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How does Conservation Agriculture contribute to sustainable agricultural production systems?

– A case study from the southeastern of Mexico: Frailesca region.

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Summary

It is unclear how and for whom Conservation Agriculture (CA) can contribute to make agricultural production systems more sustainable. The boundaries of CA are blurred, its agronomic performance is highly site specific, and it does not fit all contexts. The aim of this studywas to contribute to the identification of issues around CA in the southeastern of Mexico: the Frailesca region.

First, the study looked at the way CA is promoted and disseminated by the MasAgro program, and one of its partners in the Frailesca region, RED A.C.)(Chapter 3). In-depth interviews were held with managers and technicians of the program. In addition, participant observations during field work of technicians, field day demonstrations, and other events of the MasAgro program, form part of the qualitative data collection. Second, this research attempted to gather empirical agronomic evidence to evaluate whether it is justified to promote CA in the agro-ecological conditions of the Frailesca region (Chapter 4). Third, surveys were conducted to identify Frailescan farmers' adoption constraints with respect to CA (Chapter 5).

It was found that MasAgro's innovation system to tailor CA to the local circumstances was not yet functioning as intended in the Frailesca region. Interaction between key actors was limited, and consequently, the program failed to respond adequately to issues arising from farmers' fields. In addition, empirical agronomic evidence to justify the promotion of CA in the Frailesca region was lacking. However, on the other hand, analysis of CA's performance in agro-ecological regions across Mexico indicated that CA is expected to provide agro-ecological benefits for Frailescan farmers.

Application of the first CA principle, i.e. minimal soil disturbance, was widespread in the region. But adoption of the second and third principle (i.e. residue retention and crop diversification, respectively), was limited. Frailescan smallholders mainly faced socio-economic constraints to adopt these principles. Most important constraints for residue retention were: (1) the priority of farmers with cattle to feed their animals with crop residues, and (2), the possibility for farmers without cattle to obtain immediate incomes from selling grazing rights. With respect to crop diversification, most important constraints were: (1) the absence of a stable market to sell alternative crops than maize, and (2) too little farmland as they prioritized a certain amount of maize yield. In line with literature, this study showed that cattle is a serious threat for the adoption of the second CA-principle, i.e. permanent soil cover, by smallholder farmers. Cattle drastically increases pressure on residue trade-offs. However, in contrast, this study showed that cattle can also serve as an adoption trigger for smallholder farmers with respect to the third CA-principle. In the absence of a stable market alternative crops can be used to feed cattle, and thus production systems which include cattle can create their own "market."

Due to these constraints, Frailescan farmers often adopted only one or two principles of CA. Partial adoption was found to be detrimental in certain situations, for example when zero tillage is not accompanied with a sufficient amount of soil cover. So at the moment, CA is only contributing to the sustainability of a limited number of Frailescan farmers. This includes farmers who have sufficient amounts of farmland, can manage to feed their cattle without exhaustive in-situ grazing, do not have the necessity or willingness to obtain direct income from selling grazing rights, and are able to find purposes for alternative crops in the absence of a stable market. Generally, these were relatively larger farmers. A well-functioning regional innovation system can help to reveal whether forms of partial adoption can provide benefits, or when they are undesirable. In addition, the establishment of such innovation systems can tailor CA towards local circumstances. As a result, CA is likely to fit in a wider variety of farmers' realities, and thus to contribute to the sustainability of a wider variety of agricultural production systems, provided that it also results in agro-ecological benefits. In cases

where CA does not work for certain types of farmers, well-established innovation systems can adapt and promote non-CA technologies. For farmers, it does not matter if a certain set of practices is labeled true CA or not. They just want a practice to provide benefits with respect to their production aims. Blurring of CA does however contribute to the debate around the concept of adoption.

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Finally, I would like to thank CIMMYT for their support to finance traveling costs. This allowed me to visit farmers and conduct the surveys.

Chapter 1 Introduction

This chapter first highlights the need for developing sustainable agricultural production systems worldwide. Subsequently, there is elaborated on the concept of conservation agriculture (CA) with respect to its potential to fulfill this need. Thereafter, the debate around CA in literature, and the poor adoption of CA by smallholders is described. Finally, the current situation in the Frailesca region (Mexico) is outlined. In this region, CA is promoted by a rural research and development program.

1.1 Introduction to CA and global context

The need for developing sustainable agricultural production systems has been widely advocated in recent decades. On the one hand, agricultural production has to increase to fulfill future food demands (Foley et al., 2011). On the other hand, natural resources (e.g. fresh water, land, biodiversity) have to be conserved to mitigate the effects of climate change, e.g. higher global temperatures, increased atmospheric CO_2-levels, more unpredictable and heavier rainfalls, and longer periods of drought (Stern, 2007; Foley et al., 2011; Kassam et al., 2009). To increase agricultural production while minimizing the pressure on natural resources and the impact on climate change, technical innovations are needed.

In the search and efforts for building sustainability into agricultural production systems, many prominent scientists, organizations, and local and international NGOs strongly adhere the concept of CA, e.g. the Food and Agriculture Organization of the United Nations (FAO), and the International Center for Agricultural Research in the Dry Areas (ICARDA) (Kassam et al., 2009; Verhulst et al., 2012). They are convinced that CA can serve as a baseline towards sustainable intensification. CA constitutes three principles: (1) minimal soil disturbance (zero- or reduced tillage), (2) permanent soil cover by a growing crop or residue retention (mulch), and (3) diversification of crop species (crop rotation, and or intercropping) (Farooq & Siddique, 2015; FAO, 2016). The principles of CA are part of so-called ‘Good Agricultural Practices’ (GAP). GAPs are a collection of practices that are applied for on-farm production and post-production processes, resulting in safe and healthy agricultural products while considering economic, social, and environmental sustainability (FAO, 2013). Zero tillage, or minimal soil disturbance, is expected to reduce soil degradation and soil erosion (Baker et al., 2002; Putte et al., 2010). In addition, applying less tillage applications comes with using less fuel, resulting in cost savings (Wortmann et al., 2010). The practice of retaining crop residues in the field after harvest is well known for its potential effects. It reduces water runoff and increases infiltration (Thierfelder & Wall, 2009; Corbeels et al., 2011). Thereby, the retention of residues increases soil organic matter content (Erenstein, 2002; Beuchelt et al., 2015). The last principle of CA, crop rotation, is also reported to result in a number of agronomic benefits. It results in an increased soil fertility, especially when legumes are used in rotation (Mupangwa et al., 2012; Duc et al., 2015; Yu et al., 2016; . In addition, crop rotation results in the maintenance or improvement of soil structure and a decrease in risk of pest and diseases (Smith et al., 2008; Mupangwa et al., 2012; Thierfelder et al., 2013b).

1.2 Variability of yield response to CA

Yield responses to CA are highly variable among sites and seasons (Rusinamhodzi et al., 2011; Pittelkow et al., 2015). In general, appropriate CA which consists of the close alignment of all three CA principles, results in long-term yield increases (Derpsch et al., 2014). On the short-term however, no yield benefits or even yield penalties are just as likely (Giller et al., 2009). The short-term effect of CA on yield is not only influenced by the agro-ecological environment, it is also influenced by other agricultural practices, such as the application of fertilizer (Erenstein, 2002; Rusinamhodzi et al., 2011). This complicates the process to predict the effect of CA on yield even more. Despite those complex interactions, some environmental conditions have been identified in which CA can also result in yield benefits on a somewhat shorter term (after 1-3 years). Several meta-analyses show that CA is expected to increase yields under rain-fed conditions in relatively dry climates (e.g. Rusinamhodzi et al., 2011; Pittelkow et al., 2015). Presumably, this is due to the fact that a soil cover increases infiltration and simultaneously reduces evaporation, resulting in a higher water use efficiency (Franzluebbers, 2002; Lampurlanés & Cantero-Martínez, 2006; Ling-ling et al., 2011). In contrast, decreasing run-off in relatively wet areas is often unwanted, as this can result in yield penalties due to waterlogging. To tailor CA towards specific agro-ecological conditions, it is necessary to understand the complex set of conditions that favor CA in general, and subsequently analyze if these comply with local agro-ecological environments.

1.3 The debate around CA and poor adoption by smallholder farmers

Across a variety of agro-ecologies, CA is considered to have the potential to address problems such as land degradation and soil erosion, while at the same time improving yield. For this reason, CA has been widely promoted during last decade. In Africa for example, CA is being promoted by prominent institutes such as the FAO, by several regional organizations (e.g. Southern African Development Community (SADC)), by international research centers (e.g. International Maize and Wheat improvement Center (CIMMYT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and ICARDA), and by a substantial number of local and international NGOs (e.g. Conservation Agriculture Promotion (PROMAC)) (Giller et al., 2015). In general, medium- and large scale farmers succeeded to implement CA in their production systems (Derpsch et al., 2015). In large scale production systems in Brazil, United States, and Australia, examples exist of successful implementation of CA. Farm incomes were increased, mainly through reductions in production costs by saving fossil fuel and labor inputs (Farooq & Siddique, 2015). However, despite massive efforts to promote CA among smallholders, adoption by smallholder farmers has remained limited. This has raised questions among scientist if the promotion of CA among smallholders is justified.

A number of reviews about CA (e.g. Giller et al., 2009; Giller et al., 2011; Corbeels et al., 2014; Derpsch et al., 2015; Giller et al., 2015), strongly doubt if CA can be made to fit all circumstances. In particular, the suitability of CA with respect to the socio-economic context of smallholders is questioned. For example, Giller et al. (2015) reported that farmers tend to maximize benefits at the whole farm level, while minimizing production risks (Giller et al., 2015). This would mean that potential benefits at field level (e.g. increase in yield, reduction of soil erosion) are generally not decisive for farmers regarding the adoption of CA (Corbeels et al., 2014). Another frequently described phenomenon for the limited adoption of CA by smallholders, is their short-term horizon and immediate needs for food security (Corbeels, et al., 2014). CA can provide agronomic benefits on the long-term (e.g. yield increase, higher soil fertility), and thus has the potential to increase farm income in the long run. However, smallholders are generally not willing or able to overcome the initial phase of CA, which is often accompanied with a temporary decrease in farm income (Beuchelt et al., 2015). So, commonly there is a mismatch between CA and the production aims of smallholder farmers. Also the retention of appropriate amounts of crop residues after harvest is a widely recognized adoption constraint of CA among smallholders. As CA includes the retention of a substantial part of crop residues (i.e. a minimum of 30%), it often leads to an increased pressure on residue trade-offs in production systems of smallholder farmers (Beuchelt et al., 2015). For example, smallholders with livestock were generally found to prioritize the practice of feeding crop residues to their animals over soil mulching (Giller et al., 2009; Erenstein et al., 2012; Beuchelt et al., 2015).

“True” CA is only practiced when all three principles are applied in careful alignment (Derpsch et al., 2014). In addition, as described above, smallholder farmers often face agro-ecological and socio-economic adoption constraints. Especially the adoption of residue retention and crop rotation is often lacking or insufficient among smallholder farmers to consider them as true CA adopters (Derpsch et al., 2015). Adoption constraints not only originate from the plot and farm-level, they can also arise from the wider market, institutional and policy context (Andersson & D'Souza, 2014). Partial adoption of CA can result in undesired effects. For example, some studies showed that when no-tillage is practiced in the absence of a minimum amount of soil cover, yield will decrease due to an increase in soil erosion and soil compaction (Tadesse et al., 1996; Ling-ling et al., 2011).

1.4 Study area

1.4.1 CA in Mexico

Recently (2011), CA is being promoted among Mexican farmers through a program named "Modernización Sustentable de la Agricultura Tradicional" (MasAgro), or in English: Sustainable Modernization of Traditional Agriculture. The MasAgro program is a collaboration between the Mexican government and CIMMYT. The objective of the program is to make maize and wheat production in Mexico more sustainable by (1) helping Mexican farmers raise and stabilize their yields, (2) increasing their incomes, and (3) mitigating the effects of climate change. Within the MasAgro program, CA is considered as the basis for the development of sustainable crop management technologies. (MasAgro, 2016; Camacho-Villa et al., 2016). Chapter 3 will describe the functioning of the program in more detail.

1.4.2 Agriculture and the introduction of CA in the Frailesca region

Chiapas is one of the Mexican states in which MasAgro is implementing and promoting CA (Fig. 1.1). The state is located in the southeastern part of Mexico and borders to Guatemala in the south, and the Pacific Ocean in the east. The Frailesca region, a region in Chiapas, is the state's most important agricultural production region. Maize is the principal crop. The farmer community of the Frailesca region is highly diverse in terms of crop diversification, mechanization, use of inputs, and commercialization (Camacho-Villa et al., 2016). Some smallholder farmers cultivate one or two hectares for home-consumption only. Medium-scale farmers up to 70 ha produce for home-consumption as well as for commercial purposes. Maize (*Zea mays* L.) is the dominant crop and grown by virtually all farmers. It is a principal part of people's diet. Other crops cultivated in the Frailesca region include beans (*Phaseolus vulgaris*), pumpkin (*Cucurbita pepo*), sorghum (*Sorghum bicolor)*, and canavalia (*Canavalia ensiformis*), or sometimes called "Jack bean." Canavalia is a legume which is used for both animal and human nutrition.

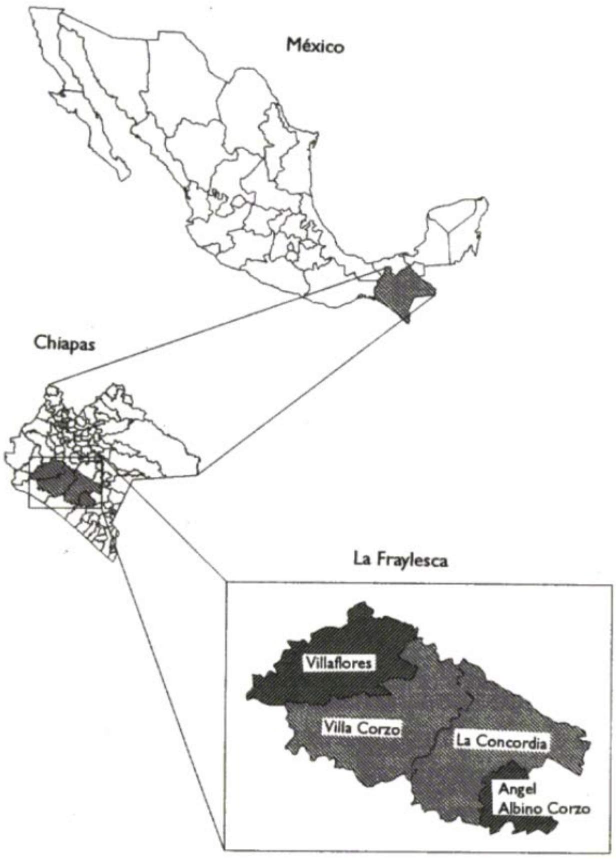

Figure 1.1. The Frailesca region, Chiapas, Mexico (Sánchez-Perez et al., 2015).

The landscape of the Frailesca region consists of valleys with hills in a tropical lowland setting, relatively similar divided into agricultural land, forest, fallow, and grassland (Box A). Steep hillsides

(>20%) are alternated by terraces and river plains (<20%) (Hellin et al., 2013). The climate is defined as 'dry tropics.' Two main seasons can be identified, a wet and a dry season, both during approximately six months. The wet season is generally from May-June until November-December. Farmers without access to irrigation have one growing season per year, which lasts from May-June until November-December. The growing season includes the wet period. The average annual rainfall in the region is 1200 mm (De la Piedra, 2016). In fields located in hilly areas, land preparation does not include tillage, simply because mechanization is not suitable. Traditionally, hillside farmers are used to chop the maize stover, and burn the crop residues, before planting with a stick after the start of the first rains (May-June). In contrast, traditional land preparation in flat areas does include tillage, usually consisting of 1-3 tillage operations. Also in flat areas, planting is mostly still done manually with a stick (Hellin et al., 2013).

A substantial part of Frailescan farmers has integrated livestock in their farms, so-called mixed crop-livestock production systems. In terms of livestock, cattle is the dominant type (Hellin et al., 2013). It serves for meat and milk. Cattle is generally kept in an extensive way. The number of cattle varies. Some farmers have just a few cows, while other farmers have 80 or more. Also farmers in remote hilly areas sometimes have large numbers of cattle.

1.5 Problem statement

Currently, Frailescan farmers with conventional production systems are facing problems such as a decrease in land productivity due to soil erosion, soil compaction and soil degradation, acidification, and the altering rainfall pattern due to climate change (Santiago, 2016; Ovando et al., 2013). In addition, inputs (e.g. fertilizers, seeds, and pesticides) have become more expensive, while on average the market price of maize has decreased and became unstable. Technical innovations are needed to increase the sustainability of Frailescan production systems, and secure future food demands in the region.

In their aim to make agricultural production systems more sustainable, and face contemporary issues, the MasAgro program is promoting CA among Frailescan farmers. However, scientific evidence to justify this promotion in the Frailesca region seems poor. So, it is unclear how, and for whom CA can contribute to make Frailescan production systems more sustainable. As was described above, agronomic effects of CA are highly variable between different agro-ecological environments. Additionally, benefits of CA at farm level, and thus its suitability for farmers, is dependent on specific socio-economic contexts. Only analysis of the local situation can reveal if CA is able to make particular production systems in a certain region more sustainable.

Box A. Landscape impression of farmers' fields in flat areas (top) and hilly areas (bottom)

Not only in the Frailescan region it unclear how, and for whom CA can contribute to make agricultural production systems more sustainable. Also in literature this debate hinges around. It seems variable for whom CA can work, because (1) the performance of the technology is different among agro-ecological environments, (2) CA does not fit in the socio-economic context of all types of farmers, (3) its definition is not used consistently (i.e. different combinations of principles are reported), and (4), the lines of "adoption" are blurring (i.e. when can a farmer be labeled as an adopter).

This research aims to help clarifying the issues prevailing around CA, by conducting a case study in the Frailesca region. The case study examines how, and for which type of Frailescan farmers CA can contribute to make production systems more sustainable. Therefore, adoption constraints have to be identified and the agronomic performance of CA in the agro-ecological conditions of the Frailesca region needs to be assessed. So, it is necessary to investigate if, and which CA practices, are beneficial under which circumstances. Not only the technology itself is important when examining the potential of CA to contribute to more sustainable agricultural production systems. Also how CA is promoted and introduced is crucial, as this process is key to which extend CA can be locally adapted to fit in farmers reality. Close interaction between a wide variety of actors allows to identify emerging issues and strategies to adapt CA to threats and opportunities. Results of the case study can be placed in the broader perspective and debate around CA.

