison to quantitative methods that can be generalised based on a significant sample of the population, the generalisation from case studies is rather different. Yin (2013) suggests that an 'analytical generalisation' can be made based on the theoretical principles, lessons or concepts of a research that can be further applied for reinterpretation of other studies. This is better explained by Bryman (2015) who asserted that: 'the crucial question is not whether findings can be generalised to a wider universe but how well the research generates theory out of the finding[s]' (p.64).

The analytical generalisation that is produced in a single case study is even stronger when the researcher develops multiple case studies, as is done in this research. The main argument that favours the use of multi-case studies is that they improve theory building, and the researcher is in a better position to establish circumstances in which theory principles may hold (Bryman, 2015; Yin, 2013, 2009). By contrasting case studies, this research has the opportunity to examine the use of theoretical principles in different institutional contexts, which can improve the generalisation of the innovation-diffusion theory.

Despite using multi-case studies in this research, the different diffusion processes in each case cannot escape from having outlier features. The theoretical principles that result from this work still have some limitations. Therefore, the results and conclusions have the potential to initiate discussion on further scenarios of centralised-technology diffusion and therefore contribute to the advancement of the theory of innovation-diffusion.

4.5 Research strategy and operationalisation of research questions and theoretical framework

Following Figure 4.1, the research strategy to operationalise the theoretical framework and answer the research questions posed, involves three phases. The operationalisation and measurements of variables that we used in each phase are outlined in Table 4.1.

Table 4.1: Operationalisation of the theoretical framework of centralised-technology diffusion

Explanatory variables	Variations	Analysis of variations
Formal rules	Governance and configuration cluster	Types of selected participants within the agreement Control of decision-making process Roles and commitments for technology transfer
Vertical networks	Size and interactions	Number of actors and (weak and strong) interactions Number of relationships incident upon smallholders
	Brokerage beyond the smallholders	Brokering action (brokers and groups of information sources connected to smallholders through brokers)
	Central positions	Central actors controlling interactions and acting as intermediaries
Dependent variable	**Variations**	**Analysis of variations**
Technology adoption	Levels of technology adoption of shock and preventive practices	Number of users Number of users considered separately by shock and preventive practices

Source: Based on Granovetter (1973), Freeman (1978), Feder et al. (1985), Key and Runsten (1999), Lin (2002), Kirsten and Sartorius (2002), Burt (2005), Darr and Pretzsch (2008) and Barrett et al. (2012).

In the first phase, and consistent with the studies of CFAs developed by Key and Runsten (1999), Kirsten and Sartorius (2002) and Barrett et al. (2012), this research differentiates the institutional configuration of the three oil palm nuclei in Colombia by characterising: 1) the types of participants negotiating the arrangement; 2) the types of governance, and 3) the technical roles and commitments of those actors in crop management and technology transfer. Regarding the participants, we identify actors and selection rules within each CFA. In terms of governance, it is understood here to be the degree of participation of anchor companies (or leading change agents) and smallholders in decisions related to crop management. Finally, roles and commitments are described as the formal and informal distribution of technical responsibilities that actors assumed in respect to diffusion of technology.

In the second phase, the network structures that resulted from the formal rules were studied and nuclei were compared using the structural characteristics of size and interactions (Granovetter, 1973; Darr and Pretzsch, 2008), brokerage (Lin, 2002; Burt, 2005) and central positions (Freeman, 1978). Thus, it was possible to explain how farmers had access to technologies and information, and how change agents had influenced the farmers.

Finally, in the third phase, the impact of technical relationships and conditions of formal rules in each cluster were analysed in terms of technology adoption. This study measures aggregate levels of adoption, i.e. total number of users and non-users (Feder et al., 1985) (see Sub-Section 2.5.1 for the definition of aggregate adoption)[39]. More importantly, these levels were analysed considering short-term practices (implemented after a stress occurs) and long-term practices (intended for long-term development and resistance of crops) separately (see p.73-74 for an explanation of these two types of practices). Subsequently, agricultural practices were classified as either preventive or shock practices. As was indicated in Chapter 3 (and other studies dealing with stress situations in agriculture, for example the work of Smit and Skinner (2002), this differentiation between types of practices was especially important in these circumstances. Although shock practices are necessary to control the spread of PC disease in the short term, neglecting preventive

[39] It is important to highlight that technology adoption of smallholders affected by conditions out of their control were not considered within the analysis of adoption in each group of practices. This was because none of these conditions was related to variations in factors of technology diffusion referred to in this thesis. For example, practices whose adoption can be affected by physical or climatic conditions are the cultivation of leguminous plants and construction of drain channels. Practices whose adoption depends on the current existence of infected trees are fertilisation, PC monitoring, and PC surgery. Practices whose adoption depends on the plant age are soil and frond analyses.

practices could predispose crops to future stress, thereby risking the future development of the crops.

In the phases of research strategy, technology adoption was the dependent variable, and the types of formal rules and variations of network structures were the explanatory variables. Both variables explained the contrasting pathways of centralised diffusion during the epidemics in the Colombian oil palm agribusiness.

4.6 Sources of data and information

After selecting the three clusters, the identification of the population size and actors to be surveyed and interviewed relied on the criteria defined by network analysis and 'snowballing techniques'. The 'snowballing technique' is about asking participants and interviewees to identify possible actors that fit the selection criteria and can participate in the research (Ritchie et al., 2003). Actors were selected on the basis of their participation within the CFA and their contribution to the technology transfer in each nucleus.

According to Wellman (1997), network analysts:

> '[…] must define the boundaries of a population, compile a list of all the members of this population, collect a list of all the direct ties (of the sort the analyst interested in) between the members of this population, and employ a variety of statistical and mathematical techniques to tease out some underlying structural properties of the social systems' (p.26).

Thus, the researcher sets a limit on the network actors and relationships. By following this criterion, the indefinite collection of data is avoided, as well as the necessity of manipulating large amounts of information.

In this research, the limits of the population were defined by what this thesis calls the 'third level network boundary'. As illustrated in Figure 4.2, network boundaries were defined by three levels of actors and relationships: the first level refers to participants of an agreement, in this case, all smallholders and leading change agents belonging to a nucleus, and the connections between them; the second level includes the contacts to which the actors in the first level were connected, and the connections between them; and the third level refers to the contacts to which the actors in the second level were connected. It was required that the total population of smallholders, leading change agents within each nucleus (first level), and other actors who demonstrated a pivotal role in diffusion, participated in the surveys.

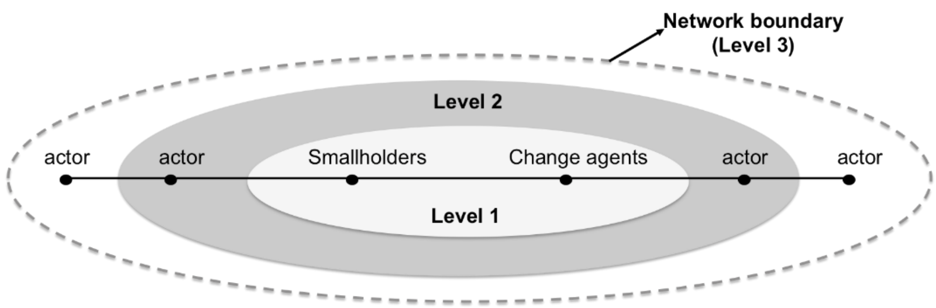

Figure 4.2: Network levels for data collection

Source: Own elaboration from survey data and interviews

The preliminary analysis of surveys, together with the snowballing technique, were used to complete the list of actors to be interviewed and surveyed. A diverse universe of actors who were able to influence technology diffusion included: 1) small-scale growers[40]; 2) medium and large-scale producers[41]; 3) anchor companies; 4) farmer organisations and alliances between agribusiness companies; 5) academic and research entities; 6) government institutions; and 7) social organisations. The diversity of participants helped to achieve a range of responses on the interview questions and to triangulate the information provided by interviewees and survey respondents. Table 4.2 shows the distribution of the total number of surveys and interviews amongst the participants.

[40] See page 81 for the definition of small-scale producers that was used in this thesis.
[41] See page 81 for the definitions of medium and large-scale producers that were used in this thesis.

Table 4.2: Number and distribution of surveys and interviews conducted by type of actor

Type of actor	No. Survey	No. Interviews
Case study: Nucleus A		
Small-scale producers	35	6
Anchor company	1	2
Case study: Nucleus B		
Small-scale producers	33	4
Anchor company	1	2
Case study: Nucleus C		
Small-scale producers	62	5
Anchor company	1	2
Contributors to all case studies and contextual actors		
Small-scale producers	0	3
Medium-size producers	3	2
Farmer Associations/Cooperatives	4	4
Agro-industrial organisations	2	2
Government actors	1	3
Social organisations	2	2
Sectoral entities	2	2
Total	**147**	**39**

Source: Own elaboration from survey data and interviews

As can be seen in Table 4.2, 120 small-scale producers were surveyed (out of 2,331 smallholders that were located in the Central zone) and, from this population, 15 were interviewed. This selection of survey participants was guided by the type of nucleus and small-scale producers required in this research, namely clusters in which agro-industry companies had technical relationships with their fruit providers and in which producers were willing to adopt technical practices addressed to deal with the epidemic. It was previously explained that the epidemic had a significant impact on small-scale producers of the Central zone who, in several cases, stopped adopting crop and PC-related practices and seeking technical assistance (p.113-114). This was mostly the case of producers belonging to the towns where ICA announced the official declaration of a plant disease epidemic (see p.9). Contrary to that case, we selected 120 small-scale producers that: 1) were located in towns of the Central zone with a latent risk of epidemic, 2) were still able to treat and control the disease in their plantations, and 3) were receiving regular and significant support from agro-industry firms to deal with the crisis, such as the assistance provided by Anchor Companies A, B and C.

Based on the preliminary SNA of the survey feedback and the interview responses given by medium and large-scale producers, representatives of anchor companies, and leaders of farmer organisations, it was possible to select a group of 15 smallholders for the interview stage. Of these, 3 were producers with a high number of network links, 3 were producers with a low number of links and 9 were producers that were identified to be playing a crucial role in the decision-making processes of technology diffusion.

Interviewed smallholders and technical assistants of agro-industrial companies were the main source of information and data. Amongst other interviewees were researchers and staff of Fedepalma and Cenipalma, which lead the development and the transfer of agricultural practices for PC management in Colombia. We also interviewed the head of what this thesis called the 'UG alliance'[42], which was the regional strategy developed by some anchor companies to deal with PC disease in the Central zone and included the anchor companies leading the technology transfer in nuclei A, B and C.

This study employed primary and secondary sources of information, as well as qualitative and quantitative data. The primary source data were gathered from interviews and surveys that were undertook in two stages of fieldwork, from March to July 2015. Most information was collected from primary sources such as surveys and semi-structured interviews based on specific oil palm clusters, and, to a lesser extent, observations from

[42] The real name of the alliance is not disclosed in order to comply with confidentiality agreements that were signed by the author with the companies of this study.

meetings. This information was complemented with secondary resources such as articles, academic documents, handbooks, sectoral and governmental documents, online news, reports, and statistics of the agribusiness that were mostly collected from public websites of sectoral organisations.

An additional reason that justifies the combination of methods in this work was the need for verification or *triangulation*. According to Creswell (2013), Mabry (2008) and Yin (2013), triangulation enables a researcher to enhance validity and check the accuracy of the data collected through different methods (*triangulation by method*) and sources of evidence (*triangulation by data source*). In short, this research ensured the reliability of the data collected by using qualitative and quantitative methods. Quantitative data, for example, was cross-checked during interviews and meetings with other actors.

The strategy to reach actors mainly involved the support of Anchor Companies A, B and C and agro-industrial organisations. Cenipalma acted as the intermediary between the researcher and the three anchor companies. These companies then helped to reach the majority of smallholders and provided logistical support to access the farms of producers efficiently. The strategy to reach the rest of the interviewees mostly involved telephone and email contacts.

4.7 Data and information collection

The fieldwork was undertaken in four phases; the pre-fieldwork phase, fieldwork phase I, fieldwork phase II, and the post-fieldwork phase. The research questions and the main concepts and relationships of the theoretical framework guided the data collection. The primary and secondary data were gathered during all four stages of fieldwork and at different geographical locations in Colombia. The primary data were mainly collected in fieldwork phases I and II. Interviews and surveys were conducted by the researcher in smallholders' farms, in the main offices of anchor companies, and in different cities of the

Central zone[43] and in Bogotá. The secondary data were collected during intermittent periods of the research, but especially during the pre-fieldwork and post-fieldwork phases.

4.7.1 Pre-fieldwork phase: Selection of nuclei and identification of participants

In the pre-fieldwork phase, secondary sources were examined with the aim of studying background information and identifying key actors that impact technology diffusion in the Colombian oil palm sector, especially during PC epidemics. More importantly, case studies in the Central zone of Colombia were studied and selected during this stage.

4.7.2 Fieldwork phase I: Data collection and preliminary analysis

This phase corresponds to the collection of data for the creation of networks and the assessment of technology adoption. This helped to answer the second and third research questions. To do this, a survey was initially conducted with smallholders and representatives of anchor companies in each nucleus. Based on the information provided by those actors, and following snowballing sampling for networks suggested by Wasserman and Faust (1994), it was possible to identify other actors that would complement the corresponding network.

Questionnaires were standardised in order to gather data that could be compared across the case studies. The main purposes of the questionnaires were: 1) to identify actors and technical relationships; and 2) to gather information about levels of technology adoption.

The main questions asked of respondents were: 'From whom have you (or your organisation) received technical support in the last three years[44] and how important was this to you (or to your organisation)'? 'Technical support' included: provision of technical

[43] Exact names of cities are not revealed since that would enable readers to identify the real names of the anchor companies; this would violate the confidentiality agreement between the author of this thesis and the anchor companies of this research.

[44] This type of question belongs to the *sociometric* method referenced by Rogers (2010) in which the researcher asks respondents who they sought for information or advice about a particular topic. Similar wording is also used by other authors in the study of networks, such as Ramirez (2014).

knowledge and information (e.g. handbooks, instructions, and flyers), and supervision, training and sharing of technical experiences. To evaluate the importance of the relationships, the researcher followed the 'Likert scale' method; this is a multiple indicator that measures the intensity of people's feelings about the area in question (Bryman, 2015). By using this method, respondents were asked to rank technical connections from 1-4 in ascending order of importance. The period of three years covered by the survey was chosen on the basis that, according to interviewed technical assistants in the three anchor companies, the activities for technology diffusion were intensified after 2013, when the epidemic of PC disease was officially announced. This research also ensured that data did not correspond to an early stage of processes of diffusion and technology adoption, during which there may have been high variability in the decision-making process of smallholders, and results may not be reliable.

Questions about technology adoption of PC-related practices were also formulated in the survey. Based on the recommendations of Silva and Martinez (2009), Torres et al. (2010) and Arias et al. (2014) about fundamental practices that help in dealing with the epidemics of PC disease in Colombia, eight agricultural practices were assessed and grouped according to their immediacy of reward attributes:

- Preventive practices (long-term practices): 1) cultivation of leguminous plants, 2) frond analysis, 3) soil analysis, and 4) maintenance of drain channels.
- Shock practices (short-term practices): 1) PC monitoring, 2) PC surgery (removal of diseased tissue), 3) eradication of diseased trees, and 4) application of additional fertilisers to diseased trees.

All questionnaires were conducted in person by the researcher and around 70% were administered face-to-face whilst the rest were collected by phone calls.

4.7.3 Fieldwork phase II: Interviews to key actors

In this phase, representatives of entities were selected, interviewed, and asked to comment on the reliability of the data collected in the previous phase. Following the preliminary network analyses and results of the first phase of fieldwork, semi-structured interviews[45] were conducted with other key actors. The semi-structured interview technique was chosen as the data-gathering instrument because it mainly helped to provide answers to the first research question related to characteristics of CFAs and to complete the information required for the rest of the questions. Interviewees also gave additional feedback on the resulting network maps and helped to improve the understanding of those structures. Furthermore, they ensured reliability of the data.

The semi-structured interviews included about 15 open questions that were adapted to three groups of actors (nucleus participants, contributors to technology diffusion of nuclei, and contextual and sectoral actors) and their roles in the technology-diffusion process of the sector in general, and during the PC disease epidemics. For example, the questions addressed to smallholders as receptors of technology were formulated differently from the questions addressed to research and academic institutions as developers of technologies.

The overall objective of these questions was to gather information about:

1. CFAs for crop management and technical assistance focusing on agreements regarding PC management (e.g. what were the technical arrangements and responsibilities of participants in PC management).
2. Technical relationships between actors during the PC disease epidemics and additional features of these relationships and formal rules (e.g. whether values of

[45]Semi-structured interviews refer to a series of questions that are in the general form of an interview schedule but whose sequence can vary. The interviewers can also ask further questions in response to what they consider to be significant answers (Bryman, 2015: 212)

trust and friendship did or did not influence the technical relationships and commitments between smallholders and other change agents).

3. Technical support in the adoption and implementation of agricultural practices for PC management (e.g. who influenced and participated in the final implementation of practices).

4. Historical and institutional backgrounds of the agricultural epidemic that affected the transfer of agricultural practices for PC management (e.g. how sectoral and institutional actors supported the processes of centralised-technology diffusion).

4.7.4 Post-fieldwork: feedback and data triangulation

On returning from fieldwork, the collected data and information were reviewed and organised following the elements of the theoretical framework of this thesis. In order to determine the accuracy of the qualitative findings, *member checking* was used where the researcher asked other actors in the sector for accuracy or misrepresentation of results (Creswell, 2013; Stake, 2013; Yin, 2013). Thus, the evidence was completed and outcomes of technology adoption were explained based on specific questions that were formulated to the head of the UG alliance and technical assistants of the three nuclei.

4.8 Data and information analysis

Quantitative and qualitative analyses were conducted on the data and information: both methods involved comparative analysis between case studies. The methodology for each is presented below.

4.8.1 Qualitative analysis

The qualitative method was particularly helpful in answering the first question about how different types of formal rules were associated with pathways of technology diffusion. This method also helped to identify informal relationships embedded in contractual interactions between participants of the CFAs and their influence on diffusion processes; this completed the answer to the first and second research questions. In addition, it contributed to the explanation of the results of adoption based on relationships and formal rules; in this way it answered the third research question.

We initiated an analytic strategy through which the data and information of each case study were organised; after this organisation, a comparative technique for cross-case analysis was employed to draw conclusions. The analytical strategy required the construction of categories and sub-categories where collected evidence was placed. The categories corresponded to the three phases of the research strategy (Figure 4.1). Table 4.3 indicates categories and sub-categories for every element of the theoretical framework that required qualitative analysis.

Table. 4.3: Taxonomy for qualitative analysis

<table>
<tr><th colspan="2">Categories</th><th>Sub-categories</th><th>Information assessed</th></tr>
<tr><td rowspan="5">Institutional configuration</td><td rowspan="5">Formal rules</td><td>Type of participants in the agreements</td><td>Selection criteria of smallholders
Type of smallholders</td></tr>
<tr><td rowspan="4">Governance: Roles and commitments for technology transfer</td><td>Leadership in technology transfer</td></tr>
<tr><td>Participation in decision-making processes for planning and implementation of practices in crop and PC management and for selecting sources of technologies and innovation</td></tr>
<tr><td>Provision of inputs, equipment, financial support and technical support (e.g. information, knowledge, training) for technology adoption of practices in crop and PC management</td></tr>
<tr><td>Technical responsibilities of change actors in PC management</td></tr>
<tr><td>Technical Relationships</td><td>Vertical networks</td><td>Interactions</td><td>Informal relationships explaining formal rules and technical interactions (e.g. trust-based relationships)</td></tr>
<tr><td>Outcomes</td><td>Technology adoption</td><td>Levels of technology adoption</td><td>Technology adoption of preventive and shock practices explained by results of network structures and formal rules.</td></tr>
</table>

Source: Own elaboration from analysis of the literature review (see Chapter 2)

Considering that the research method of this thesis is a multi-case study and a cross-sectional study, the analytical strategy used to draw conclusions was the cross-case synthesis technique (Yin, 2013). Under this technique, and based on the data and information, a profile for each case study was built and compared according to the categories in Table 4.3.

4.8.2 Quantitative analysis

Quantitative analysis mainly helped to answer the second and part of the third research question concerning network structures and technology adoption. The first element was operationalised through variables of size and interactions, brokerage and the central positions of actors, whilst the second element was operationalised through aggregate levels of adoption of agricultural practices (see Table 4.1). Table 4.4 specifies which indicators were used to evaluate these elements.

Table 4.4: Indicators for quantitative analysis

Variables	Indicators	Description and Utility in diffusion of agricultural practices
Network size and Individual interactions	Size	Description: measures the number of actors and relationships in a network. Utility: identifies participants and relationships that contribute to the process of centralised-technology diffusion.
	In-degree of smallholders	Description: indicates the number of relationships bringing information (also called incoming links) to a smallholder. Utility: identifies the level of interaction and sources that are available to smallholders.
	Link usage	Description: measures the number of links transferring information regarding each particular practice from change agents and other key actors to smallholders Utility: details the type of information being transferred to smallholders by other change agents
Brokerage beyond the group	Brokerage	Description: measures the number of main brokers that are good at connecting areas between two or more densely connected subgroups in a network (brokerage measured by redundancy and efficiency,

		see Appendix D and E) Utility: helps to find actors able to broker different sources of information outside the nucleus to smallholders.
	In-degree of brokers	Description: measures the number of incoming relationships of brokers in a network. Utility: identifies the level of interactions and sources that are available to brokers in the network.
Central Positions	Degree centrality of actors	Description: measures the number of relationships an actor has with other actors. Utility: indicates the central position of actors in terms of popularity in the network (number of relationships for sharing and receiving information)
	Betweenness centrality of actors	Description: identify actors mediating between other actors. Utility: indicates the central position of actors in terms of their mediation role between other actors.
	Network centralisation	Description: indicates the degree to which a network revolves around a single actor Utility: identifies the degree to which network receive or share information from a single actor.
Technology adoption	Levels of technology adoption	Description: measures number of users and non-users of agricultural practices Utility: indicates the outcomes in terms of technology adoption that result from the technology-diffusion process

Source: Wasserman and Faust (1994), Borgatti (1997), Burt (2005), De Nooy et al. (2011), Ramirez et al. (2014).

The quantitative methods combined social network analysis (SNA) and descriptive statistics to study the data collected through surveys. SNA is a technique used to describe and analyse the structural patterns of interpersonal communication in social systems (Lin, 2002; Valente, 1995).

Two SNA approaches helped to analyse each case study individually and carry out comparisons amongst the three case studies. The first perspective was the *socio-centred* *approach*, which considered the structural characteristics of an entire network in terms of the volume and organisation of connections (De Nooy et al., 2011). From this approach, relative rather than absolute comparisons and conclusions can be drawn about different network structures. Examples could be seen with the use of network size and interactions, average in-degree, network centralised and structural holes in networks in Table 4.4.

The second SNA perspective, the *ego-centred approach*, considered structural characteristics of individual actors or, in other words, the potential role of individuals and organisations in networks (De Nooy et al., 2011). The most common indicators in the network literature are centrality measures and, particularly, betweenness centrality. Freeman (1978) suggested this indicator to assess the extent to which an actor intermediates between all other actors. Some of the indicators used under this perspective can be seen in Table 4.4. They are degree centrality of actors, betweenness centrality of actors, and brokerage. Indicators and measurements of SNA of both perspectives were computed by employing the Pajek sociometric software, which also helped to visualise the networks and structural patterns.

Regarding the outcomes of the technology-diffusion process, discrete variables were used to depict the technology adoption in the case studies. The total number of users and non-users for all practices, as well as shock and preventive practices, allowed comparisons of outcomes within and between each case study.

4.9 Summary of the chapter

This research employed a multi-case study of technology-diffusion processes occurring in three nuclei in the Colombian oil palm sector during the PC disease epidemics. The multi-case study was an approach identified as a potential research method due to the low level of control over the contemporary phenomenon, and the need for contrasting scenarios in order to expand the foundations of the theory of innovation diffusion.

The research strategy to answer the research questions and operationalise the theoretical framework involved three phases. The first phase conducted a characterisation of formal rules related to the contract farming agreements in each oil palm nucleus. The second phase involved the study of network structures using characteristics of size and interactions, brokerage and central position. The third phase analysed the effects of diffusion pathways, resulting from types of formal rules and technical relationships, on technology adoption.

This research employed primary and secondary sources of information and used qualitative and quantitative methods for data collection and analysis. The primary source data were mainly collected in fieldwork phases I and II, in which surveys were administered to a set of actors and semi-structured interviews were conducted with key participants. Snowballing techniques were used to complete the list of participants in both stages. As part of the secondary sources, qualitative and quantitative documents were collected from public websites. To ensure validity and check accuracy of data and information collected, a triangulation method was used.

The analysis of data and information was carried out using qualitative and quantitative analyses, each corresponding to different research questions. The qualitative analysis employed a preliminary analytical strategy that involved a taxonomy based on the main elements of the theoretical framework (i.e. formal rules, vertical networks and technology adoption) in which evidence was placed.

The quantitative analysis was carried out using social network analysis (SNA) and descriptive statistics for the study of networks and the assessment of technology adoption. Within the SNA, this research employed both socio-centred and ego-centred approaches to visualise technical relationships, characterise structural patterns of networks, and identify structural attributes of actors’ position. A cross-case synthesis technique was used in both qualitative and quantitative methods in order to draw comparative conclusions between the three case studies.

Generalisation from this work comes from the use of analytical generalisation in multi-case studies. By having more than one case study, it may be possible to contrast different scenarios of technology diffusion and elaborate theoretical principles and lessons within the theory of innovation diffusion. Through the application of these general principles in different contexts with similar conditions, theoretical replication could be achieved.

CHAPTER 5

CASE STUDY NUCLEUS A: SEMI-AUTONOMOUS SMALL-SCALE PRODUCERS IN THE COLOMBIAN OIL PALM SECTOR

This chapter analyses the centralised-diffusion process of technologies for PC management in an oil palm cluster of the Central zone of Colombia, named nucleus A. In order to do this, the chapter will follow the theoretical framework and the research strategy posed in Chapters 2 (see Figure 2.5 p.76) and 4 (see Figure 4.1), respectively. In this framework, formal rules set an institutional basis for the formation of vertical networks, which in turn have an impact on technology adoption. A similar analysis will be developed in Chapters 6 and 7 for the other two case studies of the oil palm sector, and a comparative discussion will be held around these results in Chapter 8.

Following the theoretical framework of this thesis, this case study will begin by describing a particular set of formal rules, specifically, the technical roles of actors, the characteristics of users selected during the configuration of the cluster, the relationship between these two factors and the social attributes embedded in these rules. Technical roles of actors and selection of users are formally determined by the CFA of this cluster[46]. Users play a fundamental role in technology diffusion when it comes to: a) identifying their technical needs in terms of access to inputs, technical assistance and credits (Bijman, 2008; Barrett et al., 2012); b) selecting and adopting practices (Wejnert, 2002; Rogers, 2010). Hence, the importance of studying user features will be emphasised. It will be shown that the combination of formal rules and the *nature of users,* as well as the decisions of these users led by their nature, may influence the type of centralised diffusion, the manner of diffusion and the type of adopted practices. This thesis defines the nature of users as their

[46] As was mentioned in Sub-Section 2.3.1, rules are formalised through CFAs agreed by parties.

socio-economic conditions, whether they have a short- or long-term vision, whether they act as an individual or a group, and the level of attachment to their land.

Together with Chapters 6 and 7, this chapter will provide empirical evidence to examine the three research questions of this thesis, namely how particular agreements may affect pathways of diffusion, how these networks may be structured, and how levels of technology adoption may vary with the different pathways. This chapter is structured in six sections. Section 5.1 describes the technical roles and the responsibilities that the CFA formally assigned to actors in nucleus A. Section 5.2 provides an overview for the configuration of this cluster and the characteristics of selected smallholders. By relating the technical roles of participants and the nature of users, Sections 5.1 and 5.2 answer the first research question.

Social attributes embedded in formal rules and in technical connections are discussed in Section 5.3, not only for being necessary elements that enable the agreement to last over time, but also for influencing smallholders' final adoption through technical relationships. Section 5.4 analyses the technical relationships and the network structures that result from the formal rules of nucleus A, therefore answering the second research question.

Section 5.5 describes the outcomes regarding the adoption levels of preventive and shock practices that result from formal rules and from the impact of network structures on technology diffusion. The final section draws conclusions about this chapter. Chapters 6 and 7 follow a similar structure of analysis to allow comparisons between the case studies.

Functions within nucleus A were determined by predominant low agro-industrial control governance in which semi-autonomous smallholders were in charge of most decision-making processes. The case study indicates that the process of technology diffusion had different impacts on the adoption of preventive and shock practices. It showed a high implementation of shock practices and low implementation of preventive practices. These results can first be attributed to the nature of rules, in which smallholders are given most responsibilities for crop management, except for those related to the adoption of shock practices. Second, they can be attributed to the nature of these producers and their relationship to oil palm production that enables them to build one-to-one relationships with other actors. These producers live predominantly in urban areas, have different sources of income including oil palm, and hire labourers to work and manage their land. These different connections for technology transfer will be shown via network structures.

5.1 Technical responsibilities and roles within formal rules of nucleus A

This section discusses the technical responsibilities and leading roles of participants of nucleus A in the centralised-diffusion process of technologies for PC management (or PC related practices)[47]. In other words, it examines the governance of nucleus A. It is important to highlight that these technical roles and commitments were a set of rules that actors negotiated at the beginning or during the development of the CFA; however, it did not guarantee that the participants would actually fulfil these obligations and that technology transfer occurred. This is also the case for the next two empirical chapters (Chapters 6 and 7).

Nucleus A was a scheme for oil palm production located in the Central zone, in which 35 small-scale producers sold their product to Anchor Company A. This agro-industrial firm owned oil palm crops and a processing mill, and processed the fruit provided by other surrounding plantations. According to an interviewed technical assistant[48], this nucleus was created as a part of Anchor Company A’s business strategy, where negotiating a contract with fruit providers was more convenient for the company than extending its landowning. The small-scale producers marketing their fruit to Anchor Company A, were

[47] Apart from the interviews, surveys and fieldwork observations, there is no publicly accessible information of the CFAs corresponding to all case studies of this thesis. This is because oil palm agro-industrial firms in Colombia usually keep these contracts private.
[48] Unless otherwise stated, a technical assistant is a member of staff from Anchor Company A.

distributed in 17 towns in the Central zone[49]. Although most producers (31) were conveniently located in the same geographical department where the anchor company had its plantation and mill, there was an exceptional few (4) that were located in a neighbouring department, 116 kilometres farther from the company.

The CFA in this nucleus was mainly based on a market contract for fruit commercialisation[50], in which smallholders assumed most technical responsibilities of crop management whilst Anchor Company A had a minimum involvement with farmers' crop management. As such, this CFA had predominant features of an agreement with low agro-industrial control governance (one of the CFA typologies identified in Table 2.4).

Interviewed representatives of the company[51] asserted that the anchor company provided the seedling plants to selected producers for these growers to initiate their oil palm cultivation. Following this initial stage, the company facilitated the purchase of fertilisers to some producers and provided free technical assistance regarding agricultural management, including PC management. In exchange, smallholders agreed to sell the oil palm fruit to Anchor Company A at the international based price of FFB[52] for a period of 20 to 25 years. Within this period, the company discounted the price of the seedlings and fertilisers from the harvest sales. Interviewed technical assistants and producers of this nucleus asserted that there were no legal sanctions in the event of small-scale producers deciding side-sell to other anchor companies. However, there was a financial commitment with the company that needed to be fulfilled through the agreed discount from FFB sales. If the total cost of the credit was not paid off, legal sanctions might be applied resulting in

[49] The specific location of these towns is not provided due to confidentiality requirements between the author of this thesis and anchor companies.
[50] This type of CFA has some of the characteristics of the marketing contract of sell-purchase described on p.44.
[51] Representatives include technical assistants and the head of the department for management of fruit providers in Anchor Company A.
[52] It was mentioned that, although the Colombian agro-industrial firms adhere to international prices, the choice of smallholders to sell their harvest to certain companies depended on the additional benefits that these companies offered (see footnote 18).

breach of the arrangement and cancellation of the technical assistance provided by the anchor company to producers.

Regarding the role of Anchor Company A, this firm aimed for what company officials and technical assistants called a *non-paternalistic model*, in which the firm provided technical assistance with minimum involvement in smallholders' crop management. A technical assistant, for example, reported that 'the head manager has clarified that we shouldn't do everything for them, otherwise they will take advantage of the situation mostly because this assistance is free of charge' (E.M, personal communication, 9 July 2015). According to this scheme, the anchor company provided regular support, training and, in some cases, facilitated credits to purchase fertilisers. Several interviewed smallholders pointed out that despite having regular technical assistance (e.g. monitoring and recommendations regarding convenient periods for adoption, products and farming methods), the anchor company did not get involved in the implementation of these practices.

On their part, smallholders led the management of their own plantations without being technically or economically dependent on Anchor Company A. Although the company might have a significant influence on smallholders' decision-making processes through recommendations and training, the producers always made the final decisions and employed their own methods for technology adoption. Consistent with the low agro-industrial control governance, smallholders in this CFA had a high level of autonomy and made decisions about the provision of equipment and inputs, planning and implementation of agricultural activities, and access to sources of technical support.

There was, however, an exception in which company A became highly involved in the decision-making process and implementation of PC monitoring and PC surgeries (shock practices). The difficult situation of epidemic emergency in Puerto Wilches, required the adoption of complex and new agricultural practices that drove leaders in the Central zone and in the oil palm sector to coordinate top-down strategies. In fact, interviewed smallholders affirmed that, after the ICA declared an emergency in Puerto Wilches in 2013, Anchor Company A increased the frequency of awareness campaigns and technical assistance for PC management, particularly for the implementation of shock practices. Due to the epidemics in the Central zone, the anchor company decided to play a more leading role and undertake important responsibilities related to the management of shock practices in the nucleus.

The leadership of company A in the management of shock practices was noted by a technical assistant of this company when he said:

> '…whilst they [the owners and officials of anchor company A] don't like a paternalistic scheme in which the company does everything for smallholders, because of the epidemics of PC, they started getting highly involved in the organisation of plantations and trainings (…) we monitor the disease and sometimes help with the surgery treatment…' (C.M, personal communication, 5 July 2015).

Observations during the fieldwork indicated that company A planned, transferred and verified the strategy and the methods for adoption of shock practices. In some cases, technical staff implemented practices such as PC monitoring and surgery treatments in smallholders' plantations. According to the technical assistant, this close verification guaranteed that smallholders implemented scientific protocols that resulted from R&D processes. He asserted that '…without the pressure of the company, our farmers would not be doing the Cenipalma protocol' (E.M, personal communication, 9 July 2015).

One can argue from fieldwork observations that three reasons could explain the significant interest of Anchor Company A in controlling the spread of the PC disease in smallholders' plantations. These reasons can also explain the interests of Anchor Companies B and C in controlling the spread of PC disease in their nuclei, as will be seen in Chapters 6 and 7.

First, smallholders were an important population of fruit providers from whom the agro-industries obtained raw material for oil palm processing. In addition, the anchor company provided free seeds to smallholders to initiate the oil palm production. The reduction of the FFB supply caused by the PC disease, directly affected the investment made by the company, the amount of input that oil palm mills could process, and the efficiency of their installed production capacity. As a technical assistant said, ‘if they lose, we lose because money from us is invested in their agribusiness’ (E.M, personal communication, 9 July 2015).

Second, the PC disease represented a risk for not only the affected, but also for neighbouring plantations, including the oil palm crops of anchor companies. As was indicated at the beginning of this section, most producers were located in the same region, albeit not in the same department, where Anchor Company A had its oil palm crops and processing mill. Failure to control PC disease outbreaks in producers’ crops posed a risk of infection for the anchor company.

