Smallholder perceptions of conservation agriculture based on ten co-designed field experiments in the Lake Alaotra region, Madagascar



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Thesis report in fulfillment of the double degree MSc Agroecology

Under the major responsibility of Wageningen University (Farming Systems Ecology Chair Group)

ISARA-Lyon

September 2013

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Executive summary

Conservation agriculture (CA) encompasses three components (minimal soil disturbance, permanent soil cover, and crop rotations). It has been widely promulgated to smallholders throughout sub-Saharan Africa and Madagascar for over ten years as a strategy to enhance crop productivity by restoring inherent soil fertility. The low adoption rates, however, spurred increased interest to better understand the challenges and constraints farmers face when implementing this technology, as affected by regional and farm-specific factors. Parallel to this, there have been observations of partial adoption of the CA package, or so-called innovative cropping systems. This process has resulted in a heightened interest in participatory research, aiming to value existing farmer knowledge and evaluative abilities in terms of assessing potential benefits of existing agroecological practices. This study aimed to enhance our understanding of farmer perceptions of CA in the Lake Alaotra region in Madagascar through close monitoring of ten on-farm field demonstration-experiments which were initiated by the ABACO project. The experiments were based on CA principles, and were co-designed by farmers and technicians and managed by farmers. Each design was unique and without repetitions. Results and insights from biophysical measurements, open-ended and in-depth interviews with participating farmers, and participant observation were triangulated to assess how farmers' interpretations of the field experiments might affect future testing and on-farm decision making. Analysis also touched upon the interaction between CA and the social factors of knowledge sharing and gender.

Based on field observations, as well as other studies in the same region, it is evident that smallholders are aware of climate and demographic pressures, and have an apparent interest in innovative cropping systems based on CA practices. Comparisons between farmer expectations of experiment outcomes and biophysical measurements revealed some insights regarding farmer perception of CA practices (e.g. cover crop preferences). This seems to result from a combination of: 1) their awareness of local challenges (e.g. more erratic rainfall patterns, reduced land availability, need to improve inherent soil fertility); 2) their interest to improve their livelihoods; 3) the presence of CA-promoting development projects in the region for more than ten years; and 4) farmers' receptiveness to externally introduced knowledge that they evaluate according to their own perceptions of constraints and advantages. From an optimistic perspective, this context seems to offer strong potential to produce applicable learning outcomes through co-innovation development of CA between farmers and technicians. However, this potential is limited by the complex notion of participation, which is the very concept that facilitates co-innovation. More attention to different cultural interpretations of participation amongst stakeholders could improve the overall efficiency of work processes and the evaluation of their outcomes. It may yet be too early to assess the impact of innovative cropping systems, but future assessments will surely respond to this optimistic perception of their potential.

Based on personal observations and farmer interpretations of CA practices during this study, recommendations are proposed in two categories.

Related to the second year of ABACO field experiments. At the field level, these include: 1) more short-term impactful examples that valorize crops farmers typically use in combination with land often thought to be less fertile (e.g. steep *tanety* or sandy *baiboho*); 2) test management methods discussed during the first year (e.g. cutting or trampling dolichos and mucuna to control vertical climbing on maize); 3) address what adequate amounts of mulch to prevent erosion or weeds look like. At the level of overall project operation: 1) keep groups open to newcomers but ask farmers to propose and conduct a formal induction system; 2) Find a way to value "private" tests that farmers make, perhaps by providing moments to share observations with others during meetings or perhaps even in the field.

Related to agricultural innovation in the Lake Alaotra region. 1) Concerted attempts to enhance our understanding of the socio-cultural context in the region, with special attention to social networks, information

sharing, and power dynamics amongst farmers (e.g. ethnography) are needed. 2) Methodologies that encourage exploring non-verbal information related to innovation choices (e.g. technography) appear to be suitable to monitor innovation development pathways and processes. 3) It is preferable to capitalize on local concepts of participation and see how they may be complimented by participation concepts from external origins. Methodology that strives to understand socio-cultural complexities, such as ethnography and technography, could provide important insights.

Résumé Exécutif

L'Agriculture de Conservation (AC) (ou, le semis direct sur couverture végétale, SCV) inclut trois composants (dérangement des sols minimum, couverture des sols permanente, et rotation des cultures). Elle a été vastement promulguée aux petits agriculteurs dans toute l'Afrique subsaharienne, ainsi qu'à Madagascar, depuis plus de dix ans, comme stratégie pour renforcer la productivité des récoltes and restaurer la fertilité des sols. Cependant, le taux d'adoption ayant été bas, un nouvel intérêt a été réveillé pour mieux comprendre les défis et les contraintes auxquels les agriculteurs font face quand ils cherchent à implanter cette technologie, compte tenu des facteurs régionaux et spécifiques au terrain même. En parallèle, certaines observations d'adaptation partielle du package AC, soit le système de culture innovatrice, ont été faites. Ce processus a eu pour conséquence un intérêt intensifié pour la recherche participative, ayant pour but de valoriser la connaissance actuelle des agriculteurs et d'évaluer les capacités existantes, pour rendre compte des bénéfices potentiels des pratiques agroécologiques existantes.

Cette étude a pour but d'approfondir notre compréhension de la perception des agriculteurs AC dans la région du lac Alaotra à Madagascar, à travers d'une étude précise de dix expériences de démonstrations sur des cultures spécifiques, initiées par le projet ABACO. Ces expériences ont été fondées sur les principes AC ; elles ont été co-pensées par les agriculteurs et des techniciens, et elles ont été conduites par les agriculteurs. Chaque mis-en-œuvre fut unique and n'a pas été répété. Les résultats et les données issus d'un triangle de recherche constitué de mesures biophysiques, d'entrevues non-guidées et approfondies avec les agriculteurs participants, ainsi que d'observation participative, rendent compte des effets que l'interprétation des agriculteurs de ces expériences pourrait avoir sur des contrôles futurs, ainsi que sur la prise de décision sur place. L'analyse a également inclus un regard sur l'interaction entre AC et les facteurs sociaux du partage des connaissances et le rôle des sexes.

À partir d'observations faites sur place, ainsi que basé sur d'autres études faites dans la même région, il devient évident que les petits agriculteurs sont sensibles aux effets des changements climatique et demographique, et ont un intérêt apparent pour les systèmes de cultures innovatrices basés sur les pratiques AC. En comparant les expectations des agriculteurs vis-à-vis des résultats de ces expériences avec les mesures biophysiques, quelques données concernant la perception des agriculteurs des pratiques AC (ex. préférences de couverture de culture) ont été révélées. Elles semblent venir de: 1) leur conscience des défis locaux (ex. fréquence de pluies plus rares, disponibilité réduite de terrains, besoin d'améliorer la fertilité des sols en soi); 2) leur intérêt pour l'amélioration de leur niveau de vie; 3) la présence de projets de développement promouvant AC depuis plus de dix ans; et 4) la réceptivité des agriculteurs quant à une connaissance externe qu'ils évaluent par rapport à leurs propres perceptions des contraintes et des avantages.

D'une perspective optimiste, ce contexte semble offrir un potentiel important qui permettrait de produire des fins d'apprentissages applicables à travers d'un développement co-innovateur de AC entre agriculteurs et techniciens. Cependant, ce potentiel est limité par la notion complexe de participation, qui est en soi le concept qui facilite la co-innovation. Plus d'attention portée aux différentes interprétations culturelles des participants pourrait améliorer l'efficacité générale des processus de travail, ainsi que l'évaluation de leurs fins. Il est peut-être trop tôt pour rendre compte de l'impacte des systèmes de cultures innovatrices, mais des

études futures vont sûrement pouvoir répondre à la perception optimiste de leur potentiel.

À partir des observations personnelles et de l'interprétation des agriculteurs des pratiques AC inclues dans cette étude, des recommandations sont proposées en deux catégories.

Au sujet de la deuxième année des expériences ABACO sur place. Au niveau des cultures, ces recommandations inclues : 1)plus d'exemples avec un impacte à court terme qui valorisent les cultures que les agriculteurs typiquement utilisent en combinaison avec des terrains qui sont considérés moins fertiles (ex. *tanety* en pente raide ou *baiboho* ensablé) ; 2) méthodes de direction de contrôle discutées pendant la première année (ex. couper or piétiner les dolichos et mucuna pour contrôler la croissance verticale du maïs) ; 3) adresser la quantité de paillis qui serait adéquate pour prévenir l'érosion ou les mauvaises herbes. Au niveau opérationnel du projet en général : 1) garder les groupes ouverts aux nouveaux venus, mais demander aux agriculteurs de proposer et de maintenir un système d'introduction formel ; 2) trouver une manière de valoriser les contrôles 'privés' que font les agriculteurs, peut-être en organisant des moments d'échanges d'observations avec autrui lors de réunions ou peut-être même sur place sur les terrains.

Au sujet de l'agriculture innovatrice de la région du lac Alaotra : 1) Des essais concertés pour améliorer notre compréhension du contexte socio-culturel de la région, avec une attention spécifique portée aux réseaux sociaux, le partage d'information, et les dynamiques du pouvoir (ex. ethnographie) sont désirés. 2) Des méthodologies qui encouragent l'exploration non-verbale d'information au sujet des choix innovateurs (ex. technographie) semblent être convenable pour rendre compte du développement des voies et du processus innovateurs. 3) Il est préférable de capitaliser sur des concepts locaux de participation et de voir comment ceux-ci peuvent être complétés par des concepts de participation d'origine externe. Une méthodologie qui a pour but de comprendre les complexités socio-culturelles, tel l'ethnographie et la technographie, pourrait apporter des données importantes.

1. Introduction

Meeting the nutritional needs of an increasing world population while simultaneously addressing related social and environmental issues poses major challenges. This has resulted in a push to incorporate agroecological principles into production agriculture worldwide. Parts of South Asia and Africa feature regions that have both the highest population growth and high concentration of food-insecure people. Moreover, most of the staple foods – grains, roots and tubers - are produced on degraded soils, with little to no use of organic amendments or fertilizers (Lal, 2007). Poor local and national infrastructures and limited household resources add to the challenge. It is into this context that conservation agriculture, amongst other soil and water conservation technologies, was introduced.

1.1. Conservation agriculture (CA): definition and claims

Conservation agriculture (CA) has been promoted throughout the world as a management package to improve effective use of soil, water and biological resources. Defined by the Food and Agriculture Organization (FAO) as three inseparable principles, it requires minimal soil disturbance, permanent soil cover (>30% soil cover), and sound crop rotations (FAO, 2008). An outline of benefits associated with CA is provided in Table 1.

Globally, CA is most notably used in Canada, the USA, Argentina, Brazil and Australia, with increasing presence in Europe and Asia, while it relatively little used in Africa. Derpsch (2010) estimated the area under CA management to be more than 100 million ha worldwide. This figure, however, may be overly optimistic. Much of the estimated land is actually under partial CA practices, and also includes short term use of the technology (e.g. so-called opportunistic adoptants who may use the technology while participating in a development project, but discontinue shortly thereafter (Penot *et al*., 2011a)).

Although there are likely biophysical and environmental benefits (Table 1), some areas still require more research, especially in the tropics where there is less quantitative data available (e.g. C sequestration see Govaerts *et al*., 2009). CA's advantages are more often contested, though, with issues arising from socio-economic realities (Giller *et al*., 2009). For example, access to machinery and agrochemical inputs in the USA, Canada, Brazil, Argentina and Brazil allow for widespread use of fertilizers to counteract short-term immobilization caused by mulch, and herbicides to reduce weed pressure that results from zero tillage. These resources are not as readily available in developing countries. It is therefore crucial to consider factors that may not be obvious at the plot or field scale, that rather must take into account complex interactions and resource flows from the farm to regional level.

Stepping back further, putting aside questions about empirical evidence of benefits and logistical challenges of implementation, perhaps one of the principal challenges to diffusion of CA is its proposal of land husbandry practices that are radically different than current conventional management (Gowing and Palmer, 2008). This so-called paradigm shift requires perception of ecological systems at the field or farm level, and most notably, biological tillage principles.

Table 1. Potential benefits attributed to conservation agriculture (CA).