To be able to examine CA's potential to contribute to sustainable production systems, it is important to understand what is meant by the term 'sustainable'. The term has a vague nature. It was introduced by the Brundtland report (WCED, 1987), describing sustainable development as *"economically viable, environmentally sound, and socially acceptable development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* This research takes into account all three pillars of sustainability when examining the potential of CA to make Frailescan production systems more sustainable.

1.6 Research questions

The following research question was formulated:

How can CA contribute to sustainable agricultural production systems?

To answer this question, three sub questions were formed:

1) How is CA promoted and disseminated among smallholder farmers in the Frailesca region?
2) On the basis of which agro-ecological evidence CA is promoted and disseminated in the Frailesca region?
3) Which agro-ecological and socio-economic adoption constraints do Frailescan farmers experience with respect to practicing CA?

Chapter 2 Methodology

This research only focused on Frailescan production systems producing maize. Possibly in combination with other crops, or in combination with livestock, called mixed crop-livestock production systems. This is because maize is the principal crop in the Frailesca region, virtually grown by all Frailescan farmers.

2.1 Data collection

Data has been collected through various methods; (1) surveys, (2) participant observations, (3) depth interviews, and (4) the extraction of empirical data from a book published by MasAgro.

2.1.1 Surveys

Through surveys, data was collected about the practices which Frailescan farmers are applying in their maize production systems, including tillage practices, the use of crop residues, and diversification of crops. In addition, the survey has elucidated farmers' reasons to apply or to not apply (anymore) certain CA practices.

In total, 30 farmers were interviewed. The sample included five module farmers. Box B gives an indication of the living standards of Frailescan farmers. Module farmers are fore-runners who provide parts of their fields for on-farm trials of the MasAgro program. The role of module farmers within the program will be described in more detail in Chapter 3. The survey was conducted in collaboration with a student from the Universidad Autonoma de Chiapas (UNACH). It consisted of three main sections; (1) characteristics and evolution of the maize production system, (2) capabilities for the adoption of CA-practices offered by the MasAgro program, and (3) participation of farmers in the process of introduction and adoption of CA-practices (appendix I). Farmers responsible for a module received an additional fourth section of questions (appendix II). Both, open and closed questions were used. Open questions were sometimes continued by unstructured following-up questions to trigger a farmer to explain his opinion about particular topics or practices in more detail. This has allowed the research to go beyond the numeric part which describes what practices farmers are applying (Robson, 2011).

Box B. Interviewing a module farmer at his home.

On the right side, the farmer of the module in Monterrey. He owned cattle and was located in a flat area. On the left side, me as the interviewer/researcher. Farmers' houses were built of stone. Farmers in flat areas often had access to electricity. Farmers in remote villages, generally hilly areas, did not always have access to electricity.

The survey was conducted in six Frailescan villages; (1) Villa Corzo, (2) Calzada Larga, (3) Cuahutemoc, (4) Monterrey, (5) 24 de Febrero, and (6) Francisco Villa. All villages are part of the municipalities of Villaflores and Villa Corzo. Only the village of 24 de Febrero did not have a module farmer. Villages from the municipalities of La Concordia and Angel Albino Corzo were not included in the survey due to economic and time reasons. All five module farmers were included in the survey sample. In addition, 25 non-module farmers were selected for the survey using snowball sampling. We went to a particular village, looked for a farmer working on his land,

and asked him to take part in the survey. After the survey was done, we asked the surveyed farmer to give us some names and addresses of fellow farmers from the same village. We made a list and randomly picked one. If we did not manage to find the selected farmer in his house or in his field, we randomly took another farmer of our list.

2.1.2 Participant observations

In the period from October 2016 until January 2017, I participated in the RED A.C. team during field visits, module events (interchanges and workshops), and a demonstration day at the regional research platform. A regional research platform is a scientific research station, testing and adapting CA practices to local circumstances. The role of platforms within the MasAgro program is described in more detail in Chapter 3. During these activities I observed how the MasAgro program and the RED A.C. team were functioning. In addition, I had various small talks with farmers, technicians, the platform manager of the platform in Monterrey (Rubén), and the manager of the Chiapas hub.

2.1.3 In depth interviews

After surveys had been completed, five in depth interviews were hold with employees from RED A.C., one of the collaborating organizations of MasAgro in the Frailesca region. The relationship between RED A.C. and MasAgro, as well as the role of RED A.C. in the MasAgro program, is described in more detail in Chapter 3. RED A.C.'s manager, its program coordinator, and three technicians were interviewed. A semi-structured interview set-up was used following the guidelines of Robson Chapter 11 (2011). In advance, a list was made consisting of topics to be addressed during the interview, based on insights acquired from the surveys and participant observations. A topic on the list was introduced to the interviewee, followed by unplanned following-up questions to obtain elaborate opinions and information. Additionally, also results obtained from farmers' surveys were presented to the interviewees to check the representativeness of the results for the whole Frailesca region.

2.1.4 Extracting results of platform experiments

Empirical data was extracted from a book which described a selection of platform experiments from the experimental growing cycle of spring 2015. This book was published by MasAgro (Verhulst et al., 2015). Data was obtained regarding the performance of CA practices at MasAgro's platform stations all across Mexico. Results are shown and discussed in Chapter 4.

2.2 Data analysis

Comments and statements of farmers obtained during the surveys and participant observations were fully transcribed. The depth interviews were audio-taped and afterwards they were fully transcribed in English. Qualitative data was analyzed using the thematic coding approach (Robson, 2011). Answers were labelled, and subsequently, similar responses were merged in groups which served as a basis for further data analysis and interpretation. Frequency tables were constructed and complemented with statements from farmers obtained by the in-depth interviews, participant observations, and the survey diary.

2.3 Group division

Based on the characterization of the area, the current practices of Frailescan farmers as described in Chapter 1, and the survey results, I categorized farmers in four groups according to two criteria. Selected criteria were (1) the slope of the land; hilly- or flat areas, and (2) the inclusion of cattle in the farming system; yes or no. This categorization resulted in four farmer groups: (1) hilly areas/cattle, (2) hilly areas/no cattle, (3) flat areas /cattle, and (4) flat areas/no cattle.

The slope of the land was the first criteria, because it plays a key role in the adoption (potential) of CA practices. Farmers in hilly areas face a different abiotic growing environment than farmers in flat areas. The steep slope of fields at hillsides makes it impossible to enter the field with machinery, for example machinery to till the soil. In addition, cultivated fields in hilly areas are more susceptible to erosion, requiring the farmers in hilly areas to apply additional measures to conserve their soils. For the principle of residue retention, farmers in hilly areas have to retain a minimum soil cover of 50% to consider this CA principle as adopted. Farmers in flat areas only have to retain a minimum of 30%. Some farmers possessed fields both in flat- and in hilly areas. These farmers were assigned to either farmers in flat- or farmers in hilly areas, depending on which characteristic was dominant. Consequently, the survey questions referred to the practices which this particular farmer applied in the dominant area. So, questions were answered with respect to either flat- or hilly areas.

Presence of cattle was the second criterion. Also the possession of cattle by farmers plays a key role in the adoption (potential) of CA practices in the Frailesca region. It influences the degree of adoption, as well as how CA practices are adopted. For example, for the principle of residue retention. Cattle puts more pressure on different uses for crop residues, making adoption of this principle more difficult when crop residues are limited, as is generally the case among Frailescan farmers. On the other hand, in the absence of stable markets for particular crops, cattle provide an alternative purpose. Crops which are difficult to sell on commercial markets, can be used to feed the cattle.

Chapter 3 Promotion and dissemination of CA by MasAgro among Frailescan farmers

This chapter starts with a description of the general structure of the MasAgro program in Mexico as it is proposed by the program itself. Subsequently, the structure of the MasAgro program in the Frailesca region is described, and its functioning is compared with the general structure as intended.

3.1 General structure of the MasAgro program

Within the MasAgro program, CA is used as the baseline for the development of sustainable agricultural production systems. The program aims to develop and promote CA by establishing regional innovation systems. Innovation systems are frameworks which consider innovation as the result of a networking process and iterative learning among various actors, e.g. farmers, researchers, extension agents, policy makers, input industries, traders, and processors (Röling, 2009; Klerkx et al., 2010; Hellin et al., 2014). Within the program, those innovation systems are named 'hubs'. Several hubs were established across Mexico. Each hub represents specific ecological and agricultural production characteristics. Within a hub, all important actors can meet and interact. In this way, strategic links between public and private institutions can be established. Thereby, knowledge can be disseminated to farmers (Hellin et al., 2014). Each hub consist of smaller units, also called 'regional hubs.' A regional hub entails an experimental platform which is linked to several modules and extension areas (Fig. 3.1).

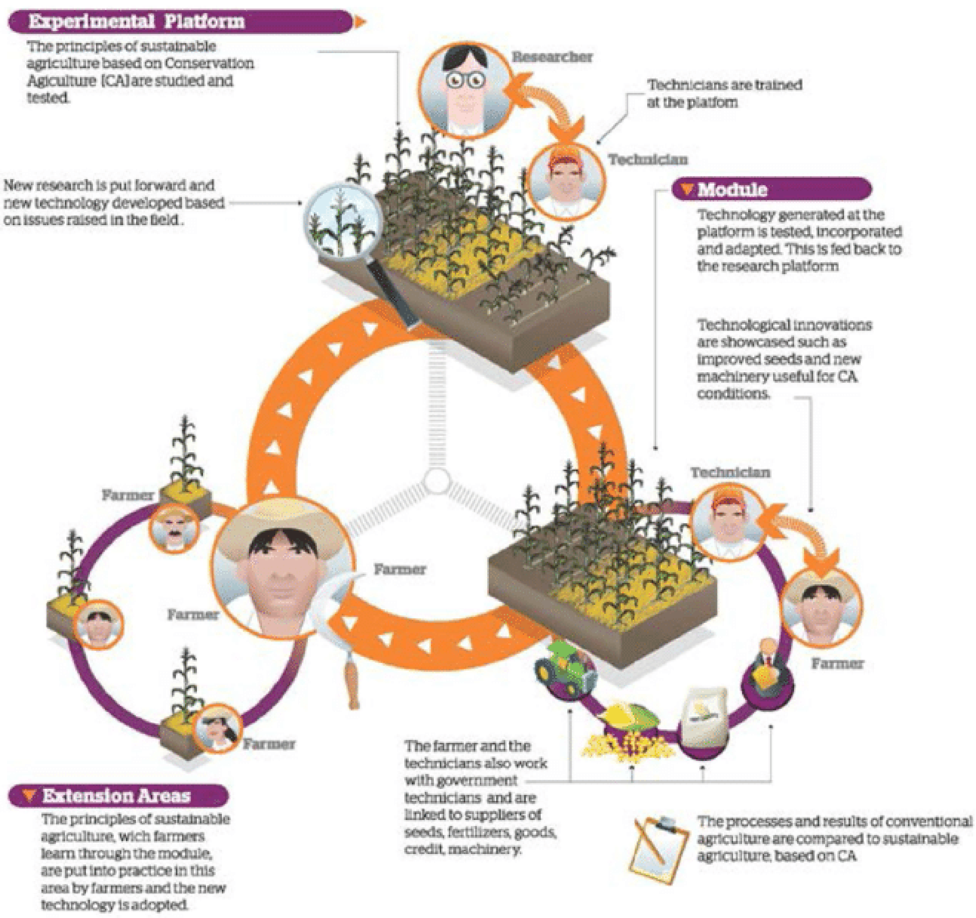

Fig. 3.1 The general structure of a regional hub of the MasAgro program in Mexico (Hellin et al., 2014).

Experimental platforms

Experimental platforms are meant to scientifically test and study sustainable agricultural practices based on CA at the local level. Those practices are proposed by the headquarters of MasAgro and CIMMYT. Besides, the platforms are supposed to find solutions for problems arising from the field that are specific to the local context. Additionally, module farmers, extension agents, and researchers are trained at the platforms to stimulate the diffusion of new technologies and practices (Hellin et al., 2014). Platforms are located within academic institutes, such as universities and research institutes.

Modules

Modules are small experimentation plots, located in fields of collaborating farmers who are interested in implementing innovative technologies using CA as a baseline. Interesting results obtained from the experimental platforms should be tested and adapted to farmers' field level. Practices of new technologies which are applied in modules are in consultation with the farmer who owns the field (e.g. which crop is chosen for an innovative crop rotation, etc.). Technicians from the responsible partners of MasAgro help farmers to implement new practices and technologies. In the modules, participatory learning takes place in the form of events, such as field day demonstrations, workshops, etc. Surrounding farmers are invited to these events. The goal of the modules is to disseminate CA-principles by convincing farmers to adopt particular CA practices or practices related to CA. Additionally, modules are expected to provide feedback to the platform. This allows the platform to adjust its experimental design, and respond to issues arising from farmers' fields. MasAgro's idea is that module farmers also act as a promoters, who convince fellow farmers to adopt practices which are demonstrated in the modules (Camacho-Villa et al., 2016; Hellin et al., 2014).

Extension areas and impact areas

In addition to modules and experimental platforms, MasAgro defines extension- and impact areas. When farmers participated in the participatory learning process at modules and or platforms, and are experimenting with at least one CA-principle, the area in which they experiment is called an extension area. Extension areas play a key role in the widespread adoption of new technologies (Hellin et al., 2014). An area in which at least one CA-principle is practiced for several years in a row, is called an impact area (Hellin et al., 2014).

3.2 Structure of the MasAgro program in the hub of Chiapas, and partners in the regional hub of the Frailesca region

3.2.1 Structure of the MasAgro program in Chiapas

The office (headquarter) of MasAgro in Chiapas is located in Berriozabal, a small city close to the capital of Chiapas: Tuxtla Gutierrez. The Chiapas-hub consists of four regional hubs: (1) the Selva region, (2) the region Centro, (3) the Meseta region, and (4), the Frailesca region. All four regional hubs represent a region of Chiapas in which growing conditions and socio-economic contexts are roughly similar (Santiago, 2016). In each regional hub, MasAgro is collaborating with a wide variety of partners (e.g. research organizations, NGOs, universities, research institutes, independent extension agents, seed companies, processing companies of grains, etc.), all having different responsibilities regarding the program. Those partners help to implement the MasAgro program.

3.2.2 Partners of the MasAgro program in the Frailesca region

RED A.C.

Also in the Frailesca region MasAgro collaborates with various partners. One of those partners is RED A.C. It a non-governmental Mexican organization aiming to contribute to the improvement of living conditions for the poorest rural sectors through (1) education and capacity-building, (2) research, (3) support and evaluation of participatory processes, and (4), building inter-institutional linkages for designing, developing, and executing projects (RED A.C., 2017). In 2012, RED A.C. started to collaborate with MasAgro. Until 2014, RED A.C. was active in all municipalities of the Frailesca region. However, since 2015 the team of RED A.C. concentrates on the municipalities of Villaflores and Villa Corzo, including all villages which are part of these municipalities. They decided to narrow down the project because of economic and time reasons. Currently, RED A.C. is responsible for five local modules, including the associated extension areas (two for each module). The manager and the coordinator of RED A.C. are also working for local universities, Universidad Autonoma de Chiapas (UNACH) and Universidad de Ciencias y Artes de Chiapas (UNICACH). These universities indirectly interact with MasAgro, as they provide students for data collection, train future technicians and extension agents, and facilitate additional research in farmers' modules.

Regional experimental platform

The modules of RED A.C. are connected to MasAgro's regional experimental platform which is located in Monterrey, a village in the Frailesca region. The platform is managed by another partner of MasAgro, Rubén de la Piedra. He is an independent agronomic researcher, hired by MasAgro to run the experimental platform.

INIFAP

Another partner in the Frailesca region which is actively involved in the MasAgro program is the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). It is the national research institute of forestry, agriculture, and livestock. Like RED A.C., also INIFAP is responsible for a number of modules. These modules, however, are not related to the modules of RED A.C. This research only included the modules of RED A.C. to see how CA is promoted and disseminated among Frailescan farmers.

3.2.3 The team of RED A.C. working for the MasAgro program

The team of RED A.C. which is responsible for the modules consist of five people, one coordinator and four technicians. The coordinator is responsible for the establishment of the modules and decides were to locate them. The four technicians intensively work together under the supervision of the coordinator. Three of them are responsible for executing and evaluating the experiments in the modules, the operative part. They evaluate for example which practices perform best with respect to certain field characteristics, e.g. slope of the field, level of soil erosion and compaction, soil organic matter content, etc. One of the technicians is responsible for the extension of successful experiments executed in the modules to other local farmers.

3.3 Strategies to disseminate CA: RED A.C. and MasAgro

Although RED A.C. is helping MasAgro to implement the MasAgro program, I found them to have different strategies to promote and disseminate CA. MasAgro tries to increase farmers' yields when implementing CA in agricultural production systems. A proposal to increase yields with 30% by 2020 was accepted by the former president of Mexico. At the moment, in the headquarters of CIMMYT, the coordinator of the MasAgro program is still using this as a political discourse. As the manager of RED A.C. mentioned: *"If they don't reach the goal upon they agreed, the Mexican government will presumably stop the subsidy and the program cannot continue. When MasAgro came to Chiapas, they initially wanted to work only with bigger farmers in flat areas. With this type of farmers it is easier to increase the yield from one year to another, and thus to reach the yield goal more quickly."* However, in Chiapas, 80-90% of farmers are small-scale farmers located in hilly areas (Reyes-Muro et al., 2013; Guevara-Hernández, personal communication, January 2017). The contribution of these small-scale farmers is important for the total maize production in the state (Guevara-Hernández, personal communication, January 2017), and thus for the national level of production since the state of Chiapas is the fifth largest producer of maize in Mexico (Reyes-Muro et al., 2013; Arellano-Vicente et al., 2016).

In contrast to MasAgro, its partner RED A.C. focuses on the efficiency of farmers' production systems when implementing CA. This is necessary because Frailescan farmers, especially smallholders, face difficulties in maintaining the profitability of their maize production systems. As one farmer stated: *"The price of fertilizers and seeds has almost doubled during last years."* In addition, the market price of maize is relatively low at the moment. Because the majority of Frailescan farmers are smallholders, RED A.C. is trying to accommodate knowledge and technologies into smallholder farmers' conditions. All what has been researched within the MasAgro program by RED A.C., has been translated into local practices for this target audience.

To improve the input efficiency of Frailescan production systems, RED A.C. tries to decrease the amount of expensive inputs while maintaining yields. One of the most expensive inputs are fertilizers. As a technician of RED A.C. stated: *"Many farmers here in the region haphazardly apply fertilizers. Sometimes they apply three to four times the amount of fertilizers the soil is demanding. We are learning them how to estimate the amount and type of fertilizers they should apply in certain situation."* If farmers can obtain similar yields using less fertilizer, money is saved.