A third reason was related to the regional strategy for PC epidemic control that Anchor Company A took on, together with Anchor Companies B, C and other agro-industrial firms in the Central zone. Due to the epidemic in Puerto Wilches, these companies developed a regional strategy and committed themselves in what this thesis named a UG alliance, mainly to establish procedures and follow scientific protocols for the control of PC disease[53]. Through this alliance, the anchor companies joined financial and technical efforts to systematically monitor plantations, unify criteria for PC management, and verify these criteria in their respective nucleus. These criteria were based on the Cenipalma protocols and the shared experiences of technical assistants, mainly concerning shock practices such as monitoring, treatment and eradication of diseased trees. Thus, we can infer that there was a top-down strategy establishing a hierarchy in the decision-making process for the shock practices, in which the UG alliance defined rules for its members and from these companies to smallholders.

[53] Later, the UG alliance dealt with other types of oil palm pests and diseases in the region.

In order to fulfil the commitments defined by the top-down strategy of the UG alliance, Anchor Company A had to play more of a leading role in the management of shock practices than would typically be dictated by its non-paternalistic model. Interviewed technical assistants affirmed that the anchor company had to hire technical workers to be in charge of recording accurate information and verifying the implementation of shock practices in producers' plantations (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015). Technical workers indicated during the fieldwork that in exceptional cases, with delayed or unskilled producers, they directly implemented PC surgery treatments to support these plantations.

The high emphasis on shock practices by Anchor Company A also ensured the involvement of Cenipalma, who not only developed these practices but also trained technical assistants and smallholders in their correct adoption. It was observed during the fieldwork that Cenipalma was one of the main sources from which company A acquired technical knowledge that was subsequently transferred to smallholders. Interviewed technical assistants asserted that Anchor Company A first and foremost followed protocols recommended by Cenipalma and criteria decided by the UG alliance.

This section described the type of CFA that participants of nucleus A agreed for crop management. From this characterisation, it is possible to infer two important aspects of this agreement. First, this agreement showed that the priority of Anchor Company A was the adoption of shock practices rather than preventive practices. Second, with the exception of shock practices, these rules gave high autonomy to smallholders to implement preventive practices and other agricultural practices. The rest of the chapter discusses what the implications were in terms of technical support to both shock and preventive practices and in levels of adoption.

5.2 Semi-autonomous and better-off producers

In addition to the roles and technical functions of participants, the theoretical framework of this thesis suggested that the type of users is another aspect explaining the variations of formal rules and their impact on centralised-diffusion processes. The configuration of nuclei, specifically the characteristics of users, is a fundamental element in understanding the technical roles and responsibilities that actors assume in PC management. From the literature of CFAs and innovation diffusion discussed in Chapter 2, we interpreted that producers' characteristics could indicate the economic capacity of smallholders to access necessary inputs and services for production (e.g. credits and technical services) and for technology adoption (Sub-Section 2.1.2). From these characteristics, it could be possible to establish whether or not producers require the support of an agro-industrial company within a CFA. This section will go further and suggest that the nature of users can be significant for the technology-diffusion theory as they indicate the level of support that smallholders receive from an agro-industrial firm and from other sources of information, as well as their level of participation in the implementation of practices.

The selection criteria for members, and the historical conditions under which configuration of nucleus A took place, helps to explain the type of smallholders that participated in this contract and the links they established with other actors in the sector. The selection criteria are the requirements by which an anchor company determines whether a smallholder is eligible to participate in the CFA and in the nucleus (see Sub-Section 2.3.4). The socio-economic characteristics of smallholders were fundamental aspects in the selection requirements of this nucleus. Interviewed technical assistants asserted that as part of the anchor company's business strategy, this agro-industrial firm accepted medium and large producers as well as smallholders (from 2000 to 2014) in the CFA scheme of this cluster (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015).

Yet, the interviewed technical assistants explained that the anchor company undertook a rigorous selection of smallholders based on their socio-economic conditions. The company preferentially selected better-off producers who were not fully dependent on the oil palm business as their only income source. A technical assistant reported:

> 'the company does a selection [of producers] considering the socio-economic conditions of oil palm growers and if they will be able to maintain their oil palm crop (…) the head of the company doesn't like to accept producers in the nucleus with limited resources who, for example, might need to build a deep well for water maintenance in the future but won't have the economic resources to afford it. Therefore, they [the company] search for producers who either have good socio-economic conditions or have other alternative sources of income' (C.M, personal communication, 5 July 2015).

The rigorous selection of better-off producers was intended to reduce anchor company A's responsibilities and transaction costs for the provision of inputs and services. During the selection of small-scale producers, the anchor company evaluated the economic sustainability of these projects and the economic capacity of these producers to develop their agribusiness in both the short and long term. According to technical assistants, most producers were not traditional farmers, but were characterised as having a business profile and were engaged in additional farming and/or non-farming activities (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015). With higher socio-economic conditions, these producers were expected to cover all agricultural costs, including management of practices for the control of pests and diseases, and to be economically independent from the anchor company.

The analysis of data collected during fieldwork confirms the socio-economic characteristics of smallholders as a result of the selection criteria applied by company A. Table 5.1 shows that the majority of growers had plantations with more than 10 hectares and exploited additional livelihoods in addition to oil palm; these included staple crops, non-farming activities and cattle activities, for which they showed considerable preference. For example, two interviewed smallholders owned around 245 hectares where they raised cattle. Additionally, the data indicated that producers of this nucleus usually lived in urban areas, some of them (66%) had sufficient economic capacity to employ crop managers, while others (34%) led the management themselves or left it to their relatives.

The data also reveal that most producers had completed primary education, and a significant important proportion (34%) had completed a university level course. It was confirmed by interviewed technical assistants that some of these producers had a business background.

Table 5.1. Socio-economic conditions of small-scale producers in nucleus A

Variable	Mean	Frequency of producers
Size (No. Hectares)	Mean = 26 Min = 3 Max = 50	0 – 10 = 5 (14%) 11 - 20 = 12 (34%) 21 - 30 = 7 (20%) 31 - 40 = 4 (11%) 40 - 50 = 7 (20%)
Income source	N/A	Only oil palm agribusiness: 0 (0%) People with livestock: 8 (23%) Staple crops[54]: 9 (25%) Livestock and other staple crops: 3 (9%) Non-farming activities: 8 (23%) NI: 7 (20%)
Participation income (based on producers' perceptions)	N/A	High dependence on oil palm[1]: 15 (43%) Low dependence on oil palm[2]: 16 (46%) Equally dependence on oil palm and other livelihoods: 4 (11%)
Education	N/A	Primary: 10 (32%) Secondary: 12 (34%) University: 12 (34%) Technical career: 0 (0%)

[1]more than 50% of their income comes from oil palm
[2]less than 50% of their income comes from oil palm
NI: No Information available
N/A: Not applicable

Source: Own elaboration based on fieldwork

The socio-economic characteristics of producers in this nucleus indicated that they had high incomes and profitable alternatives to oil palm agribusiness that could be used to

[54] For example, yam, plantain, fruit trees, corn.

finance the expenses required for oil palm cultivation. Under these conditions, producers were highly autonomous and could lead the processes of production on their own, making the main decisions about crop management for themselves. The following paragraphs will analyse how these characteristics may have affected their tendency to adopt short- rather than long-term practices and to choose their own technology information sources.

First, the business profile, the high levels of education, and the low dependency of these producers on the oil palm agribusiness suggest that these growers used the cultivation as a profitable investment rather than a sustainable livelihood. This can also be explained by the fact that several producers lived in urban areas far from their plantations, or that a significant number employed crop managers. It is possible to say that these producers seemed detached from their land and less concerned than other rural farmers about the agricultural sustainability of their crops. As a result, one could also propose that since producers in this nucleus might tend to expect immediate profits, they put greater attention on short-term practices, for example shock practices, which favour this type of benefit.

The nature of these producers also suggests that they had more resources available with which to respond rapidly to stress situations in comparison with poor farmers. Favourable economic conditions could enable better-off producers to afford shock practices and deal with urgent situations that jeopardise their production levels and their immediate benefits.

At the same time, having more available resources may give these producers the autonomy to select their own sources for the provision of inputs and services. Based on Sub-Section 2.3.4 of this thesis, the CFA literature indicated that contracting with larger and better-off producers may reduce agro-industrial firms' transactional costs associated with the provision of inputs and services (Bijman, 2008; Barrett et al., 2012). This opened up room for other suppliers in the sector, as can be seen in the following example.

During 2013, up until the beginning of 2014, a group of large, medium and some small-scale fruit providers of Anchor Company A refused to follow the company's technical recommendations and protocols. Instead, these producers hired and adopted practices recommended by private sources of information that, according to interviewed technical assistants and researchers of Cenipalma, were not scientifically recognised by sectoral organisations. The influence coming from these external sources of information drove this group not to believe in the efficiency of shock practices for PC management, as promoted by Anchor Company A and Cenipalma. Consequently, technical assistants suggested that these producers lost control of the PC disease (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015). Even though the majority of smallholders were adopting the shock practices recommended by the anchor company, the PC disease spread to those neighbouring the affected plantation and, in addition to other factors[55], caused the rapid increase of PC disease in most of these producers' areas between May 2014 and March 2015; this is shown in Figure 5.1. Interviewed technical assistants affirmed that after the spike in PC incidence levels, affected producers adopted shock practices and accepted the lead of the anchor company and UG alliance in the management of PC disease (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015).

[55] One of these reasons was the adverse climatic condition in the area, such as high relative humidity and frequent rainy periods that also favoured the development and spread of the PC.

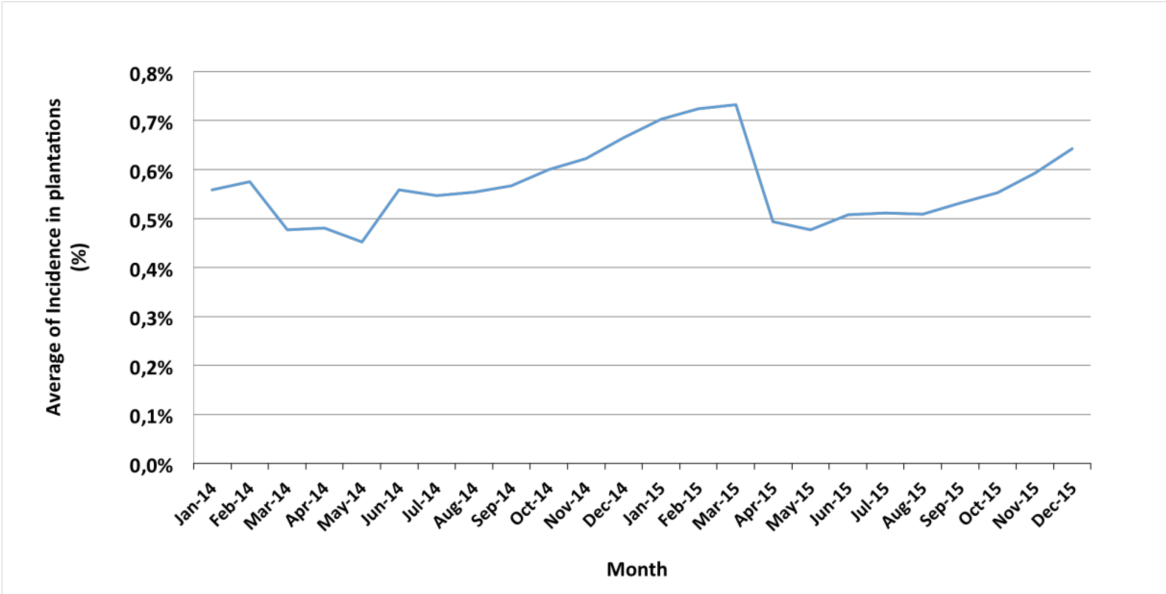

Figure 5.1: Levels of PC incidence of smallholders in cluster A between 2014-2015

Source: Own elaboration based on data provided by anchor companies of this study

This example shows that unanticipated outcomes can occur when a particular set of rules is established for the selection of fruit providers. Whilst the selection of better-off producers was intended to reduce the involvement of Anchor Company A, their unexpected autonomy gave them the confidence to access alternative sources. The better economic conditions and the business profile of some producers in this cluster may have given them more independency and caused them to act more individualistically when it came to looking for technical assistance in the market. These sources then gave advice contrary to that of the anchor company, which was then adopted and ultimately caused a significant increase in the level of PC incidence.

This section shows that the nature of users mattered for the process of technology diffusion and for the adoption of different practices in a different way than studies of CFA and innovation-diffusion might expect. The importance of individual characteristics in the literature as part of the selection criteria of smallholders in a CFA that can determine the access to technical assistance and the adoption of agricultural practices, was referenced in Sub-Sections 2.1.2 and 2.3.4 of this thesis. However, these works do not contemplate a different way that other features, or that the nature of smallholders, can impact the diffusions process. It is argued here that better socio-economic conditions may give the capacity for producers to act more individualistically and therefore connect to different information sources. Also, better-off producers may put greater attention efforts in adopting short-term practices (e.g. shock practices) in order to increase their short-term benefits.

From this section, it is possible to suggest a relationship between the technical responsibilities of a CFA with low agro-industrial governance, the nature and expectations of users (selected under the particular set of formal rules), and the tendency of producers to adopt certain practices. The fact that most smallholders in nucleus A had favourable socio-economic conditions was the reason why the CFA of this cluster gave them leading roles as well as most technical responsibilities in crop management, except for those related to shock practices. This approach is premised by the conviction that these producers had resources available to afford necessary practices, including protocols to deal with epidemic emergencies. Nevertheless, the keen interest of better-off producers to favour short-term profits, led them to give more emphasis to shock practices than to strategies that guaranteed long-term sustainability of the agribusiness, for instance preventive practices. Therefore, one may conclude that these formal rules did not favour conditions for the adoption of long-term practices but for the adoption of short-term practices.

The important assistance that Anchor Company A provided as a part of this CFA, and the favourable socio-economic conditions of smallholders in this cluster, were necessary but not sufficient factors to ensure the diffusion and final adoption of shock practices. Social values embedded into the formal rules, and thus technical relationships, were also fundamental to achieving the effective diffusion and adoption of shock practices, as will be explained in the next section below.

5.3 Trust-based relationships underpinning the formal rules of nucleus A

Despite the arms-length rules established in this nucleus by formal agreements and the favourable socio-economic characteristics that gave more autonomy to users, smallholders accepted the greater involvement of Anchor Company A in the management of shock practices. This is because values of trust made the relationship between these two actors go beyond technical and contractual interactions within their corresponding CFA, which is an interesting point as a part of formal rules to elaborate in this section.

The explanation of Kirsten and Sartorius (2002), Fafchamps and Minten (2002), and Barret et al. (2012) given in Sub-Section 2.4.2 about the importance of good communication and trust-based relationships between contracting parties was useful to understand how responsibilities assigned by the formal rules in nucleus A did not turn into mere technical connections. Trust-based relationships and friendship between smallholders and Anchor Company A, as a part of their formal rules, allowed not only the leadership by this company in the management of shock practices but also the continuation of the CFA and the long-term assistance to producers. With the exception of the smallholders mentioned in the example given Section 5.2, the majority of producers considered the company as a trustworthy source of information. This anchor company had an important influence on smallholders and could make them adopt targeted strategies, for instance, shock practices. Thus, we could say that informal relationships and values of trust are actually required to make formal rules work in the nucleus.

Trust and friendship were characteristic values of the technical relationship between smallholders and technical assistants of Anchor Company A. Most smallholders reported having a high reliance on and friendly relationships with these assistants. According to an interviewed technical assistant, this was supported by the fact that assistance was not limited to mere technical instructions but also to ‘social support’. This was described in the following way:

> '…in most farms, the technical visit becomes a social visit in which you not only give assistance but also have a cup of coffee with them, ask about their families (…) one creates a bond of personal friendship with them (smallholders) which is what strengthens the partnership (…)' (E.M, personal communication, 9 July 2015).

Trust-based relationships were also the result of the long-term commercial relationships based on smallholders' loyalty for fruit provision and the anchor company's regular support. As pointed out by the interviewed technical assistants, smallholders could side-sell FFB to other companies in the region. However, the long-term relationships between participants of the agreement underpinned the relationships of loyalty in this nucleus (C.M, personal communication, 5 July 2015; E.M, personal communication, 9 July 2015). This was demonstrated by the fact that, with the exception of two smallholders[56], all oil palm producers of nucleus A exclusively marketed their fruit to Anchor Company A, despite not having any legal sanctions if they chose to side-sell to other companies.

An interviewed smallholder observed that this loyalty was explained by the long-term commitment between smallholders and Anchor Company A within the CFA and the reliance on technical experience of the agro-industrial firm (L.M, personal communication, 3 July 2015). Supporting this, another smallholder reported '[in comparison to peers] I rely more on the technical assistants (…) If I see any anomaly in my crop, the first thing I do is to call the technical assistant' (L.M, personal communication, 3 July 2015). In addition, both interviewed smallholders and technical assistants agreed that personalised and regular support had been essential factors for building trust relationships between them. These interviewees also asserted that the use of persuasive instead of coercive methods by the anchor company stimulated the effective adoption of agricultural practices.

Embedded values of trust within technical relationships can have two impacts in the diffusion process. First, these relationships not only established connections through which technology transfer occurs, but also enabled other actors to be connected to the

[56] These two smallholders admitted being part of a previous CFA with other companies before participating in the CFA with Anchor Company A. After initiating a new oil palm cultivation, they were allowed to participate in nucleus A with these crops without breaching previous agreements with the other companies.

CFA participants. For example, Anchor Company A strictly followed Cenipalma's recommendations for agricultural management. The anchor company either transferred these protocols by itself or brought in Cenipalma researchers to train and provide technical assistance to both the company and smallholders.

Second, the trust-based relationships underpinning the CFA between company A and smallholders also impacted the adoption of shock practices during the epidemic. The agreement provided a technical platform for a range of technical responsibilities, mainly for the management of shock practices. This platform was built on trust-based relationships that enabled the anchor company to recommend and give instructions as well as to raise awareness, strengthen its credibility and persuade smallholders to adopt shock practices.

Although this trust helped to support the adoption of shock practices and, therefore, to lower the average levels of PC incidence, this had not been always the case during the whole period. The evidence of the previous section suggests that lack of credibility amongst some smallholders during 2013, up until the beginning of 2014, contributed to worsening the outbreak of PC in the period between June 2014 and March 2015. Technical assistants reported that the group of smallholders that did not follow the official recommendations before the outbreak paid little attention to the adoption of shock practices, because they did not believe in the impact of PC disease, despite the company's warnings.

The rejection of Anchor Company A's recommendations by large and medium size plantations (referred to in Section 5.2) and by smallholders during 2013 and 2014, drew attention to a missing element within the technology transfer of nucleus A that is closely related with trust: credibility[57]. Without this element, the transfer and final adoption of

[57] Within the innovation diffusion literature, the works of Gorschek et al. (2006), O'Connor (2014), Peters (1996), and Walton (2013) that referred to trust and credibility, discussed these terms as inseparable concepts and no distinction was made between these terms when identifying their determining factors.

shock practices was hampered because producers were not willing to adopt these practices. This occurred because producers relied more on private information sources or did not consider the importance of Anchor Company A and Cenipalma's recommendations.

According to Ganesan and Hess (1997), credibility is one of the dimensions of trust through which partners are able to keep promises; their intentions and actions are evaluated on task specific competencies, predictability in terms of their job related behaviours, and reliability in their delivery of goods and services. In the theory of innovation-diffusion, Rogers (2010: 385) indicated that 'Change agent's success in securing the adoption of innovations by clients is positively related to credibility in the clients' eyes'. In this case, credibility is necessary for the transfer of certain types of practices that generate high impact in the short-term, for example, shock practices.

It can be concluded from this section that trust-based relationships, friendship and credibility are necessary elements for the successful transfer of shock practices. Although this seems unsurprising, the fact that trust-based relationships and loyalty for fruit provision existed between smallholders and Anchor Company A, despite not being territorially close and not having legal sanctions in the agreements for side-selling, needs to be highlighted. This is probably because of the nature of the epidemic and long-term relationships existing between smallholders and the anchor company. If formal rules are implemented integrating trust, friendship and credibility, adoption levels of shock practices may increase in a context of centralised diffusion. Having these values in vertical relationships challenges some binary views of vertical relationships, which suggests that hierarchy can only mean the use of authority. One of these views is the work of Wejnert (2002), who asserts: 'Highly centralized, stratified networks use coercive pressure on their members to achieve conformity of practices (…) increasing rates of adoption' (p.308).

Up to this point, this chapter has shown a process of centralised-diffusion with three important characteristics. First, formal rules were based on a CFA of low agro-industrial control in which smallholders led their crop management and the anchor company provided little assistance for the adoption of these practices but significant support for the adoption of shock practices. Second, smallholders were selected due to their favourable socio-economic conditions. And third, trust is a key aspect that facilitates technology transfers between smallholders and Anchor Company A. Both the formal rules and the nature of smallholders gave rise to the technical relationships and networks that will be examined in the next section.

5.4 Centralised network supporting shock practices in nucleus A

Graphical representations of networks show the different actors and technical connections amongst these actors for the transfer of technologies. They may also display other aspects of the processes of diffusion, such as characteristics of users and conditions of formal rules. Smallholders' socio-economic conditions indicate how financially independent these actors are, and therefore how autonomous they can be in selecting their information sources. On their part, formal rules dictate technical responsibilities for actors while creating conditions of mutual trust and expectations for continuing these technical relationships over a long-term period. These formalised technical responsibilities and trust-based relationships tie actors together in a network of diffusion.

This section aims to identify actors with a central position in network A, transferring information and technology for PC management to smallholders. With this in mind, we use SNA based on an ego-centred approach[58], which is also applied in the next empirical chapters.

Interesting outcomes in this section will show that networks capture the high reliance of smallholders on Anchor Company A and Cenipalma (due to the terms of agreements), and the comparatively poor relationships that smallholders had with other actors in the network (due to producers' characteristics). Despite Anchor Company A aiming for a non-

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[58] This SNA approach considers structural characteristics regarding the potential role and network position of individual actors (see Sub-Section 4.8.2 for more explanation).

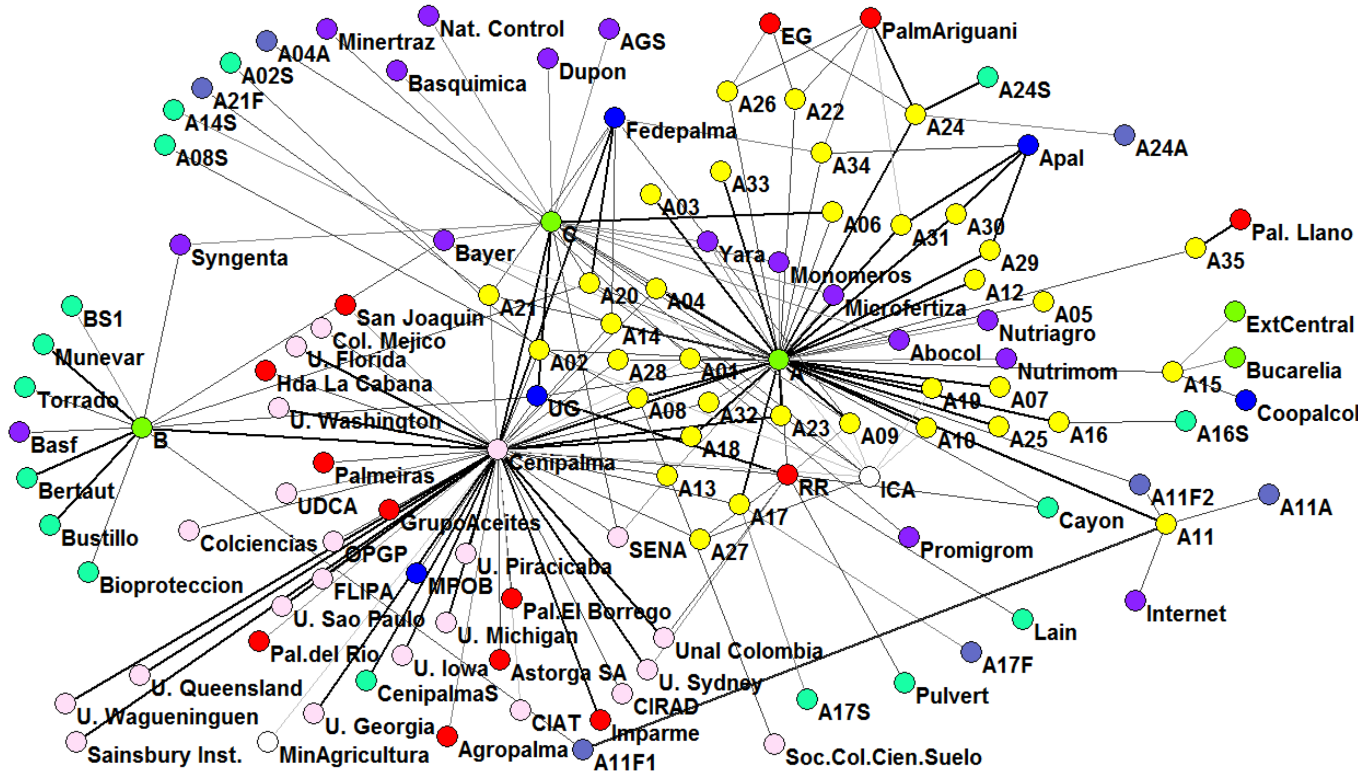
paternalistic model, and thereby providing little assistance to smallholders, this company was the leading change agent of the nucleus. The high connectedness reflects the important assistance that smallholders in this cluster received from the leading change agent for the adoption of shock practices. By contrast, producers found poor support for the adoption of preventive practices through weak links with other actors. This section answers the second research question about the network structures resulting from formal rules and the impact of these networks on information access, influence and variety of information sources.

In accordance with the interpretation made from Salancik's (1995) work in Sub-Section 2.4.1, formal rules establish an institutional framework that inhibits or imposes interactions amongst actors, thereby affecting networks. The most important connections through which smallholders received technical support in nucleus A emerged from the responsibilities that semi-autonomous smallholders and Anchor Company A assumed within their CFA. Albeit important, the role of networks in reflecting conditions of agreements was not discussed by works in the literature on the diffusion of agricultural innovations that studied relational structures for diffusion (Wyckhuys and O'Neil, 2007; Monge et al., 2008; Spielman et al., 2011), as was previously mentioned in Sub-Section 2.4.4 (pp.68-69). These studies analysed relationships and network structures but did not trace formal rules that generated these connections and helped them to persist in time.

Technical connections caused by the CFA of nucleus A are visualised and studied through network analysis. The network related to this nucleus is described through three structural characteristics corresponding to the operationalisation of the theoretical framework of this thesis (Table 4.1, p. 128), these are: network size and individual interactions, central positions and brokerage beyond smallholders.

Network size and individual interaction

Figure 5.2, below, shows an overview map of the technical connections through which participants of nucleus A received information and technologies for the PC management. The network for technology-diffusion in Figure 5.2, also named as network A, contains 122 actors related through 186 connections. Of the total number of actors, 36 belong to nucleus A (Anchor Company A and 35 smallholders) and the remaining 86 are classified into 8 types. These eight categories are medium or large producers, associations/alliances between companies, academic/research entities, government entities, supply companies, friends/relatives, external advisors, and social organisations.



Type of Organisations

- Small producer
- Anchor company
- Medium or Large producer
- Associations/ Alliances between companies
- Academic/ Research entity
- Governmental institution
- Supply company
- Friend/Relative
- External advisor
- Social organisation

Figure 5.2: Network A for technology diffusion of PC-related practices

Source: Own elaboration from survey data

A clearer view of network A is possible by examining its ‘shrunken network’ (term given by De Nooy et al., 2011) through which actors are grouped according to their organisational types. In the shrunken network A (Figure 5.3), the tie thickness of links represents the number of relationships between groups of actors, whilst the values indicate the importance of these links.

It can be seen from Figure 5.2, smallholders accessed information through connections with all types of actors but mainly with the anchor companies. Of the four anchor companies in the group, Anchor Company A has the highest number of relationships (number of links: 34; sum of importance: 121). Figure 5.3 shows that, to a lesser degree, other groups, such as academic/research entities (number of links: 15; sum of importance: 43), Medium/Large producers (number of links: 12; sum of importance: 30) and associations (number of links: 10; sum of importance: 33) contribute to this transfer. It should be highlighted that the largest contribution to the academic/research entities is that of Cenipalma (number of links: 13; sum of importance: 38). In the case of six smallholders (A03, A05, A07, A12, A25 and A33), Anchor Company A was their only source of information.

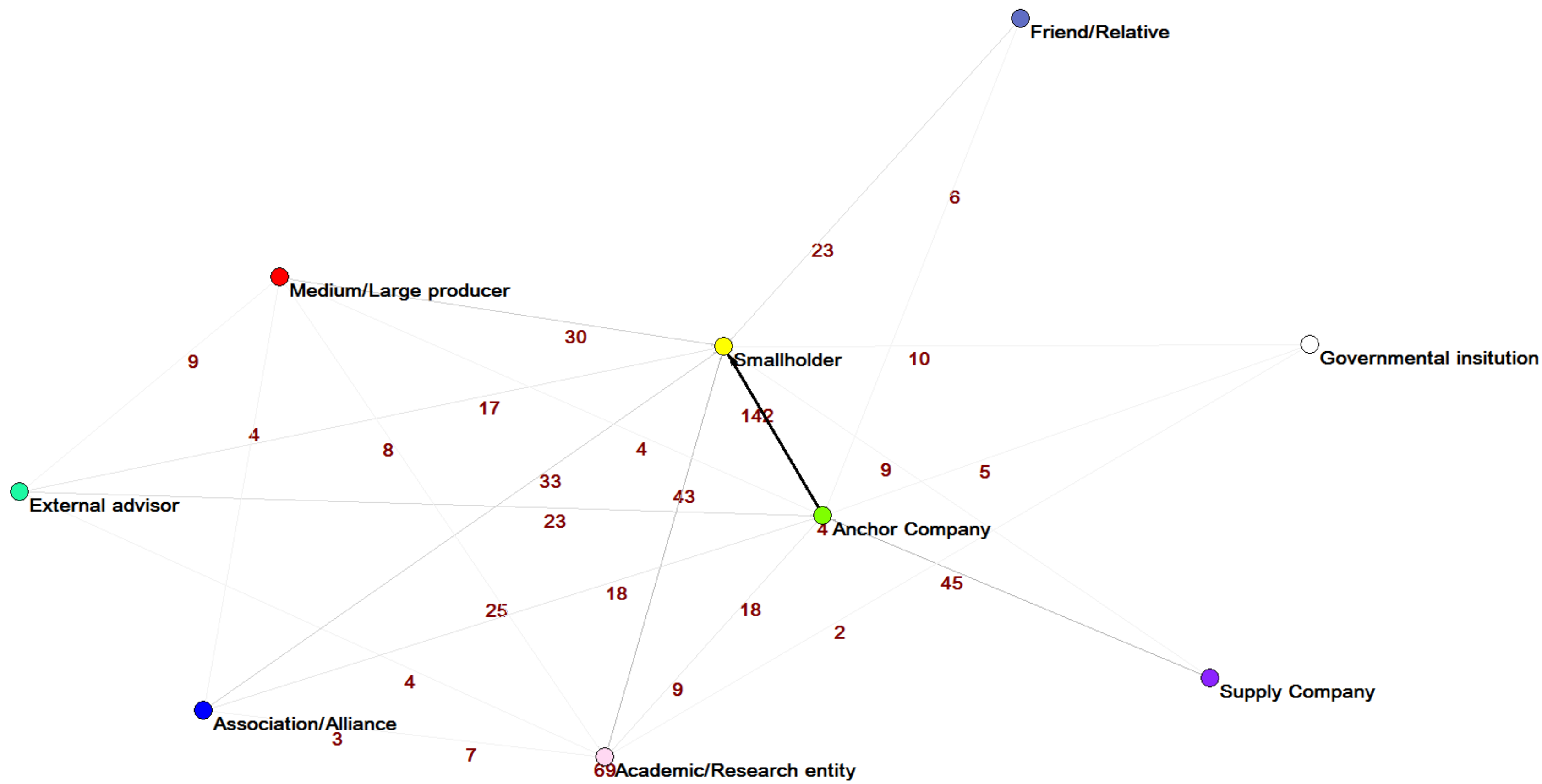


Figure 5.3: Shrunken network A for technology diffusion of PC-related practices

Source: Own elaboration from survey data

Regarding the individual interactions for information access, Figure 5.4 shows that producers had an average of almost three sources of information from which they acquired information or technical assistance (in-degree average: 2.9). The data indicates that most producers had 2-4 incoming links, thus reducing their dependency on a single source of information.

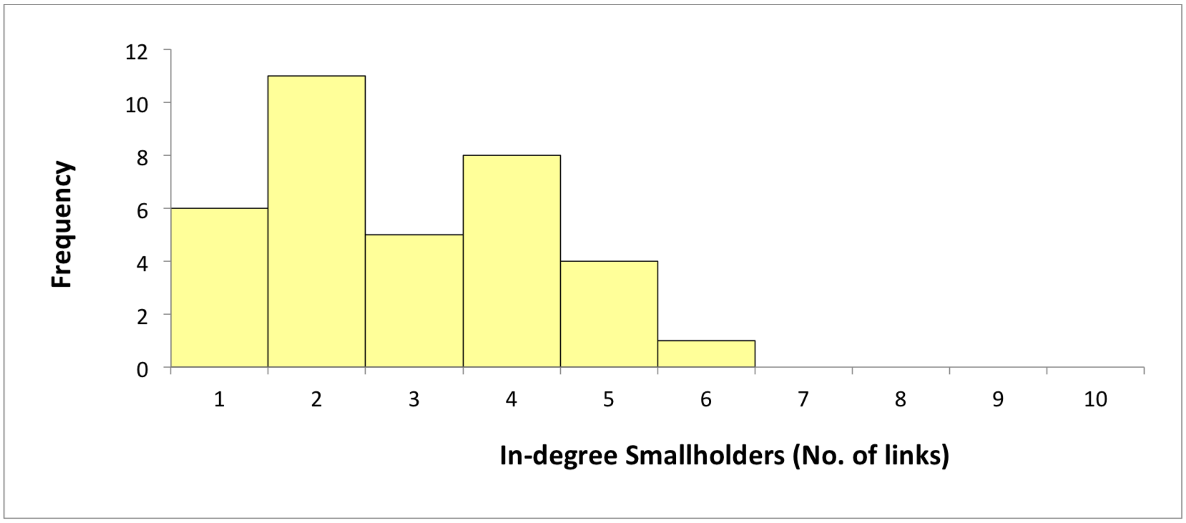


Figure 5.4: In-degree of small-scale producers belonging to nucleus A

Source: Own elaboration from survey data

In terms of the usage of these links, Table 5.2 considers the users in network A and for what information their links are being used. For example, it can be seen that 22 of the links from Anchor Company A to users were used for the transfer of information to do with monitoring. It should also be highlighted that links can be used for the transfer of multiple types of information. Anchor Company A belongs to the anchor companies group, but the link usage of this specific actor is shown separately to visualise the particular contribution of this actor. The same table shows that most of the connections bringing information and technologies for PC management to smallholders were focused on shock practices. Anchor Company A dominated most of the links for transferring both preventive and shock practices, which is not surprising given that this firm provided general assistance for crop management. However, the support provided by this company to the management of preventive practices (No. of links: 81) was not considered to be as important as the assistance provided to the adoption of shock practices (No. of links: 109).