Category	Potential benefits
Soil quality	Increased water infiltration and soil water conservation (Landers, 2007) Increased aggregate stability and soil porosity (Derpsch *et al*., 2010) Increased soil fertility (Gowing *et al*., 2008) Reduced maximum temperatures in soil surface layers (Erenstein, 2002)
Crop development and performance	Increased or more stable yields (Pretty *et al*., 2006; Kassam *et al*., 2009) Early start leads to a longer growing season (no need to plough, direct seeding) (general Hobbes *et al*., 2008; Gowing *et al*., 2008).
Environmental	Reduced wind and water erosion (Lal *et al*., 1990; Schuller *et al*., 2007) Provisioning, regulating and supporting interrelated ecosystem services (Kassam *et al*., 2009) Increase in biodiversity (Kassam *et al*., 2009; Derpsch *et al*., 2010) Likely contribution to soil C sequestration (Govaerts *et al*., 2009)
Economic	Reduction in labour time and costs (due to zero-tillage age) (Hobbes *et al*., 2008; Gowing *et al*., 2008) Reduction in overall costs (lower net inputs of fertilizer and fuel) (Hobbes *et al*., 2008; Gowing *et al*., 2008)

Potential benefits are attributed to certain or all CA practices (minimal soil disturbance, permanent soil cover, crop rotations). See Hobbes *et al*., 2008, Gowing *et al*., 2008, Kassam *et al*., 2009, and Derpsch *et al*., 2010 for reviews and more general discussion about potential benefits of CA.

1.2. CA and sub-Saharan Africa

Smallholder adoption of CA in sub-Saharan Africa

Farming in sub-Saharan Africa (SSA) is predominantly performed by smallholders. Belief in potential benefits of CA have led the FAO and other institutions to actively promote it in the effort to improve smallholder agricultural production[1]. However, in recent years promoting CA for SSA has been criticized as a false panacea, (e.g. Giller *et al*., 2009; Gowing *et al*., 2008). This criticism is partly substantiated by the very low rates of adoption in SSA (approximately 1%) compared to other parts of the world (47% South America, 39% North America, 9% Australia, and the remaining 4% in Europe and Asia) (Corbeels *et al*., 2011).

Despite potential benefits, why then are adoption rates so low in SSA? Studies during the last eight or so years point to particularities of the farming context in SSA that pose challenges to full and widespread adoption (see Machado *et al*., 2001; Gowing *et al*., 2008; Giller *et al*., 2009). Overall, experimental plots and fields under researchers' control seldom account for complex farm- or regional-scale factors that affect real farming systems. More recently, recognizing this limitation, there has been increased focus on trade-offs and constraints related to CA practices. Table 2 describes both key constraints and research focus areas relevant to CA adoption in SSA. Although Southeast Asia shares some similar challenges to widespread use of CA (see Affholder *et al*., 2010), the scope of this study exclusively focuses on sub-Saharan Africa.

Table 2. Constraints and research focus areas relevant to conservation agriculture (CA) adoption in sub-Saharan Africa (SSA).

Scale or sphere of influence	Constraints and research focus areas
Field Farm Economic	While eliminating ploughing may enable an earlier sowing date and reduce labour requirements, it has been observed to increase the presence of weeds and increase labour requirements associated with weed control (Giller *et al*., 2009).
Gender	In certain contexts, the elimination of ploughing might reduce men's labour while increasing women's weeding responsibilities (Giller *et al*., 2009). In a case study of conservation agriculture in southern Zambia, it was noticed that adequate crop rotations were challenged by cultural norms of separating responsibility for crops by gender; men typically raised cash crops of maize and cotton on larger areas than women, who produced minor crops such as groundnuts cowpea (Baudron *et al*. 2007).

[1] For example: donors such as Agence Française de Développement (AFD), US Agency for International Development (USAID), UK Department for International Development (DFID); NGOs such as CARE International, Worldvision; research institutions such as Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); and national governments.

Market Economic	The costs and often limited availability of external inputs (herbicides, fertilizers, cover crop seeds) and limited product outlets or infrastructure to connect to markets (Machado *et al*., 2001).
Field	Adequate knowledge and technical mastery (e.g. adequate soil cover, counteracting immobilizing effects of mulch, appropriate leguminous intercrops) (Machado *et al*., 2001), and the resulting, challenging paradigm shift (Gowing and Palmer, 2008)
Farm Market	Crop rotation recommendations for SSA stress inclusion of legumes for their ability to biologically fix nitrogen and enhance soil fertility (Giller *et al*., 1995). Researchers have pointed out that despite their use as household food source and livestock feed, production tends to be restricted to small areas of the farm (thereby restricting potential soil improvement in those areas lacking legumes) unless there is a market to sell what the household does not consume (Giller *et al*., 2009).
Field	Regarding biophysical claims, it is important to note that the potential benefits of CA will vary depending on the existing soil conditions; severely degraded soils may need rehabilitation before CA may be implemented. Poor soils, for example, may not be able to produce enough biomass, or may be too deficient in P to support leguminous cover crops. (Giller *et al*., 2009)
Field Farm	Soil cover by dead mulch necessitates adequate biomass production, which is a constraint in relatively poor soil conditions (Erenstein, 2002; Giller *et al*., 2009; Naudin *et al*., 2011). The biomass produced is also likely to be in competition with other uses such as livestock fodder (Mazvimavi *et al*., 2010; Giller *et al*., 2011; Naudin *et al*., 2011), and may even pose threat as a habitat for pests (Vanlauwe *et al*., 2006; Brévault *et al*., 2008; Rabary *et al*., 2011).
Field Farm	Biomass is a special subject that deserves significant attention as it is a pivotal aspect of CA in (sub)tropical countries. Research has focused on the quantity and quality of the biomass being produced, how much biomass can be removed (e.g. for fodder, to be sold) before there is detriment to soil cover functions (erosion and weed prevention) (Naudin *et al*., 2011; Naudin *et al*., forthcoming).
Farm	Risk-analysis of a management style whose results are most perceivable in the long term, while requiring increased investment of precious resources in the short term, may deem it unworthy of sustained interest. As many smallholders do not have "test" areas on their farm, they try by doing (Misiko *et al*., 2011), requiring enough confidence in the technology-in-question to deem worth taking the risk.

Each constraint or research focus area is referenced to the field or farm scale, or other spheres of influence (socio-economic, market).

Need for improved understanding of farmer perceptions of CA

Despite many studies that seek to explain or predict CA adoption by smallholders, no universal variables have yet been identified, in SSA or worldwide (Knowler *et al*., 2007). However, though adoption rates of CA *sensu-stricto* are limited, some studies have found evidence of partial adoption and spontaneous diffusion, albeit within restricted contexts (Ekboir *et al*., 2002; Baudron *et al*., 2007; Lal *et al*., 2007; Penot *et al*., 2011a). Though a host of constraints are recognized (Table 2), reasons for farmer selection and use of certain practices also remains unclear.

Acknowledging the apparent complexities of CA adoption in SSA, many have argued that CA should be viewed as one of several technical options (Giller *et al*., 2011; Baudron *et al*., 2012; Tittonell *et al*., 2012), and more broadly, that agro-ecological measures should be adapted to local situations (Knowler *et al*., 2007; Tittonell *et al*., 2012) rather than proposed as a general prescription.

Although research has incorporated tradeoffs from farmers' perspectives and analyzed systems at different scales, they most often prioritize economic and agronomic factors. Even when underlying social factors are part of an analysis, there has been little exploration of their consecutive influences on CA technology use and adoption. These include individual- and group- lived tensions between tradition, modernity, culture and community (Bolliger *et al*., 2008). There is also a need to pay special attention to gender roles (Tittonell *et al*., 2012) - both as they exist before the introduction of innovations and during the time that follows – this in order to design and disseminate appropriate technologies (Table 2). All of these factors may be highly context-specific, implying the need for localised research that includes both biophysical and socio-economic perspectives.

1.3. Madagascar and the Lake Alaotra region

Madagascar, the fifth largest island in the world, is situated in the Indian Ocean, separated from the African continent by the Mozambique Channel. Spanning 1,580 km north to south, and 580 km east to west is located in an intertropical zone, and has a variety of landscapes and climates.

The country gained independence from France in 1960, and beginning in 1975 under Didier Ratsiraka, pursued socialist governance. There was a steady economic decline until the early 1980s, when the country underwent structural adjustment. The 1990s saw increasing privatization and liberal reforms in compliance with World Bank criteria. Since the early 2000s, political instability has negatively affected Madagascar's social and economic conditions. First elected in 2002 amidst contested elections, Marc Ravalomanana was reelected in 2006 despite a drop in popularity, then ousted in the 2009 coup and replaced by Andry Rajoelina. Political tensions continue, perpetuating conditions of poor infrastructure, instability, rising commodity prices, sanctions and aid restrictions. High food prices also contribute to the dynamics of the current political climate.

The Lake Alaotra region

Lake Alaotra, 230 km north of the capital Antananarivo, lies in the central highlands that run through the centre of the country (Figure 1) and is the primary rice production area in Madacascar. Colonized by the *Sihanaka* ethnic group in the fifteenth century, then a smaller wave of *Imerina* in the nineteenth century, and receiving attention from colonial government in the early 1900s, the region continues to attract people thanks to its relatively rich natural resource base. The population has been doubling every 18 years since the 1960s. It is predominantly farmed by smallholders, whose main crop is rice (for both subsistence and cash), while other main crops include maize, cassava, and legumes (groundnuts, rice bean). Most households are not rice self-sufficient, meaning they experience a hunger gap that can vary from one to several months each year (Ducrot, 1996).

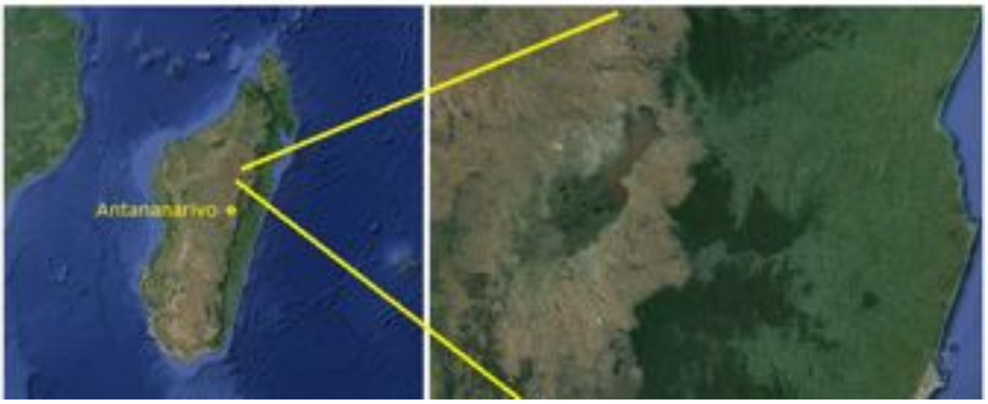

Figure 1. Map of Madagcascar and the Lake Alaotra region. Left, the east coast of Africa, Madagascar island, and the capital Antananarivo. Right, closer view of Lake Alaotra and surroundings. Source: Google Earth 4 October, 2013.

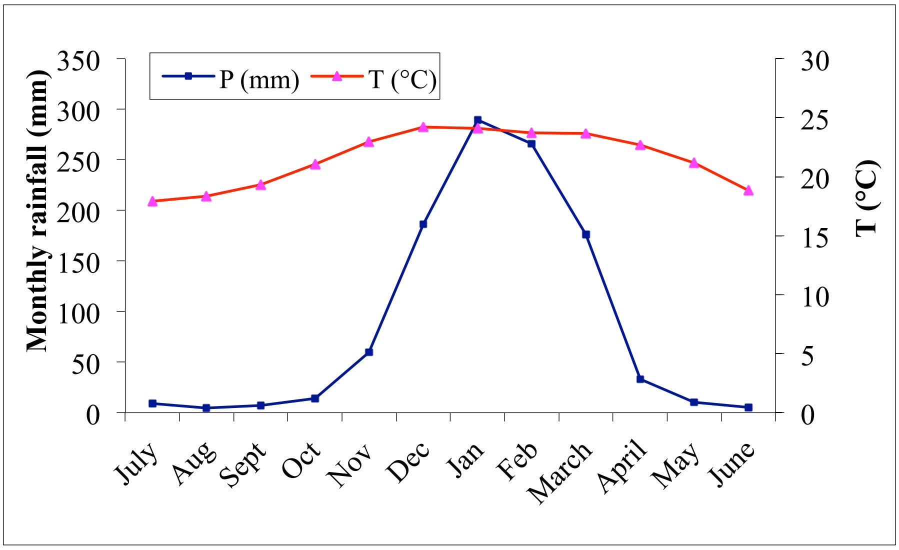

Figure 2. Average precipitation and temperature in the Lake Alaotra region (2002-2012). Source: FOFIFA, Ambohitsilaozana station.