In addition to reducing the use of expensive inputs, RED A.C. is trying to increase the productivity level of soils in a sustainable way by promoting new technologies to farmers, including CA practices. These practices are not only meant to increase the productivity of soils in terms of nitrogen level, organic matter content, water holding capacity, etc., but also in terms of avoiding (further) erosion, and dealing with specific local environmental conditions such as drought (Box C). Recovering degraded soils and increasing the natural productivity level of soils is a long-term process. The manager of RED A.C. stated: *"We choose for this long route because one, small-scale farmers in the region have the necessity to reduce high input costs to make their production systems more profitable, and two, the way without using high amounts of chemical fertilizers is more sustainable."*

Box C. Facing drought problems and decreasing the use of chemical fertilizers by the application of Bio fertilizers

Because the problem of drought is getting bigger and bigger in the region, RED A.C. is experimenting with new technologies to counteract the effects of drought. These technologies are the initiative of RED A.C., they have never been tested on the experimental platform within the hub-system. They are tested in RED A.C.s modules. In 2016 for example, RED A.C. started on-farm trials with the application of bio fertilizers during sowing, including mycorrhizas and azospirillum. A mycorrhiza is a fungi living in symbiosis with the plant. The mycorrhiza provides a more extensive root system for the plant, in exchange for sugars produced by the plant. Bio fertilizers also help farmers to reduce their high spending to chemical fertilizers, as a more extensive root system is able to explore deeper layers of the soil for obtaining nutrients. As a technician of RED A.C. stated: *"Last year we had very nice results with the experiments in which we applied bio fertilizers. The amount of chemical fertilizers the module farmers used was less than before without bio fertilizers."* As chemical fertilizers are expensive inputs, bio fertilizers have the potential to save costs as well. However, abovementioned effects of mycorrhizas

3.4 Functioning of MasAgro in the Frailesca region

The functioning of the operational entities of MasAgro in reality, and the functioning of those entities as described by MasAgro shows differences. How the experimental platform, modules, extension areas, and impact areas should work regarding MasAgro was described in section 3.1 of this chapter. From observations and insights obtained by participant observations, depth interviews, and small talks, this section describes how MasAgro's operational entities were found to function. In particular, it elaborates on the functioning of the platform and its connected modules, including their interaction.

3.4.1 Functioning of the experimental platform in the Frailesca region

Initiation of the regional experimental platform

By the initiation of the MasAgro program in the Frailesca region in 2012, the experimental platform was located within the local university of Villaflores, UNACH. MasAgro had confirmed that the platform would be established for ten years. The idea was to have one year of soil investigation at the platform site, called year zero. No experiments regarding CA were executed in year zero. So, normally there would be nine years of CA-experimentation left. However, due to sensitive reasons, and a volatile structure within MasAgro and between MasAgro and its partners (e.g. short-term contracts, commitment of farmers, resources arriving late, etc.), the location of the experimental platform was changed after the growing season of 2015. The manager of the regional experimental platform commented: *"The whole investigation process has to start from year zero again in the new location. The program started in 2012, now in 2016 we have year zero again, and in 2017 we can restart to experiment with CA and other technologies. We lost four years of investigation."* The new platform is located in Monterrey. At the moment, they are not sure how to proceed the program after 2022.

Representativeness of the regional experimental platform

With respect to production systems in flat areas, the platform is representative for the region. Like many farmers in flat areas, the soil of the platform had and has problems with soil compaction. Also plant diseases occurring in the platform are similar to diseases frequently found in farmers' fields. In addition, the soil of the platform has a low organic matter content and is relatively acid, which is comparable to soil characteristics of Frailescan farmers in flat areas (De la Piedra, personal communication, 23 December 2016). However, despite the fact that the majority of Frailescan farmers are smallholders in steep terrains, the platform does only have flat experimentation plots. As the platform manager stated: *"Practices, and effects of certain practices, are substantially different between flat and steep areas. Unfortunately, up to now, MasAgro didn't fulfill the request to have another platform area in the steep terrains of the region."* As such, the experimental platform of the Frailesca region is not able to test the agronomic performance of CA with respect to the agro-ecological conditions of Frailescan farmers in hilly areas.

Demonstration day(s)

Once a year, the experimental platform in Monterrey organizes a demonstration day for local farmers, technicians, extension agents, collaborators of MasAgro responsible for associated modules, etc. During this day, people are informed about the platform experiments. For example, during the most recent demonstration day in October 2016, an experiment was presented with various alternative crops to use in a crop rotation with maize. A technician of MasAgro explained the potential benefits of crop rotation with particular crops. The rotational crops which were used in this platform experiment were all species with high nutritional values for cattle, as the technician explained. However, evidence for the benefits of these practices was only available from literature and former experiments from the CIMMYT headquarter in El Batan. Yet, it was not continued on the local level. So, no empirical data was available about the agronomic effects of certain rotational crops in the agro-ecological conditions of the Frailesca region. The same was true for experiments to examine the effect of residue retention and zero- or reduced tillage on several factors of soil productivity. This observation was not surprising, as it was only the first year of CA-experimentation at the new platform site, and given the fact that agronomic benefits of CA tend to appear over time.

Box D. Demonstration day at the experimental platform in Monterrey, 28th October 2016

On the left photo, the hub-manager of Chiapas (Jorge) is explaining farmers the results of the experiment in which they tested several maize varieties (hybrids) on their resistance against the fungal disease Phyllachora maydis. The right picture shows the experiment in which several alternative crops were tested on their potential to be rotated with maize, at a local level.

Addressing regional problems

According to the team of RED A.C., MasAgro's regional experimental platform lacks to address regional issues arising from farmers' fields. Last year, mainly genetic materials against the fungal disease *Phyllachora maydis* were tested at the platform. A technician from RED A.C. commented: *"The platform is missing fundamental components. For example, they don't have any experiment in which maize is intercropped with pumpkin, while many farmers in the region are applying this practice."* The manager of RED A.C. added: "*The platform is addressing some regional problems, but not with the intensity that we as RED A.C. think it should be done."* As the strategy of MasAgro is mainly focused to increase yields of medium- to larger scale farmers, they seem to poorly address the needs for smallholder farmers.

3.4.2 Functioning of the modules

Selection of the modules

Respecting MasAgro's guidelines, RED A.C. selected suitable module farmers on the base of four criteria: appropriate module farmers are farmers who (1) already understand the benefits of not burning crop residues (which used to be a common practice in the region), (2) are really willing to collaborate and innovate, meaning not willing to collaborate only for input support, (3) are able to explain other farmers what is happening in their modules, and (4) who have fields which are easy accessible for other farmers and technicians (fields close to roads). Currently, modules of RED A.C. are located in Monterrey, Calzada Larga, Cuahutemoc, Villa Corzo, and Santa Rosa.

RED A.C. and "their" modules

Owners of modules are not necessarily farmers who have adopted all principles of CA. In the modules, RED A.C. is trying to develop a blueprint to change conventional production into sustainable production systems. Step by step, innovative practices are introduced using CA as a baseline. A RED A.C. technician commented: *"We are trying to change one thing in every growing cycle. It is very important that the farmers will see the logic and can follow the process of change. Changing too much at once could have counteractive effects on the adoption level of new technologies."* So, first, the module farmer has to be convinced that a certain innovative practice is beneficial (Box E). Second, the farmer has to understand how to apply new practices as he is expected to apply them himself. Third, he has to understand how implemented practices affect his production system, as he has to explain his experiences and results to fellow farmers. Therefore, on-farm trials are always in consultation with the module owner, as the technician of RED A.C. further explained. For this reason, module farmers had rarely adopted all principles of CA.

Box E. Convincing farmers

Frailescan farmers generally try new practices first in small parts of their field. If they see that a particular practice works in a small part, they are likely to try the practice in a bigger area next season. A technician of RED A.C. explained this with a hypothetic example of residue retention: "If a farmer sows 100 rows of maize, we try to convince him to sow just one row of maize in which he will retain all of his crop residues. He will see the difference between the part of the field in which he retained all of his crop residues and the part of the field in which he retained less or nothing (within the same season)*. If he sees that this is working, next year he will probably sow 15 or 20 rows in which he is applying this practice."*

Benefits of new practices are not always immediately visible for farmers. The manager of RED A.C. explained: *"Farmers want something tangible, like bigger grains or a higher yield. However, some practices don't immediately show clear benefits to farmers. In such situations, we have to explain the effect of a certain practice in more detail, so they will not lose interest."* For this reason, RED A.C. is conducting elaborate analyses of on-farm experiments in the modules. They collect additional data about e.g. plant size, soil fertility, and root development. In situations where immediate yield increases are lacking, analyses of such data can be used to explain the farmers that for example their maize has a higher quality than the year before, or that soil quality has improved. Also economic benefits, e.g. reducing inputs while maintaining yield, often turned out to be difficult to understand for Frailescan smallholders. A RED A.C. technician stated: *"We have to explain this to the farmers because they only look at yield, how many tons they have produced in comparison with previous years."*

During the growing season, the team of RED A.C. organizes several events in each module, e.g. workshops and field day demonstrations (Box F). I took part in various events in different modules. Local farmers are invited to these events. The amount of farmers taking part in these events varied from 12 to around 25 farmers. The main goal is to explain local farmers about the on-farm trials in a certain module. Additionally, practices with promising results are promoted during such an event. On these occasions, technicians build confidence and create entrances for farmers to start adopting practices based on CA. Technicians of RED A.C. encourage discussions with farmers during these days. Sometimes, farmers with long-term experience in practicing CA were invited to talk about their experiences. They talked about how they started applying certain (CA) practices, the results they obtained, and the benefits they perceived.

Differences between modules

Some modules are functioning better than others. The functioning of a module depends on many factors, e.g. willingness of the farmer to collaborate, openness to try new things, effectiveness of particular practices, technical assistance, etc. Four of the five modules seemed to function well, which included the ones in Calzada Larga, Monterrey, Cuahutemoc, and Santa Rosa. These four modules are starting to pick up new practices which are proposed by RED A.C. The only module which was observed to work poorly, was the one in Villa Corzo. The farmer of this module had not adopted any new practice as proposed by RED A.C. Additionally, the events in this module were badly visited by fellow farmers. Probably because the module farmer himself was not taking part in those module events. During the survey, the farmer of the module in Villacorzo gave a reluctant impression. He stated: *"Everyone has its own proper way of thinking and working. I believe in my own production manner and I don't need and I don't want help of technicians. Normally I harvest around 8 to 10 tons per hectare with my own method. Here in the region there is no one, also no technicians, who obtain this yield."* This farmer was not open for collaboration, and was reluctant to adopt new practices. So why did RED A.C. select this farmer to establish a module? A technician explained: *"We have chosen him as a module farmer because he is a very important person within the agricultural sector here in the region, he is a kind of leader for the farmers. If we can manage that he will actively take part in what we are trying to do, that would open a lot of possibilities. He is the key to a bigger support base.* Although, the module farmer seemed to have a different idea about a future collaboration. During the survey, he mentioned that he is not willing to continue with the establishment of the module in his field. It doesn't earn him anything, it is just a loss of land as he said. So, for RED A.C., it seems to be a waste of energy and resources in trying to convince and involve this farmer in a beneficial collaboration.

Box F. Impression of a workshop at a farmer's module with fellow local farmers.

Events started with a small presentation, emphasizing importance, relevance, and benefits of particular practices applied in the modules (upper photo). Afterwards, they visited the test field of the module to see how a certain technology was functioning in farmer's fields (bottom photo).

A module which was observed to work properly was the module in Francisco Villa. It closely approached the functioning of a module as was initially described by MasAgro. The farmer of this module, adopted many practices which had been tested in his module field (e.g. minimum tillage and the retention of residues). On about three hectares he was applying true CA, i.e. applying all three CA principles in close alignment. He stated that his harvest increased by 2.5-3 tons per hectare during the last three years. Before, he produced around 3.5-5 tons per hectare. At the moment, he is producing 6.5 to 8 tons/ha. This module farmer was very open to collaborate. He was not only collaborating in module events at his own module, he also participated in other events of RED A.C. and MasAgro to share his experiences with fellow farmers.

3.4.3 Interaction between the experimental platform, modules, and other collaborators of MasAgro

Collaboration between the modules of RED A.C. and the regional experimental platform in Monterrey.

The interaction between the modules of RED A.C. and the platform in Monterrey managed by Rubén de la Piedra was far from optimal. Responsible people of both parties only meet once a year during the platform event. As a technician from RED A.C. stated: *"It is nothing more than getting to know their work, the experiments they are doing and the results they obtain. We are not directly involved in the design of the experiments at the platform."* The design of the platform experiments is exclusive to Rubén and its team, and the office of MasAgro. So, input is only coming from the top level. The manager of RED A.C. commented:

> *"If we would be involved in the design the experiments at the platform, we would start saying that they should change certain experiments because they are not addressing the needs of local smallholder farmers. Before, we tried to give some feedback, provide some inputs, but the people from the platform are more open to listen to what people at the MasAgro office level are saying. At the office level of MasAgro they want to show the headquarters of CIMMYT that platforms are nice presentable and working properly. They have to collect data to deliver to the headquarters, so they can publish things to maintain the subsidy of the government."*

So according to RED A.C., the regional experimental platform in Monterrey (and MasAgro) should listen more to local technicians, and should collaborate more intensively with module partners when designing platform experiments. In this way, issues arising from farmers' fields can be addressed, and CA can be tested and adapted locally. Nowadays, the modules of RED A.C. are performing tasks the platform is supposed to do. RED A.C.'s manager explained: *"There are many things in the platform we shall not test in the modules, simply because it is not suitable for regional farmers, or farmers are not interested. The other way around as well; some practices we are testing in the modules have not been tested by the platform. An important example is intercropping."* Originally, modules are designed to transfer the technologies. But, because the platform is not addressing important regional issues, and is going in a different direction than the modules, RED A.C. decided to run their own scientific experiments in the modules. RED A.C. gets some theses and other scientific evaluations from the modules. They started doing this on their own initiative because they wanted to get information for publications. They publish articles about what is happening with the farmers in the region (Guevara-Hernández, 2017). In addition, they can use these data to explain farmers the benefits of particular practices which are not easily visible in the field, as mentioned before.

Collaboration between different partners responsible for MasAgro's modules in the Frailesca region

Like the interaction between the experimental platform and the modules, also the interaction between different partners of MasAgro responsible for the modules is limited. As a partner responsible for a number of modules, RED A.C. is supposed to interact with the regional experimental platform. According to MasAgro, RED A.C. is not required to exchange information with other partners. Nevertheless, the RED A.C. team does exchange information with Walter, a technician from INIFAP which is responsible for the module in Francisco Villa. As the coordinator of RED A.C. stated: *"Sometimes we are visiting a module of Walter. If we see something striking during this visit we will* *communicate this with him. It is also the other way around. If Walter mentions something unusual in one of our modules, he tells us to have a look there."* So, partners of MasAgro only communicate about striking observations from module visits. There is no alignment of strategies to establish well-functioning modules.

3.5 Technical assistance

3.5.1 Technical assistance for module farmers, and farmers of extension areas

The technical assistance provided by technicians from RED A.C. to module farmers is intensive and is equally divided among all five modules in terms of time, independent of distance and farmer. However, the content of the technical advice the module farmers receive differs between the modules, depending on the field conditions. As a RED A.C. technician explained: *"In modules with a steep slope we try to avoid soil erosion, while in modules located in flat areas we concentrate on different aspects since soil erosion is not a big problem there."* Modules are visited regularly, 15-20 times a year. Just before the growing season starts (March-April), module farmers are visited to talk about: (1) if the farmer is still interested in working together, (2) how the project will look like during the coming year, (3) which practices RED A.C. is planning to try in the modules, and (4) which practices the farmer agrees to apply in the module field. Afterwards, dates will be arranged for sowing, application of certain practices, module events, etc. In addition to module farmers, also farmers of extension areas are supported with technical assistance. For every module, RED A.C. has two extension areas in which they provide this service.

3.5.2 Technical assistance in the transfer of technology from modules to other farmers' fields

Information obtained through surveys, participant observations, and small talks with farmers during module events, shows that non-module farmers often perceive a lack of technical assistance after they have observed an interesting practice in one of RED A.C.'s modules. As one farmer stated during a module event: *"I took part in a workshop at a module and became interested in the technique of 'counter lines'* (a technique promoted by MasAgro to reduce erosion). *I wanted to try this in my own field, however, they didn't help me with the implementation of this technology. I didn't know how to apply it myself, so in the end I rejected this technology."* Another farmer added: *"During field day demonstrations and workshops technicians say exactly which practices we should apply in our fields in certain situations. They say apply this, practice that. After these workshops we know which practices to apply, however, we don't know how to apply them."* So, for farmers who took part in RED A.C.'s module events, there was little accompaniment in the extension of proposed practices from the modules to other farmers' fields. In some situations, this led to a loss of interest for the practice in case, and thus to a loss of potential adopters of CA practices.

Technicians from RED A.C. confirmed that many farmers who are participating in the module events would like to receive more technical help in their own fields to implement new practices. RED A.C. is doing their best to help as many farmers as possible. A technicians of RED A.C. commented: *"We are not able to assist all farmers in their own fields, simply because we lack time. For example, in such a module event generally 15 to 20 farmers will join all having different problems and questions. We can visit a couple of these farmers in their fields, but actually this is not the objective of the project."* According to MasAgro, the module farmer has to establish a connection with fellow farmers when there are practical questions. The module farmer should explain fellow farmers how they should practice particular practices or technologies. However, without receiving any compensation, it cannot be expected from module farmers to help all fellow farmers with practical problems or questions. They are farmers, not extension agents.

3.6 Input support

3.6.1 Input support to module farmers

As collaborators of RED A.C., and thus of MasAgro, farmers in charge of modules receive various inputs for making their fields available for on-farm experiments. As a RED A.C. technician mentioned: *"Basically, module farmers receive the inputs which are needed to conduct the experiments in their module plots. Seeds, fertilizers, agrochemicals, all these stuff we take with us, but just for the experimental area, not for the rest of their fields. Usually this is around half a hectare."* So the tangible inputs RED A.C. provides to module farmers are minimal, it is just a little part of all the inputs they need. As a technician explained: *"We make them clear that the goal of the project is not supporting them with inputs. It is about transferring knowledge. It is about that they are participating to learn from what we know, so they can profit from us by improving their production system."*

In addition to tangible inputs, module farmers receive an explanation about the treatments of the experiments in their fields. In this way, the farmer can recognize the effects of each practice on their maize crop. Also technical assistance while establishing their modules, can be seen as an input provided by RED A.C. Farmers are intensively supported in their production process. When a module farmer would like to extend the practices from his module plot to other fields of his farm, he also receives technical assistance for doing so.