Table 5.2: Link usage; detailing the type of information being transferred to users in network A

Actor	Total	Preventive practices				Shock practices			
		Drain	Soil	Frond	Leguminous	Monitoring	Surgeries	Fertilisation	Eradication
Anchor company A	126	8	16	15	3	22	21	21	20
Cenipalma	19	0	3	2	1	4	6	2	1
Anchor companies[1]	9	0	2	2	0	2	1	1	1
Medium/Large producer	12	2	2	4	2	0	1	1	0
Associations	10	3	2	2	1	0	0	2	0
Friends/ Relatives	8	3	2	2	1	0	0	0	0
External advisor	6	2	1	0	0	3	0	0	0
		Total links: 81				**Total links: 109**			

[1]: not including anchor company A

Source: Own elaboration from survey data

Primary data gathered during interviews also revealed that Cenipalma exerted important influence on farmers' final decisions about the adoption of shock practices, even though not many producers mentioned their connections with this centre. For instance, an interviewed technical assistant and several smallholders mentioned the Sanipalma[59] programme for agricultural extension that was implemented in the past by the research centre and had a remarkable impact on producers' actions.

It can be said that, except for the links with core actors (Anchor Company A and Cenipalma), several connections of smallholders can be justified by these producers' socio-economic conditions. Under market imperfections (see Sub-Section 2.3.2, particularly Table 2.3), one might think that rural and poor small-scale producers do not have the financial capacity to hire assistance in addition to the general support provided by an anchor company. In this case study, some of the better-off producers employed external advisors whilst others had regular contacts with medium and large-scale producers and anchor companies in the area (see Table 5.2). Producers mainly used these connections to access knowledge and technologies related to preventive practices.

Central positions

At first glance, Figure 5.2 shows that network A was highly centralised around a few actors to which small-scale producers of nucleus A were mostly linked. This network evidences that Anchor Company A and, to a lesser extent, Cenipalma were fundamental actors to facilitate technologies and technical knowledge, mostly supporting the adoption of shock practices. Reinforcing this visualisation, Table 5.3 shows the 10 most central actors in terms of their number of links (degree). They included Cenipalma, Anchor Companies A, B and C, the government entity ICA, and medium-scale producer RR.

Anchor companies and Cenipalma also had a central role of intermediation amongst network actors, and therefore were useful brokers between smallholders and these other

[59] See page 107 for an explanation of the programme.

sources of information. The levels of betweenness centrality[60] in Table 5.3 show that Cenipalma and Anchor Companies A, B and C were important brokers in network A. For example, Cenipalma mostly integrated information from international and national academic institutions and large- and medium-scale producers (with which this research centre interacts, and has experiments and demonstration plots) to the network. In the case of intermediation by the anchor companies, interviewed technical assistants affirmed that the majority of information these companies brought to the network came from their debates within the UG alliance, supply companies, academic and research entities and external advisors. This information was mainly related to strategies that aimed to stop the rapid spread of the disease in the short term. It should be noted that actors A01, A02, A03 and A05, have a betweenness value of zero, and are included in Table 5.3 to highlight the fact that only the top six actors listed have any measurable level of betweenness.

Table 5.3: Degree and Betweenness indicators within nucleus A

Actor	Degree
Cenipalma	56
A	48
C	23
B	14
ICA	10
RR	10
Fedepalma	8
A11	6
UG	6
A02	5

Actor	Betweenness
Cenipalma	0.125186
A	0.099264
B	0.025426
C	0.02328
RR	0.007756
A11F1	0.000587
A01	0
A02	0
A03	0
A05	0

Source: Own elaboration from survey data

[60] As was explained in Sub-Section 2.4.4 (See p.63), betweenness centrality indicates to what extent an actor may control the flow of information due to their position in the knowledge network.

Brokerage beyond smallholders

The structural holes (the non-redundant information flows) in network A indicate a high reliance on a small number of broker entities that had unique channels through which to communicate between different groups of information. From the analysis of central positions (degree and betweenness centrality), it was possible to identify four actors that had both high degree and betweenness centrality. At the same, these four actors played a brokering role within the network of nucleus A and were more likely to bring completely new knowledge to the group of smallholders. Table 5.4 shows the number of information sources connected to these brokers (in-degree centrality), the number of links between these brokers and smallholders (out-degree to smallholders), the importance of these links, their levels of redundancy, and levels of efficiency. Following Borgatti (1997), these last two measures are used to assess the efficiency of these brokers to connect groups of actors through structural holes.

Table 5.4: Measurements of structural holes for broker organisations

Broker	In-Degree Centrality	Out-Degree links (broker-smallholders)	Importance of Out-Degree links (broker-smallholders [1]	Efficiency	Redundancy
B	11	1	3	98%	0.63
Cenipalma	36	13	37.7	97%	1.4
A	13	34	122.4	97%	1.6
C	15	5	14	88%	2.1

[1]: Out-Degree links weighted by their average importance
Source: Own elaboration from survey data

According to the levels of efficiency and redundancy, Table 5.4 shows that B, Cenipalma, A and C have key positions in the network and could also influence smallholders by being connected either to several sources of information or to several producers. Although Anchor Company B had less redundancy and, in turn, more efficiency (Redundancy: 0.63 and Efficiency: 98%), the amount of information that this actor received and the number of smallholders that were connected to him were the lowest within the group of brokers. This limited the amount of knowledge that smallholders were likely to receive from Anchor Company B.

Regarding Anchor Company A and Cenipalma, it is not surprising that both actors had brokering roles due to the relatively high number of network links. As has been highlighted, Anchor Company A led the technology transfer to smallholders (Out-degree: 34), which increased its role as broker. At the same time, the research centre was active in networking with other academic institutions, producers, international agencies, experts and governmental actors (In-degree: 36). However, if these brokers were not highly focused on supporting shock practices, then their role could have been fully exploited by producers to acquire technical support in all PC-related practices.

This section discussed how formal rules and the nature of users had impacts on the structure of a network. The network resulting from the type of formal rules that were negotiated in nucleus A was highly centralised on two brokers: Anchor Company A and Cenipalma. The high number of links supporting the adoption of shock practices reflected the important assistance provided by Anchor Company A and its leadership role in the CFA. Unlike shock practices, few links supported the adoption of preventive practices. These weak connections originated from other actors in the sectors with whom producers could relate due to their favourable socio-economic conditions. The outcomes of this type of network are analysed in the following section.

5.5 Adoption of PC-related practices in nucleus A

Following the theoretical framework for centralised-diffusion systems formulated in Chapter 2, this section explains the impacts of the diffusion processes that result from network structures and formal rules on levels of adoption of preventive and shock practices in nucleus A. It is shown that the dominance of a few actors transferring mainly shock practices, and the poor but diverse interactions between smallholders and other actors for access to preventive practices, resulted in levels of adoption of shock practices being much greater than the adoption levels of preventive practices. An additional factor that may also explain these lower levels of adoption is the nature of selected smallholders and their priorities, when implementing practices, towards short-term benefits. From there, it is possible to answer the third research question about how technology adoption varies with the different pathways of diffusion in a context of highly centralised models.

As was explained in Sub-Section 4.8.2 (Table 4.4), the number of users for each agricultural practice is used to measure levels of technology adoption. Based on the results of surveyed smallholders in nucleus A, the average percentage of users was 73%. When agricultural practices were considered separately, it was seen that shock practices (93%) far exceeded the percentage of users of preventive practices (54%). A breakdown of each group of practices revealed that the major percentage of non-users was registered on the cultivation of leguminous plants and maintenance of drain channels. Contrary to this, practices with major support, such as PC monitoring and PC surgery, were adopted by 100% and 92% of smallholders, respectively (Figure 5.5).

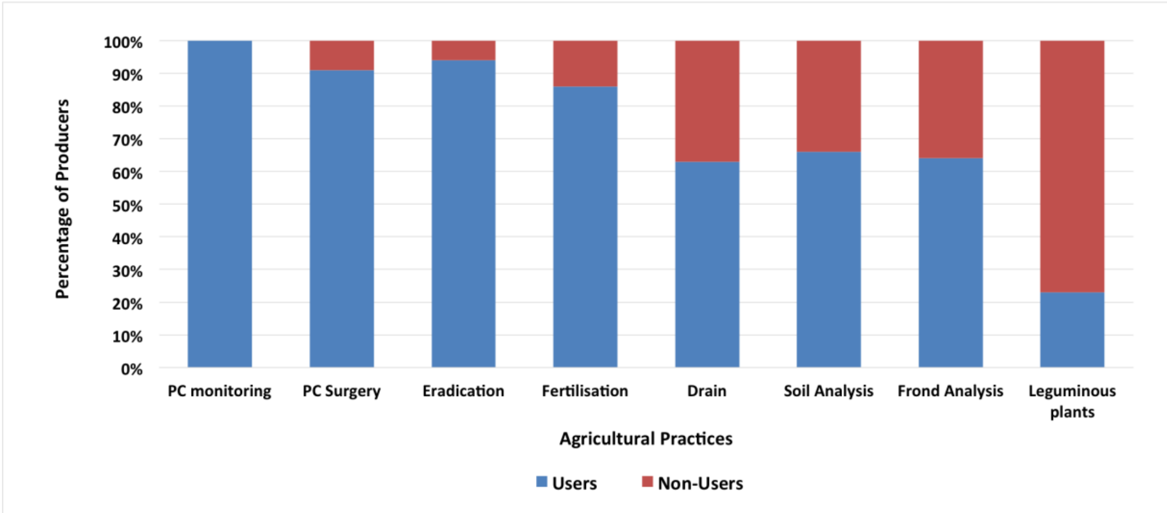


Figure 5.5: Levels of technology adoption by small-scale producers in nucleus A in 2015

Source: Own elaboration from survey data

The impact that the structure of network A had on technology diffusion and the nature of users in this cluster can add to the understanding of the results of the above figure. The higher levels of shock practice adoption can be explained by the major support given by central actors in the context of these techniques. Comparatively, the lower levels of adoption of preventive practices can illustrate the lack of technical assistance provided by these actors to these activities.

It is suggested that technical relationships can be a significant factor to increase the adoption levels of shock practices. As will be seen below, Anchor Company A exerted influence on smallholders' processes of decision-making through these connections by, first, providing close verification and guarantees for the implementation of both PC monitoring and PC surgeries, and second, raising awareness in the nucleus.

First, evidence from fieldwork indicates that Anchor Company A regularly trained and supervised smallholders on detecting degrees of infection severity and incidence levels (i.e. PC monitoring), and on applying advised methods to perform PC surgeries. As it was seen in Section 5.2, the anchor company implemented these practices in some of the plantations to ensure that the official guide for PC monitoring and surgeries were done on a timely basis.

Second, strategies for raising awareness about PC and its detrimental effects were also critical elements in improving the willingness of smallholders towards the adoption of shock practices. For instance, an interviewed technical assistant affirmed that by taking smallholders to the affected area of Puerto Wilches, Anchor Company A prompted smallholders to implement PC monitoring and PC surgeries. According to interviewed smallholders, after visiting the area of the epidemic, these producers were more keen to change their own practices and adopt the Cenipalma protocol under the instruction of the anchor company. With respect to this, an interviewed producer said:

> ‘after the visit to Puerto Wilches, people started paying more attention to the technical assistance because what we saw was that the epidemic of PC caused a state of terror that has made smallholders to act and look for technical assistance’ (L.M, personal communication, 3 July 2015).

Contrary to shock practices, preventive practices received less attention from central actors and were supported by very few other actors, as was seen in network A. In addition to the network structure, other factors can explain the low adoption levels of these practices, such as lack of interest and limited financial resources of smallholders. Consequently it is argued that these factors can be explained by the nature of producers in this cluster.

Figure 5.6 shows the non-users’ reasons for not implementing preventive practices. Several surveyed producers affirmed not being interested in performing soil and frond analyses and in cultivating leguminous plants because their adoption did not seem as urgent as the adoption of practices that helped to control the spread of the disease. Additionally, an interviewed technical assistant pointed out that although the anchor company selected better-off smallholders, drain channels and cultivation of leguminous plants involved producers investing a significant amount of financial resource, which was not usually available in the short term (G.C, personal communication, 30 July 2015). For example, only 26% of smallholders cultivated leguminous plants, which, according to interviewed producers, was not an essential practice and involved the high costs of sowing and maintenance.

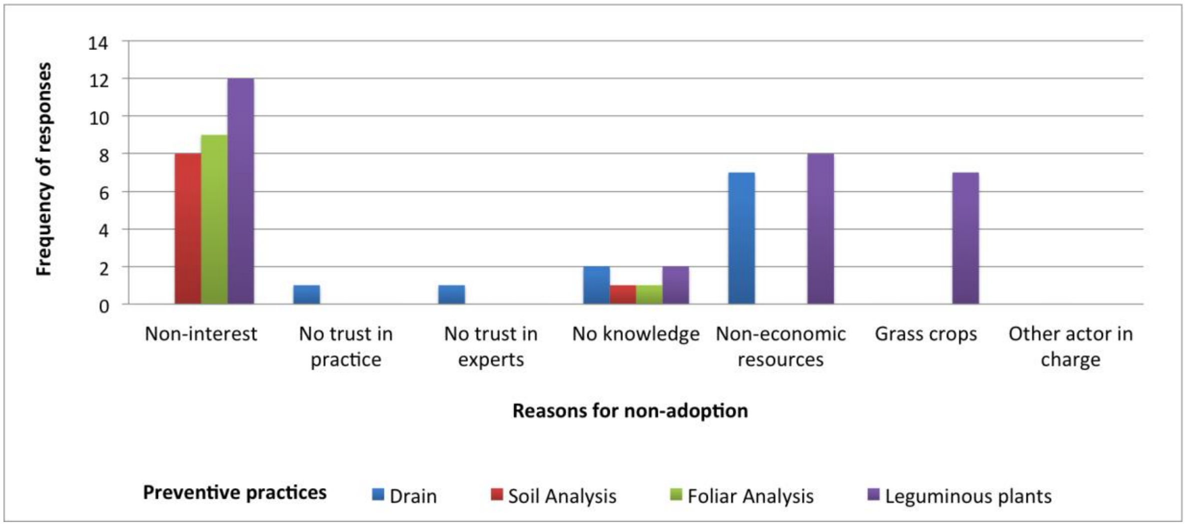


Figure 5.6: Reasons for non-adoption of preventive practices in nucleus A

Source: Own elaboration from survey data

The reasons for the non-adoption of preventive practices can be associated with the background and economic characteristics of smallholders. As implied in Section 5.2, it is likely that the business profiles of smallholders in this nucleus made them more responsive and quick in tackling issues of greatest concern that could impact their immediate benefits, such as disease outbreaks. Therefore, these producers may have low interest in, and may make fewer financial efforts towards, those practices whose benefits cannot be observed in the short term. In fact, the choice to plant grass for cattle between oil palms, which is considered by experts as a harmful practice for oil palm cultivation, instead of cultivating leguminous plants (see Figure 5.6), clearly evidenced the preference of smallholders for cattle breeding. This is likely due to the desire for the short-term profits that can be seen from cattle breeding, rather than the long-term benefits from the cultivation of leguminous plants.

The level of low-interest reveals the key importance of users' attitudes in the decision process, which is not new to the theory of innovation diffusion. According to the model of innovation-decision process developed by Rogers (2010), the 'knowledge stage' in which 'an individual (or other decision-making unit) is exposed to an innovation's existence and gains an understanding of how it functions' (p.171) is followed by a 'persuasion stage'. At this phase, 'the individual forms a favourable or unfavourable attitude towards the innovation' (Rogers, 2010, p.174).

Following the results of this case study, we link this element of attitude towards the adoption of certain technologies to the nature of producers. Better-off producers seemed to have a more favourable attitude towards shock practices and were therefore more willing to adopt them. Interviewed technical assistants affirmed that they highly depended on this willingness to have positive results in the adoption of any agricultural practice.

The low interest of smallholders and change agents can be also associated to network structures. Through technical links, leading change agents made strong and effective efforts to influence smallholders' attitudes aimed at raising the awareness of users about the need for shock practices. In contrast, no important efforts forming a more positive attitude towards long-term practices were seen in the connections of smallholders and other actors in the network. Based on the little attention that users and change agents gave to the implementation of preventive practices, one can suggest that both actors were responsible for their low adoption levels.

The following table summarises most of the reasons that impacted the technology adoption in nucleus A related to the technology-diffusion process and the nature of selected smallholders.

Table 5.5: Factors affecting the adoption of PC-related practices in nucleus A

Shock Practices	
Fertilisation of diseased trees	· Trust in technical assistance provided by Anchor Company A · Availability of economic resources and access to credits from Anchor Company A and from banks to buy fertilisers
PC monitoring	· Trust in technical assistance provided by Anchor Company A and additional training by Cenipalma · Availability of resources to hire fieldworkers and expert advisors who implement practice or complement smallholders' adoption · Free PC monitoring service and verification provided by technical teams of Anchor Company A to some smallholders
PC Surgery	· Trust in technical assistance and regular training provided by Anchor Company A · Availability of resources to hire fieldworkers and expert advisors who implement practice or complement smallholders' adoption · Free PC surgery service and verification provided by technical teams of Anchor Company A to some smallholders · Verification of PC surgery by Anchor Company A · Availability of economic resources
Eradication	· Trust in technical assistance provided by Anchor Company A · Availability of resources to hire expert advisors who implement practice
Preventive Practices	
Drain infrastructure	· Adoption from previous farm activities (e.g. livestock) · High costs of equipment and infrastructure
Soil Analysis	· Technical relationships of some smallholders with other anchor companies and a local association that provides additional support · No interest in adoption
Frond Analysis	· Technical relationships of some smallholders with other anchor companies that provide additional support to some smallholders · No interest in adoption

Cultivation of Leguminous plants	· No interest in adoption · No availability of economic resources for covering the high costs of adoption (e.g. high time, labour force and money consuming for land preparation, inputs and maintenance) · Interest in planting grass for cattle between oil palms

Source: Analysis from author survey and interviews of oil palm producers

The evidence shows that the formal rules of nucleus A, specifically the type of CFA, selection criteria and trust-based relationships amongst participants of this agreement, did not favour conditions for the implementation of preventive practices but for the adoption of shock practices. Sections 5.1 and 5.2 indicated that the CFA of this cluster was characterised by the governance of low agro-industrial control and a selection of better-off and semi-autonomous producers. On the one hand, and according to this set of rules, Anchor Company A assumed few responsibilities in the implementation of preventive practices, and better-off producers, albeit in charge of preventive practices, had little interest in supporting them. On the other hand, this CFA showed that the priority of the anchor company was the adoption of shock practices. The business profile of the selected producers also explained their efforts in adopting shock practices that helped them to avoid loss of profit. Trust-based relationships underpinning the rules between producers and Anchor Company A were also necessary values for the successful introduction of shock practices. As a result of these formal rules, nucleus A exhibited a high adoption of shock practices and low adoption of preventive practices.

The resulting adoption of PC-related practices from the implementation of the CFA, and the trust-based relationships amongst producers and the anchor company in nucleus A, may have had beneficial impacts in controlling the spread of the disease, but adverse effects on their long-term sustainability. Although the adoption of shock practices may have helped to treat affected trees and control the spread of PC, at the time of this research, the low adoption of preventive practices might have threatened the agricultural sustainability of the oil palm crops. Based on collected data and the decision-criteria to asses levels of PC incidence[61], we can argue that, by adopting shock practices, smallholders of nucleus A almost certainly helped to keep the annual average levels of PC incidence down (0.57%) between January-2014 and December-2015.

As was argued in Sub-Section 3.4.1 (pp. 104-105), shock practices such as PC monitoring and surgeries can lead to the recovery of diseased trees and, in this way, reduce the risk of infection in the nucleus. This recovery will then enable the trees to produce oil palm fruit again. However, failure to implement preventive practices may reduce the agricultural sustainability of producers. As was asserted in Sub-Section 3.4.1, soil and frond analyses and the maintenance of drainage conditions are practices that can limit the development of PC disease. The neglect of these preventive practices could predispose the oil palm trees to future attacks of PC disease (Munévar and Acosta, 2002). Since a considerable number of producers did not carry out soil and frond analysis, they did not know the type and quantity of nutrients their oil palm crops needed in order to develop properly and to resist a PC disease attack.

In answering the research question about the variation of outcomes with the different pathways of technology diffusion, this section suggested that the strong and weak connections transferring knowledge and information within the networks can be linked to the results in adoption levels of shock and preventive practices, independently. In addition to this, the nature of users in terms of socio-economic conditions and willingness towards adoption was a factor that also needed to be considered in the diffusion process of different types of practices.

The case study clearly shows that formal rules and their associated network structures were important, but not sufficient to encourage the implementation of agricultural practices. Factors such as trust, change agents' credibility, and smallholders' willingness

[61] The decision criteria to assess annual average levels of PC incidence is based on the potential effectiveness of shock practices for certain levels of incidence. If the level of PC incidence in a plantation is lower than 10%, the package for PC management proposed by Cenipalma is likely to be effective; if the incidence is higher than 20% and there is a high degree of infection severity, it is said that the grower is dealing with an epidemic (Arias et al., 2014).

cannot be underestimated in the diffusion and adoption of technologies, since they can help in both the efficient communication amongst actors and final implementation practices. It was argued that the individualistic vision and detachment from the land that characterises those better-off producers with business profiles, may well explain their unwillingness to implement preventive practices in this nucleus.

5.6 Summary of chapter

This chapter discussed the technology-diffusion process of oil palm nucleus A, based on the description and analysis of the three elements set out by the theoretical framework in Chapter 2: formal rules, vertical networks, and technology adoption. From this chapter it is possible to conclude that the type of technical support that smallholders received from key change agents, the leading change agent in this nucleus being Anchor Company A, and other actors explains the focus placed on the implementation of a particular type of practice. In nucleus A, the lower adoption of preventive practices resulted from: a) the limited assistance that the leading change agent provided to smallholders compared to the support that this actor gave for the adoption of shock practices; and b) the poor attention of selected smallholders in the adoption of these practices.

The limited assistance of the agro-industrial firm was explained by the type of formal rules that assigned specific technical responsibilities to this leading change agent and smallholders through a CFA of low agro-industrial control. In this nucleus the leading change agent did not lead or closely monitor the adoption of all practices, except shock practices, and left users to direct their own crop management, including that related to preventive practices.

Past experiences have shown that the independence of producers was not always the best alternative during stress situations. In epidemics, a close, and to some degree hierarchical, relationship ensuring the adoption of shock practices can be important to avoid deviation from recommended practices. Nevertheless, this needed to be a relationship built on trust and a change agent's credibility to facilitate information flows and achieve the successful implementation of shock practices.

A second reason explaining the low levels of adoption was related to the type of users that were selected in the CFAs, in this case, better-off and semi-autonomous producers having a business profile. The nature of these producers suggested that these actors had low interest in adopting practices from which they could not benefit in the short-term.

The technical responsibilities and roles within these types of formal rules and the nature of smallholders led to the creation of a type of diffusion network that was highly centralised on a few change agents. This particular type expressed high emphasis on short-term practices, because of the important support provided by change agents, and low focus on long-term practices, because of the creation of one-to-one relationships between smallholders and other actors.

Three insightful points that can be raised from this case study need to be integrated to the theoretical framework for centralised-technology diffusion. First, the nature of users, which was defined initially during the establishment of formal rules, and is a fundamental factor of centralised-diffusion systems. Second, market contracts that provide more autonomy to smallholders may not be supportive of the implementation of long-term practices. Finally, trust and credibility characteristics embedded in hierarchical relationships were significant aspects for the adoption of short-term practices.

CHAPTER 6

CASE STUDY NUCLEUS B: DOMINANT CONTROL OF AN AGRO-INDUSTRIAL FIRM IN THE COLOMBIAN OIL PALM SECTOR

This chapter studies the centralised-diffusion process of PC-related technologies in a nucleus organised under the high control of a leading change agent, which in this case is Anchor Company B. Unlike nucleus A, the smallholders of this cluster were not autonomous in making decisions related to crop management. As in the previous chapter, this analysis relies on three basic elements of the theoretical framework (see Figure 2.5): formal rules, vertical networks, and technology adoption.

For the sake of comparison, this chapter follows the same structure as that in Chapter 5. In order to answer the first research question about how different formal rules affect pathways of diffusion, Sections 6.1 and 6.2 discusses the set of rules for the CFA and the type of smallholders selected in this cluster, respectively. Section 6.3 explains the problematic relationship between participants of cluster B caused by both the CFA and the different nature of smallholders. Section 6.4 presents the resulting network structure and technical support from change agents to smallholders, which helps to answer the second research question about the influence of central actors and network structures, affected by types of formal rules, on technology diffusion. Section 6.5 relates the different adoption levels with the formal rules and network structures of the cluster. With this section we answer the third research question, about the impact of pathways of diffusion on adoption. Conclusions are then presented in the final section.

This chapter presents two narratives about how this particular centralised-diffusion system deals with the adoption of short- and long-term practices. These narratives serve to explain the higher adoption levels of shock practices, compared with those of preventive practices. In the first narrative, despite the intention of the leading change agent to determine the crop management under a CFA of high agro-industrial control, formal rules in this cluster allow smallholders to choose their degree of involvement in the adoption of some long-term practices. According to these rules, the change agent leads the PC management in the cluster and is responsible for the adoption of shock practices and some preventive practices, in which high levels of expertise are required (e.g. soil and frond analyses). By contrast, the adoption of preventive practices requiring low levels of expertise and other agricultural practices affecting crop development are at the discretion of smallholders. As will be discussed, the nature of smallholders (e.g. socio-economic conditions, attachment to the land and interest in long-term sustainability) will be a crucial factor that drives their willingness to be involved in the adoption of these practices.

In the second narrative, as dictated by the CFA of the case study, the anchor company has a decisive influence, not only on adopted practices but also on the selection of users based on their nature. Under a business-based approach, this company decides about the selection of users and the adoption of PC-related practices. As a result, the company selects smallholders with suitable cropping conditions, but little attention is paid to issues such as attachment to oil palm production or agricultural background. Subsequently, the selected users include an important proportion of producers with little or no interest in implementing long-term practices. Furthermore, as will be shown, with the business-based approach, the leading change agent tends towards the adoption of short-term practices, in this case, with shock practices as its main priority. The case discusses the consequences of establishing different responsibilities as a result of selecting different users on technology diffusion.

6.1 Technical responsibilities and roles within formal rules of nucleus B

In this section, the formal rules of nucleus B regarding roles and technical commitments that were agreed during the CFA[62] for technology diffusion are studied. The set of rules of this cluster were characterised by the leading role of Anchor Company B in crop input supply, provision of technical services and credits, and crop management, which also

[62] CFAs considered as the formalisation of rules between parties (see Section 2.3.1 and 2.3.2).

included PC management. These predominant characteristics indicated that nucleus B was governed by a CFA of high agro-industrial control (see Section 2.3.3 for CFA typologies). As mentioned in the previous chapter, these roles and responsibilities were negotiated at the beginning or during the development of the CFA and did not guarantee that the participants would actually fulfil these obligations.

The productive and strategic alliance of nucleus B was one of the multiple projects initiated by Anchor Company B in 2007 and supported by the Colombian government for the benefit of both the company and smallholders in the Central zone. With this alliance, agro-industrial firm B could support the FFB provision to its processing mill through 'third parties' without expanding its own area for cultivation. The project gave the opportunity to 104 small- and medium-scale landholders of the zone to access credits and participate in the agribusiness. From this group, only 33 smallholders were complying with the commercial requirements of the CFA (i.e. non-side selling of fruit) at the time of the fieldwork.

Although government entities such as Finagro and the Colombian Agrarian Bank were the main funders of this alliance, Anchor Company B financed part of the initial stage of oil palm cultivation. The government institutions established three compulsory requirements to fund this alliance: a marketing contract between smallholders and the anchor company over the oil palm production, the formation of a smallholder cooperative, and a provider of *logistical operation*, also called a *logistical operator*. Although the last requirement comprises the backbone of the formal rules for technology transfer in nucleus B, problems related to the other specifications can explain why those rules could not be applied properly.

A marketing contract guaranteed the sale and purchase of the oil palm product at an agreed price and, therefore, the payment of financial obligations and services by smallholders. In this case, Anchor Company B had to purchase the FFB of oil palm to producers whilst producers had to sell their fruit exclusively to this company for a 28-year period (or until producers settled the debt). With this arrangement, small-scale producers were provided with a secure market at the international based price of FFB[63] and could repay their financial obligations.

The formation of a producer cooperative in charge of settling the collective debt of smallholders was another legal requirement in this alliance. All interviewed producers affirmed that financial institutions did not often approve individual credits to small-scale producers. Instead, these entities issued collective credits to smallholder organisations that acted as guarantors for the debt repayment. Producers of this nucleus were grouped into cooperatives that were in charge of settling the associative credits with their members' FFB sales. If one member failed to meet their economic obligations with the cooperative, the rest of the members had to make up the difference. It is important to point out that these cooperatives only played a financial role and did not provide any technical service to their members.

The provision of logistical operations was another requirement from the funding organisations. This role was played by Anchor Company B and included credit management, provision of technical assistance, legal and environmental support, monitoring of crop practices, and logistics for harvesting and transportation. The logistical operator also monitored the appropriate use of the project's resources and guaranteed that revenues from FFB sales were used to repay debts. For the cost of logistical operation, interviewed technical assistants indicated that 8% was deducted from the FFB sales.

As part of the CFA, and, in turn, of the formal rules, Anchor Company B had three main technical responsibilities in the nucleus. First, interviewees affirmed that the anchor company shouldered the initial investment costs and provided seedlings and fertilisers. For those smallholders who requested or required it, this company also financed equipment and infrastructure. After this initial stage, agro-industrial firm B continued

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[63] As with the previous case, the FFB price is standardised and it is the additional benefits that influence smallholders' choice of anchor company (see footnote 18 on page 90).

providing agrochemicals and inputs for PC management. The costs of services and inputs, provided by Anchor Company B during all stages of the oil palm cultivation, were paid by producer cooperatives with the income from the FFB sales.

A second, and most crucial, responsibility was the leadership in decision-making processes related to crop management. Anchor Company B was in charge of the development and planning of practices, the transfer of technical services, the selection of information sources, and the definition of guidelines for adoption of all technologies. Through technical visits, the anchor company trained smallholders and farm workers, monitored plantations and provided instructions. Interviewed smallholders and technical assistants indicated that at the beginning of the project, company B and other subject-experts (e.g. technical assistants of the MIDAS programme[64]) used to organise group trainings. Over the course of time, the low rate in farmers' attendance at these workshops and the problematic relationships within the nucleus led to a reduction in the number of sessions and to focusing on personalised trainings.

Another responsibility that Anchor Company B assumed was the direct implementation of disease and pest-related practices. It was mandatory that the staff of Anchor Company B implemented shock practices for the control of PC disease in the plantations of the nucleus. As in the previous case study, the reasons for the high involvement of Anchor Company B in the adoption of shock practices were the need to ensure the FFB provision to its processing mill from smallholders' crops, the need to control the spreading of PC disease in this area, and the obligation to follow the regional strategy set up by the UG alliance[65], of which agro-industrial firm B was a member. Anchor Company B strictly applied the protocols recommended by Cenipalma and the PC management criteria established by the UG alliance for the adoption of shock practices.

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[64] See footnote 23 (p.95) for more explanation about the MIDAS programme.

[65] It should be remembered that the UG alliance was the regional strategy developed by a few anchor companies, including agro-industries A, B and C, to establish the joint criteria of procedures for controlling PC disease.

As was affirmed, Anchor Company B had complete and absolute control over crop decisions in the nucleus, especially in the definition of practices. The implementation of shock practices and preventive practices, that required high levels of expertise (e.g. frond and soil analyses), were assumed by Anchor Company B. However, the adoption of other preventive practices (e.g. cultivation of leguminous and maintenance of drainage channels) and non-PC-related practices (e.g. fertilisation and management of weeds) were implemented at the discretion of smallholders. In this case, most producers assumed the responsibility of cultivating leguminous plants and maintaining their drainage channels. For other practices, such as fertilisation or management of weeds, some producers left the implementation to Anchor Company B and others took these responsibilities on directly. When implementing these practices, users could choose not to be remunerated by Anchor Company B and therefore reduce the amount of debt owed to the company. Hence, in contrast to the shock practices that were imposed top-down style with the backing of formal rules, support and implementation for preventive practices combined centralised and decentralised approaches.

It could be said that due to the high control of Anchor Company B as the logistical operator, diffusion in this nucleus was highly vertical. The evidence suggests that no matter who implemented shock and preventive practices (e.g. smallholders or Anchor Company B), the agro-industrial firm always provided instructions and decided on the basis of technology adoption. In terms of the theoretical framework of this thesis, the governance in this alliance resembles a model of high control by an agro-industrial company and a CFA of full agro-industrial control (see Table 2.4). From there, one could contribute to answering the first research question of how formal rules are associated to pathways of diffusion.

The CFA in nucleus B was characterised by the dominant leadership of agro-industrial firm B and the multiple responsibilities that this actor formally assumed in crop management. Surprisingly, under this set of rules, smallholders could choose to participate in the implementation of some preventive techniques for PC management and other practices for crop management and, in turn, impact adoption. Contrary to these practices, the anchor company was in charge of adopting shock practices and other preventive practices that required technical expertise. The high control of the agro-industrial company suggests that, under this CFA, smallholders were guaranteed technical support and the implementation of crucial PC-related activities from company B, a firm with well-known labour organisation and economic capacity. Nevertheless, as will be seen Section 6.5, smallholders were heavily dependent on the agro-industry's decisions and priorities that might cause adverse effects on technology adoption and agricultural sustainability if company does not target both immediate and long-term sustainability of producers. The next section discusses how the smallholders' choice of getting involved in technology adoption could be affected by the characteristic nature of these users.

6.2 Heterogeneous population of small-scale producers in nucleus B

Combined with technical responsibilities and roles that characterise formal rules, the nature of selected smallholders helps to explain other results of technology adoption in nucleus B. Anchor Company B had a high level of control over crop management but left space for producer participation in the implementation of certain practices. It is suggested that the producers' decision regarding this participation was driven by the nature of users in terms of their socio-economic characteristics and economic expectations of the agribusiness. This is a different way of understanding the importance of socio-economic characteristics for the diffusion process to what the studies of CFAs and innovation-diffusion theory indicated. To explain this and the nature of users, the historical configuration of nucleus B, the selection criteria, and the resulting socio-economic characteristics of its members from this selection are described.

The selection criteria for smallholders participating in the CFA of nucleus B was established by formal rules between producers and the agro-industrial company. The CFA negotiated in nucleus B comes from the scheme of productive and strategic alliance that was proposed in Colombia in 1993 (Cano et al., 2006). Under this scheme, agro-industrial firms would guarantee the provision of oil palm fruit without purchasing land, and smallholders could access credits to start up the cultivation. According to Lizarralde (2012), strategic alliances offered a way for producers to join the agroindustry as well as to improve their livelihoods and development. Similar purposes drove the creation of the alliance in nucleus B that, according to representatives of company B[66], was intended to improve the living conditions of smallholders in the zone.

Despite the initial reasons driving the formation of this alliance, the requirements set out by Anchor Company B and the resulting selection of producers seemed to target short-term benefits, rather than improving smallholders' living conditions in the long term. From information collected during the fieldwork, it was clear that Anchor Company B had a decisive influence on the selection process of smallholders. Interviewed technical assistants asserted that the agro-industrial firm searched for landowners in the region with suitable land, in terms of soils and weather conditions, for oil palm cultivation (L.M, personal communication, 3 July 2015). Additionally, they assessed the road access infrastructure for the transportation of FFB to the processing mill.

This research suggests that, as a result of the few requirements for selection, the population in nucleus B was highly heterogeneous: smallholders were geographically dispersed across 14 towns in the Central zone. Interviewed technical assistants stated that due to these regional differences, the soils and weather conditions of plantations, as well as the socio-economic conditions, were very different between smallholders (W.B, personal communication, 7 July 2015). The following Table 6.1 displays a survey analysis showing this heterogeneity.