Average annual rainfall amounts to 1200 mm, with a range of 800-2000mm (Figure 2). The tropical upland climatic region has two distinct seasons: a rainy season from November to March, delivering on average 1000-1200 mm of rain; and a cool dry season running from April to October. Irregular rainfall (especially at the start of the rainy season) is related to storm patterns on the east coast. For 1 in 3 years, annual rainfall is more than 10% below average, and of 1 in 4 it is above average (Ducrot and Capillon, 2004). Average annual temperatures are around 20°C, with an average low of 14°C.

The lake as an area of about 900m^2 with a maximum depth of 2.5m (Ferry *et al*, 2009). It is situated in a relatively fertile plain at about 800 meters above sea level. The ferralitic hills surrounding the lake rise to about 1500 m in the west, and to about 1000 m in the east. The region is characterized by several toposequences (Figure 3). Immediately surrounding the lake are marshes and rice fields with varying degrees of water control. With more than 100,000 ha under rice fields, the region is known as "the rice basin" of Madagascar. Moving further away from the lake to slightly higher land are the *baiboho,* fields which do not have standing water but may continue to produce vegetables during the dry season through capillary rise. Continuing out and upwards, the terraced fields at lower elevations are gradually replaced by rainfed plots of upland rice, maize, cassava, green beans and groundnuts.

The hillsides (*tanety*) also provide grazing land for zebu. *Tanety* generally demonstrate lower inherent soil fertility than the lower lands, but this varies around the lake. The richer soils of the eastern hills, for example, may be compared to the relatively low organic matter content, leached, ferrallitic soils in the west. The colluvial deposition of silt and clay in the *baiboho* and lower elevations has historically contributed to their reputation as relative fertile soils. However, this may not always actually be true due to continual cropping and mining of inherent soil fertility. Nevertheless, the fragile soils of the slopes are more prone to erosion and soil degradation. The gaping red gullies throughout the hills, known as *lavaka,* are visible reminders.

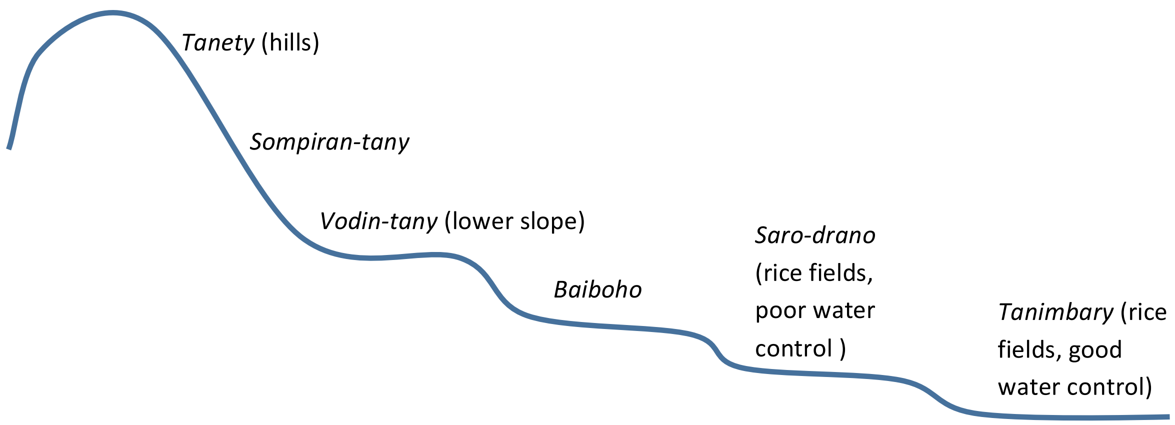

Figure 3. General representation of toposequences in the Lake Alaotra region. Names in Malagasy and English when known.

CA in the Lake Alaotra region

The area has received attention by various development projects that have usually focused on intensifying rice production in the lowlands. During the the 1960s and 70s, for instance, rice production was intensified under hydro-agricultural schemes managed by Société Malgache d'Aménagement du Lac Alaotra (SOMALAC).

However, due to a high population growth rate, and the preferred lower lands already claimed, current land use expansion mainly occurs on the hillsides (*tanety*). Hillside cultivation alongside deforestation has already led to silting up of the waterways and the lake, and there is concern about sustainable use of natural resources on the fragile *tanety* soils and future consequences for the waterways below. It was in this context of a rapidly expanding population and land degradation, as well as the need to increase smallholder food production and farm-household resources, that conservation agriculture was introduced to the Lake Alaotra region in the late 1990s.

The promotion and research of CA in the area has involved several organisations and institutions. The NGO TAFA ("terre et developpement") conducted the first CA experiments in the Alaotra region in 1998. In 2003, project Mise en valeur et protection des Bassins Versants du Lac Alaotra (BVLac) began. BVLac was conducted in two phases. The first one used a technical-based "top-down" field and plot focused approach (2003-2008). During the second phase, the focus shifted and evolved into a more holistic, systems-based approach (2008- May 2013). The objectives were to sustain and increase farm income by increasing productivity while protecting natural resources with a focus on the watershed. It was assisted by the local operators TAFA, Bas Rhône Languedoc (BRL) and Bureau d'Expertise Sociale et de diffusion technique (BEST). Also involved were staff from Groupement Semi-Direct de Magadascar (GSDM), an umbrella organization that unites different organizations working to promote CA practices. The Centre Régional de Recherche Moyen Est (CALA), run by the national body for applied rural development research (FOFIFA) and the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) also continue to play a role in the region.

These entities have generated a body of knowledge in the area that continues to grow. This includes farm typologies (Durand *et al*., 2008), biophysical impacts and benefits such as biomass tradeoffs (Naudin *et al*., 2011; Naudin *et al*., *forthcoming*), along with both short- to long-term economic effects (Mac Dowall, 2011), and reasons behind (non/partial) adoption and spontaneous diffusion (Chabierski *et al*., 2008; Penot *et al*., 2011a, Ranaivoson, 2012)). A detailed technical manual jointly produced by local actors also aims towards technicians, researchers and farmers (Husson, 2013). It is also clear that farmers have also generated their own body of knowledge.

Discussion of constraints is limited in this study as most farmers have yet to test CA techniques themselves. For studies on CA and constraints in the Lake Alaotra region see: Penot and Andriatsitohaina, (2011b) for constraints and opportunities; Penot *et al*., (2013a) for economic and political constraints; Penot *et al*., (2013b) for technical constraints; and Chabierski *et al*., (2009), Durand *et al*., (2012), Fabre (2011) Penot *et al*., (2012b) for general discussion.

Though it remains to be substantiated with additional research studies, CA management in the region has been observed to increase yields slightly, and inferred from the increased yield stability, to offer a buffer against climatic hazards (Mac Dowall, 2011). Research focusing on carbon sequestration, pest, weed and disease control, runoff and erosion are ongoing. Questions pertaining to tradeoffs in terms of biomass use were investigated by Naudin *et al*., (2011; *forthcoming*). Based on results it appears that some farming systems may produce enough biomass for soil cover required by CA, although they may not be able to produce enough to satisfy high demand situations (such as 95% soil cover for weed control and simultaneous forage functions). The same research also showed that CA systems on the hillsides and lower lands may be synergistic with livestock and/or dairy production.

A study on the economic impact of CA systems on modeled farm holdings, using counterfactual analysis (*ex-post* on the results of the 5 previous years and prospective next 5 years) (Mac Dowell, 2011) showed that the effect of CA is nuanced in the medium term while the short-term impact is not significant for farms that are currently economically viable (usually those with irrigated rice paddies). Although there may be short-term positive results at the plot-level, it may take up to ten years before cumulative effects may be detectable at the farm level. Moreover; the impact of CA increases as the area of irrigated rice fields per farm decreases.

Some studies reported increasing use of CA amongst farmers during the BVLac project (Chabierski *et al*., 2008). The number of participating farmers was just under 600 in 2004, and grew to about 1200 in 2007 while the area under CA also increased. In the highlands it was 51 ha in 2003 and increased to 365 ha in 2007 while the corresponding values for the plains were 24 and 243 ha, respectively. Penot *et al*. (2011a) estimated the real area under CA to be approximately 419 ha in 2010, and the number of adopting farmers being between 600-1000. The same study reported that most farmers (40-60 %) abandoned the use of CA during the first three years (year 0, 1, 2)[2] (Figure 4), with an overall decrease of abandonment over time. Most farmers abandon during the first year, and from a negative perspective may be considered to be opportunistic adoptees who just wanted to benefit from advantages of participating in a development project (Penot *et al*, 2011a). Reasons for abandonment during subsequent years were attributed to lack of land tenure, difficulties in mastering the complex CA package of practices, and lack of financial resources to invest in initial costs (Penot *et al*., 2011a).

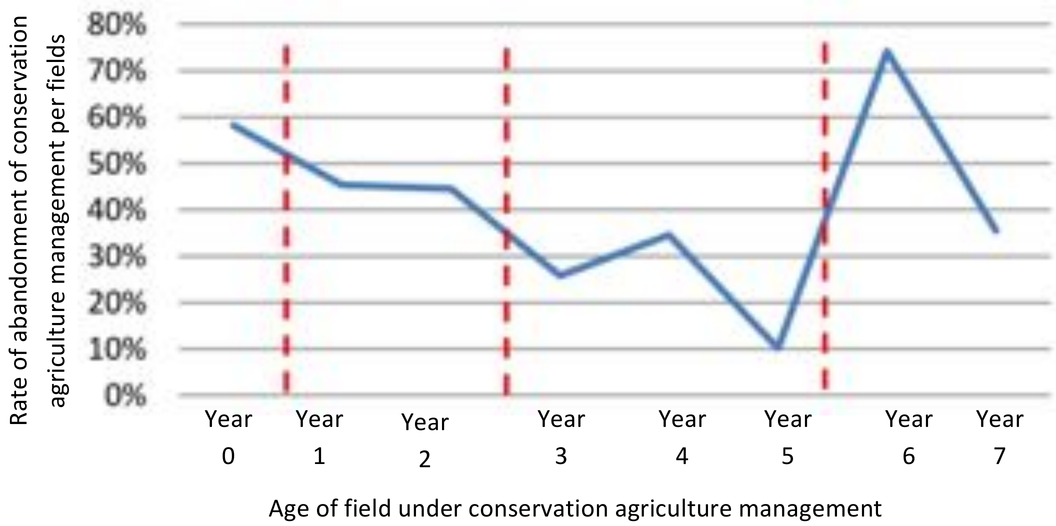

Figure 4. Rate of abandonment of conservation agriculture management per fields, according to age under conservation agriculture. Adapted from Fabre, 2011.

Though there are doubts about farmers' ability or receptiveness to implementing the complete package of CA practices, based on observations of practices in farmer fields it appears that there is strong spontaneous diffusion of select parts of the CA technical package (Mac Dowall, 2011; Penot *et al*., 2011a). Farmers have been shown to modify the CA system to suit their specific needs, creating so-called innovative cropping systems (ICS), prioritizing family needs according to local and household constraints rather than aiming for maximum productivity (Fabre, 2011; Penot 2012a). Crop rotation seems to be the practice most readily adopted by farmers (Mac Dowall, 2011) with the most common crop rotation patterns being maize associated with a legume (e.g. *Dolichos lablab*, *Vigna umbellata*, *Vigna unguiculata*, *Stylosanthes guianensis*), followed by upland rice associated with *Cajanus cajan* and/or *Crotalaria sp*.) (Chabierski *et al*., 2008). Despite these findings, why and how farmers select certain systems still requires additional research. If development support were to focus on encouraging farmers to experiment and adapt the CA system as they find appropriate, what would the systems look like? The next section addresses methodology that responds to the question.

[2] Conservation agriculture management requires initial tillage and use of a cover crop in year 0, followed by zero-tillage or minimal soil disturbance in the years that follow. Years under CA management are denoted n + 1, n being year).