The reason why RED A.C. provides inputs to module farmers is to facilitate the adoption process. The idea is to motivate farmers to experiment with new things, as a technician explained with a hypothetical example: *"Some farmers prefer to buy sulphate as fertilizer rather than urea, because urea is more expensive. In such a situation we buy this farmer some urea so he can see that it functions better and that it is worth the money. Afterwards he will change from buying sulphate to buying urea, even if we don't give it to him."*

In practice, module farmers only seem to receive inputs during the first few years of collaboration. As the module farmer in Francisco Villa, stated: *"During the first years I have received a lot of inputs. Afterwards they kept promising me more inputs, e.g. fertilizers, herbicides, pesticides, seeds, etc. But I didn't receive anything, just once a small 5kg sack of fertilizers."*

3.6.2 Input support to farmers of extension- and impact areas

Generally, farmers of extension areas or impact areas, or farmers visiting module events, do not receive any tangible inputs from RED A.C. They only obtain knowledge and information from the technicians. However, occasionally, when inputs are left from the module experiments, non-module farmers are provided with leftovers. As a RED A.C. technician explained: *"With small amounts of leftovers from the module trials, they can experiment in a small part of their fields, around 1/4th of a hectare. If they see that it is working they will probably try the new practice in a larger area next year, but then of course they have to buy these inputs themselves. In this way they try technologies which are within their capacity."*

3.6.3 Frailescan farmers are accustomed to input support

Frailescan farmers are used to input support when collaborating in any type of program or project. When a technician from any type of organization or project arrives at a farm, the farmers expect them to bring some inputs. As a technician of RED A.C. explained: *"They are looking for a direct benefit, personally or for their families. If they don't see a direct benefit, they are generally not willing to collaborate."* This cultural phenomenon is partly due to the government. There are different governmental programs providing subsidies to farmers, it is a very common pattern in the whole country. Subsidies to farmers or farmer's families are given in various forms, such as seeds, pesticides, credits, health insurances, education for children, etc. The poorer one is, the more subsidy one usually gets. Because farmers are expecting such inputs, it is a big challenge for RED A.C. to involve farmers in the program since they have minimal resources. RED A.C. only collaborates with farmers who are really interested in adopting new technologies, not with farmers who are only interested to receive inputs. As the manager of RED A.C. commented: *"Farmers whom are only collaborating for receiving inputs are not real adopters of new technologies. After input support is stopped, they will also stop practicing these new technologies. We are telling them that we don't have money, we only have technologies, knowledge, and information that we can share with them. We invest in 'real participation."* The manager seems to have rationale. A farmer in 24 de Febrero used to have an extension area. The first year he received two bags of fertilizer and some herbicides as he mentioned during the survey. However, afterwards he did not receive anything. Therefore he decided to stop the collaboration and he quitted the program.

3.7 Synthesis

3.7.1 The establishment of well-functioning iterative feedback mechanisms to locally adapt CA

In the Frailesca region, CA was promoted and disseminated by the establishment of a regional hub of the MasAgro program. This research showed that the regional hub in the Frailesca region, was not functioning yet as was initially intended. As stated by MasAgro itself, research at regional experimental platforms should locally adapt, meaning that issues arising from on-farm trials at the modules should be integrated in CA experiments at the platform level. MasAgro claims to use an innovation system approach. However, collaboration between MasAgro's regional experimental platform, and the local modules managed by RED A.C., was found to be limited. Responsible employees of both operational entities of the MasAgro program, only met once a year. Up to now, CA experiments at the regional experimental platform were solely designed by inputs from the top level (i.e. headquarters of MasAgro and CIMMYT). Therefore, the Frailescan experimental platform often failed to address important local issues, arising from farmers' fields.

The observation that MasAgro's regional hub in the Frailesca region was not functioning yet as was proposed, is not surprising. The MasAgro program is relatively young in the region. It was initiated in 2012. Hellin et al. (2014) argued that it will take several years before a hub-system has evolved to the extent that smooth and iterative feedback mechanisms are working effectively and efficiently. An innovation network has to be build, which includes an intensified connection between several actors, directly or indirectly linked to the program (e.g. NGOs, policymakers, seed companies, farmers, the market, technicians, network brokers, machinery producers, etc.). This requires considerable efforts of all actors involved. A well-functioning iterative feedback mechanism between the operational entities of the MasAgro program (i.e. the platform and the modules), combined with a dynamically interacting network of actors, is crucial to be able to adapt CA locally, and respond to rising threats and opportunities (Klerkx et al., 2010; Hellin et al., 2014).

3.7.2 A technology dissemination strategy with minimal resources

Frailescan farmers are used to receive inputs when collaborating in governmental extension programs (e.g. seeds, fertilizers, pesticides, credits, health insurances, education for children, etc.). Also in other extension projects across the world it is a common feature that the promotion of CA involves the supply of input packages (Giller et al., 2009; Marongwe et al., 2011; Andersson & Giller, 2012). This makes the assessment of CA difficult. In such situations, the questions rises if CA uptake by smallholders is really caused by the benefits of the promoted technologies, or if it is the effect of the additional inputs provided. Andersson & D'Souza (2014) argued that input support does not only influences the uptake of CA, but also the sustainability of such uptake. Farmers who are only collaborating to receive inputs are not real adopters of a technology.

In contrast to the majority of extension projects which are promoting CA accompanied with input support, RED A.C. provides minimal inputs to farmers taking part in the program. Module farmers only receive inputs to conduct experiments at their module fields. Non-module farmers who are interested in adopting proposed practices, generally do not receive any inputs. Without the support of inputs, it is a big challenge to convince farmers to take part in the program, or to convince farmers to experiment with new practices or technologies. However, with this strategy, only farmers will participate in the program who are really interested in a practice itself, and not in receiving inputs.

Without providing input packages, developing and diffusing complex technologies for smallholder farmers, such as CA, requires a long-term commitment. It requires more dynamic and flexible approaches to project management, research, and extension methods (Hellin et al., 2014). Despite the volatile structure within MasAgro, RED A.C. is investing in a long-term collaboration with farmers. It is not their goal to immediately increase the yield of Frailescan smallholders. They are trying to increase the efficiency (input-output ratio) of the production systems, because Frailescan farmers are facing difficulties in maintaining the profitability of their maize production systems. They also try to conserve the soils, which will increase future productivity. However, it is a very long-term process. In accordance to the strategy of RED A.C., Derpsch et al. (2015) suggests to apply long-term, adaptable approaches when conducting CA extension work among smallholder farmers.

While RED A.C. is focusing on mainly smallholder farmers to increase the efficiency of their production systems by implementing CA, MasAgro focuses on a yield increase when implementing CA. They have to reach the agreed goal to increase yields of Mexican farmers by 30%. With bigger farmers in flat areas it seems easier to reach this yield goal more quickly. Bigger farmers have a higher capacity to invest in future yield benefits, and overcome the initial years of CA which are often accompanied with a decrease in yield and farm income (Beuchelt et al., 2015). Given the fact that the farmer community in the Frailesca is very heterogeneous with respect to farm size (smallholders or medium- to large scale farmers), technology level (e.g. land races or hybrids), and production aims (commercial or home-consumption), the different strategies of RED A.C. and MasAgro can work in a complementary fashion. Medium- and large scale farmers can benefit from the approach of MasAgro, while smallholders can benefit from the approach of RED A.C.

3.7.3 The importance of in-situ consultancy when transferring CA to farmers' fields

A substantial number of Frailescan farmers mentioned to face difficulties when exploring new practices or technologies. If farmers became interested in a particular CA practice, they not always managed to implement it in their production systems. They often lacked knowledge about how to apply this practice, or about how to align it with other practices they applied. Several researches stated that implementing CA in an agricultural production system is knowledge intensive (Giller et al., 2009; Kassam et al., 2009; Derpsch et al., 2015). A substantial number of practices has to be changed, which requires the farmers to have a high intellect regarding crop and soil management (Erenstein, 2002). However, small-scale farmers often lack a deeper understanding of the CA concepts and practices (Derpsch et al., 2015). If smallholder farmers are interested in-, or willing to adopt CA practices, it seems important to provide in-situ consultancy. If not, Frailescan farmers are often not capable to implement CA in their production systems. Consequently, CA is not able to contribute to make those production systems more sustainable. Obviously, this is only important after CA turned out to be beneficial in specific circumstances. Finally, one has to be cautious to draw conclusions from farmers' statements, as farmers can provide misleading information for self-interest purposes. For example, farmers could mention to perceive a lack of technical assistance in their hope to receive more, as the MasAgro program does not charge money for such services.

Chapter 4 Empirical agronomic evidence to justify the promotion and dissemination of CA in the Frailesca region

This chapter first describes the search for scientific evidence which can justify the promotion and dissemination of CA among Frailescan farmers. Because this search failed to obtain regional empirical data from the experimental platform, an analysis was conducted which extracted results of scientific CA experiments from 18 experimental platforms across Mexico. To obtain an indication of the potential performance of CA under the agro-ecological conditions in the Frailesca region, results from the analysis of those 18 platforms were compared with literature and the environmental growing conditions of the Frailesca region.

4.1 The search for empirical scientific data on the performance of CA in the Frailesca region

Within the MasAgro program, it is the task of the regional experimental platforms to test if, and which CA practices are beneficial under which circumstances. Therefore, the initial plan was to gather all agronomic data from CA experiments which were conducted at the regional experimental platform since the start of the program. However, several issues made it impossible to obtain these experimental data. First, the regional experimental platform had changed location at the end of 2015. Yet, no data from the new platform site was available, as the experimental platform was just starting its CA experiments. Second, with the change of the location of the platform, also the manager of the platform changed. Experimental data collected from the CA experiments between 2013 and 2015 was saved by an employee of MasAgro. Unfortunately, his computer crashed and he was not able to provide the collected data.

The only available information with respect to the CA experiments conducted between 2013 and 2015, was the experimental design. Analysis of these experimental designs showed that CA experiments were not properly designed to draw reliable conclusions about the performance of certain CA practices. CA experiments conducted at the old platform site were not consistent. For example, treatments in particular parts of the platform site substantially differed between subsequent years. These are serious issues since agronomic effects of CA tend to appear over time.

4.2 Agronomic performance of CA at different experimental platforms of MasAgro

CA experiments at 18 experimental platforms, randomly spread across Mexico, were analyzed to extract the agronomic performance of certain CA practices under specific agro-ecological conditions. All experiments were conducted during the spring growing season of 2015. Data was obtained from CIMMYT (Verhulst et al., 2015).

From the 18 platforms included in this analysis, 14 were under rain-fed conditions (Table 4.1). In the spring season of 2015, CA practices did not have any effect on maize yield at irrigated platforms (Table 4.2). At platforms under rain-fed conditions however, CA practices were found to have a positive influence on yield in some cases: in 31% of cases for minimum- or zero tillage, and in 25% of cases for both residue retention and crop rotation. No negative correlations between practices were found, only when zero tillage was accompanied with the removal of crop residues.

Table 4.1 Outstanding results of MasAgro's experimental platforms in the production cycle of spring 2015. Data was extracted from experiments described in Verhulst et al., 2015. Yield effects of CA were only labeled positive (↑) or negative (↓) if results were statistically significant.

Platform characteristics					***CA variables included in experiment***			***Yield effects CA principles***			***Additional experimental variable(s)***		
Name	**State**	**Water manag.**	**Year of initiation**	**Altitude (m)**	**ZT or MT**	**RR**	**CD**	**ZT or MT**	**RR**	**CD**	**Variable(s)**	**Yield effect**	***Comments***
Villaflores	Chiapas	Rain-fed	2012	557	X	X	X	N.A.	N.A.	N.A.	Hybrids	↑	Resistance research
Comitán	Chiapas	Rain-fed	2014	1,558	√	√	√	?	---	?	Plant density	---	TM includes beds[3]
Tamazulapam del	Oaxaca	Rain-fed	2014	1,913	√	√	√	↑	↑	?	Fertilization	---	
San Juan Cotz.	Oaxaca	Rain-fed	2014	123	√	√	√	?	---	---	Fertilization	↑	TM includes beds
Santo Dom. Yan.	Oaxaca	Rain-fed	2012	2,138	√	√	√	↑	↑	---	Hybrids	↑	
Tlaltizapán	Morelos	Rain-fed	2011	940	√	X	√	↑	N.A.	---	-	N.A.	
Zacatepec	Morelos	Rain-fed	2012	917	√	√	√	?	---	?	Plant density	↑	CT not included
Molcaxac	Puebla	Rain-fed	2011	1,830	√	√	√	?	?	↑	Hybrids	---	MT+RR = ↑
Metepec	México	Rain-fed	2014	2,640	√	√	√	---	---	---	-	N.A.	
Texcoco I	México	Rain-fed	1991	2,240	√	√	√	↑	↑	↑	-	N.A.	ZT+Rr = ↓
Francisco I. Mad.	Hidalgo	Irrigation	2011	1,998	√	√	√	---	---	?	-		NR not included
Nopala de Vil.	Hidalgo	Rain-fed	2014	2,324	√	√	√	?	?	?	Hybrids	↑	TM includes beds
Texcoco II	México	Rain-fed	1999	2,240	√	√	X	---	---	N.A.	-	N.A.	TM includes beds
Epitacio Huerta	Michoacán	Rain-fed	2014	2,356	√	√	√	?	?	?	-	N.A.	TM includes beds
San Juan del Río I	Querétaro	Rain-fed	2013	1,972	√	√	√	?	?	↑	-	N.A.	TM includes beds
Soledad de Grac.	San Luis P.	Irrigation	1995	1,835	√	√	X	?	---	N.A.	Perman. beds	↑	TM includes beds
Pabellón de Art.	Aguascal.	Irrigation	2011	1,918	√	√	X	---	---	N.A.	-	N.A.	
Ahome	Sinaloa	Irrigation	2014	15	√	X	X	---	N.A.	N.A.	-	N.A.	TM includes beds

ZT=Zero Tillage, MT=Minimum Tillage, RR=Residue Retention, CD=Crop Diversification, TM=Tillage management, CT=Conventional Tillage, Rr=Residue removal, NR=No Rotation, N.A.=Not Applicable. Symbols for the effect on yield are defined as follows: --- =no effect demonstrated, ↑=positive effect, ↓=negative effect, **?**=effect of a particular variable was unclear due to too much confounding with other variables. So the set-up of the experiment did not allow to extract the effect of a particular variable.

Table 4.2 Yield effects of CA principles under rain-fed and irrigated conditions.

CA principle & effect on yield	Platform conditions	
	Rain-fed	*Irrigation*
Minimum- or zero tillage	n=13	n=4
--- : no effect	15%	75%
↑ : increase	31%	0%
↓ : decrease	0%	0%
? : no clear effect	54%	25%
Residue retention	n=12	n=3
--- : no effect	42%	100%
↑ : increase	25%	0%
↓ : decrease	0%	0%
? : no clear effect	33%	0%
Crop rotation	n=12	n=1
--- : no effect	33%	0%
↑ : increase	25%	0%
↓ : decrease	0%	0%
? : no clear effect	42%	100%

Thirteen out of 14 platforms under rain-fed conditions applied minimum- or zero tillage in their experiments during spring season of 2015. In some experiments, tillage management included beds. Beds were used in combination with zero tillage (permanent beds), and they were used in combination with conventional tillage or minimum tillage (not permanent). It is another technology promoted by MasAgro to hold more rainfall, prevent run-off, and promote water infiltration. In 15% of these cases, no yield differences were found between treatments with minimum- or zero tillage and conventional tillage. In 31% of those experiments, minimum- or zero tillage had a positive effect on yield compared to conventional tillage. In 54% of cases, the design of the experiment did not allow to extract results regarding the effect of minimum- or zero tillage on yield.

From platforms under rain-fed conditions, 86% had tested the effect of residue retention. In 42% of those experiments, residue retention did not have an effect on maize yield. However, 25% of the platforms showed an increase in maize yield when retaining crop residues of the previous crop. In 33% of the experiments testing residue retention under rain-fed conditions, the effect of residue was not clear.

Two platform experiments, at Molcaxac and at Texcoco I, showed an interaction between the practices of minimum- or zero tillage and residue retention. In the experiment conducted at the platform of Molcaxac, the effect on yield of minimum tillage or residue retention as separate practices was unclear. However, when minimum tillage and residue retention were combined, maize yield did increase. The experiment conducted at the platform of Texcoco I, also showed that zero tillage in combination with residue retention resulted in increased yields. But when zero tillage was combined with residue removal, a yield penalty was observed. So, minimum- or zero tillage can have opposite effects when it is not accompanied with enough soil cover from previous crops.

In the Frailesca region, technicians of RED A.C., as well as the majority of farmers, were convinced that retaining crop residues in the field is beneficial regarding soil conservation or soil productivity, especially from the longer-term perspective. The more residues are retained, the higher the benefits would be, as many of them believed. One RED A.C. technician mentioned:

> *"I know a farmer with a flat terrain who retains 100% of his crop residues for more than 20 years now. So he also experimented with this practice during the ultimate years which were very dry. His crops were looking much better than the crops of his neighbors who didn't retain their crop residues. In contrast to his neighbors, he didn't have any problems in his crop during those relatively dry years."*

The module farmer in Francisco Villa, added: *"I have a field of around three hectares in which I am retaining all of my crop residues for the last three years now. I obtained very nice results. Yield has increased by around 2 to 2.5 tons per hectare since I am applying this practice."* Despite farmers and RED A.C. technicians were convinced about the benefits of residue retention on soil fertility and reducing soil erosion, no empirical data from the regional experimental platform existed yet to prove those believes.

From platforms under rain-fed conditions, 86% had tested the effect of crop rotation. From those experiments, 33% did not show an effect of crop rotation on maize yield. In 25% of the cases, crop rotation did result in elevated maize yields. At the platform of Molcaxac for example; In treatments where maize was grown after beans, the yield was twice as high as in treatments in which maize was followed by another cycle of maize. 42% of the experiments did not show a clear effect of crop rotation, mainly because of poorly designed experiments.

In many experiments (indicated with an '**?**' in table 3.1), the experimental design did not allow to distill the results of a particular CA principle. For example in the platform of Molcaxac (Puebla), the effect of tillage and residue retention was confounded; there was a treatment with conventional tillage + the removal of residues, and a treatment with minimum tillage + the retention of residues. The first treatment obtained a yield of 806 kg/ha, compared to a yield of 1125 kg/ha obtained by the second treatment. This result shows that the combination of these two CA practices (minimum tillage + residue retention) results in a higher yield compared to conventional practices (conventional tillage + residue removal). However, with these results it cannot be concluded if the higher yield can be explained by applying minimum tillage instead of conventional tillage, or by applying residue retention instead of residue removal. In addition, some experiments did not have a control treatment, which made it impossible extract conclusions regarding particular CA practices.

4.3 Synthesis

This research showed that empirical agronomic evidence to justify the promotion and dissemination of CA in the Frailesca region is poor. Yet, the CA experiments at the new platform site were just initiated, and thus were not able to provide empirical data about the agronomic effects of CA at the local level. In addition, also the old platform was not able to provide this empirical data. First, data was lost, and second, CA experiments at the old platform site were not designed consistently over experimental years.