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[66] Representatives of Anchor Company B include the head of the department for the management of fruit providers and technical assistants.

Table 6.1: Socio-economic conditions of small-scale producers in nucleus B

Variable	Mean	Frequency of producers
Size (No. Hectares)	Mean = 24.7 Min = 10 Max = 50	0-10 = 4 (13%) 11-20 = 10 (30%) 21-30 = 10 (30%) 31-40 = 6 (18%) 40-50 = 3 (9%)
Income source	N/A	Only oil palm agribusiness: 8 (24%) People with livestock: 13 (40%) Staple crops: 0 (0%) Livestock and other staple crops: 1 (3%) Non-farming activities: 7 (21%) NI: 4 (12%)
Participation income (based on producers' perceptions)	N/A	High dependence on oil palm[1]: 15 (46%) Low dependence on oil palm[2]: 15 (46%) Equal dependence on oil palm and other livelihoods: 3 (8%)
Education	N/A	Primary: 16 (48%) Secondary: 6 (19%) University: 8 (24%) Technical career: 3 (9%)

[1]: more than 50% of their income comes from oil palm
[2]: less than 50% of their income from oil palm
NI: No Information available
N/A: Not applicable

Source: own elaboration based on fieldwork

Table 6.1 shows that 60% of the smallholders owned between 11 and 30 hectares, and that oil palm production was not the only source of income. Almost 76% of this population had alternative livelihoods, mainly concentrated on cattle farming, whilst 24% produced oil palm as their only source of income. Despite the significant proportion of producers with alternative sources of income, almost half the population indicated that it was highly dependent on the income from the oil palm production. Table 6.1 also shows that there was a high proportion of producers below levels of technical or university education.

Specifically, 48% of the population only attended primary school, as opposed to the 9% and 24% that had a technical or a university degree, respectively.

Finally, collected information indicated that even though Anchor Company B led the crop management in the nucleus, a large proportion of smallholders (60%) implemented agricultural practices by themselves or by using family labour. This is mainly because these producers managed their own plantations. Contrary to this group, about one third of the population either hired private management or left this management entirely to Anchor Company B. This was a common arrangement for smallholders living in main cities.

From fieldwork observations and survey analysis, we identified two groups of smallholders within nucleus B: rural producers with an agricultural background who were highly dependent on the oil palm crop and lived in rural areas; and better off-producers with a business profile, who left the management of their crops to Anchor Company B or private managers, and lived in main urban areas. This classification helps to understand the differences between smallholders' participation in the adoption of crop activities, according to the formal rules of the nucleus.

Based on rural farmers' long-standing experience in agriculture, it is possible to say that they were more attached to their land than the better-off producers. The rural farmers also appeared to consider the oil palm crop as a livelihood and not just an additional source of income. Therefore, it was of greater interest to these producers to enhance agricultural sustainability of the crop rather than focusing on immediate benefits. This could explain why these producers often participated in the implementation of some preventive practices and other agricultural practices for crop management. Interestingly, as will be explained later, this group had better productivity.

In contrast to rural farmers, it could be inferred that the better-off producers were not particularly engaged to their land and saw oil palm production as an investment from which they could earn short-term profits. These producers lived in cities and left their plantation management to other actors, in some cases ignoring the development of their crops completely. This could imply that they were more detached from their land and so less involved in the adoption of agricultural activities than rural farmers.

From the selection of producers in this cluster, a relationship between formal rules and the nature of users can be implied. Within the formal rules, there was a dominant organisation controlling the selection of producers, and included in this selection were poor technology users. According to what was discussed in Section 6.1, these formal rules also dictated that the implementation of preventive practices with low levels of expertise and other crop practices were at the discretion of smallholders. The selection of less involved users in the technology implementation may have had major implications in diffusion, which in this case, may lead to less adoption of certain agricultural practices.

In this nucleus it was seen that, in addition to having farmer cooperatives focused on financial issues only, the cluster included rural farmers as well as better-off producers. In this scenario, it is expected that poor smallholders and cooperatives engaged in strategies from which producers could mutually learn and get support for technology diffusion. However, this did not take place due to the particular type of formal rules, the heterogeneous population of smallholders, and the lack of institutional support. Due to the dominant role of Anchor Company B, as well as the obligation of all producers to follow this company's instructions, it is likely that producers accessed similar information and therefore did not see the need to collaborate. Regarding the nature of smallholders, the representatives of Anchor Company B mentioned that producers belonged to different regions and had different educational and cultural backgrounds, which might have led them to work in a more individualistic way. In addition, neither the anchor company nor other institutions encouraged collective action in the cluster. This lack of collective action could weaken the ability of small farmers to combine efforts and learn, search for technical support, and adopt practices.

This section showed that the different nature of users (i.e. rural farmers and better-off producers) contributed in a surprising way to the theory of innovation diffusion. In

Chapter 2, the literature on innovation diffusion, adoption and CFAs suggested that higher economic capacity would be associated with greater adoption of technologies (Feder et al., 1985; Wejnert, 2002; Pannell et al., 2006; Marenya and Barrett, 2007; Bjornlund et al., 2009; Rogers, 2010; Mariano et al., 2012; Kassie et al., 2015; Mills et al., 2017). However this approach was overwhelmingly focused on technical and economic capability as well as on demographic characteristics, especially in the case of literature on technology adoption (see Sub-Section 2.1.2) rather than incentives. This case study shows that smallholder participation in adoption might not only be based on their economic capacity but also on other characteristics of their nature, for instance their long- or short-vision of the agribusiness and their attachment to the land.

At this point, this chapter has discussed two key aspects that characterise formal rules in nucleus B (i.e. the selection of users, and technical commitments and roles). However, this set of rules is not sufficient for building technical relationships. Problematic relationships during the implementation of formal rules can jeopardise the continuity of the agreement and the centralised-diffusion process in the long-term, as well as the economic sustainability of smallholders. That is why any breach of contracts and break down of technical interactions occurring in this nucleus needs to be examined.

6.3 Problematic relationships undermining the centralised-diffusion process in nucleus B

As pointed out earlier, and as part of the formal rules of nucleus B, company B established its technical relationships with farmers primarily through a CFA of high agro-industrial control and influenced the selection of producers through particular criteria. Little attention was paid to the social characteristics embedded in the formal rules of this cluster. Although producers of nucleus B relied on the anchor company for technical issues, two main problems affected technology transfer: breach of the agreements and break down in technical relationships. These issues not only impacted the current technical relationships in the nucleus but might also have impacted the interactions in the past; it could also impact the adoption of agricultural practices in the future.

6.3.1 Low economic benefits causing problems in honouring agreements

According to the information provided by representatives of Anchor Company B, smallholders and heads of cooperatives, the setting up and development of oil palm cultivation in nucleus B generated increasing costs of production that outweighed the economic benefits for producers. As a result, several participants breached the commercial contract, which generated problematic relationships within the cluster.

The collected information indicated that the project generated unexpectedly high costs of production that were paid by Anchor Company B. Interviewees reported that, in addition to the underestimation of costs, additional reasons explained the exhaustion of financial resources and the increasing debt of smallholders. One of these reasons was the disproportionate expenditure of various smallholders that, in some cases, was not appropriate for their plantation size. Interviewee smallholders repeatedly said that the anchor company approved credit requests for producers to build a sophisticated infrastructure, for instance, complex cableway systems for harvesting[67]. One smallholder said ‘the cable-way was an expenditure that would have been impossible to afford by producers themselves and the banks wouldn’t have lent to them for that investment. The company had to support it’ (D.P, personal communication, 7 July 2015). Another producer reported:

> ‘there were some producers that wanted to leave the project after they started harvesting. They used to complain because they were selling fruit to the company but were not receiving profits from the sales. That happened because they spent a lot of the funding in building infrastructure at the beginning of the project and were still paying off the credit to the company. Others built cableway which increased the cost of the oil palm project’ (E.R, personal communication, 6 July 2015).

Another factor contributing to the increase of the project expenditure was the high costs of administration and services provided by Anchor Company B and its multiple legal,

[67] According to Castiblanco et al.'s (2010) study, cableway systems for harvesting are not cost-efficient in small-scale plantations but in plantations with more than 300 hectares.

financial and technical obligations within the contract. Smallholders and staff from other anchor companies in the area criticised the fact that, under this leadership, Anchor Company B assigned various assistants to the technical supervision of each plantation and the management of several plantations in the nucleus. A technical assistant from Anchor Company C said:

> 'company B assigned more than one technical assistant, one for supervision, another for maintenance. This is not economically reasonable considering that these are small-scale plantations and smallholders can manage those activities by themselves' (G.M, personal communication, 8 July 2015).

The plantation management could have been less costly under the producers' own control than under that of the agro-industrial firm.

In addition to the type of contract, we could associate the high costs of production and its consequential increase in the collective debt, to the low involvement of several users in the adoption of practices and plantation management. Observations from the fieldwork and collected information indicated that the majority of rural farmers were not responsible for the increase of their collective debt. Technical assistants explained that because these producers often led their plantation management and the implementation of most practices, they did not cause high production costs and in this way reduced the burden of the debt. Contrary to these farmers, producers who did not participate in management or technology adoption, or passed the entire responsibility of these functions to the anchor company, increased the production costs and extended the payment period for the collective debt of their cooperatives.

Given that the costs were outweighing the economic profits of the alliance, various producers eventually stopped trying to fulfil their obligations. According to interviewed smallholders, because producers had not received the expected net profits, several of them breached the contract by side-selling the FFB of oil palm to other companies. At the time of the fieldwork, technical assistants asserted that only 33 out of 74 smallholders that initially participated in the cluster complied with the commercial commitment.

The previous issue created a difficult situation within cooperatives; in order for the cooperatives to continue with the payment of the associated credit[68], loyal producers had to take on the debt of non-loyal producers. An interviewed smallholder asserted:

> 'I have already paid for my share of the debt, as have many others, but we are still paying the associative credit (…) look at producer X[69], he doesn't want to pay his debt and is selling fruit to company Y[70] instead of selling to anchor company B' (J.P, personal communication, 6 July 2015).

This situation created discomfort among loyal producers and those who had reached the break-even point of agribusinesses in which their initial investment was covered and net income was generated.

The disloyalty of several producers and the discomfort of loyal producers were factors affecting technical relationships within this nucleus as detailed below.

6.3.2 Breaking down of technical relationships within nucleus

In technical terms, smallholders relied heavily on Anchor Company B and allowed it to implement shock and other agricultural practices on their plantations due to its well-known trajectory and experience in the Central zone. However, the problematic relationships that were described in Sub-Section 6.3.1 caused a deterioration of the trust-based and friendly relationships between smallholders and the agro-industrial firm, as well as amongst the smallholders themselves.

Problematic relationships between smallholders and Anchor Company B resulted from unfulfilled expectations of producers, as well as from the breach of the contracts by non-loyal producers. Some of the interviewed smallholders felt that the economic benefits

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[68] It needs to be recalled from the configuration of the alliance that funding organisations approved an associative credit to each cooperative rather than an individual credit to each smallholder. Therefore, cooperatives had to pay its financial responsibilities even if one or more of its members failed to comply with their obligations (see pp.192-193 for more explanation).
[69] Name redacted in order to protect the identities of interviewees.
[70] Name redacted in order to protect the identities of interviewees.

that they were expecting to gain from the agreement had not yet been met at the time of the fieldwork.

The problems of trust within the nucleus made the technology transfer between smallholders and Anchor Company B difficult in a number of ways. For example, interviewed representatives of Anchor Company B affirmed that during the first stage of oil palm cultivation, the majority of smallholders would attend training sessions. With the breaching of agreements, the rate of attendance to these training sessions dramatically reduced. Technical assistants also explained that the anchor company stopped providing technical services and agrochemical inputs to non-loyal farmers. In other cases, the staff of Anchor Company B in charge of technical visits and implementation of agricultural practices were refused entry to some plantations. Thus, problematic social and business relationships threatened the technical relationships between actors, thereby jeopardising the process of technology transfer and the continuation of the CFA.

The previous discussion suggested that tensions between the agro-industrial firm and smallholders might have impacted the adoption of shock and preventive practices. First, since some smallholders denied entry to the technical staff, it is possible that they were not adopting PC-related practices, especially as Anchor Company B was the main source of technology for producers. Second, the problematic relationships may have led the anchor company to adopt a pessimistic view about the continuation of the arrangement in the long-term. This could have discouraged the anchor company from emphasising the use of long-term practices and focusing on short-term practices.

The relationships amongst smallholders, particularly between loyal and non-loyal producers, also deteriorated with the breach of the agreements. As one could see during internal meetings of farmer cooperatives, loyal producers were unhappy with the fact that they had to take over the debt burden of non-loyal producers.

To sum up, this section discussed how problematic relationships between participants of nucleus B affected the processes of technology transfer. These problematic relationships were associated with the types of formal rules and the different types of users in the cluster. The formal rules increased the technical responsibilities of the anchor company and, in turn, generated high costs of administration and services for producers. Within the types of users, there was a group of smallholders generating high costs of production and increasing the burden of the collective debt. With the high costs and low expected benefits, several producers breached the contract and this affected the trust-based and technical relationships in cluster B. It could be concluded from this section that the persistence of these issues could lead to the potential dissolution of the CFA, thereby threatening the centralised-diffusion process.

So far, this chapter has analysed three aspects that influenced the technical relationships and the effect of these relationships towards the implementation of certain types of agricultural practices in nucleus B. The three aspects are; first, formal rules with the strong leadership of agro-industrial firm B, which emphasised the adoption of shock practices and the involvement of smallholders in the adoption of some preventive practices. Second, the selection criteria, based on soil suitability and adequacy of infrastructure, which explained the heterogeneity of the smallholders. Third, the problematic trust-based relationships that existed in the cluster due to the breach of agreements and break down in technical relationships. These aspects can also be seen in the network structure, as will be explained in the following section.

6.4 High centralised network on a leading change agent

Networks can give an overview of technical interactions in a centralised-diffusion process. They can also illustrate important characteristics of formal rules and highlight some of the problematic trust-based relationships between actors of a cluster. Whilst formal rules can determine technical responsibilities, central roles and interactions of actors, problematic trust-based relationships underpinning these rules can break down, thus weakening and threatening these interactions in the long term. As in the previous case study, SNA is mostly used in this section to identify key actors and their influence on smallholders; therefore the analysis was based on an ego-centric approach.

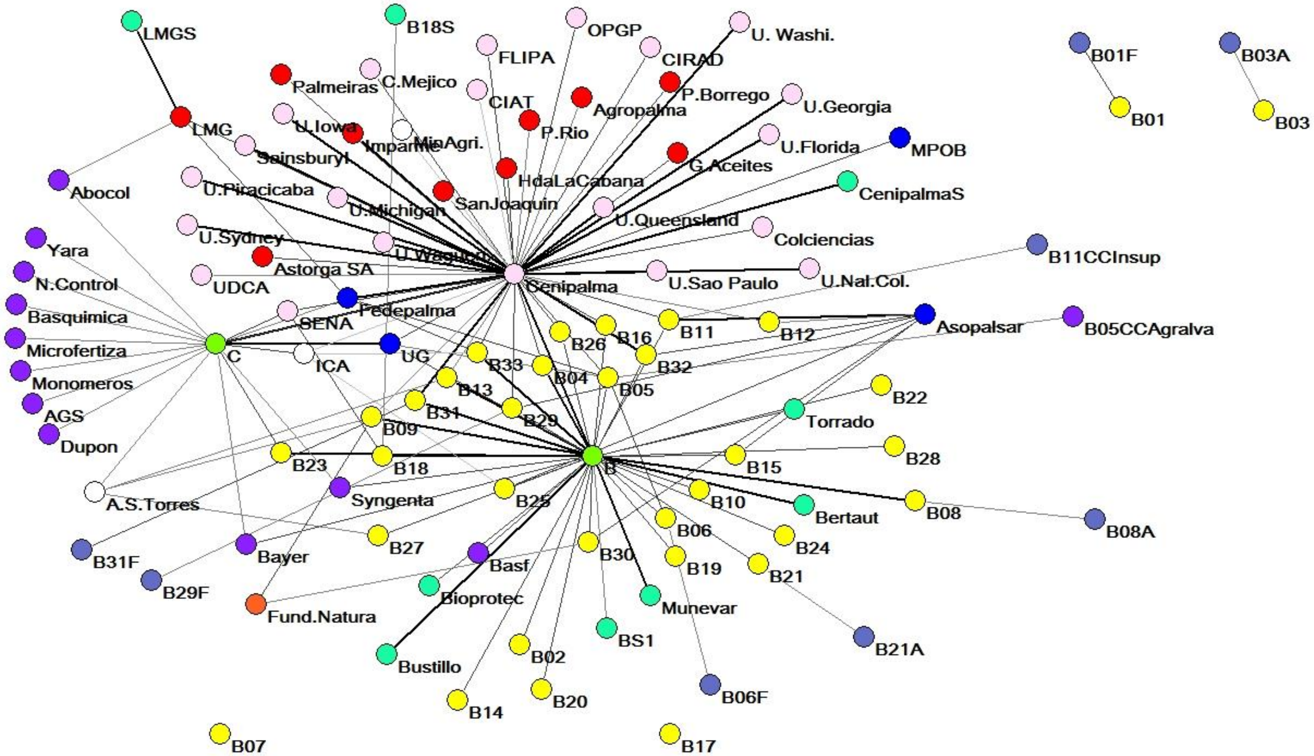
This section shows a network structure that is highly centralised around Anchor Company B (which has a decisive role in technology transfer given by formal rules) and, to a lesser extent, around Cenipalma. High interactions in the network reflect the significant attention that change agents gave to the transfer of shock practices. In contrast, the degree of fragmentation resulted from the non-existent relationships amongst producers and the isolation of some of them from the network. It is possible to argue that a bigger network could have existed during the initial years of the alliance before any smallholders had withdrawn from the agreement.

The theoretical framework of this thesis indicated that formal rules can dictate the interactions and, in this way, give shape to networks of diffusion. In this case study, the dominant role of Anchor Company B and its interest in shock practices, mostly determined the network connections and the focus of those relationships. The close relationship between formal rules and network interactions showed why it is important for research in the diffusion of agricultural innovations to give more attention to formal rules.

As in the last chapter, the network structure of this case study will be described in terms of network size and individual interactions, central positions, and brokerage beyond the smallholders. In the same way, the impacts of these structural aspects on diffusion will be evaluated in terms of access to information, influence of other actors, and availability of multiple information sources to smallholders.

Network size and individual interaction

The technical relationships for transfer of PC-related practices that emerged from the CFA negotiated between 33 smallholders and Anchor Company B are displayed in Figure 6.1. This network, referred to as network B, consists of 105 nodes, classified by 8 types and connected through 149 technical interactions.



Type of Organisations

- Small producer
- Anchor company
- Medium or Large producer
- Associations/ Alliances between companies
- Academic/ Research entity
- Governmental institution
- Supply company
- Friend/Relative
- External advisor
- Social organisation

Figure 6.1: Network B for technology diffusion of PC-related practices
Source: Own elaboration from survey data

According to Figure 6.1, Anchor Company B was the most important source of information for smallholders (number of links: 28; sum of importance: 92); this is followed by Cenipalma (number of links: 13; sum of importance: 32). This is not surprising given the fact that the anchor company transferred and adopted shock practices to all plantations of the nucleus. In the case of Cenipalma, this centre was one of the most important change agents supporting Anchor Company B through training sessions and the development of protocols for the management of shock practices. In contrast to nucleus A, Cenipalma did not have an important impact on producers of nucleus B. For example, one of the surveyed smallholders said 'I have received handbooks and flyers from Cenipalma but have not read them'.

One aspect that stands out in Figure 6.1 is the isolation of smallholders B01, B03, B07 and B17 that causes the fragmentation of network B. Despite being part of the alliance, there were no technical interactions between Anchor Company B and these five smallholders. According to survey information, these owners gave Anchor Company B full responsibility for their plantations' management and therefore did not know which agricultural practices were being adopted there. In fact, one of these surveyed smallholders said to the researcher 'you should address this survey to anchor company B and not to me because I don't know the information you are asking for'. One can conclude that the excessive take-up of responsibilities by the agro-industrial company in nucleus B could affect the links for technology transfer and cause the fragmentation in the network.

Figure 6.1 also reflects the low communication amongst farmers. This was not surprising taking into account the evident individualistic behaviour of smallholders due to reasons that were explained in the previous sections: high control of technical responsibilities by the leading change agent, marked differences amongst the heterogeneous population of smallholders, and problematic relationships between participants of the alliance.

The following figure helps to examine the transfer of agricultural technologies to the group of smallholders by classifying the different information sources by types of actors.

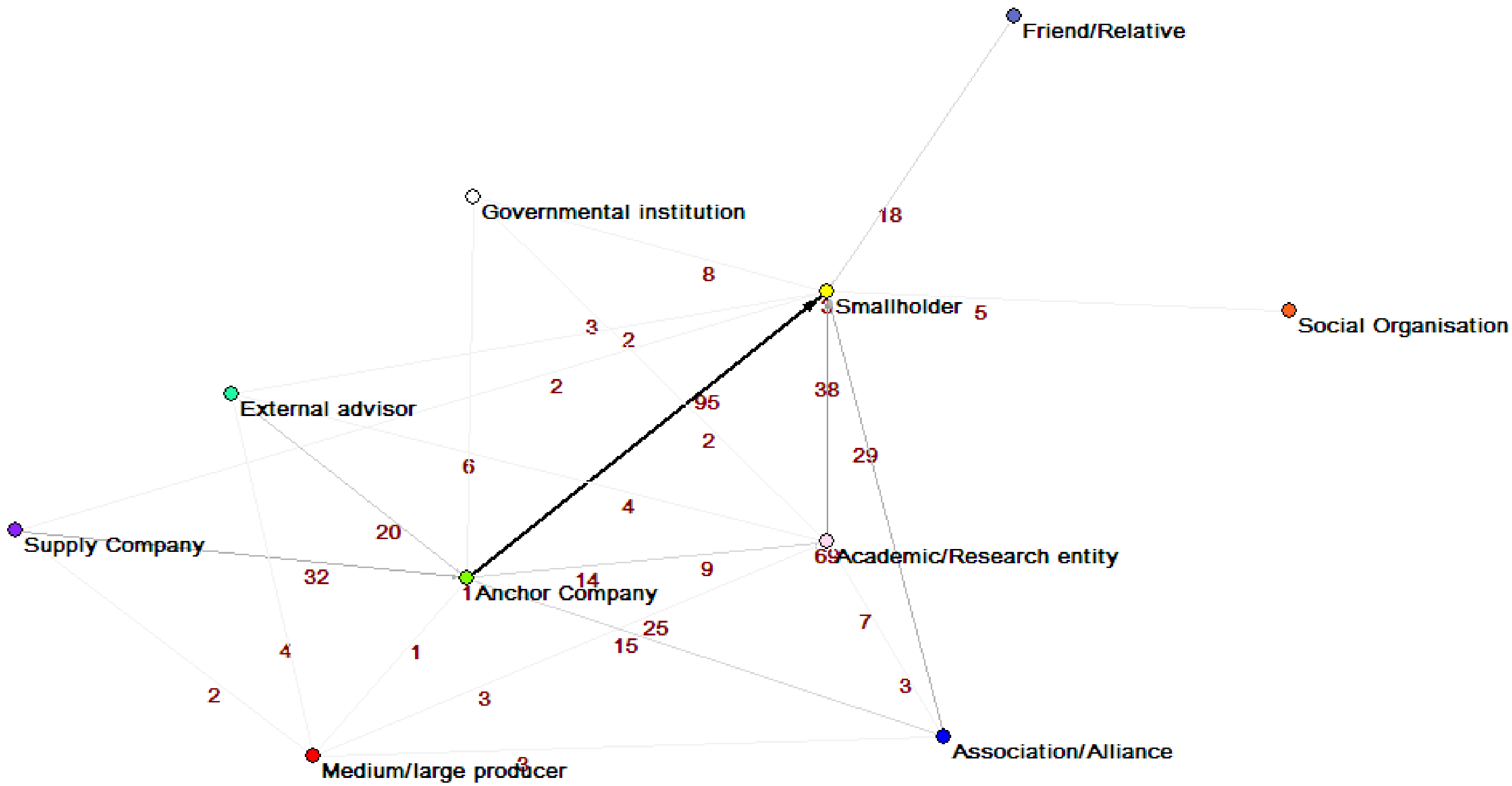


Figure 6.2: Shrunken network B for technology diffusion of PC-related practices

Source: Own elaboration from survey data

Figure 6.2 shows that farmers perceived their relationships with Anchor Company B as being more significant than with other actors. The data indicated that the importance of links connecting smallholders with the company (sum of importance: 92) was higher than with other actors such as Cenipalma (sum of importance: 32) or academic institutions (sum of importance: 38).

Looking at the smallholders' individual interactions (Figure 6.3), most producers relied on one or two channels of information (in-degree average: 2), the interaction with Anchor Company B being one of these. Since smallholders paid for Anchor Company B's support[71] and it was mandatory for them to follow its instructions, additional services and information sources would seem unnecessary for these producers. In some cases, farmers accessed information only through their links with this company (e.g. B02, B14, B19, B20, B22, B24 and B28).

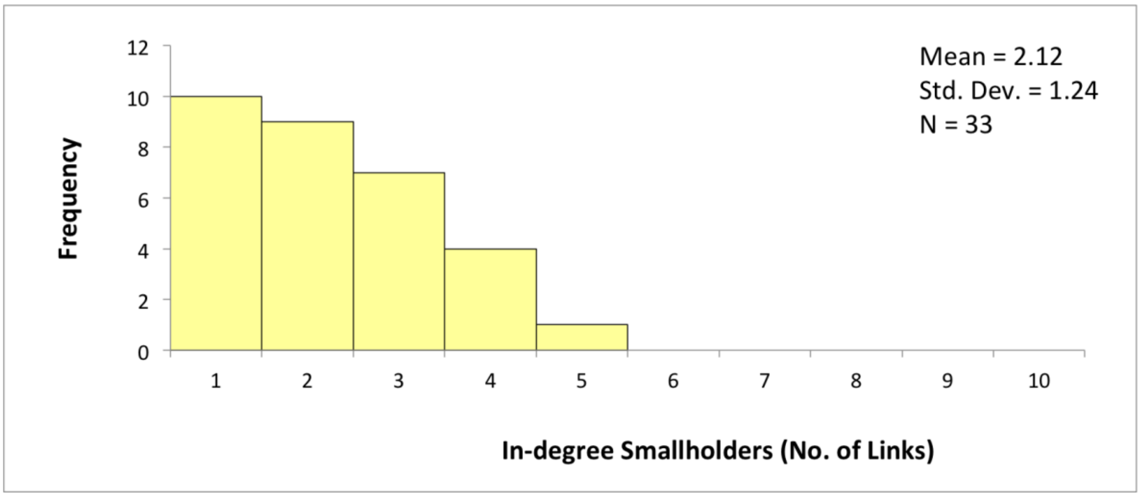


Figure 6.3: In-degree of small-scale producers belonging to nucleus B

Source: Own elaboration from survey data

Table 6.2 considers the users in network B and for what information their links were used. For example, it can be seen that nine links from Anchor Company B to users were used for the transfer of information to do with the cultivation of leguminous plants.

[71] This support is included in the logistical operation and the cost is discounted from the value of the FFB sales.

Whilst Anchor Company B does belong to the anchor company actor type, their link usage is shown separately to visualise their important contribution. It should also be noted that links can be used for the transfer of multiple types of information. This table shows that the majority of network connections were used for shock practices; the number of supporting links (133) largely exceeds the assistance provided for preventive practices (61).

Table 6.2: Link usage; detailing the type of information being transferred to users in network B

Actor	**Total**	**Preventive practices**				**Shock practices**			
		Drain	**Soil**	**Frond**	**Leguminous**	**Monitoring**	**Surgeries**	**Fertilisation**	**Eradication**
Anchor Company B	147	18	11	4	9	27	28	24	26
Academic institutions (Cenipalma)	14	0	0	0	0	6	8	0	0
Associations	19	1	5	2	3	1	3	3	1
Social organisations	1	1	0	0	0	0	0	0	0
Friends/ relatives	4	3	0	0	1	0	0	0	0
Government institutions	5	3	0	0	1	0	0	1	0
Supply companies	1	0	0	0	0	0	0	1	0
Anchor companies[1]	4	0	0	0	0	1	1	1	1
		Total links: 61				**Total links: 133**			

[1]: not including anchor company B

Source: Own elaboration from survey data

Central positions

The main central actors leading the process of technology diffusion of nucleus B are easily detected when inspecting network B (Figure 6.1). The map shows that Anchor Company B and Cenipalma were the most popular actors in terms of the number of ties connecting them to other actors in the network. The centrality of company B was explained by its significant role in the transference of shock practices to smallholders (Table 6.2). The central role of Cenipalma resulted from the significant number of incoming links (In-degree centrality: 36) and its connections for transferring shock practices to 13 smallholders.

The fact that Anchor Company B and Cenipalma were connected to a considerable number of nodes that would not have been connected otherwise to the network, also gave these two actors a crucial role in intermediation. Table 6.3 indicates that both of these actors had high levels of betweenness centrality, which can be explained by their location in the geodesics[72] between smallholders and other actors. Whilst Cenipalma connected smallholders with academic institutions and agro-industrial firms, Anchor Company B connected producers with supply companies and external advisors. Although it is not obvious from Figure 6.1, Table 6.3 shows that Anchor Company C had high levels of degree and betweenness centrality. As with Cenipalma, the centrality of this anchor company is explained by its considerable number of information sources (In-degree centrality of C: 16).

[72] Geodesics refers to the shortest path between two nodes (see Appendix D).

Table 6.3: Degree and Betweenness indicators within nucleus B

Actors	Degree
Cenipalma	55
B	40
C	19
Asopalsar	7
B05	6
ICA	6
Fedepalma	6
UG	5
LMG	4

Actor	Betweenness
Cenipalma	0,153286
B	0,09466
C	0,03216
B05	0,002334
ICA	0,0021
SENA	0,0021
Abocol	0
LMG	0
Agropalma	0

Source: Own elaboration from survey data

Brokerage beyond smallholders

Brokers were identified by detecting actors with the highest levels of both degree and betweenness centrality in the network (Table 6.3). By using redundancy and efficiency measurements, Table 6.4 tests the role of these brokers in spanning structural holes.

Table 6.4: Measurements of structural holes for broker organisations

Outsider	In-Degree Centrality	Out-Degree links broker-smallholders	Importance of Out-Degree links broker-smallholders [1]	Efficiency	Redundancy
B	11	28	92.4	98%	0.63
Cenipalma	36	13	37.7	98%	1.00
C	16	1	3	93%	1.22

[1]: Out-Degree links weighted by their average importance

Source: Own elaboration from survey data

Table 6.4 shows that, due to the high levels of efficiency of Anchor Company B, Cenipalma and Anchor Company C, these actors were good at spanning structural holes. Unlike Anchor Company B and Cenipalma, Anchor Company C was only connected to one smallholder and its influence (importance of out-degree: 3) was not as high as the influence of firm B (importance of out-degree: 92.4) and Cenipalma (importance of out-degree: 37.7).

The evidence of this section implies that despite having high levels in the metrics of centrality, importance of out-degree and efficiency, the brokering roles of both Anchor Company B and Cenipalma were not fully exploited in the transfer of PC-related practices. This was due to the fact that these two actors focused their efforts on the transfer of shock practices rather than on both shock and preventive practices. If Anchor Company B and Cenipalma also provided information on preventive practices, smallholders would benefit from the information they themselves generated.

The current network does not express the problematic relationship between Anchor Company B and some of the smallholders. This is an important aspect to consider since difficult trust-based relationships can affect technical relationships and, therefore, the maintenance of networks in the long term. Some inferences can be made about the previous network structure namely, that out of 74 smallholders who joined the alliance in 2010, 41 producers had breached the contract and, as a consequence, withdrawn from the nucleus and the network by 2015. Without a resource of social capital embedded in technical relationships (in this case trust-based relationships), the survival of the agreement and the technical links for technology transfer may be at risk in addition to the centralised-diffusion process.

In conclusion, we have discussed the responsibilities for the implementation of shock practices and for uneven take-up of preventive practices within the formal rules of nucleus B. The chapter has also studied the tensions that emerged between smallholders and the leading change agent as a consequence of a contract that did not appear to benefit producers. The above can all be linked to high control of one agro-industrial firm who defined the nature of users, prioritised shock practices, and established a set of rules and financial commitments. Given these conditions, the resulting network had a highly centralised structure that reflected the interests of the leading change agent and some degrees of network fragmentation owing to the break-down of relationships between participants. Implications of this type of network structure with intensive assistance can be seen for the outcomes of diffusion process, specifically for technology adoption.

6.5 Adoption of PC-related practices in nucleus B

Following the theoretical framework of this thesis, outcomes of the centralised-diffusion process in nucleus B will be analysed in terms of technology adoption of shock and preventive practices. As in the last chapter, this adoption will be assessed by quantifying the number of users of preventive and shock practices in the nucleus. By associating these outcomes with the impact on technology diffusion of network B, this section will help to answer the third research question about how levels of technology adoption vary with the different pathway of diffusion in centralised systems. The findings show that higher adoption levels of shock practices in comparison to preventive techniques resulted from a network that was centralised around a leading change agent whose support was focused on shock rather than preventive practices. It can be observed that the lack of attention towards preventive practices was mainly due to the failure of Anchor Company B to implement those practices, which fell under its responsibility.

According to the survey results, the average percentage of smallholders adopting PC-related practices was 69%. By breaking down this value, it is possible to see that the average percentage of users was mostly pulled down by the low adoption levels of preventive practices (46%). The lower adoption levels of soil analysis (38%), frond analysis (22%), and cultivation of leguminous plants (43%) explained the average level of preventive practices. Contrary to this, the high percentage of shock practice users (91%)

was the result of having 100% and 97% of producers implementing PC monitoring and PC surgery, respectively (Figure 6.4).

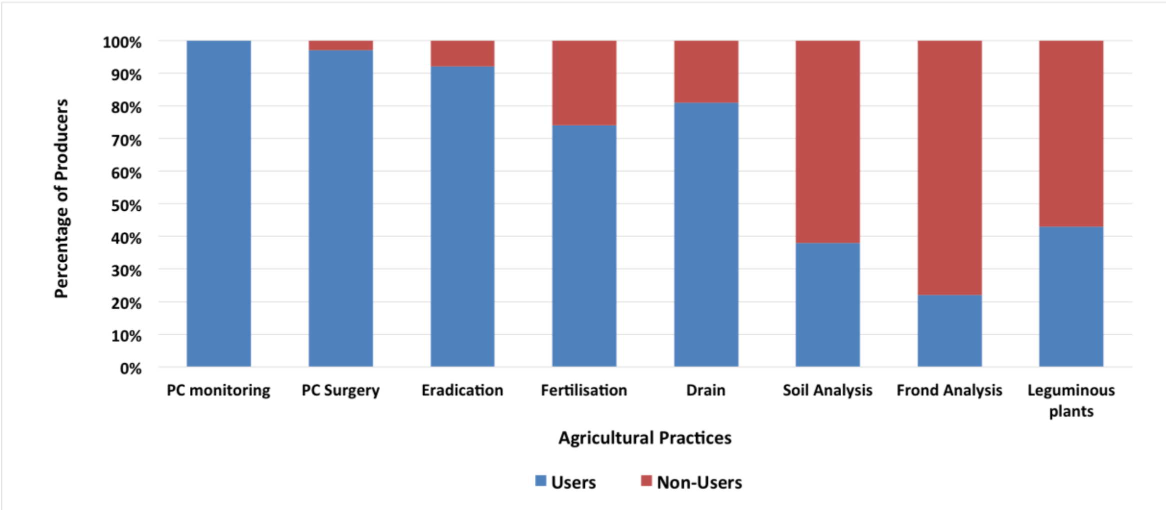


Figure 6.4: Levels of technology adoption by small-scale producers in nucleus B in 2015

Source: Calculated from author survey of oil palm producers

Based on the analysis of the last section, it is possible to associate the outcomes of adoption with the structure of network B. That structure showed that change agents, especially Anchor Company B, provided intensive support to smallholders through multiple interactions that were mostly focused on the adoption of shock practices. This was possible because producers allowed Anchor Company B to have a high level of control over the implementation of these practices.