1.4. Action, participatory, innovation research and the ABACO pilot project

Attempts to understand adaptation and adoption of conservation agriculture have produced studies and meta-reviews on determinants and predictability of CA adoption (e.g. Baudron *et al.*, 2007; Bolliger *et al.*, 2008; Mazvimavi *et al.*, 2010; Knowler *et al.*, 2007; Derpsch *et al.*, 2010; Dubreil 2011). Finding no universal factors that can predict adoption, much of this research recommends action and participatory-based research approaches to better comprehend and develop solutions for localized contexts.

Action research broadly involves implementing change through a research process, grounded in reflexivity and the recognition that knowledge is socially constructed (see Lewin, 1946 and Brydon-Miller *et al.*, 2003 for more on action research). Participatory action research (PAR) is based on similar principles, but emphasizes that stakeholders need to be actively involved during the research process as co-researchers. There is an expansive body of literature about PAR (Freire, 1970; Maguire, 1987; Whyte 1991; McIntyre, 2008) documenting its evolution and lists both strengths and weaknesses. The invaluable strength of the methodology is the potential to test and apply research findings in a "real-world" setting, while more directly responding to the specific needs of participating stakeholders. However, as to be expected, challenges may abound. From a technical perspective, these may include continuity problems, participatory miss-outs, and different approaches to observation (Misiko *et al*., 2008). In terms of other perspectives, logistical constraints (Michener, 1998) and social forces shaping the initiation, design of experiments, as well as who leads and facilitates should be carefully observed (Defoer, 2002). From a wider perspective, politics and power are also likely to influence unstated objectives and constraints. Michener (1998), for instance, observed that NGOs endeavoring to self-empower a population may undermine their reason to exist, while members of the local population may participate in order to selectively extract resources from offering organizations. Furthermore, different culturally-informed concepts of participation, itself, may be challenging when different actors try to collaborate (Blanc-Pamard and Fauroux, 2004). The point is that subtle and perhaps purposefully veiled social factors play a role in the participatory process, and recognizing them can only help inform and improve the participatory method and outcomes.

PAR's reflexivity and (often) iterative creation and testing of research findings infer an innovation process. Most recently, discourse around innovation regards the process as one of knowledge co-creation between academic and non-academic actors (Schneider *et al.*, 2012)[3]. This is in sharp contrast to previous linear conceptions of innovation (basic research, applied research and development, production and diffusion) (see Godin, 2006), and departs from the innovation-diffusion model proposed by Rogers (1993)[4]. Essentially, both imply a structured process where different actors have their own separate roles in the creation and diffusion of innovation (e.g. knowledge creators, transferors, and adopters).

[3] See Luks and Siebenhuner (2007) for an overview of the prominent concepts in the current discourse.

[4] The theory explains innovation diffusion as a logistic function (S curve), involving categories of innovators, early adopters, early majority, late majority, and laggards (Rogers, 1993).

The innovation process grounded in participatory action research and knowledge co-creation has already been applied to agricultural development with smallholders (see, for example, Ceccarelli and Grando, 2006, who promote participatory plant breeding). It seems a promising approach to apply to soil and water conservation technologies in sub-Saharan Africa (Ramisch *et al*., 2006; Misiko *et al*., 2010; Mapfumo *et al*., 2012; Tittonell *et al*., 2012).

CA2Africa and ABACO

The multi-partner research project Conservation Agriculture in AFRICA: Analysing and FoRseeing its Impacts – Comprehending its Adoption (CA2AFRICA) aims to respond to the knowledge gap concerning low rates of smallholder adoption of CA in sub-Saharan Africa. The three-year project, launched in 2009, aims to assess and learn from research about CA in SSA. In turn, the Agroecology-Based aggradation-COnservation agriculture project was created (ABACO) in reponse to an emphasised need for action during the implementation of CA2AFRICA (Tittonell *et al*., 2012).

Implemented from 2011 to 2014 in seven sub-Saharan African countries, the initiative is a collaboration between institutes, organizations and governments from the global north and south[5]. Recognizing the need to better understand farmer perspectives on agro-ecocological intensification technologies, the project aims to establish "site-specific co-innovation platforms that rely on agroecology principles and aggradative[6] measures to restore soil productivity in semi-arid regions" (Tittonell *et al*., 2012, p 2). ABACO is a pilot research project, rather than a development outreach initiative, that focuses on involving multiple stakeholders (farmers, researchers, extension agents, NGOs) to understand which principles of CA contribute to food production and land rehabilitation goals in the context of climate variability, as well as developing and promoting local adaptation of CA practices (Tittonell *et al*., 2012)[7].

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[5] Wageningen University (WUR), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), African Conservation Tillage (ACT), Soil Fertility Consortium for Southern Africa (SOFECSA), National Centre of Research Applied to Rural Development (FOFIFA, Madagascar), Natural Resources Institute of University of Greenwich, Centre International de Recherche sur l'Elevage en zone Subhumide (CIRDES, Burkina Faso), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), and Yellow Window

[6] Use of the term "aggradative" draws from physical geography, soil physical chemistry, and forest ecology to describe the gradual rehabilitation of degraded soils (Tittonell *et al*., 2012).

[7] The four specific objectives (Tittonell *et al*., 2012) are : 1) to target CA to smallholder farmers by studying which principles of CA, and under which conditions, contribute to the effects sought in terms of food production and land rehabilitation in the face of climatic variability; (2) to involve farmers, researchers, extension agents and NGOs in co-innovation platforms to promote the adaptation/appropriation of technologies by local communities; (3) to assess the social and economic viability and tradeoffs of implementing CA at farm and village scales, and across scenarios, to inform policies; (4) to promote dissemination of targeted CA alternatives and approaches through divulgation, training and capacity development

1.5. Research aim and questions, hypotheses

The purpose of this study is to 1) develop a better understanding of farmer perceptions of CA and 2) provide recommendations for future co-innovation endeavors in the Lake Alaotra region.

Research questions	**Hypothesis**
1) What are the biophysical results and interpretations of the field experiments? 1a) How are the field experiments and results perceived by farmers, technicians, and researchers? 1b) How might they impact future experiments and on-farm decisions?	Results are expected to vary per experiment, with potential differences in interpretation between different stakeholders.
2) How do farmer perceptions of CA compare between ABACO group participants? 2a) What are the key factors and processes that influence farmer participation (or not) in the co-innovation platforms? 2b) How is knowledge of CA shared amongst farmers?	Perceptions are expected to vary depending on experiences with CA. Resource-levels, personal character and experience, information networks, social cohesion, motivation to gain knowledge and other expectations of the project may influence participation in ABACO, as well as how knowledge is shared.
3) How does gender interact with questions 1 and 2?	Interaction of gender with questions 1 and 2 is likely to be relatively subtle

2. Methods and Materials

2.1. Overview

This section presents the study sites, the ABACO project background, and the socio-technical methodology. The workflow is presented in the figure below (Figure 5) and elaborated in the methodology explanation.

This research was conducted during a six-month internship with the pilot project ABACO, formalized through a contract with FOFIFA. The four months of fieldwork was conducted around ten field experiments initiated by ABACO. The experiments were based on CA systems, and were co-designed by farmers and technicians, and managed by farmers. Results and insights from biophysical measurements, interviews and participant observation were triangulated to respond to research questions, which addressed farmer interpretations of the field experiments, how the experiments might future testing and on-farm decisions, and touched upon the interaction between CA and the social factors of knowledge sharing and gender.

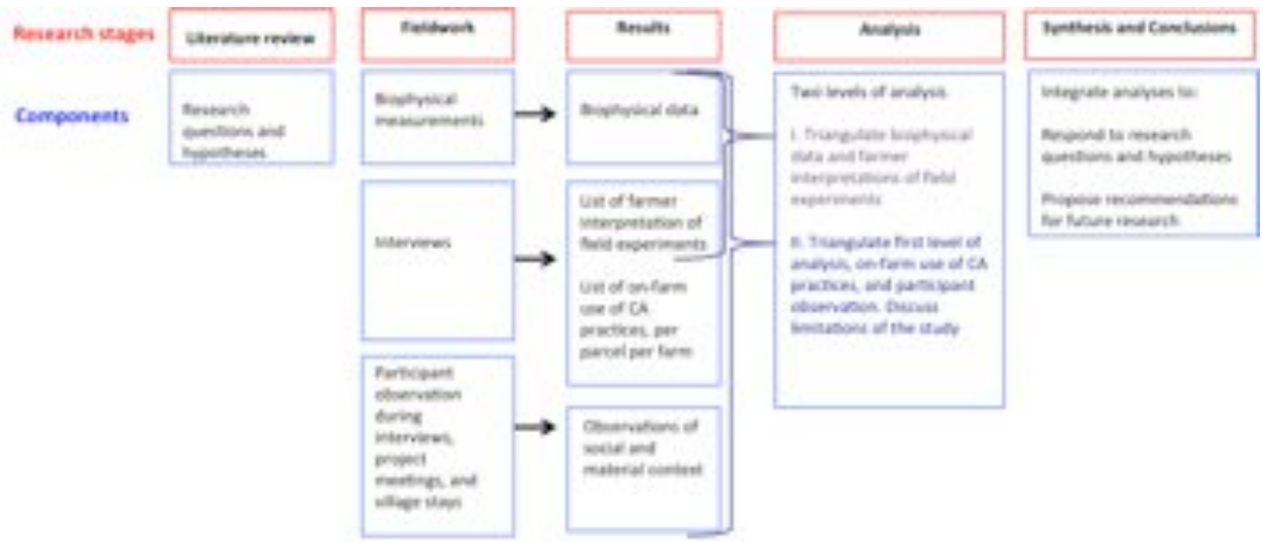

Figure 5. Research workflow. The top level (red) shows research stages and corresponding components below (blue).

2.2. Study sites

Fieldwork was conducted from the end of February to the beginning of June, 2013 in the Lake Alaotra region of Madagascar with farmers and field experiments associated with the ABACO project. Research took place in two locations: the three *fokontany* of Amparihitsokatra, Madiorano, and Morarano (in this report collectively referred to as north) and the *fokontany* of Mahatsara (south). The town of Ambatrondrazaka, which has about 70,000 inhabitants, provided a base located between the two research sites. It is connected to the villages by the main highway 44, approximately 45 km (75 minutes drive in 4x4 vehicle) to the northern site, and about 10 km (15 minutes drive on a paved road) to the southern site. See Figure 6 for a map and photos of the two sites.

Figure 6. Map and photos of the study sites. The town of Ambatondrazaka (B) was provided a base between the two research sites: about 45 km from the northern site (A), which encompassed parts of Amparihitsokatra, Madiorano, and Morarano fokontany; and about 10 km from the southern site (C) of Mahatsara *fokontany*. Photos on the left show two landscapes from the northern site: top, rice fields close to the lake (Madiorano); bottom, hilly landscape further inland (Betsianjava). Photos on the right show two landscapes from the southern site: top, rice fields (Mahatsara); bottom, hills with rice fields in the valleys. The northern site had more fields on *tanety*, and the southern site more rice fields, many of which were fed by a dam.

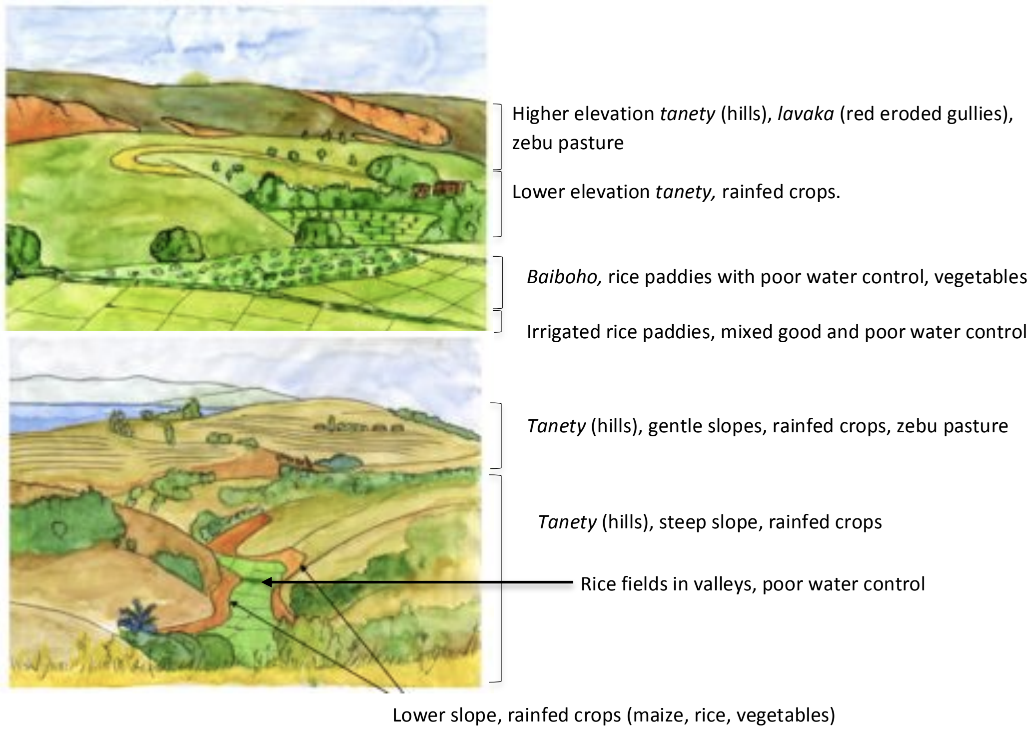

Figure 7. Typical toposequences and landscape use for the northern and southern study sites. Southern site (top) and northern site (bottom). Adapted from Fabre, 2011.