Despite the fact that poor scientific evidence is available directly from the experimental platform of the Frailesca region, CA seems to have the potential to provide agronomic benefits in the agro-ecological conditions of the Frailesca region. Literature, and the analysis of CA experiments at 18 experimental platforms of MasAgro across Mexico, have indicated this. The analysis of the 18 experimental platforms across Mexico found that positive yield responses were only observed in platforms without irrigation, so under rain-fed conditions. Literature stated that short-term yield benefits of CA are often caused by an increased availability of soil water in water-limited conditions (Franzluebbers, 2002; Lampurlanés & Cantero-Martínez, 2006; Giller et al., 2009; Corbeels et al., 2011; Ling-ling et al., 2011). All surveyed Frailescan farmers produced under rain-fed conditions, and towards the end of the growing season, water is lacking in Frailescan production systems. Therefore, CA is expected to provide potential yield benefits for Frailescan farmers, possibly also on the short-term.

The analysis of the 18 experimental platforms across Mexico also showed that if no-tillage is accompanied with a substantial removal of crop residues, yield penalties are likely to occur. This was the case at the platform of Texcoco I. So while the combination of no- or reduced tillage with residue retention leads to higher precipitation infiltration (Huang et al., 2008), and thus to yield benefits in relatively dry environments, practicing no-tillage in the absence of a sufficient soil cover results in the opposite effect (Tadesse et al., 1996; Ling-ling et al., 2011).

However, one has to be cautious when drawing conclusions from the above results. Effects of CA can differ substantially between sites and seasons. It is extremely difficult to predict the effects of CA practices in specific agro-ecological conditions, as interactions between different CA practices are not always understood. Thereby, the effects of CA practices are also influenced by other farm practices, such as nitrogen application (Rusinamhodzi et al., 2011, Pittelkow et al., 2015; Giller et al., 2015). Another reason to be cautious with respect to the results obtained through the analysis of the 18 platforms, is the fact that this analysis was based on only one experimental growing cycle: that of spring 2015. No data was available regarding experiments which were conducted previously at theses platform sites. Thus, it is unclear for how long, and which CA practices have preceded the CA experiments of spring 2015. This information is crucial as productive benefits of CA tend to accumulate over time (Erenstein, 2002). Additionally, short-term yield effects of CA are highly variable. No yield benefits, or even yield penalties, are just as likely as yield benefits. For the longer term, however, yield responses to CA tend to be neutral to positive (Giller et al., 2009; Mkoga et al., 2010; Corbeels et al., 2011; Rusinamhodzi et al., 2011; Mupangwa et al., 2012; Thierfelder & Wall, 2012; Thierfelder et al., 2013a)

Chapter 5 Agro-ecological and socio-economic adoption constraints of Frailescan farmers with respect to CA

In this chapter, first the surveyed farmers (n=30) were characterized according to the farmer groups; (1) cattle farmers in hilly areas, (2) farmers without cattle in hilly areas, (3) cattle farmers in flat areas, and (4) farmers without cattle in flat areas. Categorization of farmer groups was explained in section 2.4 of the methods. After farmers have been characterized per group, practices, and frequency of these practices will be described focusing on CA practices. In addition, farmers' reasons to apply or to not apply particular CA practices are revealed and discussed. Finally, the adoption of CA by Frailescan farmers was classified according to the classification of Brown et al. 2017. Only descriptive statistics were used. First, the sample size was relatively small and unequally divided among farmer groups. Second, this research aimed to explore Frailescan farmers' adoption constraints in relation to CA for each type of farmer, rather than testing hypotheses on differences between groups. It serves as a first indication to examine which CA practices have the potential to contribute to the sustainability of which type of production systems, and which not. Some tables only show numbers of two groups instead of four. If so, results of groups which were not shown was similar, and data was aggregated.

5.1 Farmer Characterization

Farmers had an education level of primary school (53%), secondary school (17%), or no education at all (30%). All of the surveyed farmers were producing maize under rain-fed conditions. Last year, farmers sowed their maize crop between 27 May and 25 July. Harvest took place in December and January. Of surveyed farmers, 67% owned cattle. Those farmers were considered to have mixed crop-livestock production systems. A striking fact is that farmers with cattle have substantial larger farmers, both in flat areas and in hilly areas. Mixed crop-livestock farmers not only have larger pasture areas, also cultivation area, and cultivation area with maize was much larger. Probably, farmers with mixed crop-livestock production systems are richer.

In the Frailesca region, the number of farmers having mixed crop-livestock production systems has increased rapidly during last decade. This is due to several reasons. A technician from RED A.C. explained: *"Livestock activities are much more profitable than growing maize nowadays. For not conserving their natural resources, especially the soil, their agricultural production decreased per unit of area. Thereby, the price of maize is very low at the moment while inputs such as fertilizers, pesticides, and seeds increased for around 200% during last 5-10 years."* In addition, the price of milk and meat was relatively good during last years, as the technician further explained. During the surveys, many mixed crop-livestock farmers mentioned that their cattle is economically much more important than their crops. Another technician from RED A.C. added: *"Having cattle started as a second activity, a diversification strategy for a lot of farmers in small villages to obtain milk and meat, and in times of crisis they could sell them, so they serve as a kind of saving account. But nowadays this activity is much more commercial. Cattle farming has arrived here as a new strategy for the farmers to still be productive with degraded soils."*

Also farmers without cattle sometimes dedicate farmland to pasture area. On average, farmers without cattle in hilly areas and farmers in flat areas without cattle dedicate 0.7 and 5.8 ha to pasture area, respectively. Information obtained through surveys revealed that farmers without cattle sell grazing rights to obtain additional incomes. Usually, areas of the farm with low production potentials are turned into pasture land (e.g. areas with low soil fertility, areas which are practically difficult to cultivate, and areas with high disease incidence).

Table 5.1. General characteristics of Frailescan farmers per group, and overall.

Characteristics		Averages per farmer group				Overall averages
		Hilly areas (n=15)		Flat areas (n=15)		
		Cattle n=9	No cattle n=6	Cattle n=11	No cattle n=4	**n=30**
Farmer	Age (year)	62.8	49.3	62.1	50.0	**58.1**
	Time of cultivating maize (years)	37.8	26.3	43.5	25.5	**36.0**
Farm size	Cultivated area (ha)	7.1	2.7	11.9	3.0	**7.4**
	Cultivated area with maize (ha)	6.7	2.3	11.1	2.5	**6.9**
	Pasture area (ha)	23.3	0.7	10.0	5.8	**11.6**
	Total farm size (ha)	30.4	3.4	21.9	8.8	**25.9**
Cattle (density)[1]	Total number of cattle (heads)	25.1	N.A.	17.8	N.A.	**21.1**
	Cattle per cultivated area (heads/ha)	5.3	N.A.	3.1	N.A.	**4.1**
	Cattle per pasture area (heads/ha)	1.9	N.A.	2.3	N.A.	**2.1**
Sowing	Manual	100%	100	82%	50%	**87%**
	Mechanized	0%	0%	18%	50%	**13%**
Variety use	Landrace	11%	17%	9%[1]	0%	**10%**
	Hybrid + landrace	89%	83%	100%[1]	100%	**93%**
Yield (destiny)	Average yield 2010-2016 (ton/ha)	3.9	4.0	4.0	4.7	**4.3**
	Home-consumption (% farmers)	11%	0%	9%	0%	**7%**
	Home- consumption + commercial production (% farmers)	89%	100%	91%	100%	**93%**

Overall, 87% of the farmers sowed manually. In hilly areas, 100% sows manually because no machinery can enter the steep fields. From surveyed farmers, 10% sows only landraces. The majority (90%), sows hybrids in combination with landraces. Hybrids are generally grown for commercial purposes, or served as cattle feed. Landraces are mainly used for home-consumption. Farmers who produced for commercial purposes, still sow small patches of landraces for home-consumption. One farmer stated: *"Hybrids don't have any taste, none of them. In contrast, landraces do have taste."* Landraces have a variety of colors, i.e. from white and yellow to red and black. Landraces and hybrids with a yellow color are generally used to feed animals, while other colors are used for human consumption.

Just 7% of the farmers grows maize only for home-consumption. These are farmers with only one or at maximum two hectares of maize, producing approximately 2-3 tons/ha. The majority of farmers (93%) produces for both purposes, home-consumption as well as commercial production. The average yield of all groups together during last six years was 4.3 tons/ha, ranging from 3.9 tons/ha in hilly areas with cattle till 4.7 tons/ha in flat areas without cattle.

All farmers use two applications of chemical fertilizers: the first application applied between 10-20 days after sowing and the second application applied between 35-45 days after sowing. Also herbicides and pesticides are used by all surveyed farmers. Herbicides are generally used to clean the land before sowing.

Appendix III shows the maize yields between 2010 and 2017 per farmer group. No clear relation was identified between farmer groups and yield.

5.2 Adoption of CA practices among Frailescan farmers, and their reasons to apply or to not apply CA practices

This section describes which practices Frailescan farmers are applying with respect to CA, i.e. how often and which tillage practices they apply (tillage management), which part of the crop residues they retain in the field after harvest (crop residue management), and if/how they apply crop diversification (rotational management). Additionally, farmers' reasons to apply or to not apply certain (CA) practices are revealed.

5.2.1 Tillage management

Zero tillage

In total, 77% of surveyed farmers applied zero tillage (Table 5.2). In hilly areas, all farmers practiced zero tillage, simply because no machinery could enter their steep parcels (Table 5.3). So for these farmers, the agrological environment has forced them to adopt zero tillage. Reasons of farmers with- and farmers without cattle were aggregated, as reasons to apply a certain form of tillage management were similar for both groups. From farmers in flat areas, 75% of farmers without cattle and 45% of farmers with cattle did not till the soil before sowing. Reasons for farmers in flat areas to apply zero tillage were preventing soil erosion (33%), improve soil quality (13%), and retain soil humidity (7%).

Table 5.2 Frequency of different tillage managements per type of farmer in the Frailesca region.

	% of respondents				
	Hilly areas (n=15)		Flat areas (n=15)		**Overall**
	Cattle	No cattle	Cattle	No cattle	
Tillage management	n=9	n=6	n=11	n=4	**n=30**
Zero tillage	100	100	45	75	**77**
Minimum tillage	0	0	45	25	**20**
Conventional tillage	0	0	9	0	**3**

Minimum tillage

By MasAgro, minimum tillage is defined as the application of one or at maximum two tillage applications to a depth of 15-20 cm. Usually a disk harrow was used (Box G). From surveyed farmers, 20% was applying minimum tillage before sowing (Table 5.2). These were all farmers in flat areas. Farmers gave various reasons for applying minimum- or reduced tillage (Table 5.3). Some farmers (13%) perceived economic benefits by moving from conventional tillage towards minimum tillage. Most farmers in the region don't have tillage machinery themselves and have to rent the equipment from other farmers, which makes it cost full to apply tillage practices. Minimum tillage involves less tillage practices than conventional tillage, reducing production costs. Zero tillage was not an option for most farmers who applied minimum tillage, since

Box G. A disk harrow

Minimum tillage includes at maximum two tillage applications with a disk harrow. Tilling the soil with a disk harrow shatters the main soil clods in the upper layer of the soil (10-15 cm). In addition, it cuts the crop residues at the soil surface.

soil compaction was a frequent problem among these farmers. When the soil is tilled by using a disk harrow, the upper layer of the soil is loosened. Some farmers referred to this as the 'soil is softer for sowing.' A number of farmers mentioned to perceive an increase in soil compaction when cattle was introduced in the field. Consequently, in flat areas, farmers with cattle more often tilled the soil than farmers without cattle 45% and 25% respectively.

Table 5.3 Reasons of Frailescan farmers to apply a certain form of tillage management, compared between farmers in hilly- and farmers in flat areas.

		% of respondents		
Tillage practice	**Reason**	Hilly areas n=15	Flat areas n=15	**Overall n=30**
Zero tillage	Impossible to enter the field with machinery	100	0	**50**
	Prevent soil erosion	0	33	**17**
	Improve soil quality	0	13	**7**
	Retain soil humidity	0	7	**3**
Minimum tillage	Economic benefits	0	13	**7**
	Soil is softer for sowing	0	13	**7**
	Easier to incorporate residues	0	7	**3**
	Prevent soil erosion	0	7	**3**
	Sorghum needs a pass with a disk harrow	0	7	**3**
Conventional tillage	Disk harrow + conventional plough gives higher yield	0	7	**3**

Conventional tillage

There was only one farmer practicing conventional tillage. He tilled the soil using twice a disk harrow. Additionally, he tilled the soil with a conventional plough (Box H). This farmer had cattle and was located in a flat area. *"Tilling the soil twice with a disk harrow and one with a conventional plough gives a higher yield, at least on the short term,"* as he stated. In addition, he mentioned to prefer high yields on the short-term above a yield increase in the long-term. His main concerns were to provide enough food for his family and to feed his animals.

Box H. A conventional plough

Conventional tillage includes at least one application with a plough which loosens the soil to a depth of 25-40 cm.

5.2.2 Crop residue management

Residue retention

All surveyed farmers retained at least a part of the maize plant in the field after harvest. The majority (70%), only retained a small part of the aboveground stalk, and the roots (Table 5.4). These are the plant parts not eaten by cattle. The most important reason to not retain all crop residues in the field, was the trade-off between different purposes to use crop residues, as there were generally not enough crop residues available to fulfill all purposes. Reasons of Frailescan farmers to apply certain forms of crop residue management were similar between farmers in hilly areas and farmers in flat areas. Therefore, these results were aggregated. Between farmers with- and farmers without cattle, differences appeared. From farmers with cattle, 90% prioritized to feed crop residues to their cattle (Table 5.5). When they preferred to do so, cattle was introduced in the field to eat the residues of the previous crop. In literature this practice is often referred to as 'in-situ grazing'. A technician of RED A.C. explained: *"During the dry period, when there is a lack of pasture, crop residues need to feed the cattle. This is approximately five months. Especially towards the end of the dry season when almost no pasture is left, trade-offs between different residue purposes appear."* When in-situ grazing was applied, cattle was usually allowed to fully graze the maize residues. Cattle was removed from the field after only residues were left which were not eaten by the animals: a small part of the aboveground stalk, and the roots.

Table 5.4. Frequency of practices applied by Frailescan farmers with respect to the management of crop residues.

	% of respondents				
	Hilly areas (n=15)		Flat areas (n=15)		**Overall**
Residue retention practices	Cattle n=9	No cattle n=6	Cattle n=11	No cattle n=4	**n=30**
Burning residues	0	0	0	0	**0**
Retention of small part of aboveground stalk[1]	78	67	73	50	**70**
100% retention	22	33	27	50	**30**

[1] Farmers who retained a small part of the aboveground stalk of the maize plant, retained the parts that were not eaten by cattle after in-situ grazing.

Many Frailescan farmers did perceive benefits of residue retention: increase of soil fertility (60%), reduction of soil erosion (50%), and retaining soil humidity (20%). However, for the majority of mixed crop-livestock farmers, indirect agronomic benefits did not outweigh the need to feed their cattle. During the survey, many farmers mentioned to consider their cattle more valuable than their maize production, simply because they obtained more income with it. So, residues are expendable when farmers lack pasture to feed their cattle during the dry period, especially towards the end.

Also farmers without cattle were influenced by the importance of maize to serve as cattle feed. From farmers without cattle, 40% preferred to sell their crop residues to neighbor farmers. If farmers sell their crop residues to another farmer, they actually sell grazing rights. After harvest, the livestock of the farmer who bought the grazing rights enters the field to graze the crop residues. With this practice, farmers without cattle were able to obtain an extra direct income from their crop, while the farmer with cattle obtains some extra feed for his animals during periods when land for pasture is scarce. So, also for 40% of farmers without cattle, indirect agronomic benefits did not outweigh direct incomes from selling crop residues.

The minority of Frailescan farmers (30%), retained the whole maize plant in the field after harvest, except the grains. Farmers without cattle more often retained 100% of their residues as compared to farmers with cattle, 40% and 25% respectively. Farmers who retained 100% of their crop residues in the field after harvest mentioned to do this to reduce soil erosion (23%), increase soil fertility (to increase future yields) (20%), retain soil humidity (7%), and reduce input costs (3%). The reason to reduce input costs is strongly related to the reason of increasing soil fertility, as input costs can be reduced when less fertilizers are needed. When soil fertility is higher, less fertilizers have to be applied to obtain similar yields.

Table 5.5. Reasons of Frailescan farmers to apply certain practices regarding the management of their maize residues after harvest.

Residue Retention practice	**Reason**	% of respondents Cattle n=20	 No cattle n=10	 **Overall n=30**
Retention roots and small part of the aboveground maize stalk	**Why retention of roots and small part of the maize stalk?**			
	Increase soil fertility	40	40	**40**
	Reduce soil erosion	20	40	**27**
	Retain soil humidity	20	0	**13**
	Why not 100% retention?			
	Use residues to feed cattle (part)	90	N.A.	**60**
	Sell crop residues (grazing rights)	5	40	**17**
	Problems with sowing next crop	10	20	**13**
100% retention	**Why retention?**			
	Reduce soil erosion	15	40	**23**
	Increase soil fertility	15	30	**20**
	Retain soil humidity	10	0	**7**
	Reduce input costs	0	10	**3**

Some farmers (13%) mentioned to perceive problems with sowing the next crop, if 100% of crop residues was retained in the field after harvest. As one of the farmers explained: *"It is a lot more work to sow the next crop. It is easier to clean the field when I retain less residues.* With 'cleaning the parcel', the farmer refers to the practice to prepare the seedbed. The land has to be 'clean' before sowing. A technician from RED A.C. commented: *"If they don't introduce cattle in the field after harvest, so if they retain 100% of their crop residues, they have to enter the field with a so-called 'chapeador' (a tool like a machete). With the chapeador they have to cut the stalk of the maize, which is a lot of work."* So, these farmers faced practical constraints with respect to the practice of residue retention.

5.2.3 Rotational management

No crop diversification; pure maize

Half of Frailescan farmers does not diversify with crop species, they only sow maize (Table 5.6). All farmers do sow alternative crops for home-consumption, however, when this is practiced on small parts of their land, it was not considered as crop diversification (i.e. intercropping or crop rotation).

Table 5.6 Frequency of different rotational managements among Frailescan farmers.

	% of respondents				
	Hilly areas (n=15)		Flat areas (n=15)		**Overall**
Rotational management	Cattle n=9	No cattle n=6	Cattle n=11	No cattle n=4	**n=30**
No diversification	67	33	45	50	**50**
Intercropping	22	67	45	50	**43**
Crop rotation	11	0	45	0	**20**
Total	100	100	135	100	**113**

[1]The cumulative overall percentage of no rotation, intercropping, and crop rotation is more than 100%. Also the total percentage for farmers with cattle located in flat areas is more than 100%. This is because some farmers apply intercropping as well as crop rotation.