According to interviewed technical assistants and smallholders, the formal rules made it mandatory for producers to accept the assistance of the company, by which they implemented and supervised PC surgeries and PC monitoring. In this respect, the smallholders' attitude was key to allowing this high involvement. Adding to Rogers (2010) and Mills et al. (2017), who argued that a favourable or unfavourable attitude, subjective and social norms and values towards an innovation can drive users to make decisions on adoption, it is suggested here that this attitude was also important to permit the influence of other actors on adoption.

Two major factors influenced the attitude of smallholders to accept the high involvement of Anchor Company B in the adoption of shock practices. First, despite the problematic relationships within nucleus B, producers were heavily reliant on the anchor company when it came to seeking technical assistance. Second, visits to the epidemic area of Puerto Wilches positively changed the producers' attitudes towards the technical staff responsible for adopting shock practices and increased their willingness to accept this implementation.

With regard to preventive strategies, different reasons can explain their low adoption levels. One reason was the lack of attention from the leading change agent responsible for the implementation of these practices. Observations during the fieldwork indicated that, unlike the support for shock practices, Anchor Company B did not give priority to the preventive practices that fell under its responsibility, particularly with soil and frond analyses, considering the current situation of PC epidemic. Regarding these responsibilities, an interviewed technical assistant reported

> 'we are focused on attending plantations having PC outbreaks and on making sure we can control the PC in our nucleus (…) those [soil and frond] analyses are not important at the moment' (W.B, personal communication, July 7, 2015).

Interviewed smallholders also argued that this anchor company was in charge of the adoption of soil and frond analyses due to its technical expertise. However, as Figure 6.5 shows, several surveyed producers reported that the company had failed to comply with its obligations or did not deliver the corresponding results.

Another reason for the low adoption of preventive practices was the high costs of those practices, such as cultivation of leguminous plants and maintenance of drainage channels. For example, technical assistants affirmed that some plantations were located in unsuitable areas for oil palm cultivation in respect to physical conditions. In those cases, the investment for land suitability and maintenance exceeded smallholders' available resources, thereby limiting the adoption of related practices. This adds to the literature on technology adoption in which monetary and non-monetary costs are key characteristics of agricultural practices that affect final levels of adoption (Pannell et al., 2006).

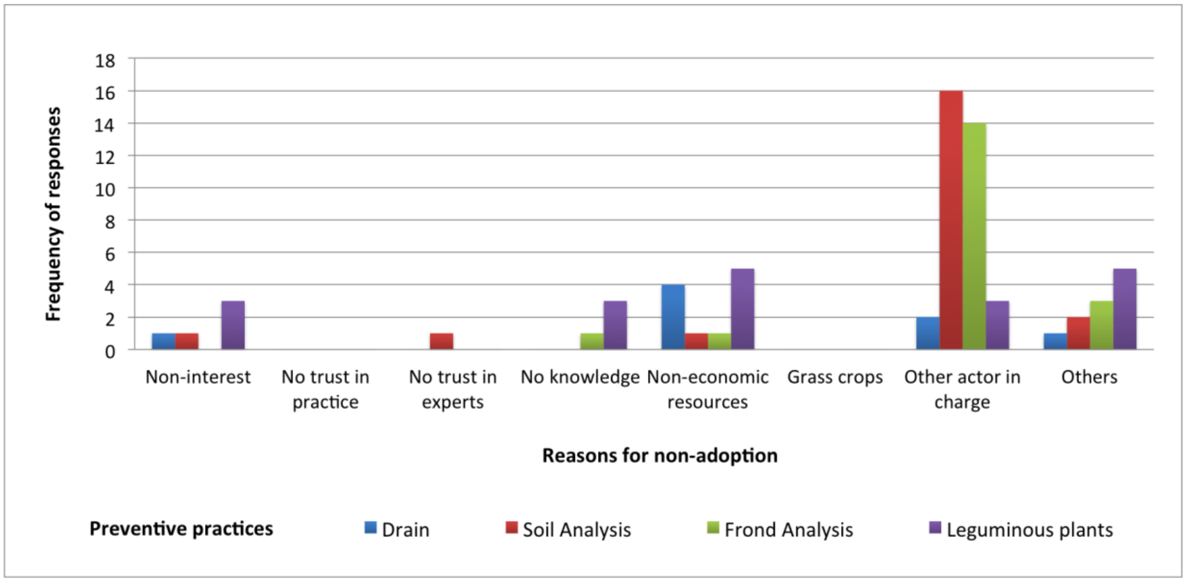


Figure 6.5: Reasons for non-adoption of preventive practices in nucleus B

Source: Calculated from author survey of oil palm producers

Looking at the adoption level of drainage channels' maintenance (81%) in Figure 6.4, it can be seen that these levels were remarkable high compared to the remaining preventive practices. From the collected information, it is shown that the participation of smallholders in the maintenance of channels is high, which can help to explain their high adoption. It should be remembered that, according to the formal rules within nucleus B, the adoption of practices requiring low levels of expertise (such as the maintenance of drainage channels) were at the discretion of smallholders. Most surveyed growers asserted that they adopted these practices with the supervision and training of the company.

Table 6.5 summarises the most important reasons impacting the technology adoption of nucleus B related to the technology-diffusion process and the nature of selected smallholders.

Table 6.5: Factors affecting the adoption of PC-related practices in nucleus B

Shock Practices	
Fertilisation of diseased trees	Responsibility of implementation was with anchor company B Access to credits from anchor company B to buy fertilisers
PC monitoring	Responsibility of implementation was with anchor company B
PC Surgery	Responsibility of implementation was with anchor company B
Eradication	Responsibility of implementation was with anchor company B
Preventive practices	
Drain infrastructure	Trust in technical assistance provided by Anchor Company B Access to credits from Anchor Company B for infrastructure Adoption from previous farm activities (e.g. rice crops) and funding from the government No availability of economic resources for covering the high costs of adoption (e.g. equipment and infrastructure)
Soil Analysis	Responsibility of implementation was with Anchor Company B No prioritisation by anchor company B
Frond Analysis	Responsibility of implementation was with Anchor Company B No prioritisation by anchor company B
Cultivation of Leguminous plants	Trust in technical assistance provided by Anchor Company B No knowledge No interests in adoption No availability of economic resources for covering the high costs of adoption (e.g. high time, labour force and money consuming for land preparation, inputs and maintenance)

Source: Analysis from author survey and interviews of oil palm producers

The different adoption levels of PC-related practices and the consequent impact on smallholders' agricultural sustainability in nucleus B can be explained by: 1) the formal responsibilities this company assumed in the CFA and the differences in the technical support given by a leading change agent, and 2) the heterogeneity of the population of selected producers according to the formal rules of the nucleus and, in turn, the differences in producer participation for the implementation of practices.

Based on the formal rules of this nucleus (see Sections 6.1, 6.2 and 6.3), the leading change agent played a key role in the provision of inputs, technical services and decision-making processes, as well as in the selection of small-scale producers, who in this case were a heterogeneous population of rural farmers and better-off producers. Regarding the implementation of PC-related practices, whilst the anchor company was in charge of adopting shock practices and other preventive practices that required technical expertise, producers chose their degree of involvement in the adoption of some other preventive techniques and crop practices.

The high implementation of shock practices reflected the high control that the agro-industrial company had in the CFA of nucleus B. But in particular, it reflected the special attention and support that the company put on the implementation of these practices due to its business-based priorities. The adoption of shock practices that resulted from this type of formal rules, and the companies' immediate priorities, could be associated, amongst many other factors, with the control of PC incidence. The intensive efforts of Anchor Company B on adopting shock practices could be related to the cluster's low levels of PC incidence (average levels: 0.3%) from 2014 to 2015. These levels were lower than the levels of the epidemic area (average levels: 76%), and lower than the acceptable level for PC management[73], of 10%.

Compared to shock practices, the adoption levels of preventive practices were lower and their variations could be related to different levels of both technical assistance and involvement of producers in their implementation. According to the CFA of nucleus B, the leading change agent was responsible for adopting preventive practices that required technical expertise. However, the case showed that this company failed to comply with its obligations, which significantly lowered the adoption levels of preventive practices, the

[73] See footnote 32, page 105.

effect of which outweighed the levels of adoption due to producer participation. The low adoption of preventive practices threatened the agricultural sustainability of crops in nucleus B. As Sub-Section 2.5.1 explained, failure to implement preventive practices made crops more vulnerable to the attack of pests and diseases, thereby affecting their ability to continue in the long term.

The above paragraph showed that an unexpected outcome of this case study was the low implementation of practices that were Anchor Company B's responsibility under the agreed CFA and despite the company's well-known expertise, labour organisation and economic capacity. From the CFA literature (Key and Runsten, 1999; Kirsten and Sartorius, 2002; Bijman, 2008; Barrett et al., 2012; Beekmans et al., 2014; Bitzer and Bijman, 2014), one can interpret that schemes with high control by agro-industrial firms have the available resources to guarantee technology adoption, but this did not occur in nucleus B.

This case study shows that it is not always appropriate to organise preventive practices through a top-down system dependent only on one leading change agent, as is the case of CFAs with high/full agro-industrial control, especially if these preventive practices are not among the company's priorities. More importantly, it also suggests that preventive practices require a long-term view, commitment to farming and own management, which, the case has suggested, may be better undertaken by small-scale farmers that were dependent on their land. The role of the large firm (or other change agents) can be to provide technical supervision and constant monitoring.

Although Anchor Company B took control of most PC-related practices, the nature of users (smallholders selected under particular formal rules) were still found to be highly relevant for the adoption of non-PC-related practices, such as fertilisation and the management of weeds. While these practices are not part of PC management, they cannot be divorced completely from the occurrence of PC as they can improve the tolerance of oil palm trees to environmental stresses. Since formal rules in nucleus B allowed smallholders to participate in the adoption of these practices, the nature of producers was critical to understand their tendency towards implementing them. Interviewed technical assistants argued that smallholders leading their plantation management and being involved in the adoption of these practices, as was the case with rural farmers, exhibited the best productivity levels. The adoption of these crop practices can also be an indication of healthy crops that were more tolerant to future PC attacks and sustainable in the long term.

To summarise, the reasons for adoption could be found in the type of formal rules that enforced the leading role of a change agent in a model of high agro-industrial control, especially for the management of shock practices, whilst opening a space for the participation of smallholders in certain practices. This role and focus was reflected in the formation of highly centralised network structures, transferring mostly shock practices. In the case of preventive practices, formal rules distributed their implementation between smallholders and a change agent. Nevertheless, these obligations were not fully met by either participant.

6.6 Summary of chapter

Following the theoretical framework, this chapter analysed the formal rules as applied to cluster B, the impact of those rules on vertical networks, and the outcomes in terms of technology adoption of the emergent pathways of diffusion. It was found that these outcomes responded to formal rules under which a leading change agent assumed most responsibilities. The types of practices that were more prevalent reflected the terms of these rules and the interests of this agent. For less prevalent practices, this agreement allowed users to participate in their adoption. The nature of users is far from insignificant for the diffusion process and can help explain the take-up of crop management, the continuation of the agreement (which strongly influences the viability of technology transfer), and the agricultural sustainability of the agribusiness.

The type of formal rules characterising the diffusion process in nucleus B were dictated by a CFA in which Anchor Company B controlled most of the technical responsibilities of crop management. Whilst the arrangement mandated that the anchor company implemented shock practices and those preventive practices that required high levels of expertise, it also allowed smallholders to get involved in the remaining agricultural practices.

As a result of the selection rules established by the leading change agent, a highly heterogeneous population of producers was selected. Two groups of smallholders were identified: rural farmers and better-off producers. Compared to the latter, rural farmers were more involved in technology adoption and in plantation management. Furthermore, these producers were not engaged in collective action, as it would be expected. This was due to the heterogeneous population of producers, the lack of institutional support, and the dominant role of Anchor Company B on which farmers relied; all received similar information.

Based on the formal rules and outcomes of adoption in this case study, it was possible to establish a relationship between these two variables. The high control level of Anchor Company B, as a characteristic type of CFA governance in this nucleus, was the dominant characteristic shaping a highly centralised network and explaining the high adoption of shock practices. The network interactions were mostly dominated by Anchor Company B and Cenipalma, but only Anchor Company B had important influence on smallholders. As these links mainly focused on the transfer of shock practices, their adoption levels were considerably higher than the levels of preventive practices. We suggest that the leadership of the anchor company contributed to reducing the levels of PC incidence in the nucleus.

Regarding the low adoption levels of preventive practices, two explanations were given. First, under the premise of transactional basis and the formal commitments that parties were supposed to undertake in the CFA, smallholders assumed that Anchor Company B would adopt some of these practices. However, the company was based on a business model in which the adoption of long-term practices was not among its priorities. Secondly, the CFA allowed smallholders to adopt preventive practices with low levels of expertise;

however, the high costs required meant that that most smallholders could not finance them due to their socio-economic conditions. As a result, the preventive practices in this nucleus were adopted haphazardly.

Although the different nature of smallholders did not impact the adoption of PC-related practices, it had an impact on the adoption of the remaining agricultural practices that also affected the long-term development and tolerance of the crop to future stress. Rural farmers in this nucleus tended to be more involved in the adoption of these practices and the management of their plantations, which may have contributed to their better levels of productivity when compared with better-off producers. This shows that leaving the selection of producers to a large company with a short term view led to the selection of a heterogeneous population of producers, including those with no interest in participating in the adoption of practices for the long-term development of the crop.

Finally, the high control of the diffusion process by Anchor Company B (due to the formal rules) and the low level of involvement of some producers (due to their nature) in crop management increased the collective debt and reduced the net profitability for smallholders. This caused threats to the long-term sustainability of the agribusiness and breach of the marketing contract; this affected technical relationships for technology transfer.

Some interesting points that enrich the theoretical framework of this thesis can be highlighted from this case study. First, under a CFA where a leading change agent is highly dominant, the quantity of support for long- and short-term practices depended on its vision and interests (i.e. immediate or long-term benefits) regarding the integration of smallholders to processes of commodity production. Second, under these agreements, giving space to smallholders' participation with long-term vision may have helped the adoption of long-term practices. Third, the nature of users was key for the continuation of the agreement and the economic sustainability of smallholders, which therefore have an impact on the diffusion process.

CHAPTER 7

CASE STUDY NUCLEUS C: SMALL-SCALE PRODUCERS CAPITALISING COLLECTIVE ACTION IN THE COLOMBIAN OIL PALM SECTOR

This chapter examines the centralised-diffusion process in an oil palm nucleus characterised by having control of crop management shared by more than one key actor and by smallholders engaged in collective action. The leading change agent, which in this cluster is Anchor Company C, played a paternalistic role and was interested in the agricultural sustainability of small-scale producers in the long term. These key features distinguish this case study from nucleus A, where the leading change agent had a low degree of control over the centralised-diffusion process and played a semi-paternalistic role, and from nucleus B, where this degree of control was high and the role of the agro-industrial firm exhibited few characteristics of being paternalistic.

We follow the three main elements of the theoretical framework (formal rules, vertical networks and technology adoption) and use the same structure of analysis that was used in Chapters 5 and 6 to answer the three research questions of this thesis. This chapter begins by explaining the technical roles and responsibilities of participants in the centralised-diffusion process (CFAs of nucleus C). Section 7.2 describes the configuration of this nucleus and the nature of its users, whilst Section 7.3 explains the social values characterising the technical relationships amongst participants of the CFA. Section 7.4 describes the network structure that results from the formal rules of this cluster, and Section 7.5 associates the network structure and the nature of users with resulting levels of shock and preventive practices. The last section concludes and specifies the contribution of this chapter to the thesis.

As in the previous chapters, this case study will discuss the important influence that both formal rules and the nature of users have on the type of centralised diffusion and the particular outcomes of adoption. It will be shown that a process of diffusion in a cluster, where grouped smallholders share responsibilities, can generate support for both shock and preventive practices, albeit with lower adoption levels for preventive practices. The support for both practices can be explained from the formal rules of partial agro-industrial control in which:

- the agro-industrial firm leads the crop management, monitors shock practices and implements preventive practices that require high levels of expertise;
- the farmer association implements shock practices such as PC surgeries and PC monitoring; and
- the smallholders reinforce PC surgeries and PC monitoring and implement the remainder of the shock and preventive practices (e.g. fertilisation of diseased trees, eradication, maintenance of drainage channels and cultivation of leguminous plants) and the remaining practices in crop management.

In this last case, the important involvement of smallholders is explained by the characteristics of their nature. Unlike the nuclei A and B, smallholders in nucleus C selected the agro-industrial firm, to whom they sold the harvest, and the members of the cluster[74]. Moreover, these producers had low-socio-economic conditions and were focused on farming activities given their attachment to land. These characteristics had an influence on the vision of the agricultural sustainability and therefore led to particular patterns of technology adoption.

Compared to shock techniques, lower adoption levels of preventive practices can be attributed to the nature of rural smallholders and their need to carry out complementary activities that replaced some of the preventive practices. Networks can reflect the characteristics of this type of formal rules, especially in the use of collective action for technical support.

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[74] It should be recalled that Anchor Companies A and B selected the producers that could participate in their corresponding nuclei according to the rules that these companies set for selection.

7.1 Sharing technical responsibilities and roles within formal rules of nucleus C

This section studies the part of formal rules of nucleus C that corresponds to formal responsibilities and the main roles of participants in the centralised-diffusion process, namely the CFA, of PC management. The CFA in this nucleus was mainly characterised by the partial agro-industrial control (see Sub-Section 2.3.3 for CFA typologies) and the participation of various actors in the provision of technical assistance and technology adoption. In particular, the formation of nucleus C will be described, as will the technical roles and commitments taken on by the leading change agent (Anchor Company C), farmer association 'AssocC1'[75], social organisation Fundepalma, and smallholders.

The formation of nucleus C was a result of the initiative of a group of poor smallholders in the Central zone, who joined the 'Project of Rural Farmers with oil palm' (referred to in Spanish as 'Proyecto de Finca Campesina con palma de aceite') in order to improve their living conditions. This project was run by the social organisation Fundepalma. These smallholders found economic advantages with Anchor Company C, whose plantation neighboured their farms and who was interested in sourcing FFB from surrounding plantations. Thus, this anchor company signed an agreement of *purchase intention* in which the firm committed to buy the future production of these farmers at the international based price of FFB[76].

As a pre-requisite of this oil palm project and the Colombian Agrarian Bank, producers had to create a farmer association, which will be referred to as 'AssocC1'. The association would be in charge of paying the collective debt[77]. In order to ensure that revenues from FFB sales were used to repay the associative credit, the association was also in charge of bulking and transporting the fruit to Anchor Company C. Once AssocC1 was formed,

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[75] The name of AssocC1 was given to the farmer association of this nucleus in order to keep the identity of the anchor company and the nucleus confidential.

[76] See footnote 18 (p.90) for better understanding of the way agro-industrial firms determine the purchase price of FFB in the oil palm sector.

[77] As in the previous case study, by having a collective debt, all associative members committed to make up the difference of a member failing to meet their economic obligations with the association.

smallholders received technical and legal support from Fundepalma. In addition, they received seedlings and technical assistance from Anchor Company C, credits from the Colombian Agrarian Bank, and subsidies from the government. Under such conditions, producers were able to initiate the oil palm cultivation in 2002.

In total, there were 62 small-scale producers in nucleus C that, unlike nuclei A and B, were concentrated in the same area and mostly shared borders with Anchor Company C's plantation. The fact that these smallholders lived in the same town and knew each other facilitated their engagement in any collective action. Although the smallholders of nucleus C individually managed their plantations and implemented most crop practices, collective action in the form of mutual collaboration and a farmer association had been a crucial strategy for the adoption of crop activities.

Regarding mutual collaboration, several interviewed smallholders affirmed that since the first phase of planting was the most difficult stage in the cultivation and there was poor funding available, producers acted as one single group and sowed, managed weeds, fertilised, and harvested in each plantation of the nucleus. With this strategy, farmers not only aimed to benefit themselves with the efficient adoption of these practices but also to support those who had no economic or physical capacity to carry out these activities. At the time of the fieldwork, this collaboration had ended and smallholders were implementing most activities for crop management (e.g. fertilisation, harvesting, and management of weeds) and some of the shock and preventive practices (e.g. fertilisation of diseased trees, eradication, maintenance of drainage channels and cultivation of leguminous plants) individually.

As for AssocC1, this farmer organisation brought an array of technical and economic benefits for smallholders. Above all, interviewed smallholders pointed out that AssocC1 significantly benefited many of its members when it took over and paid their financial debts before starting up the oil palm cultivation. Through this farmer association, producers had easy access to credits for farming (e.g. purchase of agricultural inputs) and non-farming purposes; they also had access to the government subsidies of ICR[78] and banking credits. In technical terms, AssocC1 was in charge of implementing shock practices such as PC monitoring and PC surgery. It also facilitated the flow of information from different actors to smallholders through its communication channels. Interviewed assistants of Fundepalma and Anchor Company C asserted that by using the existing channels of communication and the association meetings, these actors could easily train smallholders and transfer information to them.

Key actors, such as Fundepalma and Anchor Company C, provided technical support with different levels of intensity during the stages of oil palm development. Fundepalma took a leading role in technical, financial, legal and organisational issues during the first stage of cultivation. The head of this organisation reported that they gave free technical assistance for the development of the plant nursery, trained smallholders in the creation, legalisation and enforcement of a farmer association, organised farmer field schools (FFS) and facilitated the training from other institutions such as SENA and Cenipalma, and helped smallholders to access governmental subsidies and funding (J.P, personal communication, 14 July 2015). In this first stage, and as part of the agreed CFA, Anchor Company C provided seedlings and general technical assistance that complemented Fundepalma's support. After two years of oil palm cultivation, Fundepalma reduced its technical involvement and Anchor Company C took a more leading role in technical assistance, particularly in decision-making processes for development, planning, transfer and verification of crop management.

The efforts made by AssocC1, Anchor Company C and Fundepalma in technology transfer were intensified during the context of PC epidemics. As in nuclei A and B, the anchor company of nucleus C strongly supported the implementation of PC-related practices due to their need for maintaining their sources of FFB, reducing the risk of the disease spreading to their plantations, and complying with the regional strategy of the UG alliance,

[78] See p. 90 for an explanation of this subsidy.

of which this anchor company was member. However, the particularities of Anchor Company C and the agro-industrial firms in the previous case studies add an interesting contrast between cases. It will be seen through the chapter that, unlike Anchor Companies A and B, company C was interested in the agricultural sustainability of smallholders' agribusiness; it played a paternalistic role in the nucleus and provided important support not only for short-term but also for long-term practices. As will be seen in Section 7.5, this paternalistic role was part of the social values underpinning the formal rules of nucleus C that also would impact the levels of technology adoption of smallholders.

Amongst the responsibilities that Anchor Company C undertook within the CFA, this firm participated in the management of both shock and preventive practices. In order to intensify the transfer of shock practices and assistance to preventive practices, this agro-industrial firm created a PC-Coordination unit that was in charge of establishing, communicating and verifying the criteria and Cenipalma protocol for some shock practices, such as PC monitoring and PC surgeries. With the support of Cenipalma, technical assistants of the anchor company regularly trained the smallholders of this nucleus, increased group and personalised assistance, and monitored the levels of PC incidence in these plantations. In addition to attending shock practices, Anchor Company C assumed the adoption of preventive practices that required high levels of expertise, such as soil and frond analyses. Additionally, at the time of the fieldwork, company C was training smallholders in these practices. An interviewed technical assistant reported that with this training, the company aimed to reduce the dependency of smallholders on the company (E.C, personal communication, 9 July 2015).

The important support of AssocC1 and Fundepalma can be explained from the threat that PC disease posed to smallholders' agricultural and economic sustainability. Following the designed strategy by Anchor Company C, AssocC1 was responsible for implementing these strategies on its members' plantations. The association brought advantages to smallholders that arose from the use of collective action. The head of this association said that after visiting the affected area of Puerto Wilches, they created a skilled team of six field workers in charge of implementing PC monitoring and PC surgery in the nucleus (L.N, personal communication, 8 July 2015). This team, who strictly followed the UG alliance criteria and the Cenipalma protocol for the adoption of shock practices, was previously trained by Anchor Company C. The cost of these services was discounted from the value of smallholders' FFB sales.

Despite the services that AssocC1 provided to its members for the implementation of certain shock practices, a significant proportion of smallholders took an active role in this adoption. According to interviewed smallholders, when the association did not meet with the service scheduled, several producers assumed or reinforced these activities based on the knowledge that they gained from Anchor Company C's training and assistance.

Regarding Fundepalma's support, this social organisation assumed complementary responsibilities in the management of shock practices. According to the head of Fundepalma, they organised training sessions and assigned a full-time technical supervisor in charge of verifying PC monitoring and PC surgeries, as well as supporting other agricultural activities related to crop management (J.P, personal communication, 14 July 2015).

In terms of what was defined in the theoretical framework of this thesis, the formal rules of nucleus C resemble a model of partial agro-industrial control (Chapter 2, Figure 2.5, p.76). In this CFA, there was a clear distribution of functions for PC management amongst Anchor Company C, smallholders engaged in collective action through a farmer association, and smallholders acting individually. The anchor company was in charge of planning, transferring and verifying the adoption of all PC-related practices and was also involved in the implementation of preventive practices requiring high expertise levels. The farmer association was responsible for adopting the defined strategy for shock practices such as PC monitoring and PC surgeries. Smallholders were in charge of implementing most practices for crop management and some other preventive practices (e.g. cultivation of leguminous plants and maintenance of drain channels) and shock practices (e.g. fertilisation of diseased trees and eradication) under the guidance of Anchor Company C. Additional support for verifying shock practices was also given by a social organisation.

Unlike the case studies of Chapters 5 and 6, actors in nucleus C provided technical support to smallholders in a distributed and complementary way; this has important implications for the adoption of shock and preventive practices that will be further analysed in Section 7.5. The use of distributed support reduces the usual dependency of producers in an agribusiness on the provision of technical support by a sole leading change agent.

Unlike nucleus B, in which producers were heavily dependent on the agro-industry's priorities during decision-making processes, the impact on adoption and agricultural sustainability of smallholders in nucleus C will be associated with the action of both producers and other change agents. As mentioned above, smallholders shared several responsibilities in crop and PC management. The characterisation of these producers in terms of their nature is important in understanding their tendency towards the adoption of certain practices.

7.2 Associated rural farmers

The theoretical framework of this thesis indicated that, in addition to the formal commitment of the CFA, another characteristic aspect of formal rules is the type of users. This section will show that the producers in nucleus C were rural farmers, characterised as being committed to their land and farming livelihoods, and for capitalising collective action to gain benefits within the technology-diffusion process. We argue that in this case, the nature of users was crucial in making producers more willing to participate in the adoption of shock and preventive practices as well as in other practices for crop management.

Due to the aims of the 'Project of Rural Farmers with oil palm' (to improve the living conditions of poor small-scale producers) that initiated the formation of nucleus C, smallholders in that cluster were characterised by being rural farmers under unfavourable economic conditions. The head of Fundepalma pointed out that this project only accepted poor farmers who, despite being landowners, lacked the financial capital to make economic use of their land. In line with these objectives, the social organisation only approved groups of farmers whose members owned 30 or fewer hectares of land, and whose farms provided their main source of income (J.P, personal communication, 14 July 2015).

The collected data confirmed that, as a result of the conditions established by the project and Fundepalma, most smallholders in nucleus C were rural farmers with low socio-economic conditions. Table 7.1 reveals that these producers owned around 15 hectares of oil palm crop on average, and 93% owned between 10 to 20 hectares[79]. During the survey, farmers mentioned that they did not employ plantation managers and most of the time worked in their plantations or used family labour for different crop activities.

In terms of income sources, almost 80% of producers were highly dependent on oil palm production as their main livelihood, and 52% carried out other productive activities such as the cultivation of rice, cattle breeding or non-farming activities. Most smallholders that reported cattle activities (28%) had only a few cows that were used mainly for milk production. However, around 87% of the population, including cattle owners, were mainly focused on agricultural activities. The majority of smallholders in nucleus C had low levels of education; 85% of the population completed only primary school. Nevertheless, the population indicated having an average of 30 years' experience in agriculture.

[79] Smallholders with 30 to 50 hectares of oil palm crops, Table 7.1, affirmed that additional hectares of land were acquired several years after making a profit from the oil palm agribusiness in the 'Project of Rural Farmers with oil palm'.

Table 7.1: Socio-economic conditions of small-scale producers in nucleus C

Variable	Mean	Frequency of producers
Size (No. Hectares)	Mean = 15 Min = 5 Max = 50	0-10 = 26 (42%) 11-20 = 32 (51%) 21-30 = 1 (2%) 31-40 = 1 (2%) 40-50 = 2 (3%)
Income source	N/A	Only oil palm agribusiness: 16 (26%) People with livestock and/or rice: 18 (29%) Staple crops[80]: 14 (23%) Non-farming activities: 8 (13%) Farming and non-farming activities: 6 (10%)
Participation income (based on producers' perceptions)	N/A	High dependence on oil palm[1]: 48 (77%) Low dependence on oil palm[2]: 6 (10%) Equally dependent on oil palm and other livelihoods: 8 (13%)
Education	N/A	Primary: 53 (85%) Secondary: 6 (10%) University: 1 (1%) Technical career: 2 (3%)

[1]: more than 50% of their income comes from oil palm
[2]: less than 50% of their income from oil palm
NI: No Information available
N/A: Not applicable

Source: Own elaboration based on fieldwork

In addition to these low socio-economic conditions, one characteristic aspect in the nature of these smallholders is their engagement in collective action for supporting their crop practices. Although the main strategy of collective action was embodied in their farmer organisation (AssocC1), Section 7.1 indicated that producers also cooperated with each other during the initial stage of cultivation to implement agricultural practices.

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[80] Examples of staple crops are: yam, plantain, fruit trees, and corn.

The description of smallholders participating in nucleus C highlighted a particular nature of users. These producers were highly dependent on farming activities (mainly on oil palm production); they had control over their plantation management, they mostly worked or used family labour for technology adoption, and they capitalised on collective action strategies. Based on these characteristics, it is possible to assume that, whilst these smallholders put greater attention on the adoption of long-term practices, they did not neglect the adoption of short-term practices.

Different characteristics in the nature of producers belonging to nucleus C suggest that these smallholders used oil palm cultivation as a sustainable livelihood, and were therefore interested in adopting long-term practices (e.g. soil analysis, frond analysis and maintenance of drain channels) and other non-PC-related practices for crop management (e.g. fertilisation, harvesting, and management of weeds). For instance, the poor socio-economic conditions leading producers to join the productive project of Fundepalma indicated that these actors were searching for a livelihood and better living conditions rather than immediate short-term economic profits. These smallholders' interest in having a sustainable livelihood can be also seen from their strong attachment to the land. This attachment can be explained from smallholders' high dependency on farming activities, their high involvement in crop management, and the fact that all of them lived in a small town near to their plantations.

Finally, evidence shows that smallholders were pursuing long- rather than short-term benefits. Several interviewed smallholders mentioned that after growing oil palm, they improved their housing conditions; others could then afford to pay for some of their family members' education. One of these smallholders said, 'With the incomes from the oil palm crop we could build our house with construction materials instead of the wooden house we had before'. Another commented, 'From the agribusiness we can afford the medicines for our granddad' (J.M, personal communication, 8 July 2015). One could conclude from these examples, that by adopting long-term practices, for example preventive practices, these producers aimed at securing long-term benefits.

Another important characteristic of these users was their engagement in collective action. With a farmer organisation, producers garnered support for the implementation of shock practices and other agricultural activities. By putting more emphasis on practices that reduced the loss of production for its members in the short term, the association could also reduce the loss of income for producers and ensure the fulfilment of its financial obligations. This does not mean that this organisation did not undertake other practices. For example, whilst AssocC1 was responsible for the adoption of shock practices, it still facilitated inputs for fertilisation activities.

Despite giving important attention to long-term practices, producers in this nucleus did not neglect short-term practices completely. In fact, since a plant disease epidemic posed a risk that could cause the loss of production and income, some smallholders reinforced the services for the adoption of PC monitoring and PC surgery provided by the farmer organisation. In this way, they could protect their main source of income and livelihood strategy.

To sum up, smallholders in nucleus C had low socio-economic conditions; they were highly dependent on farming activities, attached to their land, and engaged in collective action. This section suggested that this particular nature could have a positive impact on the provision of technical support and on the adoption of both preventive and shock practices. Personal incentives of rural producers suggested that these smallholders gave greater attention to implement the former, rather than the latter, group of practices. However, shock practices were not neglected. Whilst the farmer organisation set by these producers gave support to the implementation of these practices, smallholders sometimes reinforced this adoption.

Rather than seeing the socio-economic conditions of producers as their potential capacity to access technical assistance and adopt agricultural technologies, as was mentioned in the previous chapters and in Sub-Sections 2.1.2 and 2.3.4, it is possible to view producers' characteristics in a different way within technology diffusion, for example, by associating them with their tendency to act collectively or individually. It is argued that poor smallholders tend to act collectively to support each other through farmer associations and that these organisations can help in both the adoption and the transfer of technologies to its members.

From the works of Wollni and Zeller (2007), Roy and Thorat (2008) and Rao and Qaim (2011), and results of this case study, one could associate the poor socio-economic conditions of smallholders with their tendency to join farmer organisations in agribusiness[81]. At the same time, as argued by Sartorius and Kirsten (2007) and Barrett et al. (2012), these organisations contribute to ease the information flow and access to inputs, as well as cost-effectively deliver technical services. Therefore, by engaging in collective action, this type of producer can influence both the adoption of practices in the cluster and technology transfer to its members.

Based on this and the previous section, the nature of rural farmers employing collective action strategies can be related to the CFA of partial agro-industrial control of this nucleus. The CFA of nucleus C assigned different responsibilities to participants based mainly on the nature of producers and the support they needed to adopt certain types of practices. This helps to answer the first research question of this thesis about the way formal rules impact the technology diffusion processes. Since these smallholders were focused on farming activities and took over their plantation management, they were responsible for most crop practices (with the exception of those practices that required high levels of expertise) under the leadership of Anchor Company C. By being organised in a farmer association, these producers could give technical support and assume crucial responsibilities that affected the short-term benefits of smallholders (e.g. shock practices)

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[81] Although there are multiple examples where smallholders successfully participate in agri-food markets through collective action, this is not always the case. The works of Bernard and Spielman (2009) and Fischer and Qaim (2012), for example, showed that poorer producers were less likely to join farmer organisations due the low returns they might derive from the organisation or the high financial contribution required by the organisation. According to Hellin et al. (2009), the potential benefits of a farmer organisation are very context and product specific, and depend on the concrete activities pursued.

without neglecting the adoption of other crop practices. Without a form of collective action from users, sharing roles within a CFA would be more difficult.

As in Chapters 5 and 6, embedded social values in formal rules and, thus, in technical relationships, can facilitate the transfer and ensure the final adoption of PC-related practices. The next section will discuss these necessary values.

7.3 Trust-based relationships underpinning the formal rules of nucleus C

Within the formal rules of nucleus C, the corresponding CFA assigned responsibilities that then became technical relationships between smallholders and other key actors, such as the leading change agent and farmer association. This section argues that values of trust and mechanisms of good communication are needed to back up this set of rules and technical relationships. In line with the social capital theory and the sub-category 'linking' social capital created by Woolcock (1998) to explain trust-based relationships embedded in hierarchical relationships (see Sub-Section 2.4.2) (although relationship participants in the agreement can be characterised as vertical), values could help increase smallholders' willingness not only to accept the involvement of other key actors in PC management but also to adopt PC-related practices.