Mahatsara (south)

Mahatsara, south of the lake, has relatively good access to markets due to road conditions and proximity to the town of Ambatrondrazaka, which also offers opportunities for off-farm work. The area also receives grain buyers from Tamatave (city on east coast) and Antananarivo. In terms of landscape topographic components (for terminology see Figure 7) Mahatsara has few *tanety*, but plenty of *baiboho* for rice during the rainy season and vegetables during the dry season. There are also many irrigated rice paddies (of differing levels of water control), fed by a reservoir at Bevava. CA was introduced to the area in 2000, and different CA practices can be observed today.

About 35 farmers from Mahatsara participated to varying degrees in the project, coming from the villages of Ambohimbary, Ambomanjaka, Antenereina, Ambatomainty, Ambongabe, and Mahatsara.

Amparihitsokatra, Madiorano, Morarano (north)

Amparihitsokatra to the east of the lake is more isolated, the closest large town being Imerimandroso, which is about 7 km north with a population of approximately 11,000. Poor road conditions (especially during the rainy season) and communications limit access to markets, both to sell produce and to buy inputs. Production occurs primarily on the relatively fertile *tanety*, some also on the lower slopes but few *baiboho* and no irrigation is being used. Production focuses mainly on rain-fed crops and animals (e.g. fowl, pigs, zebu). Given the lack of rice paddies (and therefore straw), there is pressure on forage resources during the dry season. The ability to grow rain-fed rice in the *tanety* was an important innovation in the area, and CA practices are apparently well distributed throughout the area after their initial introduction in 2003. The two *fokontany* of Madiorano and

Morarano border the lake. They share similarities with Amparihitsokatra, but also include rice fields fed by the lake (with varying degrees of water control), as well as fishing as an important off-farm activity during the dry season.

About 25 farmers from the north participated to varying degrees in the research project. In Amparihitsokatra, they came from villages of Ambavahadiromba and Mahatsinjorano. In Madiorano, group members were from Ambohimangabe, Ampananganana, and Madiorano villages. Members also came from other neighbouring villages such as Morarano (in Morarano *fokontany*) and Betsianjava (in Betsianjava *fokontany*).

2.3. Project background: forming two farmer groups and designing field experiments

Forming the groups

Figure 8. Maps depicting locations in the Lake Alaotra region of the ten experimental sites of the ABACO project 2012-13 and principal villages where participating farmers lived. Top: northern study site. Bottom: southern study site.

Before the start of the 2012-13 agricultural year, a call by the president of each *fokontany* drew people to an information session about ABACO and the proposed farmer-managed field experiments. It was explained that the project aim was to help farmers adapt CA to their local constraints through co-design of field experiments, and that they would observe the field development and discuss the results together. That initial meeting was followed by several more, including a one-day presentation of CA techniques and design of the ten field experiments. Meetings were held twice, one in each of the two research areas (sometimes referred to in this report as "northern" and "southern" groups). Farmers who regularly attended meetings and followed the field experiments formed the core of each group. See Figure 8 for village locations and per study area.

Brief background of group members

Both groups consisted of farmers described by project staff as adoptants, ex-adoptants, and non-adoptants of CA. They included men and women, the former being slightly over-represented. Most farmers self-identified as ethnic *Sihanaka,* though a few described themselves as mixtures between *Sihanaka* and other ethnicities, and several in Ambavahadiromba village as *Imerina*. Farmers had varied backgrounds in terms of farm activities (e.g. zebu, land area and land types farmed) and household dynamics (literacy levels, childrens' educational levels, off-farm activities and rice self-sufficiency). The groups were formed based on interest and active participation in the project, rather than being a reflection of an existing and self-initiated cohesive farmers community. Although most members from each region may have been aware of the other members, their social networks may have limited their interaction prior to the project. Both regions did have somewhat formal existing sub-groups, created around 2005 for joint-credit access facilitated by BRL and BEST. Several of these credit groups did not survive due to tensions related to (non)reimbursement and internal power struggles, but those that did ascribed the unity to kinship, friendship, and shared ideas and objectives.

Designing the field experiments

Procedures in each research site were generally conducted in the same manner. Farmers, technicians (from BRL), and an agricultural engineer (ABACO staff) worked together to discuss what aspects of CA would be interesting to test, and together designed the experimental plans. The CA cropping systems (Figure 9) discussed were a two year rotation with maize + leguminous cover crop[8] in year n and upland rice in year n+1; a multi-annual succession with a crop + *S. guianensis* in year n and *S. guianensis* alone in year n+1/2/3 to be followed by rice; cassava + *B. ruziziensis* or *S. guianensis* in year n and in year n+1/2 to be followed by rice (see Husson, 2013 for proposed CA systems in the Lake Alaotra region). Each experiment was carried out on a field that was volunteered and managed by the owner. The experimental plans were decided in August 2012. The following descriptions result from an interview with the responsible ABACO staff member, as well as her written reports (see Ranaivoson, 2012).

[8] Leguminous cover crops to be associated with maize were *Dolichos lablab*, *Mucuna pruriens*, *Vigna umbellata*

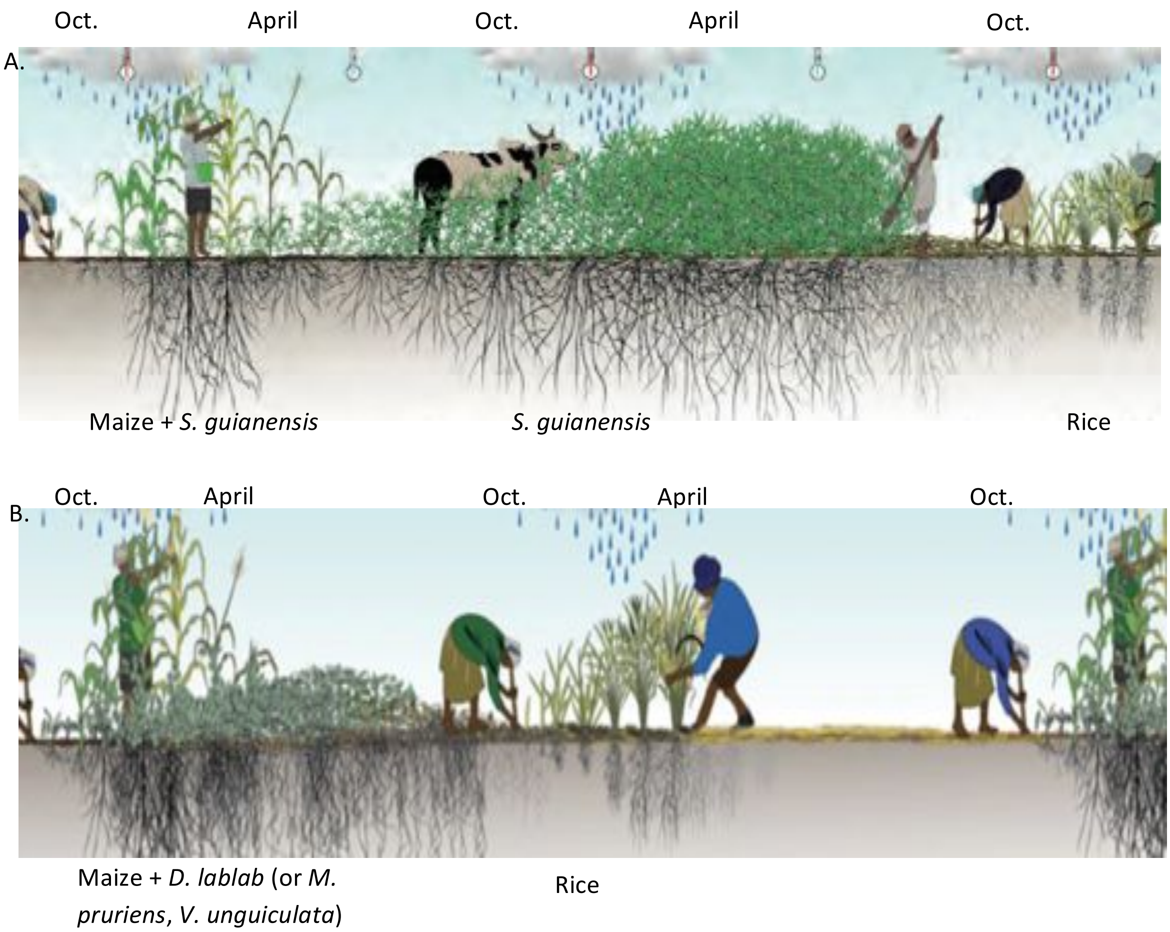

Figure 9. Examples of crop rotations discussed during the co-design of field experiments between farmers and technicians. A) a multi-annual succession with maize + *Stylosanthes guianensis* in year n and *S. guianensis* alone in year n+1/2/3, followed by rice. B) a two year rotation with maize + leguminous cover crop (*Dolichos lablab, Mucuna pruriens, Vigna umbellata*) in year n and upland rice in year n+1. Adapted from Husson, 2013.

During the meeting to design the field experiments, ABACO staff explained principles of conducting a field test (e.g. sample-sized field, different treatments managed homogenously in order compare results). It was repeated by the ABACO staff that BRL technicians and staff were present to offer advice and opinions, rather than instructions, as many farmers were accustomed to hearing. In other words, ideas from the technicians were to be discussed and even challenged. In some cases, farmers did decide differently than what the technicians proposed (see notes in individual experiment reports for details, Appendices I-X). It is important to emphasize that the farmers led decisions regarding what to test (e.g. live cover crops or dead mulch, land types), while technical staff proposed methods (e.g. layout).

ABACO purchased and delivered inputs considered difficult for farmers to acquire (due to costs, availability, and distance to markets) in the interest of facilitating the field experiments. This included seeds, NPK and urea, and phytosanitary products. NPK and urea were included because field owners from Ambavahadiromba explained that they usually used at least a small quantity. In the interest of equality, the fertilizers were also made available to all other field owners. The fertilizers were left at a central location (e.g. with the president of the *fokontany*). It was decided to put signs in the field in an effort to discourage zebu foraging. ABACO staff proposed to limit sub-plot sizes to 100m^2 in order to reduce potential problems from a lack of labour. The field owners were responsible for all other inputs and all management decisions that were not specified in the experimental plan.

The different social contexts and CA experiences of each group influenced the process of designing the experimental plans. Mahatsara members generally had very little experience with CA techniques. The group wanted to test different cropping systems on different toposequences. Initially, one woman was the first and only person to offer a field. A male farmer well experienced with CA then proposed to conduct a group tour of the surrounding land, which they did, and people volunteered their fields during the walk and proposed experimental objectives. After the tour, there was a CA training conducted by BRL staff. Following the training, other fields and objectives were proposed, and details of experimental plans were modified.

Members from the northern *fokontany* (villages of Amparihitsokatra, Madiorano, Morarano, Betsianjava) were generally more experienced with CA techniques. Many of them had followed trainings with BRL several years ago, and had maintained regular contact with technicians while practicing CA techniques. They were therefore more familiar with local constraints to CA, and all the experimental plans were decided prior to the CA training with BRL. Three women from the same village were the first to offer their land for field tests. After some time two men, each from different villages, offered the use of part of their fields. Despite their experience and keenness to follow the field tests, others refrained from offering land as they were apparently afraid to "compete" (i.e. they were afraid their experiments would not perform as well as those more experienced). Despite encouragement from ABACO staff, and assurance that it was not competitive, they remained firm in their decision to observe the first year, and perhaps manage field tests during the second year.