Farmers had various reasons for not sowing alternative crops, neither intercropped nor in rotation (Table 5.7). Reasons of farmers in hilly- and farmers in flat areas were similar, and therefore aggregated. For farmers without cattle, most important reasons were: the absence of a (stable) market to sell alternative crops (50%), and the possession of a very small terrain (50%). Most important reasons for farmers with cattle were: not interested in other crops (27%), sowing other crops is a lot of work (27%), and no confidence in other crops (27%). One farmer mentioned not to know how to sow other crops.

Table 5.7 Reasons of Frailescan farmers for not applying crop diversification.

	% of respondents		
Reason for not applying crop diversification	Cattle n=11	No cattle n=4	**Overall** n=15
Not interested in alternative crops	27	25	**27**
No market (stable) available	18	50	**27**
A lot of work to sow alternative crops	27	0	**20**
No confidence in other crops	27	0	**20**
Terrain is very small; need for maize	9	50	**20**
Don't know how to sow other crops	9	0	**7**

In the Frailesca region, the market for alternative crops is very instable. Thereby, it turned out to be difficult for farmers to find a purpose for alternative crops. One farmer stated: *"Technicians and engineers say: sow papaya, sow mango, sow lemon, sow other alternative crops different from maize. It is a nice idea to sow a wide variety, including fruits etc. But where and how do we have to sell these crops?* People from MasAgro and technicians from RED A.C. confirmed that the market for alternative crops is poor in the region. Besides maize, beans are the only crops which can be sold on a regular base. Like maize, beans are a principle part of the Frailescan diet. However, the market for beans is not as commercialized as the market for maize. Usually, beans are only sold to neighbor farmers, relatives, or acquaintances within the same village. It is not sold to traders and or processors, as in the case of maize. In the absence of a stable market, especially farmers without cattle faced difficulties in finding purposes for alternative crops, as they cannot use those crops to feed cattle.

Due to cultural reasons, farmers with small farms (i.e. one or two hectares) are not willing to implement crop rotation in their production systems. A RED A.C. technician explained:

> *"Farmers want to sow a certain area of maize for home-consumption, since maize is the principal food in their diets. They use it for making tortilla and Pozol for example. When you do an economic analysis you will find that growing maize is not very profitable compared to other crops. However, our diets contain a lot of maize, and the diets of the farmers even more. They say that when a farmer is having maize and beans he doesn't have to worry about his family for food. So farmers are not willing to abandon maize."*

So, small farmers are unlikely to ever adopt crop rotation. Maize is deeply woven in the Mexican culture, and farmers are not willing to move a away from growing maize for home-consumption. Mainly farmers without cattle mentioned to not apply crop rotation because their terrain was too small. As mentioned in section 5.1, farmers without cattle have generally smaller farms, both in terms of pasture- and in terms of cultivated area.

Some farmers did not to know how to sow alternative crops. A technician from RED A.C. stated: *"Some farmers did not learn from their parents to sow other crops than maize, it is difficult for them to apply practices they don't know how to practice*." So, due to a lack of knowledge, these farmers are not capable to integrate crop diversification in their production systems.

A number of farmers stated to have no confidence in alternative crops. Mainly agronomic aspects were mentioned. They feared the number of pests and diseases when growing alternative crops. Especially in the case of beans and sorghum. Some farmers perceived sorghum as a crop which is very intensive for the soil. Usually, farmers perceived crop yields of alternative crops to be lower than yields of maize. This is probably due to the fact that the incidence of pests and diseases are related to yield.

Results were discussed with the technicians of RED A.C. One technician mentioned a reason for not applying crop rotation which was not mentioned by surveyed farmers: *"Farmers with land in both lower and higher areas, found a way to always be secure of maize and beans. Generally, beans are sown in the higher areas, because in lower areas the risk for diseases is higher during the wet season." So,* farmers having both lower and higher fields, normally sow the same crop in the same field year after year, which cannot be considered as crop diversification. Crop diversification includes the cultivation of at least two different crops at the same location.

Intercropping

Intercropping is a common practice in the Frailesca region, it was practiced by 43% of surveyed farmers (Table 5.6). It is defined as the simultaneous cultivation of multiple crops species in a single field. Frailescan farmers who apply intercropping, sow maize between the end of May and the begin of July. The second crop (e.g. pumpkin, beans, or canavalia) is usually sown around half August. When the second crop is sown, farmers double their maize plants by middling the maize stalk right above the maize cop. In this way, more light penetrates through the canopy of maize leaves and reaches the seedlings of the second crop. A technician from RED A.C. explained: *"If they would sow the second crop later, there would be less competition between the maize and the second crop. However, when doing so, they are not sure of being able to harvest the second crop because there is* *very little rain at the end of the growing season. Without enough water the crop is not able to produce grains, and thus they will lose the crop."* So it is a big risk for farmers to sow the second crop later in the season. Most farmers were not willing to take this risk.

Farmers who applied intercropping (n=13) were asked why they practiced this form of crop diversification. From those farmers, 69% stated to obtain economic benefits from intercropping maize with pumpkin, beans, or canavalia (Table 5.8). This included 100% of farmers without cattle and 43% of farmers with cattle. Reasons of farmers in hilly- and farmers in flat areas were similar, and therefore aggregated. By intercropping, farmers can obtain two different yields in just one growing cycle, even in small fields. Two yields at separate times of the year not only increases their total income, it also spreads their income more equally throughout the season.

From farmers with cattle, 86% mentioned to apply intercropping to obtain additional cattle feed. Pumpkin and canavalia were used for this purpose. Another reason for Frailescan farmers to apply intercropping, is to obtain an additional source of food for home-consumption (31%), generally beans. Next to maize, also beans are a principal food in the region. Some farmers applied intercropping to improve the quality of the soil (15%).

Most farmers who were sowing alternative crops preferred intercropping over crop rotation. These farmers were asked why they did not apply crop rotation (Table 5.11). Most important reasons for farmers without cattle were: no (stable) market available (83%), terrain is very small; they need a certain area of maize for home-consumption (50%), and no confidence in other crops (33%). Farmers who intercropped and possessed cattle stated to not apply crop rotation because there is no (stable) market available (14%), they have no confidence in other crops (14%), and they are not interested in sowing other crops (14%).

Table 5.8 Reasons of Frailescan farmers to practice intercropping, and their reasons to not apply crop rotation.

	% of respondents		
	Cattle	No cattle	**Overall**
Reason	n=7	n=6	n=13
Why intercropping?			
Economic reasons	43	100	**69**
Cattle feed	86	N.A.	**46**
Home-consumption	29	33	**31**
Improve soil quality	14	17	**15**
Why no crop rotation?[1]			
No market (stable) available	14	83	**46**
No confidence in other crops	14	33	**23**
Terrain is very small; needs maize	0	50	**23**
Not interested in other crops	14	0	**8**

[1] From farmers with cattle, four out of seven farmers practicing intercropping were also practicing crop rotation, so the question 'why no crop rotation' was not relevant for them. Therefore, the cumulative percentage of why cattle farmers do not apply crop rotation, does not reach 100%.

The crop species used for intercropping in between the maize were pumpkin (85%), beans (38%), and canavalia (15%) (Table 5.9). These crops had different purposes (Table 5.10) (Box I). In the case of pumpkin, 82% of Frailescan farmers used the pulp to feed their cattle (82%). Recently, Frailescan farmers also started to sell the main part of their pumpkin-seeds, as the price of pumpkin-seeds was relatively high last years. At the moment, Some farmers (9%), also used the pulp of the pumpkin for home-consumption, or for soil nutrition (9%).

Table 5.9 Crops used for intercropping in the Frailesca region.

Crop used for intercropping	% of respondents		
	Cattle n=7	No cattle n=6	**Overall** n=13
Pumpkin	71	100	85
Beans	43	33	38
Canavalia	29	0	15

Table 5.10 Purpose of alternative crops used for intercropping with maize.

Crop species used for intercropping	**% of respondents**				
	Home-consumption	Sell seeds	Sell crop	Cattle feed	Soil nutrition
Pumpkin	9	100	0	82	9
Beans	100	0	40	0	0
Canavalia	0	0	0	50	50

Box I. Maize intercropped with pumpkin at a module plot in the Frailesca region (left), Canavalia (Canavalia ensiformis L.) grown at the regional experimental platform of the Frailesca region (right).

Farmers who intercropped with beans, all used them in the first place for home-consumption. From those farmers, 40% sold the surplus of their bean production. A striking finding is the fact that none of the surveyed farmers mentioned to intercrop beans to increase soil fertility, as N-fixation is a well-known effect of legumes such as beans. Technicians from RED A.C. and people from MasAgro were familiar with this agronomic benefit. However, farmers seemed to lack this knowledge. Farmers who intercropped with canavalia, were all farmers having cattle. Half of those farmers used canavalia to feed their cattle, and half of them used canavalia as green manure.

Crop rotation

From surveyed farmers in the Frailesca region, 20% was practicing crop rotation (Table 5.6). All of them were farmers who owned cattle. By MasAgro, crop rotations is defined as *"The successive sowing of different crops in the same field in a definite order."* For example, maize-beans-sunflower or maize-oat.

From farmers who applied crop rotation, 83% mentioned to use the crop in rotation with maize for feeding cattle (Table 5.11). Other important reasons of Frailescan farmers to rotate crops were conservation of the soil (50%), improve the soil quality (50%), sell the rotational crop (33%), and increase productivity (17%). From the six farmers applying crop rotation, five used a maize-sorghum rotation. One used a rotation with maize and beans. A technician from RED A.C. stated: *"Some farmers also have rotated with pumpkin this year. Because the seed of the pumpkin had a high price. There was a project which offered a package to work with pumpkin and leave from maize production. It is not a fixed market, but last years, the price was very good and the project assured farmers to obtain a fixed price per kilo."* However, none of surveyed farmers neither sowed pumpkin in rotation with maize, nor took part in this program.

Table 5.11 Reasons of Frailescan farmers to practice crop rotation.

		% of respondents		
Crop rotation management	Reason	Cattle n=6	No cattle n=0	**Overall** n=6
Rotation	Cattle feed	83	0	83
	Soil conservation	50	0	50
	Improve soil quality	50	0	50
	Sell crop	33	0	33
	Increase production	17	0	17

Only farmers who owned cattle applied crop rotations.. Farmers with cattle do not necessarily need a stable market to sell their crops, as they can use it to feed their cattle. Their cattle actually serves as their own market. During an event at the platform, I observed that the platform was growing various alternative crops. People from MasAgro discussed with farmers how to introduce alternative crops in their production systems. However, this discussion was only focused on cattle farmers. They mainly talked about the nutritional value each crop contained for cattle. No attention was paid to how to introduce one of these crops in production systems without cattle.

5.3 Overall adoption of CA among Frailescan farmers

Among surveyed Frailescan farmers, 20% applied 'true' CA, meaning that those farmers were applying all three principles of CA adequately and simultaneously (Table 5.12). Classifications were used from Brown et al. (2017). True adoption of CA was highest among farmers in hilly areas without cattle (33%), followed by the farmer groups of hilly/cattle (22%), flat/cattle (18%), and flat/no cattle (0%). Only one farmer had not adopted any principle of CA. He was located in a flat area and owned cattle. Conservation tillage, i.e. minimum tillage combined with residue retention, was only practiced by farmers in flat areas. Farmers in flat areas also applied more diversified reduced tillage, i.e. minimum tillage combined with crop diversification, than farmers in hilly areas. However, farmers in hilly areas had higher adoption rates for minimum tillage and true CA. Farmers who owned cattle more often practiced minimum tillage and true CA than farmers who did not.

Table 5.12 Overall adoption of CA among Frailescan farmers using the classification of Brown et al., 2017.

Adopted CA principles				**% of respondents**				
				Hilly areas		Flat areas		
				Cattle	No cattle	Cattle	No cattle	**Overall**
Minimum tillage	*Residue retention*	*Crop diversification*	**Classification**	n=9	n=6	n=11	n=4	n=30
X	X	X	No CA	0	0	9	0	3
√	X	X	Minimum tillage	67	33	27	0	37
X	√	X	Residue retention	0	0	0	0	0
X	X	√	Crop diversification	0	0	0	0	0
√	√	X	Conservation tillage	0	0	9	50	10
√	X	√	Diversified reduced tillage	11	33	36	50	30
X	√	√	Diversified stover cover	0	0	0	0	0
√	√	√	'True' CA	22	33	18	0	20

5.4 Synthesis

5.4.1 Adoption constraints for minimal soil disturbance

This research showed that the CA principle of minimal soil disturbance was widely practices among Frailescan farmers (97%). Only one of the surveyed farmers still applied conventional tillage. He mentioned to obtain a higher yield by applying conventional tillage. In hilly areas, all farmers applied zero tillage because no machinery could enter their steep fields. They were forced to apply no tillage by the environmental conditions of steep hillsides. So, actually we cannot speak of "adoption" in this situation. Farmers in hilly areas have always applied this practices, whereas adoption is the choice to acquire and use a new innovation. In contrast to farmers in hilly areas, farmers in flat areas have adopted the CA principle of minimal soil disturbance. By moving from conventional tillage to zero- or minimum tillage, they reduced both production costs (i.e. less tillage applications) and soil erosion. In situations of compacted soils, tillage can help to loosen the soil, increase water infiltration, and thus reduce run-off, resulting in less erosion (Aina et al., 1991). Like this research, also other studies on CA generally found few adoption constraints with respect to the first CA principle (e.g. Marongwe et al., 2011; Jat et al., 2014; Beuchelt et al., 2015).

5.4.2 Adoption constraints for residue retention

In contrast to the CA principle of minimal soil disturbance, the application of the CA principle of residue retention was poor among Frailescan farmers (30%). This research showed that trade-offs for using maize stover either for cattle feed (including the selling of grazing rights by non-cattle farmers) or soil cover, presents a serious limitation to the adoption of the second CA principle. Farmers without cattle had much smaller farms on average. Probably, these farmers are poorer. By selling their grazing rights, they were able to increase their short-term farm income. Retaining residues in the field after harvest is more beneficial in terms of soil conservation (i.e. reduces soil erosion) and soil productivity (i.e. increases soil organic matter content and improves soil structure) in the medium- to long-term (Erenstein, 2002; Hellin et al., 2013). This was also recognized by the majority of Frailescan farmers without cattle. However, smallholder farmers are usually not capable to overcome this initial phase, often accompanied with a temporary decrease in farm income due to the opportunity costs of leaving crop residues in the field (Baudron et al., 2012; Corbeels et al., 2014). They have immediate needs to feed their families.

Farmers with cattle had larger farms on average, indicating that these farmers are richer than farmers without cattle. Richer farmers have more capacity to overcome the initial phase of CA which is often accompanied with a temporary decrease in farm income. The have more space to invest in future yields. However, farmers with cattle often prioritized in-situ grazing over retaining crop residues in the field, because their cattle (i.e. milk, meat, natural saving account) is more valuable than their crops. These results were in line with numerous studies on CA (e.g. Erenstein, 2002; Baudron et al., 2012; Verhulst et al., 2012; Hellin et al., 2013; Andersson & D'Souza, 2014; Brouder & Gomez-Macpherson, 2014; Beuchelt et al., 2015; Giller et al., 2015; Pittelkow et al., 2015), which also found that smallholders prioritize to feed crop residues to their livestock over retaining a soil cover, as farmers generally make decisions on the base of farm level income on the short-term.

Retaining higher amounts of crop residues in the field after harvest is more beneficial in terms of soil conservation and soil productivity. However, it is also possible to apply in-situ grazing while at the same time retaining the minimum soil cover to consider it residue retention, and thus obtain agronomic benefits from applying this CA principle. Experiments of MasAgro showed that in flat areas, a minimum soil cover of 30% is required to obtain the desired benefits of residue retention. In hilly areas, this minimum is somewhat higher, 50% (unpublished data MasAgro). In accordance to MasAgro, also Allmaras & Dowdy (1985) reported the threshold for soil cover in flat areas at 30%.

Unfortunately, this research was not able to quantify the exact amount of crop residues left in the field by surveyed farmers who allowed in-situ grazing in their fields after harvest. However, cattle was usually allowed to graze until only plant parts were left that were not eaten by the animals (i.e. roots and a small part of the aboveground maize stalk). Hellin et al. (2014) reported that a soil cover of approximately 20% is left after a field with maize crop residues is fully grazed. With respect to CA, this is not enough to consider it residue retention. Therefore, farmers who permitted in-situ grazing were not considered as adopters of the CA principle of residue retention. Box J provides an indication of several amounts of crop residues retained in the field.

5.4.3 Adoption constraints for crop diversification

Crop rotation

This study showed that among Frailescan farmers, the practice of crop rotation was poorly adopted (20%), especially among farmers without cattle (0%). As mentioned before, farmers without cattle had smaller farms on average. Farmers with only one or two hectares are not willing to rotate. Maize is a principal part of the Mexican diet, and is deeply rooted in the Mexican culture. Therefore, smallholders are not willing to move away from producing maize for self-consumption. So, for smallholders with a limited area of farmland, crop rotation is not an option. Even though rotating crops would be beneficial for land productivity and thus future yields. In addition, farmers without cattle more often faced difficulties in finding a purpose for alternative crops, as a stable market for other crops was lacking. One should say that farmers without cattle could sell their alternative crops to fellow farmers with cattle. However, this was not observed. From farmers with cattle, 30% had adopted crop rotation. Several adoption constraints were identified, mainly originating from farmers' socio-economic contexts. Most important constraints were (1) no market available for alternative crops, (2) a lot of work, and (3) not enough land. Farmers with cattle can use alternative crops to feed their animals. So in fact, they create their own market.

Kirkegaard et al. (2014) reported another constraint for smallholder farmers to adopt crop rotation. Rotational crops, such as beans, usually produce less

Box J. Three different amounts of maize stover; 1.75 tons/ha (top), 3.8 tons/ha, and 6 tons/ha (bottom). Pictures were obtained from the hub manager of Chiapas.

Photos were obtained from a presentation of MasAgro.

1.75 tons/ha

3.8 tons/ha

6.0 tons/ha

residues than maize, leading to higher trade-offs for stover use between cattle and soil conservation on the short-term. On the other hand, other researches stated that rotational systems with legumes are expected to increase maize yield over time compared to systems in which maize is grown continuously (Giller et al., 2001; Sanchez, 2002; Kamanga et al., 2010). However, as mentioned before, smallholders are considered to have short time horizons, and usually are not able, or not willing to invest in future yields. They attribute substantial higher value to immediate costs and benefits as compared to future costs and benefits (Giller et al., 2009).