Trust-based relationships between smallholders and Anchor Company C enabled the agro-industrial firm to play a leadership role and exert an important influence on the adoption of both shock and preventive practices. These trust-based relationships can be explained from 1) the historical relationships between the local community (including smallholders), and the anchor company, 2) the multidimensional support given by this company, and 3) the methods and strategies used to transfer technology and promote loyalty for fruit provision. First of all, observations from fieldwork showed that this company had an important and historic influence in the town where farmers were located. According to interviewed smallholders and technical assistants, with the development of oil palm agribusiness by Anchor Company C, this agro-industrial firm had generated significant employment in neighbouring towns. In addition, Anchor Company C built a historical relationship of technical assistance and provision of inputs to smallholders since the cluster began.

A second reason explaining the social content of technical relationships is the different support provided by Anchor Company C that was not restricted to only technical and commercial issues. Interviewed smallholders and technical assistants pointed out that, in addition to technical support, the company advised producers about financial, legal and social issues, even though these functions were not included in the contract. According to the head of the department for the management of fruit providers, this department aimed to improve farmers' production levels as well as assisting them in other areas that could affect their crop development (E.C, personal communication, 9 July 2015). For example, at the time of the fieldwork, an interviewed smallholder had been receiving legal and social support concerning issues that were threatening her land tenure. She said:

> 'I almost lost my farm because of my ex-husband's family. The company helped me by looking for a lawyer and the engineers prepared a legal certification saying that they met me and that I have worked in that land since the beginning of the cultivation' (C.C, personal communication, 8 July 2015).

Finally, Anchor Company C used persuasive methods rather than compulsory recommendations to pressure the technology adoption in the cluster. A general shared view across interviewees was that due to the anchor company's well-known trajectory, regular trainings, monthly and personalised visits, and friendly relationship, smallholders relied heavily on the company. One interviewed smallholder, for example, considered Anchor Company C, as well as his association, as the 'godfathers' of the nucleus (J.A, personal communication, 8 July 2015). Additionally, the company increased the number of technical staff that regularly attended to producers' technical necessities.

Some interviewees, including smallholders and technical assistants of nuclei B and C, pointed out the big differences between the relationships that representatives of Anchor Company B had with smallholders in comparison to those of company C. An interviewed smallholder said, with reference to their relationship with Anchor Company C; 'I can come and go whenever I want from their facilities [referring to the headquarters of Anchor Company C] because they treat me like a friend' (R., personal communication, 8 July 2015). This was not the case in nucleus B. For example, an interviewed smallholder of nucleus B said:

> 'Anchor Company B is a 'close circle' that denies supply producers access to its facilities. You have to go through the reception and they make you to wait until you are authorised to see whoever you want to see. I see other companies like Anchor Company C where the fruit providers are rather privileged and well attended' (H.V, personal communication, 6 July 2015).

As such, it is argued that Anchor Company C played a paternal role and established trust-based and friendly relationships that allowed the company to promote the Cenipalma protocol, monitor shock practices, and take over the implementation of some preventive practices. Because of these values, smallholders also agreed to follow the company's instructions regarding PC management.

Regarding the technical relationships between smallholders and their farmer association, it is suggested that embedded values made smallholders willing to accept the technical services for the implementation of shock practices that this organisation provided. These trust-based relationships were the result of all types of benefits that AssocC1 had given to smallholders since its historical formation. Most surveyed and interviewed smallholders agreed that the association brought benefits that supported their crop development and aimed to improve the conditions of its members. Amongst these benefits, the association facilitated low-interest credits for agricultural and non-agricultural purposes, paid financial debts of several members, and established a grocery store that yielded profits for its members. One of the most important technical services that AssocC1 offered to its members during the PC epidemic was the implementation of shock practices by hired field workers. The fact that these workers were previously trained by Anchor Company C might have had an influence on smallholders' willingness to accept this specific service.

Unlike the values embedded in technical relationships between smallholders and their farmer association, there were few values of cooperation amongst association members at the time of the fieldwork. Despite the fact that solidarity and mutual support existed at the beginning of the oil palm cultivation, individualistic behaviours were common after this first stage of cropping. Referring to the members of the association, an interviewed producer said, ‘there is no unity. Each producer acts alone. A psychologist that visited us said that the association was a family and that we needed to be more generous with each other […] but we don’t have those values’ (C.C, personal communication, 8 July 2015). According to the head of the association, more cooperation existed in the past due to the lack of economic resources and the tough conditions that made producers cooperate amongst themselves. He explained, ‘after making profits, everyone started implementing agricultural activities individually and the groups we formed [for adoption of these practices] disappeared’ (L.N, personal communication, 8 July 2015).

This section showed that values of trust, friendship and solidarity could be essential to facilitate the flow of information and the technology transfer between smallholders and their peers, as well as the leading change agent and the farmer association. Historical relationships, regular assistance and persuasive strategies enabled Anchor Company C to get highly involved in both the management of shock practices and the implementation of preventive practices in smallholders’ plantations. Benefits and other services gained by smallholders from their farmer association persuaded producers to accept the assistance of the organisation for the implementation of some shock practices.

Sections 7.1 to 7.3 of this chapter have explained three key features of a centralised-diffusion process that can have important implications for technology adoption:

1) formal rules with shared participation of smallholders, a farmer organisation and a leading change agent in the management of shock and preventive practices;

2) rural famers with low socio-economic conditions engaged in a collective action strategy; and

3) trust-based relationships embedded in rules and technical relationships between two key actors (an agro-industrial firm and a farmer organisation) and smallholders.

These characteristics can be reflected by the network structure and links for technical support that will be studied next.

7.4 Low-centralised network supporting preventive and shock practices in nucleus C

This section contributes to answering the second research question of this thesis about the types of network structures that result from certain formal rules, and the impact of these networks on information access, variety of information sources and influence of other actors on producers. The outcomes will indicate that network structures can reflect the use of a collective action strategy, in the form of a farmer association, sharing responsibilities within formal rules with a leading change agent.

Based on the interpretation of Salancik's (1995) work, we built a connection between formal rules and network structures in which the former could determine the shape of the latter. This case study adds to the critique made in previous empirical chapters about the need to include the role of formal rules in the network formation within the literature of diffusion, including the works of Wyckhuys and O'Neil (2007) and Monge et al. (2008). In order to show this role, this case indicates that the most important links through which rural smallholders of nucleus C accessed information resulted from the technical responsibilities that both farmer organisation AssocC1 and Anchor Company C shared as part of the CFA. The network was analysed by using the same structural characteristics that were employed in Chapters 5 and 6.

Network size and individual interaction

Figure 7.1, also called network C, shows the map of technical ties through which smallholders of nucleus C received technologies and information related to PC management. Network C is formed by a total of 144 actors who were related through 243 ties. Out of the total number of actors, 64 participated in the CFA of nucleus C (Anchor Company C, AssocC1 and 62 smallholders) and the rest belonged to 8 types of organisations.

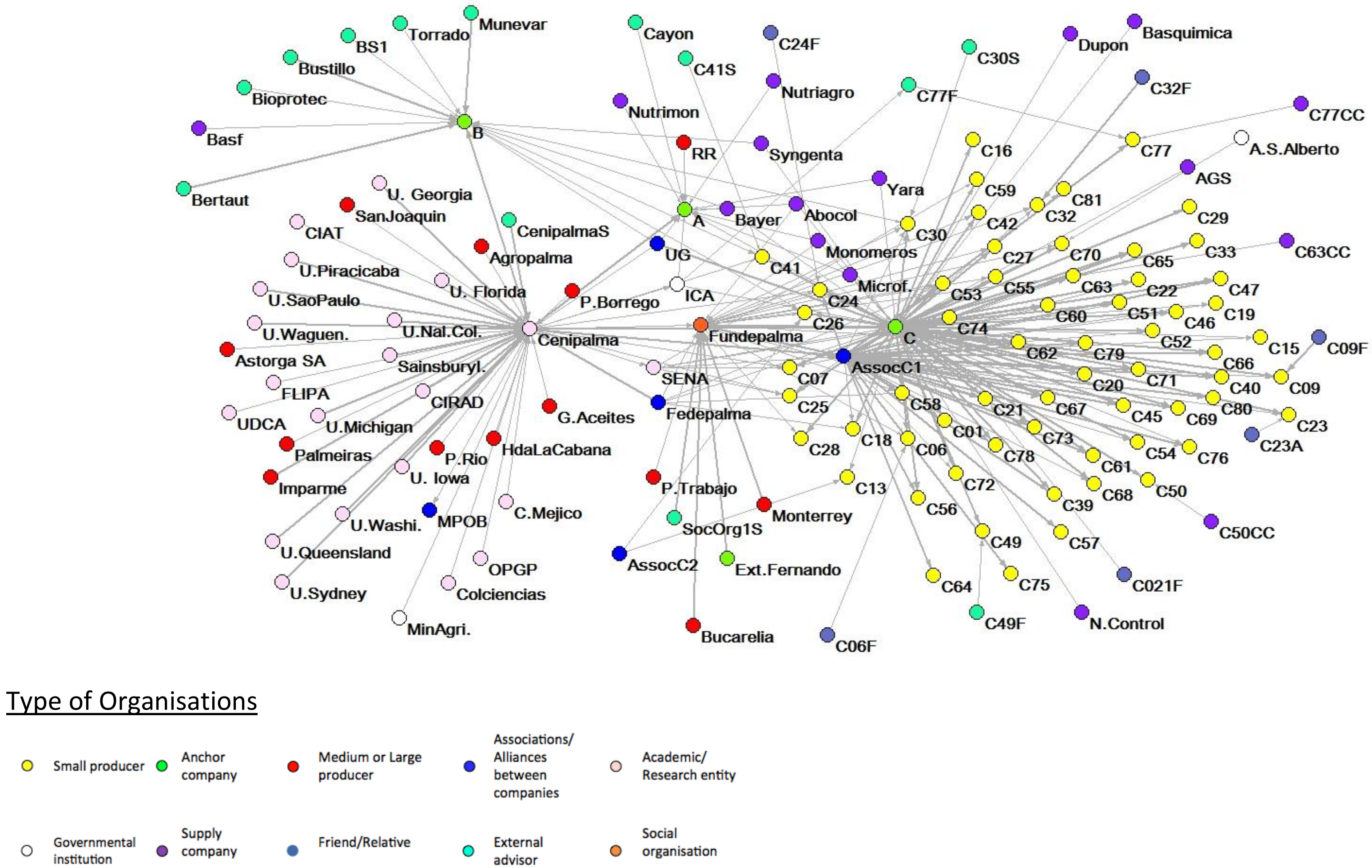

Figure 7.1: Network C for technology diffusion of PC-related practices

Source: Own elaboration from survey data

The following ‘shrunken network’, Figure 7.2, allows for a better visualisation of types of actors providing information to the smallholders of nucleus C. According to this map, the majority of relationships for the transfer of technology to producers came from anchor companies (number of links: 61; sum of importance: 232) and associations (number of links: 54; sum of importance: 185). Within these two types of organisations, as it was expected, Anchor Company C and AssocC1 were the main and most important providers of technology making use of 58 links (sum of importance: 224) and 48 links (sum of importance: 170), respectively. Compared to these two actors, Fundepalma (the only social organisation in network C) had a lower number of links with smallholders; however, one can highlight this organisation’s role that is connected to several producers in network C (number of links: 15; sum of importance: 39).

Although the participation of a farmer association in nucleus C reduced the overall centralisation of network C, the centralisation of this structure was still accentuated by the absence of links between producers (Figure 7.1). This absence resulted from the greater individualism of smallholders and their lack of effort in diffusing practices (see Section 7.3). It can also be argued that, based on the network study of developed by Clarke and Ramirez (2014) within the Peruvian mango sector, these bilateral links were uncommon because of the difficulty of these small-scale producers in sourcing new technology. The absence of bilateral links between smallholders and their peers shows that, although they were producers engaged in collective action, this does not necessarily mean that there was an arrangement of cooperative behaviour, but that a farmer association centrally coordinated a collective action strategy.

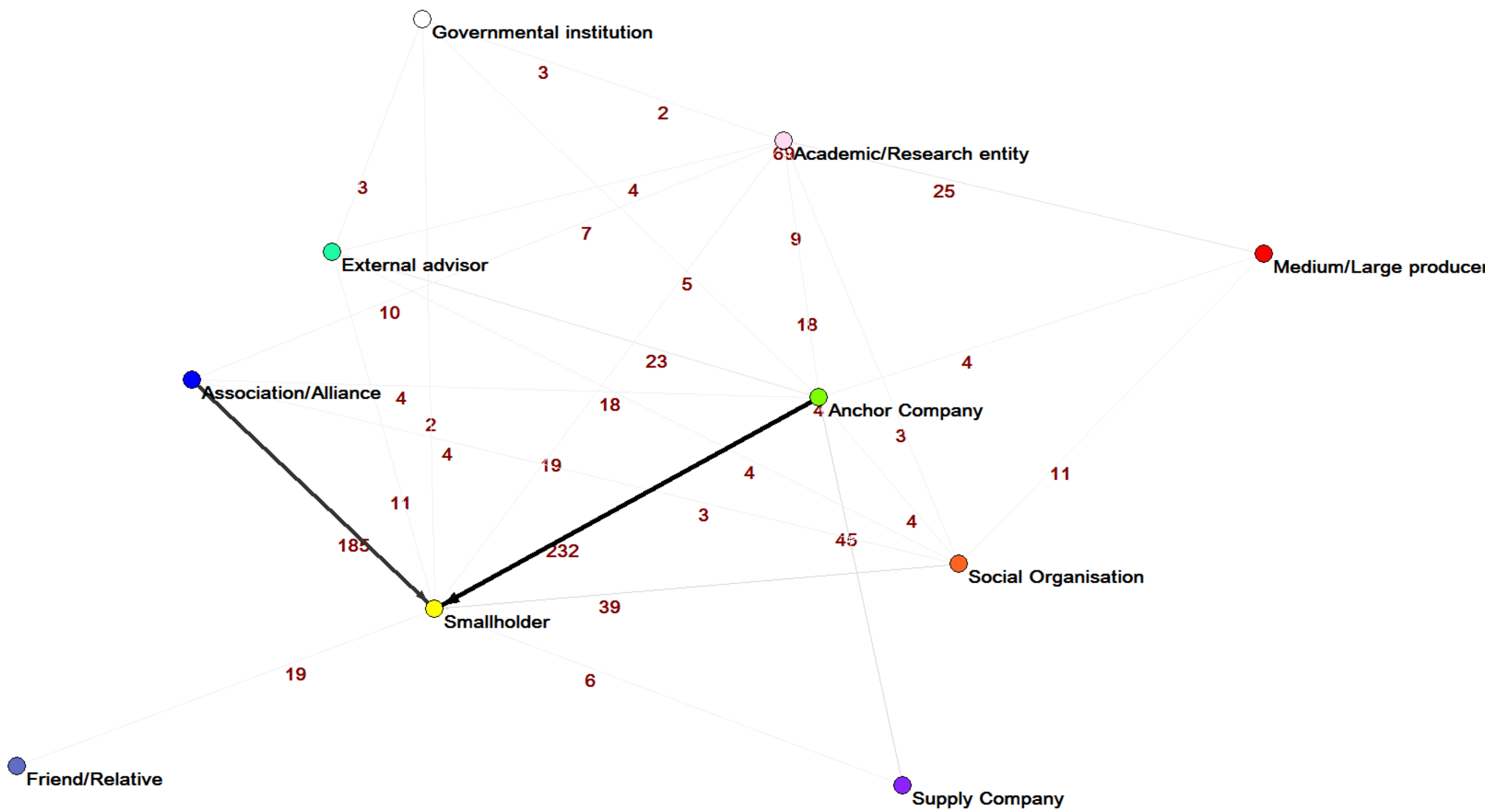

Figure 7.2: Shrunken network for technology-diffusion of PC management to nucleus C

Source: Own elaboration from survey data

On a more individual level of analysis, Figure 7.3 shows that most producers in nucleus C received information from two sources, specifically from Anchor Company C and AssocC1. Some others received information from four sources including, in most cases, Anchor Company C, Assocc1, Fundepalma and Cenipalma. This scenario is similar to both nucleus A, in which the majority of producers received information from two sources, and nucleus B, in which most producers received information from one or two sources of information. However, in A and B, producers were receiving information from their anchor companies and, in an important proportion, from Cenipalma.

It is possible to highlight from Figures 7.1 and 7.3 that the role of Cenipalma was far less crucial for smallholders in nucleus C than for producers in nuclei A and B. Although it is not surprising that Cenipalma had an important role in all networks due to its responsibility in developing protocols for PC management, the contribution of this centre was not equally important for smallholders in each cluster. For example, unlike networks A and B in which Cenipalma was related to 37% and 40% of producers, respectively, only 6% smallholders in network C were connected to this centre.

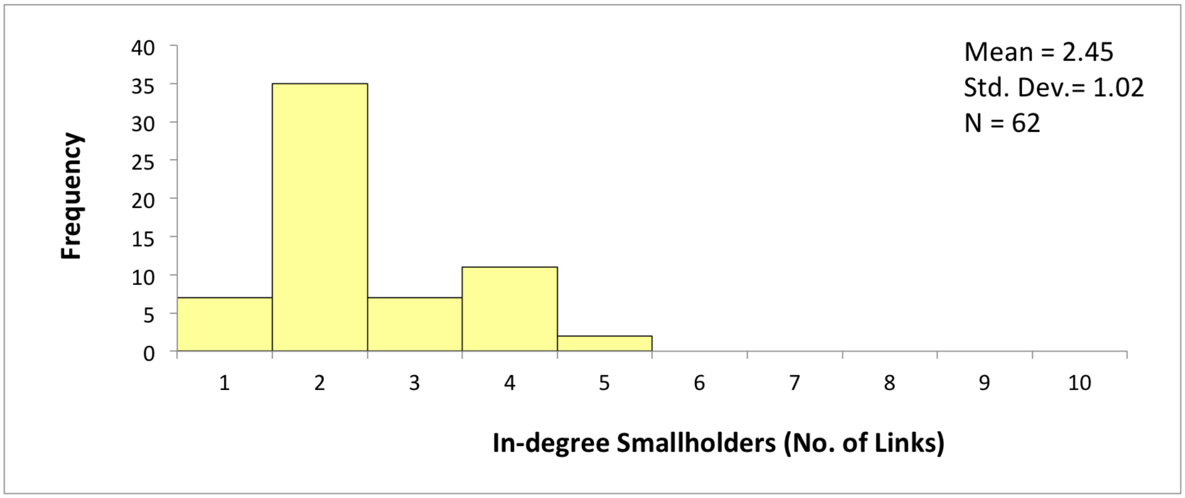

Figure 7.3: In-degree of small-scale producers belonging to nucleus C

Source: Own elaboration from survey data

Regarding the usage of these links, Table 7.2 presents which particular information was flowing through the technical channels of network C to users. In order to visualise the particular contributions of Anchor Company C and AssocC1, the link usage of these actors were shown separately from the groups of anchor companies and associations. According to this table, actors were more attentive to bringing information and technologies associated with shock practices (link usage: 354) than with preventive practices (link usage: 204). As for the dominant actors transferring particular types of information, it is possible to see that whilst Anchor Company C gave its attention to both shock practices (link usage: 148) and preventive practices (link usage: 142), AssocC1 emphasised its support on the shock practices (link usage: 129). Fundepalma also contributed to the emphasis on shock practices by providing additional verification in several plantations (link usage: 30).

Table 7.2: Link usage; detailing the type of information being transferred to users in network C

Actor	Total	Preventive practices				Shock practices			
		Drainage	Soil	Frond	Leguminous	Monitoring	Surgeries	Fertilisation	Eradication
Anchor Company C	290	14	61	61	12	50	50	30	12
AssocC1	159	4	11	9	6	58	50	7	14
Fundepalma	30	0	0	0	0	15	15	0	0
Academic institutions	35	5	3	3	5	7	4	4	4
Friends/ Relatives	23	1	1	1	1	8	6	2	3
Associations[1]	6	1	1	1	1	1	1	0	0
Anchor companies[2]	4	0	0	0	0	2	2	0	0
Governmental institutions	3	1	0	0	1	1	0	0	0
Supply companies	4	0	0	0	0	0	1	2	1
External advisors	4	0	0	0	0	2	2	0	0
		Total links: 204				**Total links: 354**			

[1]: not including AssocC1
[2]: not including anchor company C
Source: Own elaboration from survey data

Central positions

When giving a quick overview of Figure 7.1, it is possible to detect multiple core actors to which most smallholders and other actors in network C were attached. This figure also shows that Anchor Company C, AssocC1 and Cenipalma dominated the majority of links in the network. The high connectivity of the first two actors was the result of having numerous ties with smallholders related to shock and preventive practices. The important number of incoming and outgoing ties of Cenipalma was due to its connections with various academic sources and its role transferring technologies to different types of actors, including smallholders, Anchor Company C and AssocC1.

Supporting the network analysis of Figure 7.1, Table 7.3 illustrates that Fundepalma and Anchor Companies A and B also had higher levels of degree in comparison to more central actors. It is not surprising that Fundepalma played an important role in this network considering its complementary function for the verification of shock practices. In the case of Anchor Companies A and B, these actors not only brought a variety of information sources to the network, they also participated in the UG alliance[82] and shared technical information for PC management with Anchor Company C.

Table 7.3 also shows the values of betweenness centrality (or intermediation) of the most central actors in network C. Although those actors had an important role in the network, not all of them were connected to a good proportion of smallholders with other information sources. This is the case with Cenipalma, who was only connected to 13 farmers. However, these core actors were crucial in supporting other sources that were directly connected to producers, such as Anchor Company C and AssocC1. Cenipalma, for example, transferred results of R&D for PC management to Anchor Company C, AssocC1 and Fundepalma who in turn transferred these protocols to smallholders.

[82] It should be remembered that Anchor Companies A, B, C, and other oil palm agro-industrial firms, are members of the UG alliance.

Table 7.3: Degree and Betweenness indicators within nucleus C

Actors	Degree
C	77
AssocC1	53
Cenipalma	49
Fundepalma	25
B	15
A	13
Fedepalma	7
SENA	7
ICA	6
C24	5

Actor	Betweenness
Cenipalma	0.140773
C	0.097585
AssocC1	0.059638
B	0.025507
Fundepalma	0.024357
ICA	0.002634
SENA	0.001636
C77F	0.000048
Abocol	0
Agropalma	0

Source: Own elaboration from survey data

Brokerage beyond smallholders

Structural holes in network C were evaluated by measuring and comparing the redundancy and efficiency levels of five central organisations, the results of which are shown in Table 7.4. These five entities were representative for the case because they were more likely to integrate new information to nucleus C and had higher levels of both degree and betweenness centrality than other actors (see Table 7.3).

Table 7.4: Measurements of structural holes for broker organisations

Broker	In-Degree Centrality	Out-Degree links broker-smallholders	Importance of Out-Degree links broker-smallholders [1]	Efficiency	Redundancy
B	11	3	2.67	98%	1.14
C	15	58	3.86	97%	2.55
Fundepalma	10	15	2.6	97%	1.33
AssocC1	4	49	3.5	96%	0.57
Cenipalma	36	4	2.25	95%	2.50

[1]: Out-Degree links weighted by their average importance

Source: Own elaboration from survey data

According to Table 7.4, Anchor Company B was one of the most efficient actors in connecting non-redundant groups of information within network C. However, this anchor company was poorly connected to smallholders in terms of out-going ties and the significance of these relationships (out-degree to smallholders: 3; importance of links with smallholders: 2.67). Contrary to this, Anchor Company C had high levels of efficiency, was tied to 94% of smallholders, and received technical support from 15 information sources, most of which were supply companies. This gave company C the opportunity to influence the majority of smallholders from its brokerage position. For instance, this company acted as a key intermediary between smallholders and Cenipalma. Interviewed technical assistants reported that technology transfer from Cenipalma to smallholders occurred through the anchor company, on which smallholders were heavily reliant.

Table 7.4 also shows that there were two distinctive brokers in this case study: the farmer association AssocC1 and the social organisation Fundepalma. AssocC1 had the potential to bring support from other sources (e.g. government entities and social organisations) and to facilitate the communication between other actors and smallholders. For example, the head of this association indicated that by being grouped in an organisation, smallholders could receive economic and technical support from government entities (e.g. SENA, Ecopetrol) and NGOs (e.g. Fundepalma) (L.N, personal communication, 8 July 2015). The association was also capable of organising smallholders, channelling new information to them and increasing the efficiency of training sessions from external actors. This shows that collective action through a farmer association not only had an impact on the technology adoption of producers in nucleus C, but also influenced the technology transfer to its members.

As for Fundepalma, this social organisation had the capacity to easily tap into ties with various types of sectoral and non-sectoral entities that were relevant for financial and technical support. Some of these entities included social organisations (e.g. Development and Peace Corporation of Magdalena Medio, and Fruto Social de la Palma), academic and research institutions (e.g. University Institute of Peace, Cenipalma and SENA), as well as expert advisors and anchor companies (e.g. Palmas y Trabajo, Extractora San Fernando, Monterrey and Bucarelia). This last group provided funds and technical recommendations to this social organisation.

This section discussed the network structure that resulted from the type of CFA negotiated in nucleus C. In these formal rules, smallholders (grouped in a farmer organisation as a collective action strategy) and a leading change agent shared technical responsibilities for technology transfer. The resulting network shows rich connections between smallholders and multiple brokers, who each offer differentiated support in shock and/or preventive practices. It should be noted however, that, overall, there was a significant focus on shock practices over preventive practices. Whilst the farming organisation (AssocC1) focused its assistance on shock practices, the leading change agent (Anchor Company C) provided support for both practices. Other central actors (Fundepalma and Cenipalma) did not provide assistance to a high number of producers, but integrated new sources of information to the cluster.

These results help to understand the way that types of formal rules integrating collective action can impact on the structure of a vertical network. By sharing technical responsibilities within a CFA, a farmer organisation can become one of the core actors, together with a leading change agent that introduces important variations into the network structure. First, since it provides technical services to its members, this organisation can increase the number of links transferring technologies to smallholders. Second, as a result of this increase, a farmer organisation gains a central position in the network. Finally, this organisation can help smallholders to access external information sources. In that respect, Barrett et al. (2012) argue that farmer organisations can more easily tap into a social network relevant to their activities and increase the likelihood of receiving help from governments and NGOs.

Based on the results of this section, one can contribute to the theory of diffusion in an alternative way compared to other studies when including the role of farmer organisations in the diffusion process. Indeed, the work of Sangui (1995) and Oleas et al. (2010) show that farmer organisations can impact the transfer of technologies to smallholders by facilitating efficient communication of practices to members, provision of inputs and technical services, and training from other actors. These functions can be expressed as variations to network structures. From the few studies of social networks and diffusion, one could identify the role of farmer associations within network structures. For example, the works of Monge et al. (2008) and Spielman et al. (2011) show how these organisations have brokering positions in networks through methods of SNA. Unlike these studies, we link the formal rules and technical responsibilities of farmer organisations to variations of a network structure and to the use of network connections for particular practices related to crop management.

The implications for the technology-diffusion process of this type of network structure supporting the implementation of both preventive and shock practices will be reflected in the levels of adoption of the centralised-diffusion process corresponding to nucleus C.

7.5 Adoption of PC-related practices in nucleus C

The theoretical framework of this thesis suggested that the outcome of certain formal rules and, consequently, the variations of technical support through particular network structures could potentially impact the levels of adoption of long- and short-term practices. This section discusses how high adoption levels of both shock and preventive practices in nucleus C can be explained partly from a type of formal rules with broad governance structure, and a network with multiple key actors type of formal rules. Other important aspects, such as smallholders and the anchor company's motivations, contributed to this explanation. As was concluded in Section 7.4, network C was characterised by having high interactions supporting the management of both types of PC-related practices and more than one broker, one of which was a farmer organisation. It can be observed that the introduction of some of the preventive practices received significant attention from the leading change agent, who met its obligations to implement those practices according to the CFA negotiated with producers. Whilst both short- and long-term practices had high levels of adoption, long-term practices were slightly lower than short-term techniques. Lower levels of long-term practices were explained mainly from the nature of users and their preference for diversification of livelihood strategies over the adoption of long-term practices.

The data collected indicated that, on average, 89% of smallholders in nucleus C adopted agricultural practices for PC management. When comparing the types of practices, it was found that 96% of smallholders adopted shock practices whilst 83% adopted preventive practices. It can be highlighted from Figure 7.4 that 100% of smallholders implemented PC monitoring, PC surgery, soil analysis and frond analysis. This showed a significant gap with the proportion of smallholders cultivating leguminous plants, which in this case was only 41%.

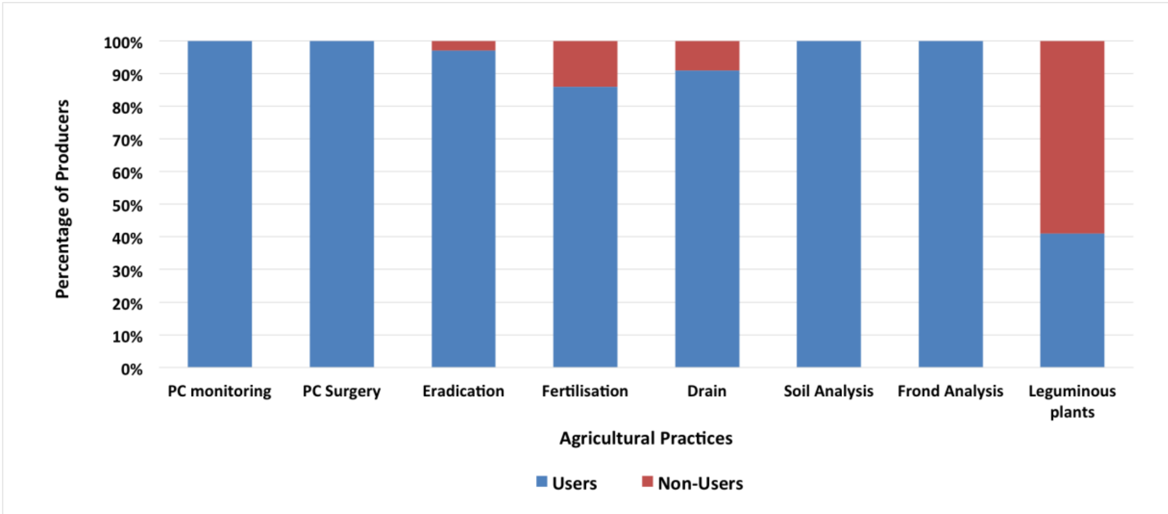

Figure 7.4: Levels of technology adoption by small-scale producers in nucleus C in 2015

Source: Own elaboration from survey data

We suggest that the main structural characteristics in network C can be the result of diverse sources of knowledge, the participation of a farmer association as a collective strategy, and the absence of bilateral links amongst producers. At the same time, the impacts on technology diffusion from this particular network structure, can explain most of the findings in Figure 7.4. The high adoption levels of both shock and preventive practices that is observed in this figure, were partly due to the shared responsibilities within the CFA and the technical support that various central actors provided to smallholders through network links.

It can be said that the high levels of adoption of shock practices result from the strong network connections through which: 1) Anchor Company C determined the management of these practices, extensively verified their correct adoption, and had a strong influence on smallholders; 2) AssocC1 implemented these practices in its members' plantations; and 3) Fundepalma provided additional verification. Additionally, the adoption of these practices was reinforced by smallholders.

Collected information indicated that agro-industrial firm C exerted important influence on the decision-making processes and willingness of smallholders in nucleus C to adopt. This was the result of different methods for technology transfer and the high reliance of smallholders on the anchor company's expertise. According to interviewed representatives of the company, because of the epidemics in the Central zone, technical assistants intensified their efforts to transfer the Cenipalma protocol of shock practices (e.g. increase the number of meetings, technical visits and training sessions) and, in a few cases, directly implemented these practices. One of the most effective strategies impacting smallholders' willingness was the fieldtrip to the affected area of Puerto Wilches. An interviewed technical assistant reported, '… at the beginning [of the epidemics] producers were not aware of how bad the PC disease was' (G.M, personal communication, 8 July 2015). After this visit, a significant number of interviewed farmers affirmed that they applied the Cenipalma protocol and monitored the levels of PC incidence in their plantations more regularly. As should be remembered, Anchor Companies A and B also showed producers the extreme consequences of PC and, in this way, were effective in the transfer of shock practices; this shows that diffusion through 'learning by watching' took place in the three clusters. Furthermore, a general shared view across smallholders and technical assistants was that producers made most decisions for management by strictly following the company's instructions. From this and the strategies for diffusion, we infer that Anchor Company C had a significant influence on smallholders of nucleus C.

Although Anchor Company C led the decision-making process determining the management of shock practices, AssocC1 was in charge of their final adoption in nucleus C. Making use of a skilled team of 6 field workers, the association provided the technical service and it ensured the implementation of PC monitoring in 58 plantations (94% of the total population) and PC surgery in 50 plantations (81% of the total population). This was one of the main reasons for the high adoption of shock practices.

Despite the fact that AssocC1 provided the service of PC monitoring and PC surgeries, smallholders sometimes complemented this adoption and stepped in to ensure the adoption of shock practices. As a result of Anchor Company C's intensive training in PC management, around 45% of smallholders carried out these activities when they wanted to reinforce these practices, or when the association failed to comply with the service schedule. Similarly, 26% of smallholders implemented PC surgeries earlier than the time schedule of the farmer association in order to prevent increases in the severity and incidence levels of PC in their plantations. This also helped to increase the adoption levels of shock practices.

The intensive assistance of Anchor Company C and the services provided by AssocC1 were complemented by the support of Fundepalma. As was mentioned in Section 7.1, this social organisation provided an additional verification of shock practices in nucleus C.

Regarding preventive practices, the high implementation of these practices can be explained by the links supporting the high adoption of soil and frond analyses. Compared to shock techniques, preventive practices had lower levels of adoption that resulted from the low cultivation of leguminous plants. This low cultivation is explained by the nature of users and their preference for livelihood diversification over the benefits of leguminous plants.

It can be suggested that the high adoption of soil and frond analyses in nucleus C was due to the interest of both smallholders and the leading change agent in adopting long-term practices and the technical support that this agent provided for this adoption. It is argued that smallholders hired the technical services for soil and frond analyses from Anchor Company C, and that this company implemented these practices driven by their interest in improving the agricultural sustainability of the crop in the long-term. Additionally, the company was providing technical training regarding the adoption of these practices at the time of the fieldwork. Technical assistants reported that they were implementing these practices, as well as training smallholders to enable them to carry out the analyses without always depending on the company (G.M, personal communication, 8 July 2015; E.C., personal communication, 9 July 2015). In fact, 8% of surveyed smallholders affirmed that they started taking these analyses by themselves. From there, we can say that, in addition to being interested in smallholders' sustainability in the long term, Anchor Company C was also interested in them having more autonomy in crop management.

With respect to the cultivation of leguminous plants, Figure 7.5 indicates that the major reason for not adopting this practice was the preference of growing grass for cattle breeding over leguminous plants. We suggest that the low socio-economic conditions and the producers' need to diversify their livelihood strategies, led smallholders to plant grass in between young oil palm trees instead of leguminous plants. According to an interviewed technical assistant, it was difficult to convince smallholders in this nucleus to abandon planting grass; this was because cattle breeding was part of their local culture and their way of complementing the oil palm production with an alternative income source. As can be seen from Table 7.1, almost 30% of smallholders in this nucleus use cattle breeding as an additional income source from which they supported living expenses.