As a result of these processes, each experiment was unique in its development, design and objectives. Details of each are described in individual experiment reports (Appendices I-X).

Other meetings throughout the year

Several field visits were conducted throughout the agricultural year of 2012-13. They included farmers who were able to participate, ABACO staff (one was based on-site, sometimes joined by visiting researchers), and the occasional local BRL technician. Two exchange visits were held during April, 2013. They brought farmers from their respective locations to the other field site, and conducted a tour of the field experiments at the CALA (the FOFIFA-managed "Centre Régional de Recherche Moyen Est") research station. Two feedback meetings were held in early June, one for each group, to present results of biophysical measurements and hold discussion about conclusions and future directions of next year's field experiments. ABACO staff led organization of logistics for all meetings, and was responsible for costs of transportation or meals during the exchange meetings.

2.4. Socio-technical methodology

This study combined qualitative and quantitative methodology to respond to research questions. Combining a literature review, initial fieldwork, and the ABACO project goals generated research questions. Fieldwork included biophysical measurements, interviews, and participant observation (during project meetings and extended village stays), and produced respective results. Analysis was facilitated by triangulating different data types. See Figure 5 for the conceptual framework used during the implementation of the field study and the structuring of this thesis.

Biophysical measurements

Geographic coordinates (GPS) and plot dimensions were recorded for all experiments. Other measurements varied per test and are described in individual experiment reports (see Result sections). They included primary crop yield (maize, upland rice varieties, and Bambara groundnuts i.e. *Vigna subterranea*) and cover crop biomass (*Stylosanthes guianensis*, *Dolichos lablab*, *Mucuna pruriens*, *Vigna umbellata*). Measurements were performed on-site (in the field or village) with a hand held scale (max=15 kg, d=20 g) or at the CALA laboratory, which was equipped with a balance (max=200 g, d=0.01 g) and a drying oven to determine dry matter content. Some tasks, such as separating and counting empty and full rice spikelets were partially performed by a CALA technician or employee. Harvest operations were carried out together with the participating field owners. Analysis also varied per experiment (see Appendices I through X)). As there were no repetitions, statistical analysis was not possible, except for one experiment (1 north) where ANOVA was used (XLSTAT 2013.2.03) (see Appendix I).

Social theory and methods

Technography and anthropology

No single social theory or method dominated this study. Rather, aspects of technography and anthropology were selected to inform the design and analysis of the qualitative research methods used.

Technography	*Description*	Technography has been described in essence as the ethnography of technology in use (Glover, 2011; Jansen and Vellema, 2011). The approach was developed by the Technology and Agrarian Development group at Wageningen University in response to limitations of existing interdisciplinary methodology that addressed social sciences and technology use. Due to its origins, it has often been applied in the agricultural domain (e.g. Almekinders *et al*., 2011; Glover, 2011). Rather than understanding technology as “in-use or not”, the methodology seeks to recognize the complex social and technical processes and relationships in three dimensions: making or doing (focus on performance); cognitive distribution (how is knowledge distributed); and the construction of rules (roles of institutions) (Jansen *et al*., 2011). Significant importance is given to performance (see Richards 1989; Richards, 1993), situated and embodied knowledge (Richards, 1989), which distinguishes the approach from its theoretical neighbours such as action research and participatory approaches (Jansen and

		Vellema, 2011).
	Methods	The methodological emphasis is on observation and participation, rather than relying upon interviews.
	Application in this study	This study applied aspects of technography to the research approach and analysis, as well as reflections for future research.
Cultural Anthropology	*Description*	The researcher's own background in cultural anthropology indirectly contributed to the design and practice of this research. Writing an ethnography, the classic text of cultural anthropology, implies constructing an understanding of a bounded social entity (e.g. a social group, a concept) using tools such as participatory observation and interviews (or, more often, discussion), observation and recording of relevant material and conceptual elements of the study area (Geertz's "thick description"). It emphasizes recognizing the influence of perspectives – the researcher's own included (see van Maanen, 1988 for a guide and reflection on ethnographic methods).
	Methods	Participant observation is a key tool of (cultural) anthropological fieldwork and technography, but is also widely employed in social research. Observing details by participating in daily activities and conversation provides insights that inform not just conclusions, but the process of research itself (e.g. designing surveys and in-depth interviews) (see van Maanen, 1988). Open-ended interviews, also not limited to a particular social science discipline, attempt to guide discussions, rather than dictate a clear structure of question-response, and to encourage interviewees to share more lengthy and complex answers than the less useful "yes or no". They may be semi-structured or in-depth.
	Application in this study	This study applied aspects of cultural anthropology to the research approach and analysis, as well as reflections for future research.

Participant observation

Participant observation was used throughout the research, including day trips to the villages for field visits or meetings, during interactions with project staff, and while working in the field experiments. During meetings, observation focused on social dynamics and perceptions of the field tests.

This technique was mostly used, though, while staying in the villages with different farmers who participated in the project. Approximately 55 days were spent in the villages throughout February to the beginning of June 2013. Some were day trips, but the vast majority spanned three to five days at a time. Most work in the field experiments was conducted from March to May. Interviews were held from April to the end of May. Farmers organized amongst themselves who would host, varying between one to three nights at a time. Observation and informal discussions about interview subjects, references to social networks, body language, material surroundings, daily rhythms, consumption and communication patterns were possible during meals, daily activities (e.g. collecting water, preparing food), and walks to and from fields. Although not all details were directly relevant to the objectives of this research, they were useful nevertheless to contextualize data and impressions. A translator present during all visits to the village and meetings, and her role was consistent from the beginning of research until the second to last week. Her high level of competence and interest in the study naturally expanded her role to include cultural interpretation, which contributed invaluable insight to interview techniques and some conclusions.

Interviews

A total of 44 farmers were interviewed (11 women, 33 men), their spouses were often present and had different levels of participation in the discussions. Individuals were selected due to attendance of the initial ABACO meetings (and may or may not have continued to participate actively, depending on their availability and interest), and because they were available during village visits in April to May. The vast majority of interviews were planned one week in advance with clear meeting times and a preview of subjects to be discussed. Presenting written invitations to key individuals (e.g. neighbor, spouse, a dynamic and communicative group member) proved helpful to coordinate logistics. Although the interviews were recorded on a dictophone at first (with consent of interviewee), it was decided to discontinue as there was adequate time to take detailed notes during moments of translation, and because farmers seemed more at ease without the device present.

There were three types of interviews:

- Forty-four individual open-ended, semi-structured interviews were held either in the interviewee's home, a neighbour's home, or the administrative office of the *fokontany*. They lasted approximately one hour. (see Appendix XI for individual interview guidelines)
- Seven open-ended, semi- structured group interviews, organized per village, were held after individuals had been completed to discuss subjects such improvements or modifications to how the groups and experiments worked, future experimental objectives, communication, and the future of the group (see Appendix XII for group interview guidelines).
- Approximately six in-depth interviews occurred informally during meals and meal preparations, while harvesting crops, and during walks to and fro fields. There were no set guidelines for these interviews. They varied depending on the farmer(s), but generally related to research conclusions, and were held towards the end of fieldwork.

Individual and group interview guidelines were structured by combining insights from:

i) previous interview-guided research conducted in the area; ii) informal discussions with BVLac, BRL and ABACO project staff; and iii) personal field observations in target villages and surrounding fields during biophysical measurements. Some aspects and question formulations were modified after pre-testing, and varied depending on the farmers addressed. However, in almost all cases, the interviews had three sections: I) questions regarding the farm and household; II) why interviewed participants were interested to engage in field experiments and to illicit suggestions for next year's work; and III) prevailing perceptions related to observations pertaining to experiments and results. Sections I and III provided two different approaches in the effort to understand experiment interpretations, which was helpful in the attempt to mitigate communication challenges between researcher and farmers.

Technography emphasizes observation of performance (what people do), and rarely relies on interview data alone. While this study did not aim to observe farmer use of CA on their own farms (performance), it was nonetheless important to improve our understanding of on-farm use of different CA practices. This technography-inspired approach served several purposes. First, it contributed answers to research questions: 1a) How were experiment and results perceived by farmers? 1b) How might this impact the structuring, design and implementation of future experiments and on-farm decisions? 2) How do farmer perceptions of CA compare between ABACO group participants? 2a) What are the key factors and processes that govern (the lack of) farmer participation in existing co-innovation platforms? Second, it provided a partial inventory and characterization of the different farmers who participated in the project. Third, it proved to be a useful approach to encourage farmers to share perceptions or interpretations of field experiments.

Technography was particularly influential in the design of part I of the individual interviews, primarily designed to respond to research questions 1b and 2 (see above). The aim was to recognize varying combinations of CA practices per field, rather than generalized per farmer or farm. To accomplish this, discussion about the farm addressed each field individually, attempting to ascertain the use zero-tillage and soil cover (defined in this study as live cover crops or dead mulch) in the past, present (defined as the agricultural year 2012-13), and anticipated future. What farmers said they would do in the future was interpreted as an expression of intent or interest. Rotations were not counted for several reasons. Firstly, zero-tillage and soil cover were the focus of most experiments. Secondly, subjects were selected in interest of time. Thirdly, though it has been observed that rotations are one of the first of the three CA techniques to be adopted during CA promotion (Penot *et al*., 2012a), most ABACO members had little experience with CA. Interviews also encouraged farmers to describe per field the land type, area, soil fertility, fertilization practices and typical crops, again with references to actual or anticipated changes over time.

Analysis of interview data

The interview data was transferred from written notes into an Excel spreadsheet, and coded by content. Analysis followed three general steps. First, general themes and patterns were identified. This produced a typology of three farmer groups: A, farmers who had used zero-tillage or soil cover at least once in the past; B, farmers who used zero-tillage or soil cover for the first time in the 2012-13 agricultural year; and C, farmers who anticipated using zero-tillage or soil cover in the future for the first time. Farm and household details were examined separately per group in order to identify patterns or themes, which were described qualitatively or represented in percentages (e.g. proportion of total farm land on rice fields vs. *tanety* and other land types).

Second, the themes and patterns were compared to expectations and impressions that had formed throughout the research. Third, conclusions from the interview data were triangulated with quantitative data from the field experiments (see next section).

Bringing qualitative and quantitative data together

Triangulation poses the possibility of combining qualitative and quantitative data, though it does not specifically address the blend of social and natural sciences[9]. It broadly refers to the technique of using different methods and perspectives to validate responses to questions, and should additionally enhance understanding of the subject in the process. It may be used at different levels of research, as it was in this study. At the most simple, it was helpful during interviews and discussion to cross-check responses. At the first level of analysis, it was used to draw conclusions from individual experiments by comparing answers to three main questions: How did farmers interpret the experiment results – through their own observations and biophysical measurements? What were the results of biophysical measurements? and How do the two compare? At the second level of analysis, it was used to gain insights from a wider perspective (combining biophysical and interview data, and participant observation). At the third level, the different complimentary methodologies were triangulated to respond to research questions.

2.5. Report structure

Each of the ten field experiments is documented by an individual description including the following components: introduction, materials and methods, results, discussion and conclusion. They are presented in the appendices (Appendices I through X). Results and discussion are presented together in one section, but consists of two parts. Part I begins with an overview of all objectives from the ten field experiments (farmer managed pilot studies). This is followed by a first level of results and analysis: a brief review of achievement of overall experimental objectives followed by a summary of conclusions drawn from related objectives along with farmers' suggestions for future pilot studies next year, and results from interview data pertaining to on-farm use of CA practices. Part II triangulates data from a yet wider perspective, discussing insights drawn across experiments, interview data, and participant observation. It also includes reflection on the limitations of the current study. The synthesis section responds directly to research questions and hypotheses. The conclusion section summarizes main points of the study and offers recommendations for the future.

[9] See Denzin (1970) for a description of four types of triangulation: of data, theory, investigators, or methodology.

3. Results and Discussion: Part I

This section presents results and a first level of analysis at the field and farm scale. It begins with an overview of the experiments (Table 3), including overall objective for the ten pilot studies. This is followed by a summary of conclusions per objective (which integrates biophysical results and farmer interpretation of experiments), farmer suggestions for future field experiments, and a presentation of on-farm use of 0-till and soil cover practices.