Intercropping

This study showed that the practice of intercropping fits better in the socio-economic context of Frailescan smallholders as a form of crop diversification. As was concluded from the survey, currently, intercropping was practiced by 43% of Frailescan farmers. Intercropping was perceived by farmers to provide both agronomic and socio-economic benefits. It was believed to improve soil quality. In addition, farmers gained economic benefits as two yields in one growing cycle were obtained at different times of the year. Despite these benefits, still many farmers faced adoption constraints. By far the most frequent constraint was the absence of a stable market for alternative crops, especially for farmers without cattle. So, the potential for further adoption of intercrop systems among Frailescan farmers, seems mainly dependent on the ability to establish stable markets for alternative crops. Additionally, for farmers who lack enough farmland to apply crop rotation, the potential to adopt intercropping seems dependent on the ability to maintain similar maize yields within an intercrop system. Farmers prioritize maize to secure their basic food requirements, and additionally, maize is virtually the only crop which can be sold commercially by Frailescan farmers. Other researchers have shown that it is possible to exploit relationships within an intercrop system to enhance species complementarity, total productivity, and economic benefits (Sangoi, 2001; Mashingaidze et al., 2000; Yu et al., 2016). By optimizing plant density, relative sowing time, and the application of nitrogen fertilizer, it is possible to steer the yields of both species in an intercrop system (Ofori & Stern, 1986; Ofori & Stern, 1987; Mashingaidze et al., 2000; Pelzer et al., 2014; Yu et al., 2016), allowing to align the performance of an intercrop system with the production aims of Frailescan farmers.

At the moment, pumpkin is the most popular crop to grow intercropped with maize in the Frailesca region. From farmers applying intercropping, 85% grew maize in combination with pumpkin. The pulp of the pumpkin was generally used to feed cattle, whereas seeds were sold. The price of pumpkin seeds was very high last year, making pumpkin attractive for smallholder farmers from an economic point of view. As reported by Mashingaidze et al. (2000), due to their prostrate and vine growth, pumpkins act as live mulch under the maize and therefore may also reduce the loss of soil moisture. Mashingaidze et al. (2000) also reported that a nil or small maize grain yield penalty is expected when smallholder farmers intercrop maize and pumpkin. From farmers applying intercropping, 38% intercropped maize with beans. As in crop production systems with maize-legume rotations, intercropping maize and legumes does increase productivity. Yu et al. (2016) stated that cereals and legumes are complementary in their acquisition of nitrogen. Legumes can fix nitrogen from the air when soil nitrogen is lacking, whereas cereals acquire nitrogen only from the soil. In a cereal-legume intercrop system, Lambers et al. (2008) found that when cereals take up soil nitrogen, and thus decrease the amount of soil nitrogen available for the legumes, legumes may be triggered to fix more nitrogen from the air. So, by fixing nitrogen, legumes are able to (partly) substitute for chemical nitrogen application, making the production system more sustainable (Duc et al., 2015). Despite all these benefits, the possibilities to intercrop maize with beans are limited in the Frailesca region. Beans are generally grown in higher areas. This is because cultivating beans in the lower and more humid areas brings high risks of disease infections. Next to beans and pumpkin, Frailescan farmers also used canavalia to intercrop with maize (15%). Like beans, canavalia is a legume and can fixate nitrogen from the air into the soil (Ramos et al., 2001). Lima et al. (2014) found that when maize is intercropped with canavalia, soil erosion is decreased compared to maize monocrops. In addition, the canavalia plants have an extensive root system (Lima et al., 2014), making the crop suitable for the relatively dry circumstances towards the end of the growing season in the Frailesca region.

5.4.4 Adoption of "true" CA among Frailescan farmers

From Frailescan farmers, 97% was practicing at least one CA principle. However, as mentioned in previous sections, "true" CA is only practiced when all three CA principles are applied in close alignment. The survey revealed that only 20% of Frailescan farmers was practicing true CA. The principle of minimal soil disturbance faced few constraints. It were rather the principles of residue retention and crop diversification that faced adoption constraints, mainly socio-economic ones. From farmers in hilly areas with cattle, 22% practiced true CA. The rest of this group of farmers either applied CA minimum tillage (i.e. practicing of only minimal soil disturbance), or CA diversified reduced tillage (i.e. practicing of minimal soil disturbance and crop diversification). From farmers with cattle in flat areas, 18% practiced true CA. The rest of this farmer group either applied CA minimum tillage, CA diversified reduced tillage, or CA conservation tillage (i.e. practicing minimal soil disturbance and residue retention). Farmers with cattle, both in hilly- and in flat areas, generally faced less adoption constraints for the principle of crop diversification than farmers without cattle. They had less problems in finding a purpose for alternative crops in the absence of a stable market. Additionally, they usually had larger farms and thus were not restricted to grow only maize for home-consumption. However, farmers with cattle generally preferred in-situ grazing over retaining crop residues, resulting in insufficient amounts of soil cover to consider it residue retention. For farmers in hilly areas with cattle, the retention of a sufficient amount of soil cover was even a more serious constraint for the adoption of residue retention. They have to retain a minimum amount of 50% to consider the principle of residue retention as adopted (Allmaras & Dowdy, 1985; unpublished data MasAgro). Also farmers without cattle faced constraints regarding residue retention, however, this was less frequent than for farmers with cattle. Farmers without cattle, presumably poorer farmers, sometimes preferred to sell grazing rights and obtain extra direct incomes. From farmers without cattle in hilly areas, 33% practiced true CA. The rest of this group of farmer either applied CA minimum tillage, or CA diversified reduced tillage. None of the farmers in flat areas without cattle practiced true CA. They either applied CA conservation tillage, or CA diversified reduced tillage. However, only four farmers were sampled from this farmer group. So, adoption constraints for the principles of residue retention and or crop diversification often resulted in partial adoption of CA by Frailescan farmers (i.e. adoption of one or two principles). One can doubt the usefulness of partial adoption of CA. A substantial number of studies have indicated that partial adoption of CA can have poor outcomes (Brown et al., 2017). In accordance to several other studies (e.g. Guto et al., 2011; Baudron et al., 2012; Erenstein et al., 2012; Pittelkow et al., 2015), this research (Chapter 4) showed that for example the adoption of no-tillage without a sufficient amount of stover cover, results in yield penalties and increased soil erosion, owing to soil compaction.

Chapter 6 Discussion & conclusions

This chapter integrates the three sub questions to provide an answer to the central research question of this study. Answers to the three sub questions were discussed at the end of the corresponding chapters. Finally, conclusions drawn from the case study are linked to the general debate around CA.

6.1 When can we label it CA, and when not?

The definition of CA is clearly formulated by the FAO (2017) as the simultaneous implementation of all three CA components: (1) continuous minimum mechanical soil disturbance; a soil disturbed area of less than 15 cm (or 24%), (2) permanent organic soil cover; 30% ground cover at planting, and (3) diversification of crop species grown in sequences and/or associations. Although this formal definition of CA has gained wide acceptance (Giller et al., 2009), in the literature there is a large diversity in what constitutes CA (Brown et al., 2017). There are numerous examples of studies which consider the practicing of only one or two principles as the adoption of CA (e.g. Derpsch et al., 2010 and Marongwe et al., 2011). Brown et al. (2017) referred to this phenomenon as a reductionist approach. Partial adoption of CA is often not adequately recognized in literature (Brown et al., 2017), and consequently, the boundaries of CA are blurred. When can we label farmers practices as CA, and when not? And, when is partial adoption beneficial, and when not? This research once again showed that partial adoption of CA can be detrimental (Chapter 4). When zero tillage is practiced in the absence of a sufficient soil cover, yield penalties and increased soil erosion are expected. On the other hand, if partial CA adoption includes the practice of crop diversification, it can provide both agro-ecological and socio-economic benefits to farmers. However, this is not recognized as full or "true" CA according the definition of FAO. For farmers it does not matter if they apply CA or not. They only care if certain practices are beneficial in relation to their production aims.

The boundaries of what constitutes CA also imply blurring with respect to when a certain CA principle can be considered adopted or not. Sometimes it is even unclear if at all the principle is applied. Glover et al. 2016 emphasizes the problem with the term "adoption". In this research for example, a rotation with maize and sorghum was recognized as the adoption of the principle of crop diversification. However, one can question if such a rotation provides the desired agronomic benefits. Both crops are cereals and have many similar characteristics. By considering a maize-sorghum rotation as the adoption of the CA principle of crop diversification, this study probably has overestimated the adoption of this CA principle in the Frailesca region. The assessment of the agronomic performance of different applications of crop diversification in Frailescan production systems was outside the scope of this research. Local research is needed to identify which rotational systems (i.e. crop species used in rotation) are able to provide the desired agronomic benefits of the third CA principle in the agro-ecological environment of the Frailesca region, and additionally, fit in the socio-economic context of Frailescan farmers. It is the task of MasAgro's regional hub-system, especially the experimental platform and its connected modules, to do so.

6.2 Potential of CA to make Frailescan production systems more sustainable

MasAgro is promoting and disseminating CA among Frailescan to make their production systems more sustainable. However, the potential of CA to make agricultural production systems in the Frailesca region more sustainable depends on its ability to comply with all three pillars of sustainability in the specific contexts of Frailescan farmers: (1) social acceptability; people, (2) environmental friendliness (planet), and (3) economic viability (profit). So, CA has to meet the current needs of farmers without compromising their future needs, or the needs of their future generations.

At the moment, CA is presumablycontributing in making 20% of Frailescan production systems more sustainable. It included three main types of farmers: (1) Farmers in hilly areas with cattle who were able to feed their cattle without exhaustive in-situ grazing. (2) Farmers in hilly areas without cattle who had sufficient farmland, did not have the necessity or willingness to obtain direct income from selling grazing rights, and were able to find purposes for alternative crops. (3) Farmers in flat areas with cattle who were able to feed their cattle without exhaustive in-situ grazing. These farmers perceived both agro-ecological (e.g. increased soil fertility, reduced soil erosion, and increased soil water content) and socio-economic benefits (e.g. reduced production costs, increased future yields) by applying “true” CA (see ...). However, empirical data to prove these agronomic benefits in the agro-ecological circumstances of the Frailesca region was lacking. The analysis of 18 experimental platforms across Mexico, in combination with literature (see ch xxx), suggest that CA can be expected to result in agronomic benefits in the agro-ecological circumstances of the Frailesca region. This is because Frailescan farmers produce in a relatively dry climate under rain-fed conditions. However, as the set of conditions that favor CA in general is complex to understand, and therefore interactions with the environment are not always clear, local research is needed to assure that CA can provide agronomic benefits to Frailescan farmers, and thus can contribute to make certain Frailescan production systems more sustainable.

For the majority of Frailescan farmers (80%), true CA was currently not able to make production systems more sustainable. They failed to adopt either the principle of residue retention, and or the principle of crop diversification. Retaining a sufficient soil cover to consider it residue retention was a serious adoption constraint (see ...) . Farmers with cattle generally preferred to feed crop residues to their animals over retaining it in the field, whereas farmers without cattle preferred to increase short-term farm income by selling grazing rights. Farmers who permitted in-situ grazing generally allowed the cattle to fully graze their fields, resulting in insufficient soil cover to consider it residue retention. These farmers however, seemed not to be aware of the possibility to manage residue trade-offs, meaning that a certain minimum amount of residues is retained while the rest is grazed by the cattle. The optimum threshold for managing crop residues trade-offs has to be identified. This would allow farmers to make deliberate decisions about important residue trade-offs according to their production aims. Depending on the farmer’s ability to retain the minimum amount of soil cover to consider it as residue retention (i.e. 30% in flat-, and 50% in hilly areas) when managing residue trade-offs, the CA principle of residue retention will fit (better) in the socio-economic context of Frailescan farmers.

The main adoption constraints among Frailescan farmers with respect to the practice of crop rotation were the absence of a stable market for alternative crops, and the small piece of land of farmers as they prioritize maize to secure their basic food requirements. Compared to crop rotation, this research showed that the practice of intercropping has the potential to fit better in the socio-economic context of Frailescan farmers. Almost half of the farmers already had adopted this practice. Farmers gained economic benefits with intercropping, as two yields in one growing cycle were obtained at different times of the year. However, at the moment, intercrop systems in the Frailesca region are not optimal for smallholders as their maize yield decreases, while maize is the only crop which can be sold on a stable commercial market. Research is able to exploit relationships within an intercrop system to enhance species complementarity, total productivity, and economic benefits. Regional research is needed to optimize these relationships for specific agro-ecological environments. If local research in the Frailesca region will manage to obtain similar maize yields in intercrop systems as compared to monocrop maize systems, the practice of intercropping will fit better in the socio-economic context of many Frailescan farmers.

6.3 The importance of a well-functioning innovation system when adapting CA to specific local circumstances

To tailor CA towards specific agro-ecological and socio-economic circumstances, it is key to develop iterative and smooth working feedback mechanisms between the different operational entities of the MasAgro program (i.e. the platform and the modules) and the farmers?. However, this research found that interaction between MasAgro's regional experimental platform, and the modules of RED A.C. was far from optimal. Up to now, CA experiments at the regional platform were merely designed by inputs from the top level (i.e. headquarters of MasAgro and CIMMYT). For this reason, the Frailescan experimental platform did not address issues that farmers considered important (Chapter 3). For example, it was found that the practice of intercropping fits better in the context of Frailescan smallholders than crop rotation. However, experiments to test the agronomic effect of CA in relation to applied intercrop systems, were not conducted at the platform. Another local issue was the residue trade-off between cattle feed and mulch as a soil cover. The identification of thresholds for residue management would allow farmers to make well-considered decisions. It is clearly the role of the platform to integrate such issues which arose from farmers' fields in their scientific experiments. In this way, they can test the agronomic effect of certain practices on the local level. To be able to address regional problems, and thus to be able to adapt CA to local circumstances, efforts have to be made to foster the development of the iterative feedback mechanism within the regional hub system of the Frailesca region. Technicians of RED A.C. should be included when designing platform experiments. As they are in close contact with farmers, they understand the socio-economic circumstances of certain farmers in detail, allowing them to identify emergent issues and respond to threats and opportunities.

6.4 Conclusions and recommendations

In conclusion, without a well-established and smooth working regional hub-system, true CA is not able to contribute to make the majority of Frailescan production systems more sustainable. If CA is not further adapted to the local circumstances, it only fits in the socio-economic context of a small part of Frailescan farmers. These include farmers who have sufficient amounts of farmland, can manage to feed their cattle without exhaustive in-situ grazing, did not have the necessity or willingness to obtain direct income from selling grazing rights, and were able to find purposes for alternative crops in the absence of a stable market. However, on the other hand, if the regional hub-system constitutes smooth and iterative feedback mechanisms between MasAgro's entities, CA can be adapted to the local circumstances. Thresholds for managing crop residue can be identified to provide farmers with essential information to make deliberate decisions about immediate and future costs and benefits. In addition, different forms of crop diversifications can be explored and optimized to align e.g. the performance of an intercrop system with the production aims of farmers. Thereby, if important regional stakeholders (e.g. seed companies, machinery manufacturers, traders, processors, etc.) are included in the innovation systems network, probably efforts can be made to establish more stable markets for alternative crops. Consequently, also the principles of residue retention and crop diversification are more likely to fit in farmers' reality and provide benefits for a wider variety of Frailescan farmers, provided that CA is able to result in agronomic benefits. The platform failed to provide empirical evidence for this. A well-functioning hub-system will help to provide useful empirical agronomic data on a regional level. However, also if adapted to the local context, CA is not able to fit in the reality of all Frailescan farmers. If CA only provides benefits for the long-term and is expected to decrease short-term farm income, poor farmers with immediate needs and short-term horizons are still not likely to adopt it.

Responding to the debate which prevails around CA, CA is certainly not able to provide benefits for all types of farmers and production systems. Therefore, in situations where CA is promoted, it should be done with caution. Smallholder farmers often face socio-economic adoption constraints with respect to the principles of residue retention and or crop diversification. This can result in partial adoption of CA, which is found to be detrimental in certain situations. Well-functioning regional innovation systems can help to reveal whether forms of partial adoption can provide benefits, or when they are undesirable. In addition, the establishment of such innovation systems can tailor CA towards local circumstances. As a result, CA is likely to fit in a wider variety of farmers' reality, and thus to contribute to the sustainability of a wider variety of agricultural production systems, provided that it also results in agro-ecological benefits. In cases where CA does not work for certain types of farmers, these systems can also adapt and promote non-CA technologies. For farmers, it does not matter if a certain set of practices is labeled true CA or not. They just want a practice to provide benefits with respect to their production aims. Blurring of CA does however contribute to the debate around the concept of adoption.

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Appendix I Survey

Encuesta sobre la tecnología de Agricultura de Conservación en la Región Frailesca, Chiapas, México

PRESENTACIÓN:

Buenas tardes estimado Sr (Sra), soy estudiantes la UNACH localizada en Villaflores, Chiapas y estoy realizando una encuesta para llevar acabo un estudio de cómo es su forma de producir el maíz. Tenga la seguridad de que sus respuestas serán confidenciales, el objetivo de esta encuesta es para la elaboración de mi tesis y su información es muy importante para culminar en tiempo y forma la investigación.

Número de cuestionario____

I. Datos Generales

1. Municipio:____
2. Ejido:____
3. Nombre del productor/a:____
4. Edad:____
5. Nivel de escolaridad alcanzado:
    1) Primaria
    2) Secundaria
    3) Preparatoria
    4) Licenciatura
    5) Maestría
    6) Ninguno

II. Eje: Características y evolución del sistema de producción de maíz

6. Tipo de suelo
1) Arenilla
2) Arcilla
3) Tierra negra

7. Precipitación media annual:____________(mm)

8. Promedio altitud de sus parcelas:______________(m)

9. Tipo de tenencia
1) Ejidal
2) Comunal
3) Pequeña propiedad
4) Rentada
5) Otro

10. Superficie dedicada a la ganadería (ha):_______________
De esta dedica a: ______________________________
1) Potreros o agostaderos (ha):_________________
2) Corraletas por número de vacas (m^2):___________________________
3) Otros (ha):________________________________

11. Número de vacas:____________(#)
12. Superficie dedicada al monte (Forestal) (ha):__________________________________
13. Superficie dedicada a la agricultura
    1) Maíz _______________
    2) Frijol _______________
    3) Otros_______________

14. ¿Cuántos años lleva sembrando maíz?
15. ¿Qué superficie ha sembrado de maíz en los últimos 7 años (ha)?

2010:	2011:	2012:	2013:	2014:	2015:	2016:

16. ¿Qué producción ha logrado de maíz en los últimos 7 años (toneladas)?

2010:	2011:	2012:	2013:	2014:	2015:	2016:

17. ¿Qué tipo de semilla usa para sembrar maíz?
    1) Criolla: ____ ¿Cuántas variedades?:________________________________
    2) Mejorada: ____ ¿Cuántas variedades?:______________________________
18. ¿Cuánto semillas usas de maíz para la siembra?
    Variedad 1:_______________(kg/ha)
    Variedad 2:_______________(kg/ha)
19. ¿Por qué siembra variedades criollas?