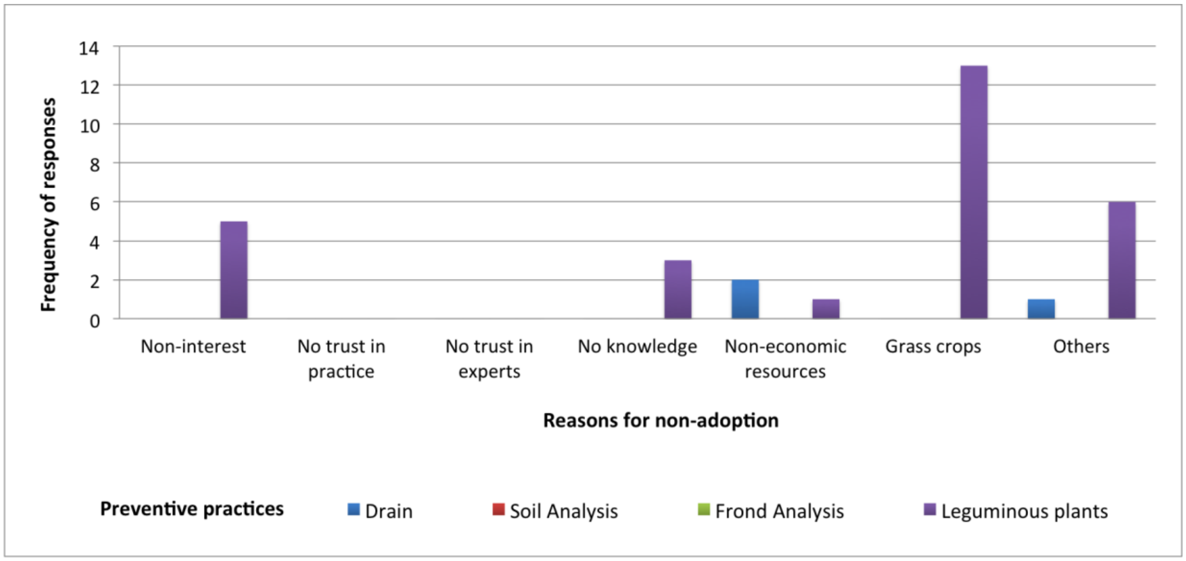

Figure 7.5: Reasons for non-adoption of preventive practices in nucleus C

Source: Calculated from author survey of oil palm producers

Table 7.5 summarises the major reasons impacting technology adoption in nucleus C related to the technology-diffusion process and the nature of selected smallholders.

Table 7.5: Factors affecting the adoption of PC-related practices in nucleus C

Shock Practices	
Fertilisation of diseased trees	· Trust in technical assistance provided by Anchor Company C · Access to credits from AssocC1 and C to buy fertilisers
PC monitoring	· Responsibility of implementation assumed by AssocC1 and complemented by farmers and/or by their relatives · Trust in training and technical assistance provided by Anchor Company C · High verification provided by Anchor Company C and Fundepalma
PC Surgery	· Responsibility of implementation assumed by AssocC1 and complemented by farmers and/or by their relatives · Trust in training and technical assistance provided by Anchor Company C · High verification provided by Anchor Company C and Fundepalma
Eradication	· Trust in training and technical assistance provided by Anchor Company C · Responsibility of implementation assumed by farmers and/or by their relatives
Preventive practices	
Drainage infrastructure	· Responsibility of maintenance assumed by farmers and/or by their relatives
Soil Analysis	· Responsibility of implementation assumed by Anchor Company C · Prioritisation by Anchor Company C · Trust in training provided by Anchor Company C
Foliar Analysis	· Responsibility of implementation assumed by Anchor Company C · Prioritisation by Anchor Company C · Trust in training provided by Anchor Company C
Cultivation of leguminous plants	· Interest in planting grass for cattle between oil palms · No availability of economic resources for covering the high costs of adoption (e.g. high time, labour force and money consuming for land preparation, inputs and maintenance) · No availability of seeds · No knowledge about this practice

Source: Analysis from author survey and interviews of oil palm producers

From these outcomes and Sections 7.1, 7.2 and 7.3, one can suggest that the formal rules of nucleus C and particular farmers contributed to the clusters' high levels of adoption of shock and preventive practices, and therefore to the smallholders' sustainability. In accordance with these rules, nucleus C was governed by a CFA of partial agro-industrial control in which rural farmers (capitalising collective action), the leading change agent and the farmer association shared responsibilities and both shock and preventive practices. Unlike the adoption of shock practices in which all participants of the CFA were involved, Anchor Company C was in charge of the implementation of preventive practices that required technical expertise whilst both producers and the farmer association were responsible for the remaining activities. The nucleus was also characterised by the existing trust-based relationships and friendship between smallholders and Anchor Company C.

We argue that the high adoption of shock practices was the result of the shared responsibilities agreed with the CFA as well as the interests of smallholders, the anchor company and the farmer association in implementing and intensively supporting these practices. By implementing these practices, smallholders could help to keep the annual average level of PC incidence down in their plantations, specifically around 0.33% (less than 10%, which was the acceptable level for PC management[83]), between January-2014 and December-2015.

It can be suggested that the high implementation of preventive techniques was mainly due to the adoption of particular practices that were the responsibility of the anchor company. On the basis of the CFA and the obligations of Anchor Company C in this agreement, this company implemented preventive practices that required technical expertise. Underpinning these formal rules, the paternalistic role and interests of company C were also crucial factors for this company to comply with its obligations. In addition, positive impacts on smallholders might result in long-term agricultural sustainability due to the high proportion of producers in nucleus C implementing

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[83] See footnote 32, page 105.

preventive practices. Following Munévar and Acosta's (2002) work, with this high level of adoption, smallholders were likely to increase the ability of their crops to continue in the long term.

The highly supportive organisational structure of Anchor Company C was convenient for both smallholders, who received more regular assistance, and company C, who aimed at guaranteeing uninterrupted fruit provision. However, this structure might involve high economic costs that can make the regular provision of technical assistance unsustainable. According to technical assistants of nuclei A and B, the organisational structure set by Anchor Company C to aid smallholders was sustainable in the long term because this company had a considerable amount of small-scale providers of FFB, in this and other areas of the region (C.M., personal communication, 5 July 2015; W.B., personal communication, 7 July 2015). With an important amount of FFB providers, the company could exploit economies of scale by reducing the costs of technical assistants per plantation. Moreover, Anchor Company C was one of the biggest companies in the region (in terms of the number of employees and their area of production), showing that this firm had the financial capacity to sustain this high supportive strategy. Nevertheless, this strategy could become an unsustainable situation for the company if the firm faced serious financial problems, or if the economic costs for provision of free technical assistance outweighed the benefits in terms of FFB production.

This section contributed to answering the third research question posed by this thesis about the outcomes of a centralised-diffusion process based on a type of formal rules and network structure. It showed that a CFA of shared responsibilities, a network of multiple central brokers, and high interactions supporting both shock and preventive practices could result in high levels of adoption of these practices.

It is also argued that the higher adoption levels of shock practices compared to preventive practices were due to the different intensity of technical support, the particular nature of rural smallholders, and the long-term sustainability approach of the anchor company. First, there were more network links providing intense assistance and influencing smallholders' willingness towards the adoption of shock practices than preventive practices. Second, the nature of smallholders affected preventive practices in two contradictory manners. On the one hand, there was the need to complement their income with other sources due to their low socio-economic conditions, which led rural producers to substitute preventive practices (requiring low expertise levels) with other activities and therefore pulled the total levels of adoption down. On the other hand, the use of oil palm cultivation as a sustainable livelihood led rural smallholders to hire services for the adoption of preventive practices (requiring high expertise levels) and in consequence pushed the overall adoption levels up. Finally, the agro-industrial firm's interest in smallholders' long-term sustainability could be linked to the high adoption levels of preventive practices (requiring high expertise levels).

7.6 Summary of chapter

Oil palm nucleus C in the Colombian sector showed a process of centralised diffusion that contrasted with the two previous cases in terms of the role of the leading change agents, the participation of users, and network of supporting actors. This cluster showed high levels of technology adoption, of both short- and long-term practices, as a result of formal rules in which a leading change agent, a farmer organisation and smallholders assumed technical responsibilities and complemented each other's functions. Yet, the leading change agent had a prominent role in defining, planning and transferring practices for crop management based on high trust relationships with small farmers. The combination of these trust-based relationships, the intensive support from the leading change agent, and their defined priorities within the negotiated formal rules, led to greater adoption levels of short-term practices and of the long-term practices that require high levels of expertise. As such the case demonstrated a different vision of agribusiness; less dependence on formal contracts and more on an embedded network of relationships.

The lower adoption of long-term practices that required low levels of expertise reflected characteristics in the nature of users participating in this cluster. The preference of users to engage in specific livelihood strategies over the implementation of some long-term practices, explained how the nature of users had a significant impact on the adoption of these practices.

In the CFA of this case study, Anchor Company C, smallholders capitalising collective action through farmer organisation AssocC1, and smallholders acting individually, each took control of different responsibilities for PC management and other activities for crop management. The anchor company led the crop management and provided the technical assistance to the nucleus, defined and verified shock practices. Because this company was interested in the long-term sustainability of producers, it implemented preventive practices requiring high levels of expertise. The farmer organisation implemented PC monitoring and PC surgeries (shock practices) and supported the crop management. Smallholders adopted the fertilisation of diseased trees and eradication (shock practices) as well as maintenance of drainage channels and other non-PC-related activities. Other important actors, such as the social organisations Fundepalma and Cenipalma, provided additional support to the nucleus.

Shaped by the formal rules of this nucleus, the network structure was characterised by having two brokers transferring support to smallholders: Anchor Company C and farmer association AssocC1. These connections influenced the adoption of both shock and preventive practices, but central actors placed more emphasis on shock. A crucial factor that was determinant in these connections was trust-based relationships, without which smallholders might not have accepted the high involvement of central actors in their crop management.

Since smallholders were in charge of most agricultural practices within formal rules, their nature is a crucial aspect in the centralised-diffusion process of this nucleus. The participation of these producers in the cluster was based on their low socio-economic conditions and their necessity for improving their living conditions rather than making immediate economic profits. This population was characterised as being rural producers that led their plantation management and engaged in collective action strategies for the implementation of shock practices and support of other crop practices. The nature of these rural farmers also indicated that, due to their necessity to diversify their livelihood strategies, they grew pasture for cattle breeding instead of cultivating leguminous plants (preventive practice).

From this case study, we can raise three interesting points that need to be taken into account in the theory of innovation diffusion. First, some participative bottom-up approaches through collective action can be integrated into centralised-diffusion processes. Second, as in the previous two chapters, the nature of users is key in the adoption of long-term practices and agricultural sustainability. Third, collective action can introduce a further variety of brokers and information sources to a network that supports both short- and long-term practices.

CHAPTER 8

COMPARATIVE DISCUSSION

This chapter contrasts the three different scenarios where centralised-diffusion processes took place, which were analysed separately in Chapters 5, 6 and 7. These scenarios were:

- nucleus A, where semi-autonomous producers controlled most decision-making processes for crop management;
- nucleus B, where an agro-industrial firm controlled most technical responsibilities for the introduction of technology and crop management, especially disease and pest management; and
- nucleus C, where an agro-industrial firm, smallholders (who were engaged in a collective action), and support services, all shared control of technical responsibilities.

The empirical chapters discussed how shock practices for PC management were introduced regardless of the types of formal rules that were in place. By comparison, the adoption levels of preventive practices and the levels of support varied across each of the clusters.

The first part of this chapter makes a comparative analysis of the critical variables that were found in each case study due to their effect on diffusion and adoption. These variables were: the types of governance (broad or narrow governance structures), the types of users, and the actions and motivations of leading change agents. A preliminary discussion about how these variables contribute to the theories of diffusion and adoption takes place at the end of this section. A more complete discussion of this contribution will be undertaken in the concluding chapter of this thesis.

The second part of this chapter undertakes a comparative analysis of network structures. The SNA of previous chapters was based on an ego-centred perspective that helped to identify the key actors and the important links that facilitate the introduction and adoption of certain practices in each cluster. This chapter employs a socio-centred approach[84] to represent particular types of governance and draw conclusions about which structures appear to better support the transfer and adoption of technology by small-scale producers. The comparison of these centralised processes completes the part of the second research question that explores the resulting network structures from different types of formal rules, and the impact of these structures on technology diffusion. Moreover, by associating these structures and their impact on diffusion, this chapter completes the answer to the third research question about the variations of adoption with the different pathways of diffusion.

8.1 Contrast of centralised-diffusion processes

This section compares the centralised-diffusion processes of nuclei A, B and C, and discusses how the different outcomes of adoption resulted from differences in formal rules, priorities of leading change agents, nature of selected users and network structures. Table 8.1 contrasts the adoption levels of PC-related practices amongst nucleus A, nucleus B, and nucleus C.

[84] This SNA approach considers the structural characteristics of an entire network (see Sub-Section 4.8.2 for more explanation).

Table 8.1: Adoption levels of shock and preventive practices in nuclei A, B and C

	Percentage of users		
Agricultural practices	**Nucleus A**	**Nucleus B**	**Nucleus C**
Type of practice	**Shock Practices**		
PC Monitoring	100%	100%	100%
PC Surgery	91%	97%	100%
Eradication	94%	93%	97%
Fertilisation (of diseased trees)	86%	74%	86%
Average	**93%**	**91%**	**96%**
Type of practice	**Preventive Practices**		
Drainage	63%	81%	91%
Soil analysis	66%	38%	100%
Frond analysis	64%	22%	100%
Cultivation of leguminous plants	23%	43%	41%
Average	**54%**	**46%**	**83%**

Source: Own elaboration from survey data

The table above shows how all clusters presented high levels of the adoption of shock practices, but their adoption levels of preventive practices differed significantly. It also highlights the strong performance of nucleus C in the implementation of different PC-related practices. Reasons for these levels are explained in the following sub-sections.

8.1.1 Comparison of nuclei based on formal rules and configuration of clusters

Table 8.2 summarises the types of CFAs, the contrasting priorities of anchor companies in technical assistance, and the nature of selected smallholders.

Table 8.2: Contrasting formal rules and configuration of nuclei

	Nucleus A	Nucleus B	Nucleus C
Governance	Low control of company A over decisions Selection of smallholders by company A	High control of company B over decisions Selection of smallholders by company B	Partial control of company C over decisions Selection of company C by smallholders
Technical roles and commitments[1]	Technical assistance: company A	Technical assistance and provision of inputs: company B	Technical assistance: company C, social organisation Fundepalma Provision of inputs: farmer association AssocC1
	<u>PC Shock practices</u> *- PC monitoring, PC surgery and Eradication* Verification: company A Implementation: smallholders or company A *- Fertilisation of diseased trees* Implementation: smallholders	<u>PC Shock practices *(All practices)*</u> Verification and implementation: company B	<u>PC Shock practices</u> Verification: company C, Social organisation Fundepalma, smallholders *- PC monitoring, PC surgery and Eradication* Implementation: farmer association AssocC1 *- Fertilisation of diseased trees* Implementation: smallholders
	<u>PC Preventive practices *(All practices)*</u> Implementation: smallholders	<u>PC Preventive practices</u> *- Soil and frond analyses* Implementation: company B *- Water channels and leguminous plants* Implementation: smallholders or company B	<u>PC Preventive practices</u> *- Soil and frond analyses* Implementation: company C *- Water channels and leguminous plants* Implementation: smallholders
	<u>Other non-PC-related practices</u>[2] Implementation: smallholders	<u>Other non-PC-related practices</u> Implementation: smallholders or company B	<u>Other non-PC-related practices</u> Implementation: smallholders
Priority of company	Business-based approach	Business-based approach	Long-term sustainability approach

<table>
<tr>
<td rowspan="3">Nature of smallholders</td>
<td>Socio-economic conditions
Average size of plantations (ha): 26
High dependence on oil palm[3] (%): 43%
Education levels (%):
Primary: 32%
Secondary: 34%
University: 34%</td>
<td colspan="2">Socio-economic conditions
Average size of plantations (ha): 24.7
High dependence on oil palm (%): 46%
Education levels (%):
Primary: 48%
Secondary: 19%
University: 24%</td>
<td>Socio-economic conditions
Average size of plantations (ha): 15
High dependence on oil palm (%): 77%
Education levels (%):
Primary: 85%
Secondary: 10%
University: 1%</td>
</tr>
<tr>
<td rowspan="2">Type of users:

Better-off producers:
High socio-economic conditions
Business profile
Low dependence on oil palm
Aspiration of oil palm as a profitable investment
Detachment from land</td>
<td colspan="2">Type of users:
Heterogeneous group of producers</td>
<td rowspan="2">Type of users:

Rural farmers:
Low socio-economic conditions
Farming profile
High dependence on oil palm
Aspiration of oil palm as a sustainable livelihood
Attachment to land
Engagement in collective action strategies</td>
</tr>
<tr>
<td>1. Better-off producers:
High socio-economic conditions
Business profile
Low dependence on oil palm
Aspiration of oil palm as a profitable investment
Detachment from land</td>
<td>2. Rural farmers:
Low socio-economic conditions
Farming profile
High dependence on oil palm
Aspiration of oil palm as a sustainable livelihood
Attachment to land</td>
</tr>
</table>

[1]: These technical roles and commitments are a set of rules negotiated between actors at the beginning or during the development of the agreement; however it does not guarantee that the participants will actually fulfil these obligations.
[2]: Crop practices such as fertilisation, management of weeds and harvesting. These practices are not directly related to PC management but they can improve the tolerance of oil palm trees to environmental stresses, including pests and diseases attacks.
[3]: More than 50% of their income comes from the oil palm production

Source: Analysis from author survey and interviews

Based on the results of clusters A, B and C (Tables 8.1 and 8.2), it is possible to associate contrasting formal rules and configuration of each nucleus with the adoption of shock and preventive practices.

Explanatory variables for shock practices

Table 8.2 shows that the agro-industry companies of all three clusters led the PC management and rigorously verified the implementation of shock practices, which explains their high levels of adoption. The reason behind this significant support was the major interest these companies had in the control of PC through the adoption of short-term practices, for instance PC monitoring, PC surgeries and eradication. As such, Anchor Companies A, B and C, together with other companies in the area, created a regional strategy (UG alliance), which agreed on and implemented a unified criteria of operational procedures for these shock practices. This put significant pressure on their members to encourage smallholders to adopt shock practices, which resulted in more than 90% of producers in the three clusters implementing all shock practices, with the exception of the fertilisation of diseased trees (see Table 8.1).

The preceding results supplement the work of Rogers (2010) that identified the 'immediacy of reward' as an attribute of innovations and a determining factor of adoption. Immediacy of reward is especially important when dealing with changing contexts where environmental stress and risks, for example, can exert pressure on farmers to adopt reactive (short-term) or preventive (long-term) practices, as shown by the literature on adaptive capacity and climate change (Brown et al., 2010; Deressa et al., 2009; Smit and Skinner, 2002). The case studies showed that under the presence of agricultural diseases and plagues, farmers and change agents had a preference for short-term practices that yield fast and effective results and, hence, help to prevent catastrophic situations.

Explanatory variables for preventive practices

Three interrelated factors explained the variation in the diffusion and adoption of preventive practices amongst clusters: differences in distribution of technical responsibilities (associated with rules), the motivations and roles of leading change agents, and the types of users (associated with selection criteria). These explanatory variables enriched the studies of technology adoption about the multiple factors impacting the final implementation of practices.

First, the rules in each cluster distributed functions amongst participants in quite different ways. It was found that all anchor companies provided general assistance for crop management (including both PC and non-PC related practices) and left more room for smallholder participation in the adoption of preventive practices and other non-PC-related practices (e.g. fertilisation, management of weeds and harvesting). The participation of other key actors providing technical services for crop management was only seen in nucleus C, not in nuclei A or B. From these findings, it is possible to suggest that a broad governance structure of CFA and share of functions enable smallholders to access more and different support for technology adoption. This is useful, especially when producers do not have the technical expertise or when the development and adoption of certain practices have high levels of complexity, as occurred with several preventive practices in the oil palm sector.

A second reason for having different results in levels and patterns of adoption of preventive practices was based on the anchor companies' apparent interest and motivations. The decisions of agro-industrial firms A and B were driven primarily by a business-based approach (Table 8.2), they were motivated by short-term priorities, rather than long-term considerations. By contrast, Anchor Company C adopted a long-term sustainability perspective and actively encouraged the take-up of preventive practices. This can also be explained by the informal links between anchor companies and smallholders and the different roles that these companies played in each cluster, ranging from paternalistic (in nucleus C), semi-paternalistic (in nucleus A), to non-paternalistic (in nucleus B). The different approaches and roles of anchor companies can help to explain why company C honoured its commitment regarding the implementation of soil and frond analyses and company B did not; this is despite both companies having committed to this within their rules (see Table 8.2). The result was a greater adoption of preventive practices seen by Anchor Company C.

The above results suggest that values and expectations of leading change agents can have an impact on farmers' technology adoption. It was shown that leading change agents with a long-term vision regarding smallholders' sustainability, and informal links that went beyond contractual obligations, could have a positive relationship with adoption. Although the discussion of values and attitudes as key drivers of adoption is not new, studies usually focus on the way these factors affect farmers' willingness to adopt innovations (Pannell et al., 2006; Mills et al., 2017). Since change agents play a crucial role in the decision-making process and final adoption of technologies through the provision of support or direct implementation of practices, the values and preferences stimulating this support need to be considered in this discussion.

It should be noted that anchor companies and other technical experts were mostly in charge of PC-related practices that required high levels of expertise or economic resources, such as soil and frond analyses and cultivation of leguminous plants. This happened because agricultural practices in the oil palm sector are usually designed without considering the particular conditions of smallholders regarding their levels of expertise or the availability of economic resources. Consequently, involving producers in the implementation of these complex practices, as in nucleus A, might not result in their adoption. Based on this evidence, it is clear that the oil palm sector did not consider key drivers of technology adoption such as farmers' education, training and financial capital that were previously studied by Feder et al. (1985), Wejnert (2002), Marenya and Barrett (2007) and Kassie et al. (2015).

In addition to the impact on the adoption of preventive practices, it is important to highlight that the anchor companies’ attitude may also have had an impact on the long-term sustainability of the formal rules and therefore on the technology transfer in each cluster. The informal links and paternalistic roles in nuclei A and C helped to ensure the loyalty of fruit suppliers and the acceptance of technical assistance by smallholders. Crucially, this entailed the commitment of users to adoption and the continuation of the formal rules in the long term. By contrast, in nucleus B smallholders accepted and followed the instructions of Anchor Company B due to the imposition of compulsory commitments that they accepted during the negotiation of their formal rules. In addition, problematic trust-based relationships in this cluster jeopardised the continuation of the formal rules amongst its participants, which may have led the anchor company to adopt a pessimistic view concerning the future of the cluster, which subsequently discouraged this actor from adopting long-term practices.

Finally, two types of users that explain the differences in adoption of preventive practices are also identified in Table 8.2. On the one hand, in nucleus A, and to a lesser degree nucleus B, there was a set of economically wealthier producers that tended to live in larger urban areas, deriving their income from a range of activities, palm oil being just one of them. These producers tended to have short-term perspectives and little interest in supporting practices that did not lead to short term profits, such as preventive practices and other non-PC-related practices. A second set of users in nucleus C were rural farmers with long-term perspectives derived from high dependence on palm oil for income. They lived and worked in the local area, had a lower socio-economic income, and showed higher interest in adopting long-term practices. For example, smallholders in nucleus C hired Anchor Company C for the implementation of soil and frond analyses; in this way they could reach higher adoption levels of preventive practices than in the other two nuclei. It is possible to say that with the adoption of preventive practices in nucleus C, the rural farmers in this cluster were less vulnerable to future PC attacks than other producers, thereby increasing their long-term agricultural sustainability.

Therefore, a key difference between users was that rural farmers tended to have a lower socio-income level and were more involved in the implementation of preventive, non-PC-related practices, and plantation management than better-off producers. These better-off producers were, overall, less committed and less embedded in palm oil production. On the contrary, the increased participation of the rural farmers encouraged the adoption of preventative and non-PC-related practices, which likely resulted in an increase in economic sustainability, as was seen in nucleus B.

As indicated in Sub-Section 2.1.2, socioeconomic conditions, as well as values, attitudes and expectations that affect farmers' willingness to adopt certain technologies are traditionally considered in the adoption literature. Pannell et al. (2006) and Mills et al. (2017), for example, show that this willingness depends on aspects such as perceptions, subjective expectations, personal goals, behavioural beliefs, norms and cultural background. We can add to these works that long-term perspectives, attachment to land, commitment to agricultural production, and expectations about long-term sustainability can make smallholders more willing to adopt preventive techniques.

8.1.2 Network structures from different types of formal rules and nature of users

This sub-section uses a socio-centred approach to compare the structural characteristics of networks generated by the different types of formal rules. This allows us to address the second research question concerning the impact that different network structures have on technical support given to small-scale producers when affected by formal rules. It is also possible to address the reasons for the variation in the introduction and adoption of practices within the different network structures, which completes the answer to the third research question. As may be recalled, these questions were partly answered in the previous empirical chapters where it was identified that key actors influencing the adoption of PC-related practices were Anchor Company A and Cenipalma in nucleus A, Anchor Company B and Cenipalma in nucleus B, and Anchor Company C, AssocC1 and Fundepalma in nucleus C. This sub-section applies network structures in an instrumental way to show the different types of governance in top-down contexts. By comparing the structural differences among the networks of case studies A, B and C and their corresponding levels of adoption, it is possible to draw conclusions about which structures are likely to favour the introduction of PC-related practices[85].

Networks A, B and C were compared by analysing structural characteristics from a socio-centred approach. The indicators used in this comparison were average in-degree, importance in-degree, and network centralisation (see Table 4.4 for an explanation of these indicators). The results are shown in Table 8.3.

[85] Comparing results based on correlation analysis between structural variables (e.g. average In-degree of smallholders and network centralisation) and levels of technology adoption, it would not be possible to produce significant results due to the small sample of networks (n=3).

Table 8.3: Comparison of socio-centred indicators for networks A, B and C

Variables	Indicators	Network A	Network B	Network C	Statistical significant difference
Individual interactions	Average In-degree of smallholders	2.9	2	2.5	3.15*
	Average importance of In-degree of smallholders[1]	3.2	2.6	3.5	21.43**
Brokerage beyond smallholders	Primary brokers	B Cenipalma A C	B Cenipalma C	B C Fundepalma AssocC1 Cenipalma	-
Central Positions	Network centralisation (%)	44%	54%	51%	-

[1]: See p. 339 for an explanation of the evaluation of importance.
*F Critical value (3.09) < 3.15, therefore the differences between Average In-degree of the three networks are significant (See Appendix E).
**F Critical value (3.09) < 21.43, therefore the differences between Average Importance In-degree of the three networks are significant (See Appendix E).

Source: Calculated from author survey of oil palm producers

The statistical significance was calculated based on the following null hypotheses: 1) all clusters have the same average in-degree and average importance; and 2) all clusters have the same average importance. The resulting F-critical values indicate that both hypotheses are statistically likely to be false, for a p value of 0.05. In other words, it is unlikely that all the clusters have the same average in-degree and average importance.

Table 8.3 associates the types of formal rules in each cluster with particular network structures. In the table, nucleus A is characterised by the low level of control of Anchor Company A, and was associated with a structure in which autonomous and better-off producers were better connected (average in-degree: 2.9) than producers of networks B and C. Despite this higher connectivity, these relationships were weaker than the links bringing information to smallholders in nucleus C (importance in-degree: 3.5). This is due to the fact that the relationships that smallholders had with other key actors in network C (Anchor Company C, AssocC1 and Fundepalma) were stronger that the multiple connections between smallholders and other actors in network A. From this comparison, it is possible to say that having important links with key actors in charge of supporting various practices may be more important for small-scale producers than having numerous formal links with other actors in the sector.

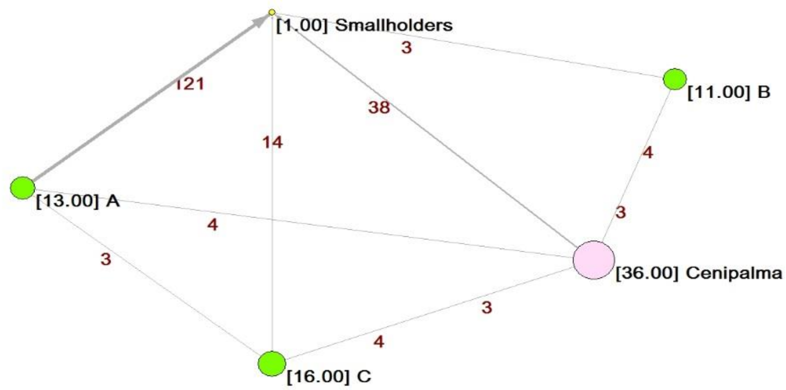
In the case of nucleus B, which is characterised by the high control of Anchor Company B, this cluster was associated with a highly centralised network in which the agro-industrial firm dominated most technical relationships with smallholders. Table 8.3 shows that, compared to nuclei A and C, network B exhibited the highest levels of centralisation (centralisation: 54%). Although these levels were close to the centralisation levels of network C (centralisation: 51%), there were more central actors in network C than in the other two networks. This reduced producers' dependence on the technical assistance provided by the anchor company. Furthermore, since Anchor Company C had partial control within nucleus C, this cluster can be understood as a network with multiple brokers intermediating between producers and other sources of information and technology. This was mainly because of a broader structure of governance, in which formal rules distributed responsibilities among various key actors. Whilst this existed in nucleus C, it was not present in nuclei A or B.

Chapters 5, 6 and 7 identified the main brokers transferring information to smallholders (see Table 8.3). Figure 8.1 offers a visualisation and comparison of brokerage beyond smallholders amongst the three networks. This figure contrasts the number and type of brokers, the number of interactions between smallholders and brokers (shown by the thickness of these ties), the importance of these connections (shown by the numbers next to the connections), and in-degree interactions of brokers (shown by the size of brokers' nodes).

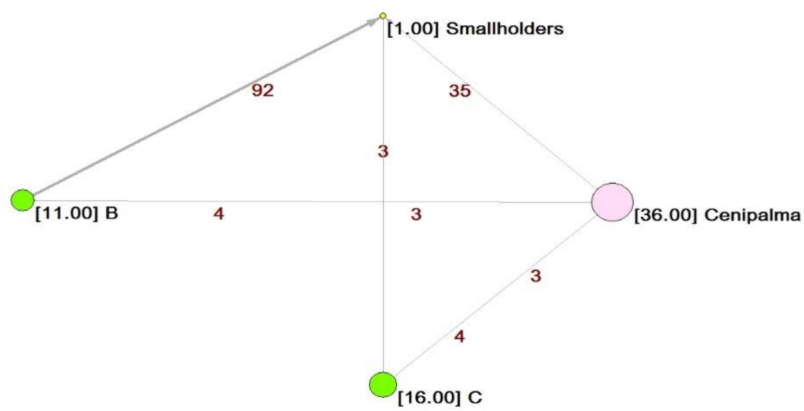
This figure not only clearly illustrates the higher number and types of brokers in network C, but also the richer and more diverse structure in terms of links, information sources, and types of brokers. This is likely a consequence of having a broader governance structure in which various key actors participate in the negotiation of formal rules. The networks also suggest that a richer structure can be related to higher levels of adoption. A broader governance structure can distribute responsibilities among various key actors and increase the support to different practices, including both short- and long-term practices. This was the case for network C, where various brokers either supported specific practices or complemented the assistance of other brokers on unattended practices during the epidemic. The widely distributed governance and specific support that central actors gave to smallholders in network C compared to networks A and B, can be seen when comparing the link usage and the type of information being transferred to users in Tables 5.2 (p.174), 6.2 (p.212) and 7.2 (p.250).

Consistent with what was said in Sub-Section 2.4.3, the above explanation suggested a link between formal rules and network structures, in which the distribution of responsibilities within clusters generated specific connections of technical support, and thereby certain network structures. This relationship between formal rules was not seen in the innovation diffusion literature, especially in network studies. For example, the works of Díaz-José et al. (2016), Monge et al. (2008), and Spielman et al. (2011) within the technology diffusion and adoption literature, compared network structures from different sectors and regions, and their impact on technology adoption. This work adds to these studies by exploring the institutional factors, in terms of formal rules, that led change agents and producers to be related in the first place and generate certain network structures.

a) Brokers in Network A



b) Brokers in Network B



c) Brokers in Network C

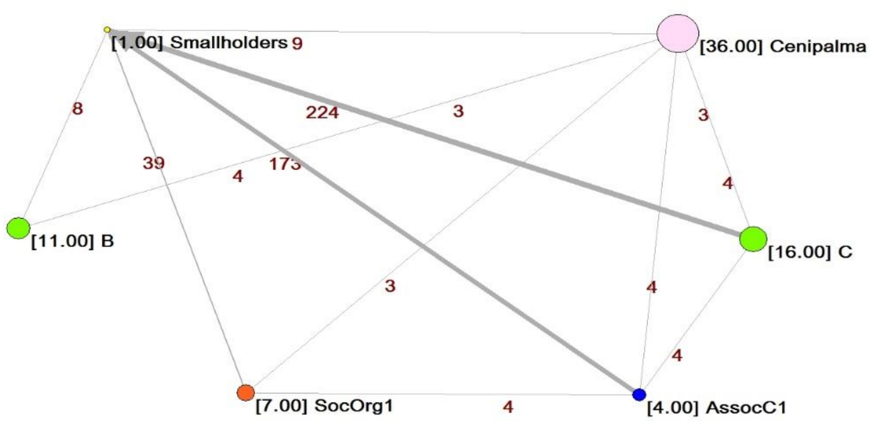


Figure 8.1: Brokerage for technology transfer to small-scale producers in networks A, B and C

Source: Own elaboration from survey data

This section showed that under stress situations, whilst shock practices were successfully introduced irrespective of the types of formal top-down rules, preventive practices were not. The formal rules within clusters A and B were based on a narrow structure of governance, meaning they did not have a wide distribution of functions for PC management. Combined with the participants' (small-scale producers and anchor companies) interests in short-term benefits, this resulted in low implementation levels of preventive practices.

In contrast to this, higher levels of adoption of these practices were found in cluster C. This cluster had a more distributed pattern of technical responsibilities amongst key actors, higher involvement of users in adoption, and participants of the agreement with a long-term vision of the smallholder agribusiness. This cluster, unlike clusters A and B, exhibited a network structure with different central brokers supporting short-term as well as long-term practices and, in this way, helped to improve the agricultural and economic sustainability of the oil palm agribusiness.

From the empirical chapters and this discussion chapter, it can be said that nuclei A, B and C showed three types of formal rules; these rules generated two pathways of technology diffusion. One pathway, based on the diffusion processes in nuclei A and B, is referred to in this thesis as the *diffusion pathway of governance dictated by dominant change agent control*. In this scenario, the agro-industrial firms act as the only key change agents having a leading role in the selection of producers, the provision of technical assistance and the implementation of some or just the most important practices. A second pathway, based on the diffusion process in nucleus C, is referred to in this thesis as the *diffusion pathway of governance dictated by change agent control and user participation*. In this model, a leading change agent defines and closely monitors agricultural practices but shares decisions for the selection of participants and implementation of practices with producers.

8.2 Summary of chapter

The oil palm nuclei A, B and C in the Colombian sector showed three different centralised-diffusion processes, each with high implementation of short-term practices but differences in the adoption of long-term practices. The successful introduction of shock practices in the clusters was mainly due to the strong leadership of the anchor companies in the management of these practices and, in the cases of clusters A and C, the non-formal relationships through which these companies persuaded smallholders towards the introduction of these practices. The different levels of support for preventive practices and other crop practices were explained by the contrasting formal rules, the nature of users, and the priorities of agro-industrial firms.