3.1. Field experiments: overview of objectives

Table 3. Key agronomic features of the ten field experiments in two study sites (north, south) conducted in 2012-13 with the ABACO project in the Lake Alaotra region. Primary crops were maize (*Zea mays*), upland rice varieties (CNA 136, B22, 2366, SEBOTA 406), cassava (*Manihot esculenta*) and bambara groundnuts (*Vigna subterranea*); and cover crops were *Stylosanthes guianensis*, *Dolichos lablab*, *Mucuna pruriens*, two crotalaria varieties (*C. juncea* and *C. ochroleuca*), and rice bean (local name *tsiasisa*) (*Vigna umbellata*).

Field experiment (NORTH)	1	2	3	4	5
Toposequence	lower slope	lower slope	lower slope	rice field, poor water control	*tanety*
Crops	Rice varieties: • 2366 • SEBOTA 406 • CNA 4136	• Maize • Dolichos • Rice bean (*tsiasisa*)	• Rice varieties CNA 136, 2366 • Mucuna • Dolichos	• Rice (SEBOTA 406) • *Crotolaria juncea* • *Crotalaria ochroleuca*	• Maize • Dolichos • Mucuna
Treatments and sub-plot size	18 (2 x 12.5 m)	3 (10 x 10 m)	4 (10 x 10 m)	4 (8 x 10 m)	2 (5 x 10 m)

Field experiment (SOUTH)	1	2	3	4	5
Toposequence	sandy *baiboho*	*tanety*	steep *tanety*	gently sloped *tanety*	sandy lower slope
Crops	• Maize • Rice (B22) • Rice bean • Mucuna • Stylosanthes • Brachiaria	• Rice (B22) • Beans • Dolichos • Stylosanthes (residues)	• Maize • Beans • Dolichos • Mucuna • Rice bean • Sorgum	• Cassava • Maize • Stylosanthes • Brachiaria • Mucuna • Dolichos	• Bambara groundnut • Brachiaria residues
Treatments and sub-plot size	4 (8 x 10 m)	5 (7 x 10 m)	4 (5 x 20 m)	4 (two 10 x 10 m; two 12 x 10 m)	2 (5 x 20 m)

Objectives categorized by similarities

Although each experiment was unique (Table 3), the majority of objectives from the ten experiments may be grouped into 3 categories.

1) Observe and compare different cover crop:

- development
- development with different sowing dates
- ability to improve soil fertility
- effects on maize yield
- effects on soil cover and weeds

2) Comparing crop performance with different soil management:

- between year 0 and year 5 under CA management
- between two different fertilization treatments
- between fields with and without mulched residues

3) Objectives concerning rice production:

- Compare effects on yield between different upland rice varieties
- Compare effects on soil cover and weeds between different rice sowing densities
- Improve soil cover by relay sowing cover crops in rice
- Observe upland rice on *tanety*

Additional objectives included to produce dolichos seeds and to valorize use of *tanety*.

Achievement of objectives

Of all the objectives across experiments, some were not achieved this year (intentionally or unintentionally), some were partially achieved (intentionally or unintentionally), and others were achieved (Figure 10).

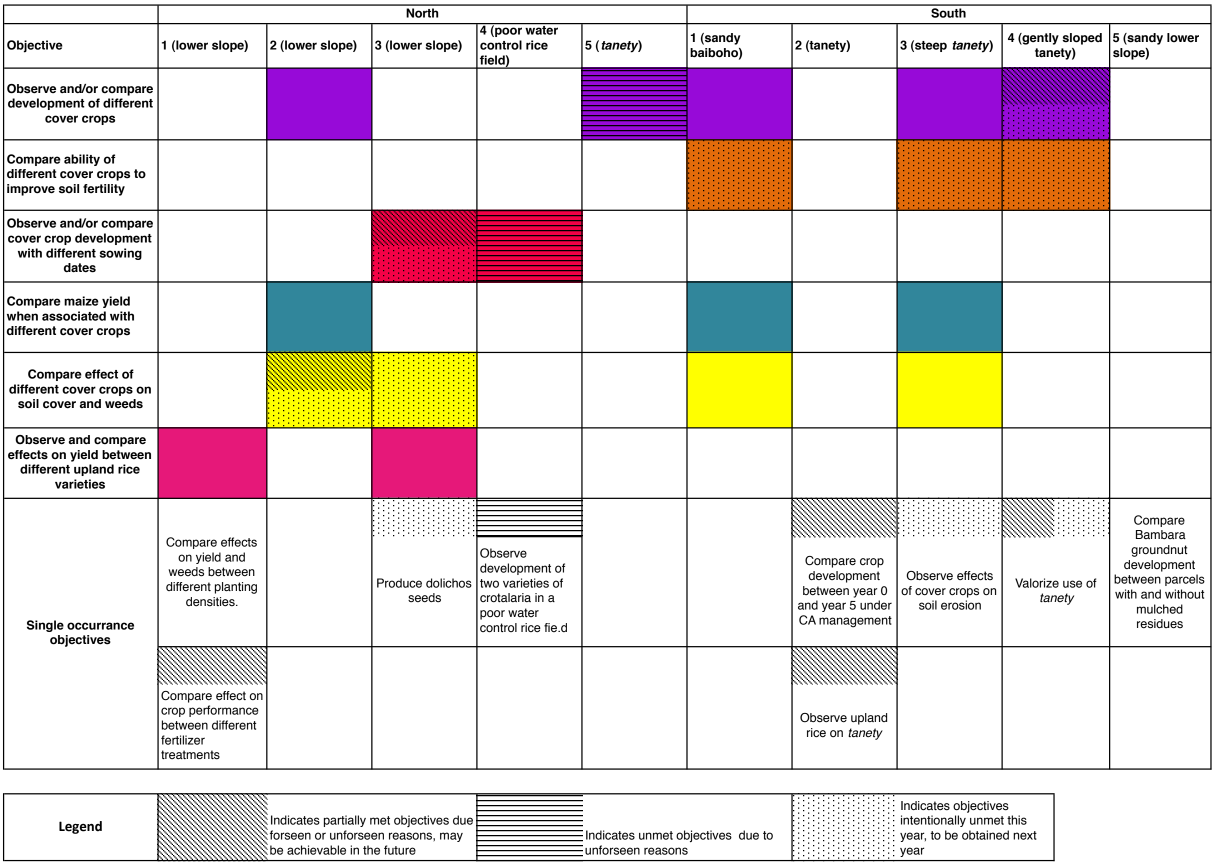

Figure 10. Overview of objectives and toposequences for the ten field experiments in two study regions (north and south) of the ABACO project 2012-13, Lake Alaotra. Marked boxes are indicative of objectives that were either partially achieved or not achieved (see legend) during the agricultural year 2012-13. No pattern indicates that the objective was fully achieved.

Four objectives were intentionally not achieved this year for certain experiments, and may be obtained next year:

- Compare effects of different cover crops on soil fertility (experiments 1 south, 3 south – will also compare effects on erosion, and 4 south)
- Compare effects of different cover crops on soil cover and weeds (experiments 2 north, 3 north)
- Produce dolichos seeds (experiment 3 north)

Due to unforeseen reasons, the objectives were not achieved for two experiments.

- For 4 north, a comparison of cover crop development with different sowing dates, and observation of the development of two varieties of crotalaria in a poor water control rice field were unfulfilled due to heavy rains that washed away most of the crotalaria seeds.
- For 5 north, observation of cover crop development on *tanety* was not met due to management mistakes and lack of interest by the owner. Nevertheless, 5 north still afforded discussions about cover crop performance and zero-tillage management.

Six objectives were partially achieved for certain experiments due to foreseen and unforeseen reasons

- Observation of different cover crop growth as affected by different sowing dates in 3 north began before completion of this research and will be fulfilled in the future.

- The objectives valorize *tanety* and observe cover crop development on *tanety* for experiment 4 south were only partially fulfilled due to dry weather and a misidentification of cover crop seeds. Observations may continue throughout the next year.
- Comparison of the effect of different cover crops on soil cover in 2 north was partially met. Observation of the field plots planted with both dolichos and rice bean (*Vigna umbellata*, locally referred to as *tsiasisa*).
- A comparison of the rice yield between two different fertilization treatments in 1 north was partially achieved because the field owner applied only one liquid compost application, compared to two of NPK and urea. It was generally agreed that she should have applied two liquid compost treatments.
- Both objectives of experiment 2 south - observation of upland rice on *tanety* and comparison of crop performance between year 0 and 5 under CA management - were partially achieved due to theft of the rice. Most members did not see the rice during maturation. However, those farmers who were able to shared their observations, and an estimate of the stolen rice yield was made based on remaining panicles and data collected earlier in the season.

Seven objectives were achieved for certain experiments:

- Compare development of different cover crops (1 south, 3 south, 2 north)
- Compare maize yield when associated with different cover crops (2 north, 1 south, 3 south)
- Compare effect of different cover crops on soil cover and weeds (1 south, 3 south)
- Compare crop performance between year 0 and year 5 under CA management (2 south)
- Compare effects on yield between different upland rice varieties (1 north, 3 north)
- Compare effects on rice yield and weeds between different sowing densities (1 north)
- Compare crop performance between fields with and without mulched residues (5 south)

3.2. Conclusions from achieved and partially achieved objectives

This section summarizes conclusions per objective (achieved or partially achieved) across experiments. Where possible, each objective is discussed in terms of farmer perceptions and biophysical results. See experiment reports for individual experimental plans, complete results, discussion, conclusions, photographs, and details such as comments and observations by the field owner and other farmers (Appendix X).

Observing and comparing different cover crops

Farmers were able to **observe and compare cover crop development** in four of five experiments: 2 north (lower slope); 1 south (sandy *baiboho*); 3 south (steep *tanety*) and 4 south (gently sloped tanety). It should also be noted that farmers actually had the opportunity to view cover crops at different stages of development and conditions in nine of the ten experiments even though it was not the stated objective.

People were generally pleased with cover crop development. They expressed surprise to see what they described as “good growth” on the sandy *baiboho* and steep *tanety*, these being associated with relatively infertile soils. mucuna and dolichos were generally perceived to have similar characteristics due to leaf shape, similar vertical climbing behavior, and continued production of leaves after flowering (see Results and Discussion: part II for a more detailed discussion about perceptions of cover crops). Farmers usually compared them against *tsiasisa*, which did not climb as high on the maize, and died after grain production. The tendency of mucuna and dolichos to climb high on the maize plants was perceived negatively, as farmers expected that it would lower maize yields. *Tsiasisa* also climbed on maize, but remained relatively lower. Their effect on maize yield is discussed below. Aside from overall approval of their growth, there were no general conclusions about stylosanthes or brachiaria, perhaps due to their early stages of growth.

Dry weather and insect damage caused farmers to express concern about their ability to produce seeds for consumption from *tsiasisa*. However, they positively evaluated tisasisa's ability to produce biomass for potential improvement of soil fertility. Indeed, in all three experiments *tsiasisa* produced either the highest or second highest amount of biomass out of three cover crops (Figure 11). All biomass samples were harvested during flowering, between 6 to 17 May[10]. However, the plant that produced the highest biomass at flowering was not farmers' preferred cover crop, as they considered other factors such as biomass produced over time, as well (discussed further below).