____
____
____

20. ¿Por qué siembra variedades mejoradas?

____
____
____

21. ¿Cómo realiza la siembra?
    1) Manual
    2) Mecanizada
22. ¿Por qué siembra manual?

____
____
____

23. ¿Por qué siembra de forma mecanizada?

____
____
____

24. La pendiente de su parcela es:
    1) Ladera
    2) Llana
    3) Mixta
25. ¿Cómo prepara su terreno?

____
____

26. ¿Cuál practicas y cuántas veces las realiza en su terreno antes de la siembra?
    1) Rastra:_________(# pasos)
    2) Barbecho:_________(# pasos)
    3) Surca:_________(# pasos)
    4) Otro, especifique:_____________________________(# pasos)

27. ¿Conoce o sabe lo que es la labranza cero y labranza mínima?
    1) Sí
    2) No
28. Si realiza labranza cero o labranza mínima ¿Por qué lo hace?
    ____
    ____
29. Si realiza labranza tradicional ¿Ha considerado realizar labranza cero o labranza mínima?
    1) Sí
    2) No
30. Si realiza labranza tradicional ¿Por qué no realiza labranza cero o labranza mínima?
    ____
    ____

31. Utiliza camas en su parcela? Si ulitiza ¿cuál es la medida?
    1) Sí, camas anchas, medida:_______________(cm)
    2) Sí, camas angostas, medida:________________(cm)
    3) No

32. ¿Fecha de siembra?
    ____

33. ¿Aplica fertilizantes?
    1) Si
    2) No
34. ¿Qué tipo de fertilizantes aplica?
    1) Urea
    2) Sulfato de amonio
    3) Nitrato de amonio
    4) DAP
    5) KCl
    6) Formula completa
    7) Otro
35. ¿Qué cantidad (bolsas/ha) aplica por tipo de fertilizante?
    1) Urea
    2) Sulfato de amonio
    3) Nitrato de amonio
    4) DAP
    5) KCl
    6) Formula completa
    7) Otro
36. ¿Costo (bolsas/ha) por tipo de fertilizante que aplica?

____
____

37. ¿Cuántas aplicaciones de fertilizante realiza?
    1) 1
    2) 2
    3) Más de 3 (Especifique)_________________________________
38. ¿A los cuantos días después de la siembra le aplica el fertilizante?

____
____

39. ¿Cómo aplica la fertilización?
    1) Superficial
    2) Enterrado
    3) Otra forma
40. ¿Hace cuantos años uso por primera vez el fertilizante?

____

41. ¿Por qué lo uso?

____
____

42. ¿Qué cantidad de fertilizante utilizaba antes de entrar al programa MasAgro, cuanto de fertilizante utilizo estando en el programa del mismo y cuanto de fertilizante utiliza actualmente (bolsas/ha)?

Nombre del fertilizante	Antes del programa MasAgro (bolsas/ha)	Adentro del programa MasAgro (bolsas/ha)	Actualmente en el programa MasAgro (bolsas/ha)
1) Urea			
2) Sulfato de amonio			
3) Nitrato de amonio			
4) DAP			
5) KCl			
6) Formula completa			
7) Otro			

43. ¿Cómo sabe el tipo de fertilizante que hay que aplicar?
    1) Me lo enseñaron los técnicos
    2) Porque la planta lo indica
    3) Por costumbre
    4) Me lo dijo otro productor
    5) Así lo aprendió
    6) Otras razones. ¿Cuáles?
44. ¿Cómo sabe la cantidad de fertilizante que hay que aplicar?
    1) Por el análisis de suelo
    2) Porque me lo dijeron los técnicos
    3) Porque la planta lo indica
    4) Al tanteo
    5) Así lo aprendió
    6) Otras razones. ¿Cuáles?
45. ¿Dónde consiguió por primera vez el fertilizante?
    1) Lo compró
    2) Se lo regalaron____
    3) Por medio de un crédito____
    4) Otro (Especifique)____
46. ¿Cómo realiza la limpia de maíz?

1) Manual. ¿Por qué?

____
____
____

2) Química. ¿Por qué?

____
____
____

47. ¿Qué tipo de herbicida usa?

____
____
____

48. ¿Qué cantidad de herbicida usa por tipos de herbicidas (L/ha)

____
____
____

49. ¿Cuántas aplicaciones de herbicida realiza por ha?
    1) 1
    2) 2
    3) 3
    4) Más de 3
50. ¿Quién le enseño a usar los herbicidas?
    1) Un vecino
    2) Un técnico de ____
    3) Familiar
    4) Comisariado
    5) Programa de radio
    6) Nadie me informo
    7) Otro (Especifique)____
51. ¿Dónde consiguió por primera vez los herbicidas?

____
____

52. ¿Qué tipos de plagas afectan su sistema de producción?

____
____

53. ¿Qué plaguicidas utiliza para controlarlo?

____
____

54. ¿Qué cantidad de plaguicida utiliza por hectárea?

____
____

55. ¿Qué tipos de enfermedades atacan su sistema de producción?

____
____

56. ¿Qué aplica o qué realiza para prevenir o acabar con la enfermedad que afecta su sistema de producción? y ¿Qué cantidad utiliza por hectárea?

____
____

57. ¿Cómo cosecha el maíz?
    1) Grano
    2) Elote

58. ¿Qué destino le da a la cosecha de maíz?
    1) Venta
    2) Consumo
    3) Ambos
59. ¿A qué precio vende el maíz (pesos/kg)?

____

60. ¿Qué otros usos le da al maíz?

____
____

61. ¿Cómo conserva el maíz?

____
____

62. ¿Cómo selecciona la semilla para la siembra del otro año?

____
____

63. Mencione tres problemas que más le afecta en la producción de maíz

____
____

64. ¿Cómo califica la productividad de su parcela?
    1) Muy bajo
    2) Bajo
    3) Medio
    4) Alto
    5) Muy alto

65. ¿Cómo ha desarrollado la productividad de su parcela en los últimos 5 años?
    1) Disminuido
    2) Lo mismo
    3) Mejorado
66. Cómo califica el nivel de erosión del suelo en su parcela?
    1) Bajo
    2) Medio
    3) Alto
67. Cómo califica el nivel de compactación del suelo en su parcela?
    1) Bajo
    2) Medio
    3) Alto

68. ¿Siembra cultivos intercalados?
    1) Sí   Cuáles: a)   b)   c)
    2) No
69. Si no siembra en rotación con otros cultivos ¿Ha considerado sembrar en rotación?
    1) Sí
    2) No
70. Si no siembra en rotación ¿Por qué no lo hace?
    ____
    ____

71. Si siembra en rotación ¿Por qué lo hace?
    ____
    ____
72. Si siembra en rotación ¿Qué tipo de rotación utiliza?
    1) De relevo
    2) Intercalado
    3) Unicultivo
    4) Otro, especifique:________________
73. Si siembra en rotación ¿Qué destino(s) le da a la cosecha de cultivo en rotación con maíz?
    1) Venta:__________(%)
    2) Consumo:__________(%)
    3) Alimentación de la ganadería:___________(%)
    4) Mejorar el suelo

III. Eje: Capacidades para la adopción de las prácticas de Agricultura de Conservación ofertadas por el programa MasAgro

74. ¿Sabe lo que es la Agricultura de Conservación?
    1) Si
    2) No
75. ¿Conoce los principios de la Agricultura de Conservación?
    1) Si
    2) No
76. ¿En qué año empezó a realizar por primera vez prácticas de Agricultura de Conservación?

____
____

77. ¿Cuál de los principios de Agricultura de Conservación realiza en su parcela?
    1) Labranza cero
    2) Labranza mínima
    3) Labranza tradicional
    4) Rotación de cultivos
    5) Incorporación de rastrojo
    6) Los tres

78. ¿Cuántos años ha realizado las prácticas de Agricultura de Conservación en su parcela?
    1) Labranza mínima o labranza cero:____________(años)
    2) Dejar el rastrojo:____________(años)
    3) Rotación de cultivos___________(años)
    4) Otro, especifique:____________(años)

79. ¿Dónde aprendió a hacer Agricultura de Conservación?

1) En la parcela de otro productor
2) En mi parcela
3) En la plataforma de la UNACH
4) En la plataforma de INIFAP
5) En un centro de investigación
6) En los módulos de AC
7) Otras fuentes. ¿Cuales?

80. ¿Considera que las prácticas de Agricultura de Conservación son benéficas para su cultivo?
    1) Si
    2) No
81. ¿Qué tipo de beneficio Ud. ve en las prácticas de Agricultura de Conservación?
    1) Mas producción
    2) Se conserva el suelo
    3) Mayor ganancia
    4) Otros
82. ¿Qué problemas se le ha presentado cuando realiza práctica de Agricultura de Conservación?

____
____
____

83. ¿Sobre qué aspectos considera que impacta más la Agricultura de Conservación?
    1) Control de malezas
    2) Rendimiento
    3) Conservación del suelo
    4) Ingresos económicos
    5) Otro
84. ¿Considera que con la Agricultura de Conservación va a cambiar la forma tradicional de sembrar el maíz?
    1) Si
    2) No
85. ¿En qué sentido considera que las prácticas de Agricultura de Conservación cambiarían la forma de cultivar el maíz?

____
____

86. ¿Por qué adoptó la Agricultura de Conservación y luego lo dejo de practicar?

____
____

87. ¿Cuál es la razón del porque no quiere adoptar la Agricultura de Conservación?

____
____

88. ¿Qué hace con el rastrojo del maíz cuando termina la cosecha? (En porcentajes (%))
    1) Lo quema:_____________(%)
    2) Lo incorpora al suelo:______________(%)
    3) Lo deja en su parcela:______________(%)
    4) Se lo da a sus animales:______________(%)
    5) Introduce el ganado a pastar luego de la cosecha
    6) Lo vende:_____________(%)
    7) Otro, especifique:_____________(%)

89. Si deja el rastrojo en su parcela, ¿Cuál parte(s) de la planta deja? Y qué es la altura del rastrojo qué deja?
    parte(s) de la planta:____________________________
    altura:___________(%)

90. Si deja el rastrojo en su parcela, diga una razón de por qué lo hace

____

____

91. Si no deja el rastrojo en su parcela ¿Ha considerado dejar el rastrojo en su parcela?
    1) Sí
    2) No
92. Si no deja el rastrojo en su parcela ¿Por qué no lo deja?
    ____
    ____

93. ¿Quema en su parcela antes de sembrar?
    1) Si
    2) No
94. Si quema, diga ¿por qué lo hace? y ¿Hace cuánto tiempo?

____

____

95. Si no quema, diga ¿por qué no lo hace? y ¿Hace cuánto tiempo?

____

____

96. ¿Quién le informo primero acerca de la no quema?
    1) Un vecino
    2) Un técnico de _____________________
    3) Familiar
    4) Comisariado
    5) Programa de radio
    6) Nadie me informo
    7) Otro (Especifique)
97. ¿Ha experimentado alguna vez alguna práctica de Agricultura de Conservación?
    1) Si
    2) No
98. Mencione algunas prácticas que Ud. Considere innovadora en su sistema de producción de maíz

____

____

99. Desde que siembra maíz, ¿ha usado la misma técnica para sembrarlo?
    1) Si
    2) No
100. ¿Qué técnica realiza para sembrar el maíz?

____

____

101. ¿Qué es lo que le gustaría mejorar del sistema de producción de maíz?

____
____

102. ¿Ha recibido algún tipo de asesoramiento para mejorar su sistema de producción?
    1) Si
    2) No
103. ¿Qué tipo de asesoramiento ha recibido?
    1) Participación en un proyecto
    2) Asistencia técnica
    3) Otro
104. ¿Ha recibido alguna capacitación sobre el cultivo de maíz?
    1) Si
    2) No
105. ¿Qué tipo de capacitación ha recibido?
    1) Curso
    2) Talleres
    3) Seminarios
    4) Intercambio con otros productores
    5) Charlas de técnicos
    6) Otro tipo de capacitación
106. ¿Ha recibido algún tipo de apoyo para su sistema de producción?
    1) Si
    2) No

107. ¿Qué tipo de apoyo ha recibido?

____
____

108. ¿Le han apoyado alguna vez para que aplique alguna técnica nueva en su parcela de maíz?
    1) Si
    2) No
109. ¿Le han apoyado para que siembre alguna nueva variedad en su parcela?
    1) Si
    2) No
110. ¿Le han apoyado para que use algún producto químico (herbicida o insecticida) nuevo en su parcela?
    1) Si
    2) No
111. ¿Lleva el control de los gastos que realiza en su parcela de maíz?
    1) Si
    2) No
112. Si no lo hace diga ¿Por qué?
    1) No sabe
    2) No le interesa
    3) Otra razón
113. ¿Conoce cuál es el mayor gasto que realiza en su parcela de maíz?
    1) Si ¿Cuál?
    2) No
114. ¿Cuál tipo de capacitación cree que es mejor?
    1) Talleres

2) Platicas
3) Intercambio con otros productores

115. ¿Con quién prefiere aprender?
1) Instituciones
2) Gobierno
3) Despachos
4) Con otros productores

116. ¿Qué lo motiva a adoptar prácticas de Agricultura de Conservación?
1) Aprender
2) Mejorar los ingresos
3) Tener mayores rendimientos
4) Que le apoyen con recursos
5) Conserva el suelo
6) Otras motivaciones

V. Eje: Participación de los productores en el proceso de introducción y adopción de las prácticas de Agricultura de Conservación

117. ¿Se siente comprometido con el proceso de adopción de las prácticas de Agricultura de Conservación?
1) Si
2) No
3) ¿Por qué?

118. ¿Qué instituciones/organizaciones/grupos han venido a promocionar alguna tecnología de Agricultura de Conservación?

____
____

119. ¿Existe participación de técnicos de alguna institución?
1) Si
2) No

120. ¿Cómo valora la participación del técnico?
1) Mucha participación
2) Mediana
3) Poca
4) Ninguna

121. ¿Qué valores ha identificado que se generan a partir de la participación de los técnicos?
1) Solidaridad
2) Compromiso
3) Respeto mutuo
4) Confianza
5) Otro

122. ¿Cómo valora el trabajo del técnico?
1) Bueno
2) Malo
3) Regular

123. ¿Considera que el técnico le explica con detalle las tecnologías que desea introducir?
1) Si
2) No

124. ¿Cómo le informa a otros productores que prueben sus prácticas?
1) Cuando visito su parcela
2) Cuando el visita mi parcela

3) En reuniones de productores en el ejido (Casa ejidal)
4) En intercambios que hemos tenido a través de proyectos
5) Otras vías

125. ¿Considera que está capacitado para desarrollar prácticas de Agricultura de Conservación

1) Si
2) No

126. ¿Por qué?

____
____

127. ¿En que otro tema le gustaría capacitarse?

____
____

Encuestador: ____
Fecha: ___________________________________

Appendix II Additional survey questions for module farmers

1. En qué año empezó con el módulo en su parcela?_______________

2. Qué recibe por participar en el programa cómo un productor de un módulo?
   1) Apoyado técnico
   2) Insumos (cómo fertilizantes, herbicidas, semillas, etc.)
   3) Dinero
   4) Otro, especifique:_________________

3. ¿Por qué decidió participar en el programa de MasAgro cómo productor responsable de un módulo?

____
____
____

4. ¿Cuántas prácticas qué se realiza en su módulo realiza en otras de sus parcelas?
   1) Ninguna
   2) Muy pocas
   3) Algunas prácticas
   4) Muchas prácticas
   5) Todas

5. ¿Qué piensa a cerca del programa de MasAgro?

____
____
____

6. ¿Podría mencionar un aspecto positivo sobre el programa MasAgro?

____
____

7. ¿Podría mencionar un aspecto negativo sobre el programa MasAgro?

____
____

Appendix III Maize yields per farmer group

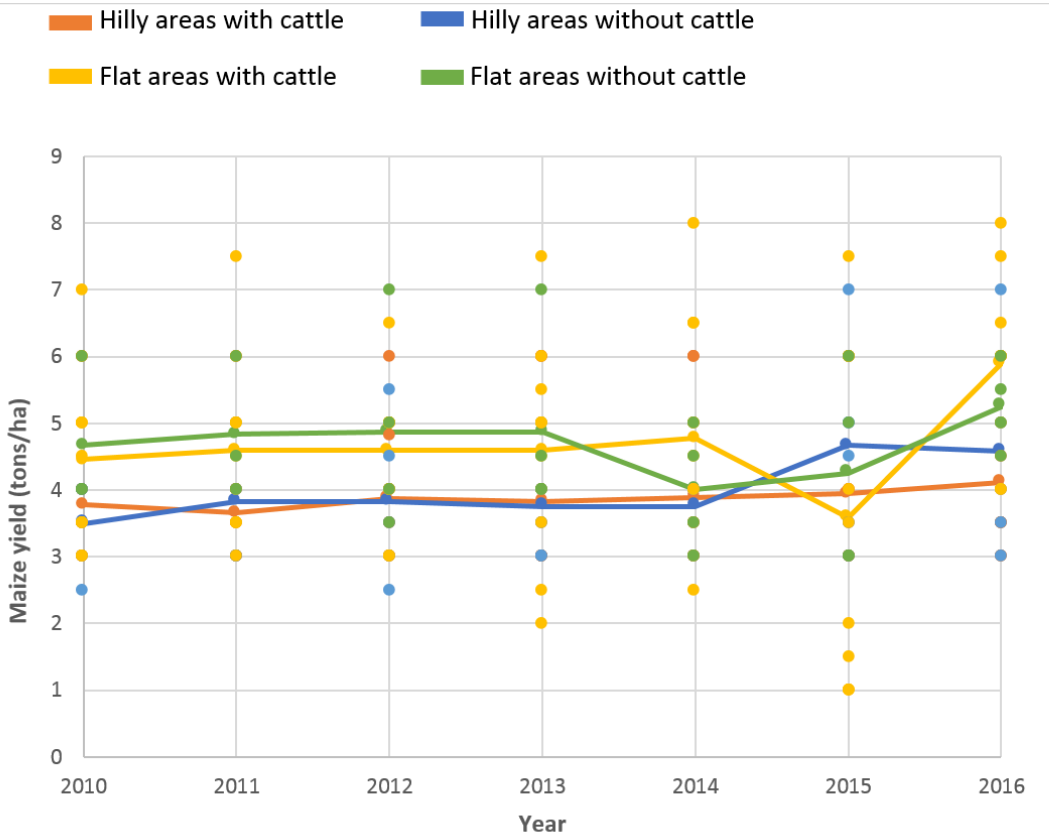

Fig. 1 Average maize yield (tons/ha) per farmer group per year. Fitted lines represent the average maize yields per farmer group.