The high levels of support and adoption of preventive practices that was seen in cluster C, was explained by the established broad governance structures, working with small-scale producers, as well as by the high interest levels of both the producers and anchor companies in long-term practices. Consequently, this generated a network with multiple brokers. The low levels of support and adoption of preventive practices in clusters A and B resulted from the poor distribution of responsibilities in formal rules, the high interests of participants in short-term practices, and the highly centralised networks with few key actors.

The three case studies suggest that the type formal rules established in nuclei A, B and C are a critical factor in the creation of two key scenarios of diffusion: the diffusion pathway of governance dictated by dominant change agent control, and the diffusion pathway of governance dictated by change agent control and user participation. These conclusions, together with the findings of Chapters 5, 6 and 7, help to establish the primary contributions of this thesis.

CHAPTER 9

CONCLUSIONS

The first section of the concluding chapter revisits the research problem and the argument of this thesis. The second section revises the research questions and the application of the theoretical framework. Section 9.3 summarises the main findings of this research, while Section 9.4 discusses the theoretical and methodological contributions that this thesis makes to the literature on technology diffusion in centralised systems, based in agriculture. Policy and practitioner suggestions are also made for the improvement of both technology transfer and adoption of short-term and long-term practices during stress situations. The final section discusses some limitations of the study and potential further areas of research.

9.1 Research problem and argument of this thesis

This research aimed to understand the different pathways of technology diffusion that can emerge in the context of top-down governance and the results of these different pathways in terms of technology adoption by small-scale producers. These pathways were analysed in the developmental context of the Colombian oil palm sector, where technical experts were trying to introduce agricultural technologies to try and deal with the rapid spread of PC disease. The use of centralised-diffusion processes in a context of a stress situation was justified based on the necessity of having a homogeneous response and increasing the efficiency in the time of these responses.

The oil palm producers in the north-east region of Colombia have faced one of the worst plant disease epidemics since 2006. PC disease destroyed more than 37,400 hectares and affected more than 70% of the area; this was located in five towns across the region, representing a risk for neighbouring plantations. The rapid spread of PC caused a plant disease epidemic and, consequently, losses of more than US$129 million, and caused a serious economic and social crisis in these areas. Numerous small-scale producers affected by the epidemic had production losses and had to eradicate a considerable part, or all, of their plantations. As a result, several of them abandoned the agricultural management of their crops, sold their lands at bargain prices, or had their lands confiscated by banks.

The plant disease epidemic evidenced failures in the transfer of official technologies and protocols for PC management, which negatively impacted the adoption of recommended practices. This was due to the fact that a considerable part of the population in the affected areas did not rely on technical experts, but were influenced by other local community actors and paid little attention to the serious consequences of the rapid spread of PC . This stress situation highlighted that it was not sufficient for technical experts in the oil palm sector to accelerate the development of scientific strategies for PC treatment and prevention, and then for government institutions to implement reactive measures towards the adoption of PC-shock practices. It was also necessary to improve the process of centralised-technology diffusion and the configuration of agricultural clusters during the initial stages.

This thesis argues that in agricultural contexts of top-down control, there is more than one pathway of technology diffusion that emerges from particular types of rules, determined by types of governance. These different types of formal rules lead to the emergence of technical relationships and central roles of actors; they also create certain network structures for diffusion. The support and adoption of short-term and long-term practices in each pathway depends on the type of formal rules and their corresponding governance structures, as well as other critical elements such as non-formal systems of relationships between change agents and users, the nature of users, and the motivations of change agents.

9.2 Research questions and research methods

Within the agricultural context of centralised-diffusion systems, this thesis formulated three research questions that were answered by analysing three oil palm nuclei in Colombia dealing with the stress situation of PC epidemics. These questions were:

1. How do different types of formal rules lead to different pathways of technology diffusion?

The aim of this research question was to associate governance structures of formal rules with scenarios of technology diffusion. This involved understanding the role of formal rules within centralised-diffusion systems, distinguishing the different levels of participation and control of change agents, and the different types of smallholders in planning, transferring and adopting practices.

2. What is the influence of network structures, affected by different types of formal rules, on technology diffusion?

Following the creation of different pathways based on the types of formal rules, this research question aimed to understand how the technology diffusion in these pathways actually occurred, and how network structures and the central actors of these networks reflected these variations.

To do so, it was crucial to characterise the network structures that emerged from the different types of formal rules and to examine their impact on diffusion in terms of information access, variety of information sources and influence.

3. How does technology adoption vary with the different pathways of diffusion and how do these variations impact the adoption of long-term and short-term practices separately?

This research question was formulated to investigate the outcomes of particular pathways of diffusion regarding the levels of technology adoption. In agriculture, these outcomes could differ when the types of agricultural practices are considered separately. This work separated the types of practices according to the immediacy of reward, namely; short-term or long-term practices.

The literature on innovation diffusion, social capital and contract farming arrangements helped to answer these research questions. Considering both the literature and the research questions, a theoretical framework was proposed; this framework provided guidelines for systematically analysing centralised-diffusion processes in agriculture through the study of formal rules, vertical networks, and technology adoption.

To answer the research questions, this work employed a multi-case study approach under which three clusters in the Colombian oil palm sector were analysed. The main unit of analysis in this research was the small-scale producers organised in schemes for production. Other units of analysis, such as formal rules, network structures, and technology adoption by smallholders, were also used. The research strategy to answer the questions involved three phases. The first phase addressed the first question and characterised the responsibilities and roles of selected participants for crop management in the CFA of each nucleus. In the second phase, the network structures that resulted from formal rules were studied, contributing to the second research question. Finally, in the third phase, the impact of network structures on levels of adoption of short-term and long-term practices were analysed.

Data and information were mainly collected through 147 surveys and 39 interviews, the subjects of which included the participants of the CFA negotiation in each nucleus, actors having an influence on the diffusion processes of these clusters, and contextual actors. Secondary data were especially useful for understanding the background of the centralised-diffusion process and the PC epidemic in the oil palm sector. The collected data and information were analysed using cross-case techniques amongst profiles of technology diffusion of each case study (qualitative analysis), and by adopting SNA methods and descriptive statistics (quantitative methods).

9.3 Summary of case studies

Following the aim of this research, it was found that the three case studies selected for this work operated under three different formal rules or CFAs. Specifically, these were: high control by a change agent; partial control by a change agent and smallholders; and low control by a change agent. These three types of formal rules led to two pathways of technology diffusion within centralised systems. The first scenario, based on case studies A and B, was a *diffusion pathway of governance dictated by dominant change agent control*, whereas the second scenario, case study C, was a *diffusion pathway of governance dictated by change agent control and user participation*. The first pathway is predominantly controlled by a change agent and a narrow governance structure, whereas the second pathway is a centralised system that distributed responsibilities between users and change agents and allowed the former to get involved in technology adoption. Regarding the impact on technology adoption, these different scenarios showed that shock practices for PC management were introduced within each cluster, regardless of the types of formal rules. In the case of preventive practices, their levels of adoption varied across the clusters.

The findings below show that, while it is an important factor in the distribution of technical functions in crop management, the types of formal rules needed to be combined with other factors to work efficiently in terms of adoption. These factors were:

- the nature of smallholders (i.e. socio-economic conditions, long/short term vision, attachment to land, engagement in collective/individual action);

- interests of anchor companies regarding the integration of smallholders into agribusiness (immediate or long-term benefits); and
- existing values embedded in relationships between smallholders and agro-industrial firms (e.g. trust and friendship).

The first case study analysed in this thesis (Chapter 5) was that of oil palm nucleus A, in which semi-autonomous smallholders controlled decisions for most crop management, with the exception of shock practices. The set of formal rules in this nucleus led to individual interests dominating amongst the wealthier farmers, and long-term practices being poorly introduced. The exploitation of land resources as a mere commodity was one of the underlying reasons for this. These rules also dictated that Anchor Company A provided general assistance to smallholders, with specific emphasis on shock practices, but did not interfere financially or technically in the direct management of crop practices. Instead, the favourable conditions of these producers enabled them to build one-to-one interactions with other non-central actors in the sector. This forms a network with very few central actors (Anchor Company A and Cenipalma) and numerous technical relationships, although not always with reliable sources of information. It is important to highlight that the connections between the company and the smallholders endured because of the embedded trust-based relationships and the semi-paternalistic role assumed by the company.

Nucleus B was the second case study that this thesis looked at, and discussed in Chapter 6. It was found that for the formal rules of this nucleus, Anchor Company B had complete and absolute control over crop decisions and the selection of producers. In this case, the anchor company selected a highly heterogeneous population of producers with different motivations; these were distinguished as rural farmers and better-off producers. The formal rules dictated that shock practices and preventive practices, requiring high levels of expertise, were the responsibility of the anchor company. The adoption of preventive practices requiring low levels of expertise, and non-PC-related practices were implemented at the discretion of smallholders under the company's instructions. Unlike the shock practices, preventive practices were implemented haphazardly, mainly because the company, who was partly in charge of adoption, was using a business model for which long-term practices were not amongst its priorities. This marked an important difference between this case and nucleus A, in which the management of practices was not highly controlled by the anchor company, and therefore the adoption did not heavily depend on how good this actor was in fulfilling its technical responsibilities.

With regard to other non-PC-related practices, it was seen that rural farmers tended to be more involved in their plantations (which therefore seemed to be more economically sustainable), than wealthier producers. Finally, the dominant control of the anchor company over crop management generated a highly centralised network of diffusion from which small-scale producers accessed technologies and information. Unlike the previous case, problematic relationships were embedded in the relationships between smallholders and the anchor company, which might risk the future continuation of the CFA and the diffusion process.

A third case study, nucleus C, was analysed in Chapter 7. In this type of formal rules, poorer producers capitalised on collective action, selected the participants of the agreement and shared technical responsibilities with Anchor Company C. The adoption of shock and preventive practices were higher than in both of the previous case studies for three major reasons. First, there was a wider distribution of responsibilities amongst participants of this cluster (smallholders, Anchor Company C, farmer AssocC1 and the social organisation Fundepalma). Second, there was an important commitment from Anchor Company C and group action towards the long-term sustainability of rural farmers, which was reflected in economic and technical assistance provided to support these practices. Anchor Company C also adopted a paternalistic role and built non-formal relationships with smallholders, which ensured the adoption of shock practices. Finally, there was an individual motivation that encouraged poorer producers to commit more to the use and sustainability of the land resources than wealthier producers in other clusters. Unlike the network structures of cases A and B, the resulting network from this type of formal rules showed a structure with multiple and diverse central actors playing brokering roles.

9.4 Contributions to knowledge and policy implications

This thesis aimed to enrich the literature of innovation diffusion in theoretical and methodological ways by adding some essential elements that need to be considered. In the course of this research, we also had unexpected findings that complemented the theory of technology adoption. From these contributions, conclusions were drawn regarding policy implications.

9.4.1 Theoretical contributions

This research contributes to the innovation diffusion and technology adoption literature in three ways.

1. Building multiple scenarios of centralised diffusion

The central topic of this research was to understand the different pathways of technology diffusion that could emerge in centralised-diffusion systems and their impact on technology adoption. The literature review of this thesis (Section 2.2) showed that studies in innovation diffusion commonly describe the theoretical models of centralised diffusion as linear relationships between change agents and users (Röling, 2004; Knickel et al., 2009). As was argued by Röling (2004):

> ‘[in linear models] Science ensures progress. Extension *delivers* these ideas to users […] Transfer of technology assumes one-way and uninterrupted flow of technologies from fundamental scientists, to ultimate users via various intermediaries and delivery mechanisms’ (pp.12-13).

In contrast, this study focused on change agent-farmer interactions and the possible scenarios of diffusion around these interactions.

The first research question formulated in this thesis asked whether, and how, different formal rules could lead to different pathways for technology diffusion in an agricultural context of centralised-diffusion systems. The motivation behind this question was that, despite the fact that formal rules underpin change agent-user interactions and have a critical function in creating multiple scenarios of centralised diffusion, the role of these rules is not fully explored in the diffusion literature. Monge et al. (2008), and Rogers (2010) and Krishnan and Patnam (2014) included the transfer of information and knowledge between change agents and farmers in their analyses, but did not provide a description about the formal rules that governed those interactions. In order to add these missing details and answer the first research question, this thesis reviewed the literature on CFA (Kirsten and Sartorius, 2002; Bijman, 2008; Barrett et al., 2012) and social capital (Adler and Kwon, 2000; Ostrom, 2000), and collected fieldwork data. This enabled the results to demonstrate that formal rules are important because they distribute responsibilities for technical support amongst participants of an agreement, and give rise to technical and long-term relationships underpinning mutual expectations and values of trust and friendships between change agents and users. The literature and evidence also helped to explain the emergence of two types of pathways in centralised-diffusion systems: *the diffusion pathway of governance dictated by dominant change agent control* and *the diffusion pathway of governance dictated by change agent control and user participation* (explanations of these pathways are given in Section 9.3).

2. Considering impacts of diffusion pathways on short-term and long-term practices

In answering the third question, this research explored the way that different pathways of diffusion impacted technology adoption, particularly in the cases of long-term and short-term practices, in the context of centralised-diffusion systems. It was indicated in the literature review (Section 2.5) that innovation-diffusion studies, such as the works of Monge et al. (2008) and Spielman et al. (2011), analysed different network structures for diffusion and found that having more interactions for the transfer of technical and financial resources had a positive impact on the technology adoption of farmers. Regarding central roles, the study of Spielman et al. (2011) showed that heterogeneous links with brokers helped to improve the adoption of farmers. Unlike the aforementioned studies that focus on one type of practice, Wyckhuys and O'Neil (2007) and Díaz-José et al. (2016) evaluated the impact of multiple sources of information on the adoption of various practices and found that farmers gained most of their information through links with their peers. This research showed that by considering the impact of diffusion separately according to the immediacy of reward (one of the innovation characteristics), interesting nuances enriched the theoretical framework of centralised-diffusion systems.

This research found that both diffusion pathways of governance favoured the introduction of codified knowledge and short-term practices. However, each model behaved differently in the adoption of long-term practices. This is consistent with the contribution of Rogers (2010) to the literature on technology adoption by which the author distinguished immediacy of reward as a crucial factor in decision-making process of adoption.

Considering the first pathway model, neither nucleus A nor B showed high adoption levels of preventive practices. In nucleus A, this was mainly due to the lack of motivation for long-term sustainability. However, in nucleus B, this was because Anchor Company B did not honour its commitments towards the adoption of practices that required high levels of expertise. In contrast, considering the second pathway model, nucleus C was more successful in the adoption of long-term practices due to its clearly distributed functions amongst participants, which included users with long-term sustainability motivations. These results showed that the adoption of long-term practices is predicated on additional elements other than formal rules.

In terms of the broader understanding of the literature on top-down innovation diffusion and technology adoption, it is clear that types of formal rules are essential in creating expectations about actors' responsibilities for transactional type tasks and supporting farmers in the implementation of practices, for which there are clear guidelines, and results can be measured in the short term. However, a more holistic view of farmer practices within these predominantly top-down systems revealed that there are different paths or configurations for diffusion, in which formal rules are relied on to a greater (nucleus C) or lesser extent (nucleus A). Each of these relies on certain types of users and change agents.

Clearly the nature of users is a critical factor in the discussion. Following the literature on technology adoption (Sub-Sections 2.1.2) and the characterisation of users within CFAs (Sub-Section 2.3.4), the literature on the diffusion of agricultural innovations has tended to distinguish small-scale producers based on their socio-economic conditions, their group management, their timing of adoption, and their economic capacity to adopt technologies and access technical support (Sangui, 1995; Wejnert, 2002; Bandiera and Rasul, 2006; Maertens and Barrett, 2013).

It has been shown that in the specific case of small-scale agriculture in developing clusters, the factors that came to the forefront were the degree of attachment to agricultural production, long/short term vision, and engagement in collective action. Without having long-term visions, for example, the technologies that are transferred to smallholders and that enable agricultural long-term sustainability, are unlikely to be adopted due to insufficient emphasis. As a part of smallholders' behaviours, preferences and attitudes towards long-term or immediate profitability, these factors were key drivers of adoption and, in turn, complemented the studies of Pannell et al. (2006) and Mills et al. (2017) within this field.

Another aspect that affected the paths of centralised diffusion was the motivation and functions of change agents in decision-making processes. Studies in innovation diffusion, including works in the diffusion of agricultural innovations, that describe change agents, typically characterise these actors in terms of their capacity of persuasiveness, their empathy, and their efforts to trigger the adoption of innovation among users (Monge et al., 2008; Rogers, 2010). Adding to these attributes, we consider that the models under which change agents make decisions (short-term business-based or long-term sustainability approaches) and their interests regarding the integration of smallholders into agribusiness (immediate or long-term benefits) need to be considered in this context. The interests of change agents were vital for diffusion because they helped to explain the levels of support that these actors provided for the adoption of short-term and long-term practices. In the same way that attitudes and preferences affect farmers' willingness to implement agricultural practices (Pannell et al., 2006; Mills et al., 2017), motivations and interests of change agents can be direct (when doing by themselves) or indirect (when influencing smallholders) determinants of technology adoption; they can, therefore, enrich this body of literature.

3. Integrating 'linking' social capital to centralised-diffusion systems

The studies of Wyckhuys and O'Neil (2007), Monge et al. (2008), Spielman et al. (2011) and Díaz-José et al. (2016) showed different network structures of technical diffusion affecting the final adoption of farmers and, in this way, answered the third research question. This was indicated by the second theoretical contribution that this thesis makes to the innovation diffusion literature (see p. 295). It is argued that one underpinning feature of these network structures is social capital. In innovation diffusion studies, the literature on social capital is usually used to explain farmer-to-farmer relationships, or the horizontal links between producers and other actors, through the concepts of bonding and bridging social capital (Monge et al., 2008; Ramirez et al., 2014). This research found that farmers in the three oil palm nuclei studied relied on the technically competent change agents (e.g. agro-industrial firms and Cenipalma) and trusted that those agents acted in the producers' favour. Combined with friendship and other non-formal systems of relationships within hierarchical links between small-scale producers and change agents, these values had a positive impact on technology adoption, especially in the implementation of shock practices.

This research considers that the social capital literature, especially the concept of 'linking' social capital, introduced by Woolcock (1998) (see Sub-Section 2.4.2), is necessary to study informal relationships embedded in vertical interactions between certain change agents and farmers. Thus, it is considered that 'linking' social capital needs to be further integrated into the literature on the diffusion of agricultural innovations in order to understand the continuity and repeated change agent-farmer interactions, and the adoption of short-term practices. The findings of this research are therefore consistent with those of Szreter and Woolcock (2004) who argued that:

> '[…] without attention to the quality of the relationships between those with differential access to power and without paying attention to the need to build extensive transitive networks of respect and trust in such frequently met circumstances […] service provision to the poor are unlikely to succeed' (p.656).

9.4.2 Methodological contribution

The second research question relates to the influence of central actors and network structures, affected by different types of formal rules, on technology diffusion. The underlying question aims to describe which central roles and network structures result from different types of formal rules, and to understand the way these structures impact on smallholders in relation to information access, influence, and variety of information sources. From the answers to these questions, it was possible to contribute methodologically to the innovation diffusion literature.

In addressing these questions this research found that there could be important insights made by analysing the relationship between formal rules and network structures.

Network studies within the innovation diffusion and technology adoption literature typically focus on quantitative analyses that associate farmers' relationships with their levels of adoption, as was shown in the previous section (Conley and Udry, 2001; Bandiera and Rasul, 2006; Monge et al., 2008; Spielman et al., 2011; Krishnan and Patnam, 2014; Díaz-José et al., 2016). It is possible to complement this work by analysing the formal rules from which these networks emerge and are sustained. In order to do this, we consider that network structures and quantitative methods of SNA have the potential to highlight qualitative features of types of formal rules in terms of governance, for example, the variety of key actors transferring particular technologies to users that are not apparent when undertaking a rigorous characterisation of formal rules. With this analysis it is possible to show which types of network structures could support the adoption of certain practices.

This research employed two SNA methods that could be helpful in linking types of formal rules with types of networks. The socio-centred approach showed the distribution or concentration of functions on key actors providing technical support to smallholders in each type of governance. In this research, a type of formal rules with low control by change agent (as in nucleus A) generated a low centralised network and various non-central actors as sources of information. A type of rules with high control by change agent (as in nucleus B) gave rise to a highly centralised network with few brokers supporting the adoption of long-term practices. Formal rules with partial control by a change agent (as in nucleus C) had a high distribution of functions, reduced its network centralisation and integrated various brokers who supported the adoption of both short-term and long-term practices through important relationships with smallholders.

By using the ego-centric approach of SNA, it was possible to understand the focus that supporting relationships put on the adoption of particular practices. Whereas the emphasis of relationships in the type governed by high control depended on the interests of a small number of central actors, the alternative type of governance had more variety of technical support for adoption coming from diverse key actors.

9.4.3 Policy and practitioner implications

Throughout the oil palm epidemics of PC in Colombia, the government was focused on adopting reactive measures, for example, the provision of financial assistance to affected producers and the creation of an institutional framework that forced the adoption of shock practices. However, as discussed, reactive measures reflect only one set of practices. It was shown that combining short with longer-term practices is possible and has been undertaken, but partnerships between agro-industrial firms and small-scale producers within agricultural systems are required. These partnerships can exist, even where the use of centralised models for the technology diffusion continues to dominate, for example, in agribusiness sectors or particular stress situations.

In this sense, this thesis has shown that at least two paths are available within centralised-diffusion processes supporting the adoption of agricultural practices in developing countries. One path indicates that the selection of smallholders and the technical support to these actors are dictated by predominant top-down governance. In an alternative model, top-down governance distributes functions amongst participants of formal rules. Each model generates different costs and, most importantly, is dependent on other elements to make these scenarios work effectively in terms of technical support and adoption. These elements are the nature of users and the approaches under which change agents make decisions regarding the integration of smallholders into commodity production processes. In order to make these models work for the introduction of short-term and long-term practices, policy-makers and participants in a cluster (producers and agro-industrial firms) need a more holistic approach that coordinates the type of formal rules with the particular nature of farmers and the interests of agro-industrial firms.

It is also important that strategies, aimed at involving smallholders in technology adoption within centralised-diffusion processes, combine bottom-up approaches by working together with users on the diffusion of complex practices. In Colombia, the programmes and government[86] subsidies alone could be made more effective in enabling the participation of small-scale producers and introducing agricultural practices; this could be done by developing diffusion along small-scale producers' needs and particularities, for example, through the incorporation of principles of the 'Farmers-First-and-Last' model (Chambers and Ghildyal, 1985; Lado, 1998) in centralised systems. For instance, PC-related practices in the oil palm sector did not explicitly introduce soil analysis, frond analysis, and the cultivation of leguminous plants; this can be inferred by the fact that plans were drawn up without reference to or incorporation of smallholders and their heterogeneous population.

As with the study of Lado (1998), this work highlights the importance of considering the group of smallholders as a heterogeneous population of users with different natures. Governments and agro-industrial companies that aim to incorporate smallholders in a predominantly top-down context and improve their active role in technology adoption, need to work with these different types of producers in order to identify how suitable the technology characteristics (e.g. requirements of costs, labour and infrastructure) are to their particular conditions (e.g. level of education, ways of learning, motivations, local needs, local infrastructure, diversification needs).

We also suggest that support from policy-makers and agro-industrial companies is required for centralised-diffusion systems where other key actors help in the diffusion and adoption of technologies. One way to do this could be to support collective action strategies, for example, farmer organisations. By diversifying responsibilities amongst key

[86] For example, the 'Project to support productive alliances' (PAAP for its Spanish acronym) (Minagricultura.gov.co, 2018) and the ICR government subsidy (see p.90 for an explanation of this subsidy).

actors, it might be possible to avoid producers and change agents neglecting practices whose results may not be observed in the short-term, especially when extreme circumstances occur. Long-term practices, however, are required for the economic and agricultural sustainability of the agribusiness.

Finally, in order to ensure the effective transfer of short-term practices, it is critical that agro-industrial firms develop and implement regional strategies, and that those strategies receive institutional support from sectoral and governmental entities that push for the technology adoption in stress situations. In addition, it is essential that these agro-industrial companies build trust and friendship-based relationships with producers through which these firms can exert significant influence and lead the management of short-term practices that need to be adopted during extreme circumstances.

Summary

This thesis made three theoretical contributions and one methodological contribution to the innovation diffusion literature and, to a lesser extent, to the technology adoption literature. The first theoretical contribution considers that there can be two pathways for centralised-diffusion systems: the diffusion pathway of governance (dictated by dominant change agent control), and the diffusion pathway of governance (dictated by change agent control and user participation). The second contribution indicates that the selection of a pathway is not enough to guarantee technology adoption, and that different impacts can be seen separately in short-term and long-term practices. A more holistic approach that considers formal rules, the nature of users, and the interest of change agents, is necessary to introduce short-term and long-term practices, as well as to support the agricultural and economic sustainability of small-scale producers.

With the third contribution, the use of social capital is extended to the change agent-farmer interactions within centralised-diffusion systems. By employing the concept of linking social capital, it was possible to highlight the role of hitherto largely underexplored and under-theorised informal collaborations, such as paternal relationships and trust in top-down relationships during stress situations. Informal relationships are a critical factor that can influence farmers and drive them to accept assistance related to the adoption of short-term practices.

This research also suggested the use of ego-centred and socio-centred approaches to reflect different types of governance as the methodological contribution of this research. It was argued that network studies typically adopt quantitative methods such as SNA to relate network structures to levels of adoption. In this work it is considered that these studies can be enriched by investigating the formal rules that created these networks and the long-term relationships tying their actors together.

Ultimately, previous contributions help this research to provide recommendations that can improve the integration of small-scale producers into either of the two paths of centralised diffusion and the introduction of short-term and long-term practices. It was argued that to make either of these two strategies of diffusion work, it is necessary for policy-makers and sectoral actors to pay attention to types of formal rules, the selection and support of certain types of farmers, and the particular interests of change agents. In the case where small-scale producers were involved in technology adoption, it was suggested that use was made of principles taken from bottom-up approaches (e.g. the 'Farmers-First-and-Last' model) that incorporated farmers' characteristics in the design of agricultural practices and/or support collective action strategies. As a final recommendation, it was suggested that the support to regional strategies developed by grouped agro-industrial firms and trust based-relationships between these firms and smallholders could have an important impact on the adoption of practices, especially when it comes to short-term practices, during stress situations.

9.5 Limitations and further areas of research

Although a multi-case study approach was deployed, the analysis of a single industry-country and one type of stress situation means that care has to be taken when making inferences in other contexts. It was asserted that the strength of the methodology in this research was the in-depth analysis of three case studies under shared regional and stress circumstances. This gave us the opportunity to make a detailed contrast of the processes of centralised diffusion with the same variables (which cannot be observable with a general approach), for instance, by comparing diverse agribusiness sectors and situations. However, generalisations from this research must be made with prudence to identify the specific circumstances of centralised-diffusion systems to which it applies.

Further work on this subject could include exploring the consequences of the different pathways of centralised-diffusion following the stage of technology adoption. More specifically, looking at the benefits that smallholders received after the diffusion process. According to Rogers (2010), this is a common limitation found in the innovation diffusion literature. In order to observe the final consequences of technology adoption, the researcher needs to consider a waiting period after adoption takes place. This will vary based on the agricultural sector and the type of practice. Due to limitations in time resource, this research could not delve into the final consequences of the technology-diffusion processes, such as impacts on levels of PC incidence, levels of productivity, and resistance to other diseases or pest attacks. This research coped with this problem by making assumptions regarding the long-term sustainability and susceptibility of the producers to physical stresses and outcomes in the near-term future based on the defined functions of preventive and shock practices.

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APPENDIX A.

DETERMINANTS OF TECHNOLOGY ADOPTION IN AGRICULTURE

Type of determinant	Sub-category	Likely relationship with adoption based on research studies & Research evidence	Research studies
Farmers' abilities	Household income Financial capital Credits Household assets Accumulated savings Physical capital	Relationship with adoption: income and access to capital is required to finance several technologies. Research evidence: case study of British farmers who did not undertake environmental management activities due to financial constraints. Farmers also joined agro-environmental schemes for financial rewards (Mills et al., 2017).	Mills et al. (2017) Feder et al. (1985) Kassie et al. (2015) Marenya and Barrett (2007) Rogers (2010) Wejnert (2002) Mariano et al. (2012)
	Education Training courses Age	Relationship with adoption: beneficial innovations and application of modern technology tend to be adopted by more educated and trained and/or younger farmers. Research evidence Healthier, stronger and younger farmers in comparison to their older counterparts were more likely to adopt integrated natural resource and soil management practices, which generally require more physical effort (Mariano et al., 2012).	Feder et al. (1985) Bjornlund et al. (2009) Kassie et al. (2015) Mariano et al. (2012) Pannell et al. (2006) Aguilar-Gallegos et al. (2013)

		Negative relationship between school levels and adoption in Mexican crops of cocoa and oil palm (Aguilar-Gallegos et al., 2013).	
	Farm size Labour availability Input availability Dependency on off-farm income sources	Relationship with adoption: availability of productive factors (land, labour force and inputs) facilitates adoption. Research Evidence: smallholders with more labour, land, livestock and non-farm income from informal and non-formal agricultural employment were considerably more likely to continue with natural resources management techniques in Western Kenya (Marenya and Barrett, 2007).	Bjornlund et al. (2009) Feder et al. (1985) Marenya and Barrett (2007) Mariano et al. (2012) Mills et al. (2017)
Farmers' willingness	Values Preferences Personal attitudes (behavioural beliefs) Subjective norms and expectations Social norms Ethical standards Perceptions about benefits	Relationship with adoption: positive beliefs, perceptions and attitudes as well as social acceptation towards a technology can make famers willing to implement it. Research Evidence: adoption of conservation practices occur when rural landholders perceive that innovations will enhance their achievements of economic, social and/or environmental personal goals (Pannell et al., 2006)	Mills et al. (2017) Pannell et al. (2006) Kassie et al. (2015)
Attributes of innovations and practices	Monetary/non-monetary costs Direct/indirect costs Yields	Relationship with adoption: expensive technologies or technologies that do not seem to result in increase of profits and yields may reduce the likelihood of adoption.	Pannell et al. (2006) Rogers (2010, 1983) Wejnert (2002) Ghadim et al. (2005)

	Profits	Research Evidence: short-term profitability of new legume crops significantly influenced their adoption (Ghadim et al, 2005)	
	Immediacy of reward1	Relationship with adoption: practices or new ideas that people adopt now but whose desired rewards are distant in time have a particularly slow rate of adoption	Rogers (2010, 1983)
	Complexity2	Relationship with adoption: high complexity of new technologies can be an important barrier for adoption. Research Evidence: expansion of the portfolio of farming activities through the adoption land uses for conservation purposes require a greater intensity of management (Pannell et al., 2006)	Pannell et al. (2006) Rogers (2010, 1983)
	Compatibility3	Relationship with adoption: farmers tend to adopt technologies that are compatible with their existing technologies, agricultural activities, experiences, beliefs, values and needs. Research Evidence: intercropping oil palm with food crops is usually discouraged owing to its negative impact on the future yields of oil palm trees and food crops themselves[87]. However, farmers use intercropping to cover some of the economic costs of oil palm production and to insure	

[87] Food crops may not fully develop due to the high density of shade of oil palm crops in mature stage.

		against risks and volatility of commodity markets.	
	Trialability4	Relationship with adoption: trialing provides information and the opportunity to learn the necessary skills about a practice, increasing in this way the probability of making a correct decision regarding to adoption	
Policy, environmental and market settings	Government policies Supporting programmes Tenure security Price volatility of inputs Biophysical conditions Environmental and climate changes	Relationship with adoption: governmental regulations and supporting programmes during stress situations and high volatility of markers create better conditions for adoption. Research Evidence: Governmental regulations regarding land tenure security increase the likelihood for farmers to capture the returns from their investments and from the adoption of technologies (Kassie et al., 2015)	Feder et al. (1985) Marenya and Barrett (2007) Kassie et al. (2015) Mills et al. (2017) Pannell et al. (2006) Wejnert (2002) Deressa et al. (2009) Smit and Skinner (2002)

Social networks	Social relationships Central roles	Relationship with adoption: networks mainly facilitate the flow of information, knowledge, technologies and inputs between producers to enhance influence their decision-making processes and accelerate technology adoption. Research Evidence: British farmers, in their practice and decisions about new technologies and particularly GM crops, drew on not only a wide but also a relatively stable network of influencers such as practitioners and fellow farmers.	Bandiera and Rasul (2006) Conley and Udry (2010) Díaz-José et al., (2016) Monge et al. (2008) Oreszczyn et al. (2010) Ramirez (2013) Spielman et al. (2011)

APPENDIX B.

PROTOCOL OF CENIPALMA FOR PC SURGERIES

1) Removal of diseased tissues

2) Application of paste made of fungicides, insecticides and pesticides

3) Use of a 'plastic roof' for protection of the surgery

Source: Martinez et al, 2009.

APPENDIX C.

PC MONITORING ACCORDING TO SEVERITY SCALE DEFINED BY CENIPALMA

Degree 0: No disease

Degree 1: 0,1 - 20% of infection

Degree 2: 20,1% - 40% of infection

Degree 3: 40,1% - 60% of infection

Degree 4: 60,1% - 80% of infection

Degree 5: 80,1% - 100% of infection

Crater: Dead state

Source: Martinez et al, 2009.

APPENDIX D

GLOSARY FOR SOCIAL NETWORK ANALYSIS

Concept/measure	Description
Ego-centred approach	Consideration of structural characteristics of an individual actor
Socio-centred approach	Consideration of structural characteristics of an entire network
Node	Any actor considered individual, organisation, or entity of interest. A node can be an oil palm producer, research centre or governmental institution, among others
Network	Graphical representation of relationships that displays points to represent nodes and lines to represent ties (relationships of technical support)
Ego	Actor of interest within a network (for example, an oil palm smallholder in a nucleus)
Link or tie	Directed or undirected relationship between nodes (for example, technical relationships)
Network size	Total number of nodes and ties in a network
Walk	A series of interconnected ties
Path	Walk where each node and line is only used once
Geodesic distance	Shortest path between two nodes
Network centralisation	Concentration of interaction in a network around few central actors
Degree or Degree centrality	Number of ties a node has to other nodes

Strength of degree	Sum of importance values of the ties a node has with other nodes
In-degree or In-degree centrality	Number of ties a node receives
Strength of in-degree	Sum of importance values of the ties a node receives from other nodes
Betweenness centrality	Number of times a node occurs between a geodesic path. This indicator shows the positional advantage of an actor in connecting other pairs of actors (role as intermediation0
Structural hole	Empty spaces or weaker connections between two or more densely connected subgroups in a network. It can be measured by either effective size or redundancy.
Redundancy	Degree centrality of an ego's alters, not counting their ties with the ego. A person's ego-network is redundant to the extent that her contacts are connected to each other as well.
Effective size	Number of ties of an ego has with its alters minus redundancy of the ego-network
Efficiency	Effective size as a proportion of number of ties of an ego has with its alters

Source: adaptation from Spielman et al (2011), Borgatti (1998).

APPENDIX E

STATISTICAL SIGNIFICANT DIFFERENCE BETWEEN SOCIO-CENTRED INDICATORS OF NETWORKS A, B AND C

	In-degree	Sum Importance	Average Importance
Distribution	F(2,127)	F(2,127)	F(2,127)
F-Statistic	3,154097107	7,076059835	21,42523587
Effect size	0,047320379	0,100261475	0,252283501
Alpha level	0,05	0,05	0,05
F Critical Value {for F(2,120)}	3,09	3,09	3,09
Result	3.15 > 3.09 so reject null hypothesis	7.08 > 3.09 so reject null hypothesis	21.43 > 3.09 so reject null hypothesis

Source: Own elaboration from survey data

Null hypothesis: All clusters have the same average in-degree and average importance.

Statistically significant *p* value means that the hypothesis is likely false. The results show that it is unlikely that all the clusters have the same average in-degree and average importance.