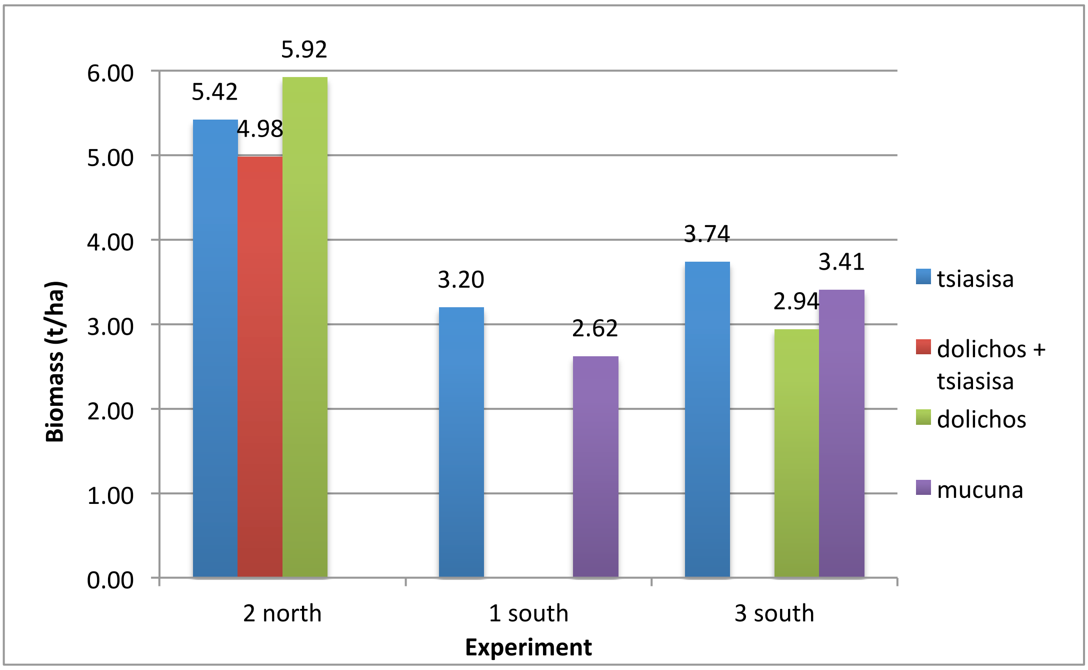

Figure 11. Biomass (t/ha) of cover crops associated with maize in three different field experiments (2 north, 1 south, 3 south) of the ABACO project 2012-13, Lake Alaotra. Data labels are cover crop biomass values.

Farmers were able to **compare the maize yield when associated with different cover crops** in three out of three experiments: 2 north (lower slope), 1 south (sandy *baiboho*), and 3 south (steep *tanety*).

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[10] Dates when biomass samples were cut, per experiment: 1 south – stylosanthes, mucuna and *tsiasisa* were cut 10 May; 3 south - *tsiasisa* was cut on 10 May, towards the end of florescence, dolichos and mucuna were cut 17 May; 2 north – dolichos, *tsiasisa*, and dolichos + *tsiasisa* were all sampled on 6 May. Cover crops were flowering when sampled, although mucuna had already started to develop seeds.

Farmers were generally pleased with the maize development, and again especially on the sandy *baiboho* and steep *tanety* fields. Yield results were actually the lowest overall for these two of the three experiments (Figure 12). It seems that farmers compared their visual observations with what they expected from general experience with these land types, rather than with a certain yield goal in mind. They also emphasized that the priority in year 0 was not to obtain a good maize yield, but to fertilize the soil, this suggesting that they would not express concern even if maize yields were relatively low.

As mentioned above, many people expressed concern about mucuna and dolichos causing lower maize yields by climbing too high and too thickly. In all three experiments, maize associated with dolichos, mucuna, or dolichos + *tsiasisa* did produce less yield than with *tsiasisa* (Figure 12). In 2 north and 3 south maize yield when grown with *tsiasisa* was approximately double the others, but in 1 south the yield of maize grown with *tsiasisa* was only slightly more than with mucuna. Although other factors may have influenced the yields, the results lend support to farmer concerns about the yield reducing effect of mucuna and dolichos's climbing behavior, while also suggesting that the effect can vary. The cover crops were not deterred or controlled in any way during the experiments. Farmers discussed several different techniques they intend to test in future experiments and on their farms (discussed in more detail later on). It seems that exploring these techniques gave confidence to the farmers in their ability to manage the crops, as they expressed strong interest in growing the both in the future despite yield results.

There did not seem to be strong competition for resources between maize and cover crops. As both were growing in the same field at the same time, competetion would have implied that enhanced growth of the cover crop would have reduced maize growth (e.g. an inverse relation). However, in general, it appeared that both seem to be indicators of overall crop productivity, with both crops performing better in more condusive production environments (Figure 13) (e.g. lower slope field of 2 north, which produced the highest maize yields and cover crop biomass, is considered to have better inhererent soil fertility than the sandy *baiboho* of 1 south and the steep *tanety* of 3 south).

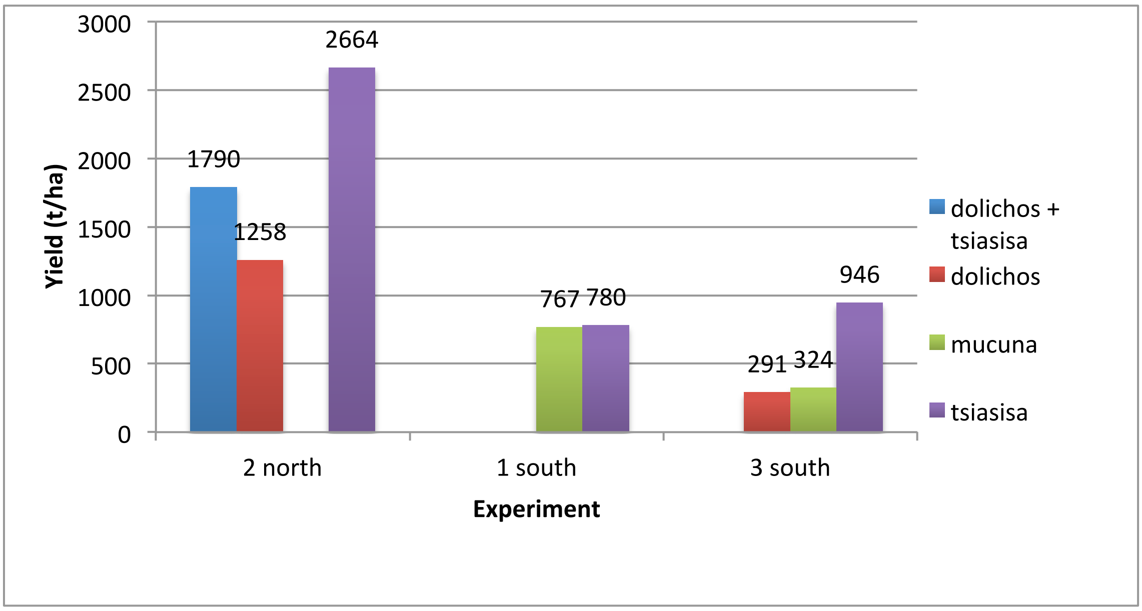

Figure 12. Maize yield (t/ha) associated with different cover crops in three experiments (2 north, 1 south, 3 south) of the ABACO project 2012-13, Lake Alaotra. Data labels are maize yield values.

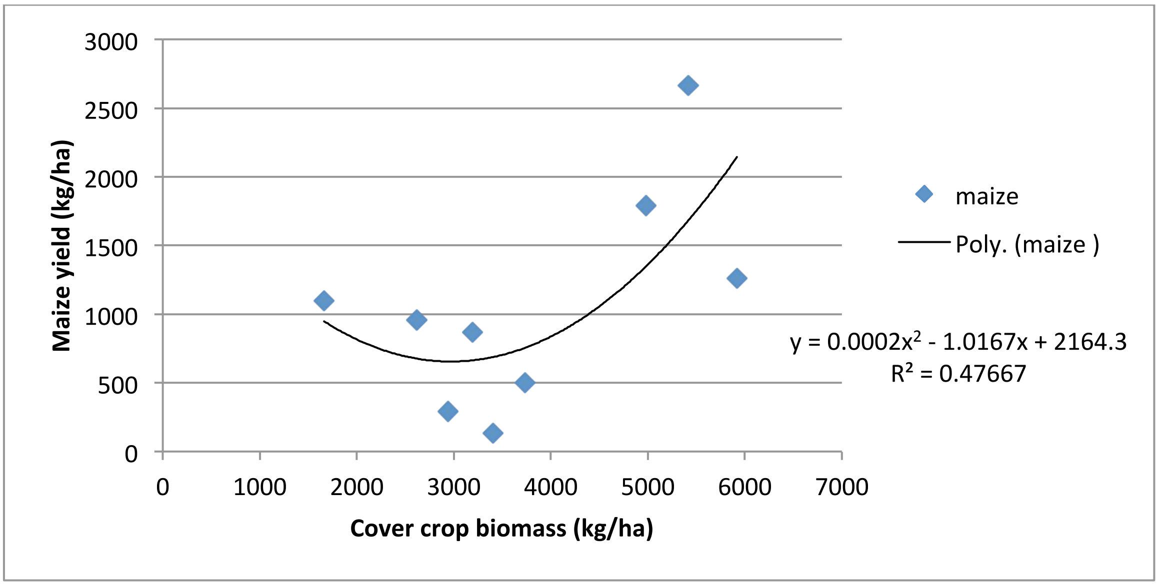

Figure 13. Relationship between cover crop biomass and maize yield in three experiments (2 north, 1 south, 3 south) of the ABACO project 2012-13, Lake Alaotra. Both are indicators of crop productivity, performing according to production environments.

In the same three experiments, farmers had the opportunity to **compare the effects of different cover crops on weeds**. According to all three field owners, the weed populations were similar between all treatments, and had less than typical crop associations (such as maize and beans). Assessment of weed populations was performed by the field owner and recounted verbally during conversations. No measurements were taken.

Comparing crop performance with different soil management

Farmers were able to **compare the performance of two different crops in year 0 and year 5 of CA management** in one experiment: 2 south (*tanety*). It was the only experiment with this objective. Under CA management, year 0 indicates that the field is tilled and crops are planted, and that tillage is discontinued from year 1 onwards. Perceptions were expressed primarily by the field owner as many farmers were not able to observe the rice in maturity before it was stolen.

Farmers generally expressed that the dry weather reduced the bean yields across fields, and that comparing production between fields was not worthwhile considering effects of dry weather and insects. Indeed, bean yields did not correspond directly with soil management choices: yields were similar between year 5 and year 0 with stylosanthes, and slightly higher with year 0 with dolichos (Table 4).

Farmers observed that in the year 5 field, rice grains were “more robust” and “fuller”, and rice tillers were greener, indicating more soil moisture. They predicted it would better survive dry conditions than the adjacent field of rice in year 0. The observation of “fuller” grains did not correspond to results (Table 5), which showed that the thousand kernel weight was higher for year 0 (33.85 g) than for year 5 (26.05 g). The difference in grain weight may be due to slower development in the year 5 field combined with the early harvest before grains were filled.

They also anticipated that the yield would be lower from year 5 than in year 0, but pointed out the expected future advantages such as better resistance in dry weather and better long-term soil health are equally important factors to consider, if not more so. The rice yield was indeed lower for the year 5 field with 2070 kg/ha compared to 3495 kg/ha for the year 0 field, corroborating farmer projections.

Although the yield was considered important in the comparison between years 0 and 5, farmer attention to additional factors indicate their concern for crop resistance during unpredictable climate and stable yields over long term. It is important to note that the dominant opinions were those of an experienced CA enthusiast.

Table 4. Actual bean yield (weighed in pods) per sub-plot (experiment 2 south of the ABACO project 2012-13, Lake Alaotra). Each subplot was 70m2.

Crop	Actual yield (kg/sub-plot) (weighed in pods)
Beans + dolichos, year 0	6.46
Beans + stylosanthes, year 0	6.10
Beans + stylosanthes mulch, year 5	6.12

Table 5. Selected rice yield components per treatment (experiment 2 south of the ABACO project 2012-13, Lake Alaotra). Each subplot was 70m2.

Treatment	N° seed holes/m^2	N° panicles/seed hole	N° spikelets/ panicle	% full spikel ets	Weight 1000 grains (g)	Yield (kg/m^2)	Yield (kg/ha)
Rice, year 5	12.20	10.33	95.50	66	26.05	0.21	2070
Rice, year 0	12.60	12.80	108.50	59	33.85	0.35	3495

Farmers had the opportunity to **compare yield between two different fertilization treatments** in one experiment: 1 north (lower slope). It was the only experiment with this objective. This experiment compared yields between three rice varieties with three different sowing densities and two fertilization treaments (NPK + urea, liquid compost).

Perceptions were few and there were no general consensus on field observations - some farmers thought the field with NPK and urea would give a higher yield, whereas others said there were more empty spikelets and shorter panicles in the same field. The field owner said she had not applied enough liquid compost (once, compared to two treatments of NPK and urea), but if she had, then the yields would be similar between treatments. Yields from fields treated with liquid compost were lower for all varieties (Figure 14), with differences of 12 to 41 % but no significant differences (see ANOVA in Appendix I). The comments suggesting higher yields with liquid compost treatment, despite the results that show otherwise, may reflect the negative opinions that some farmers hold for long term effects of NPK and urea.

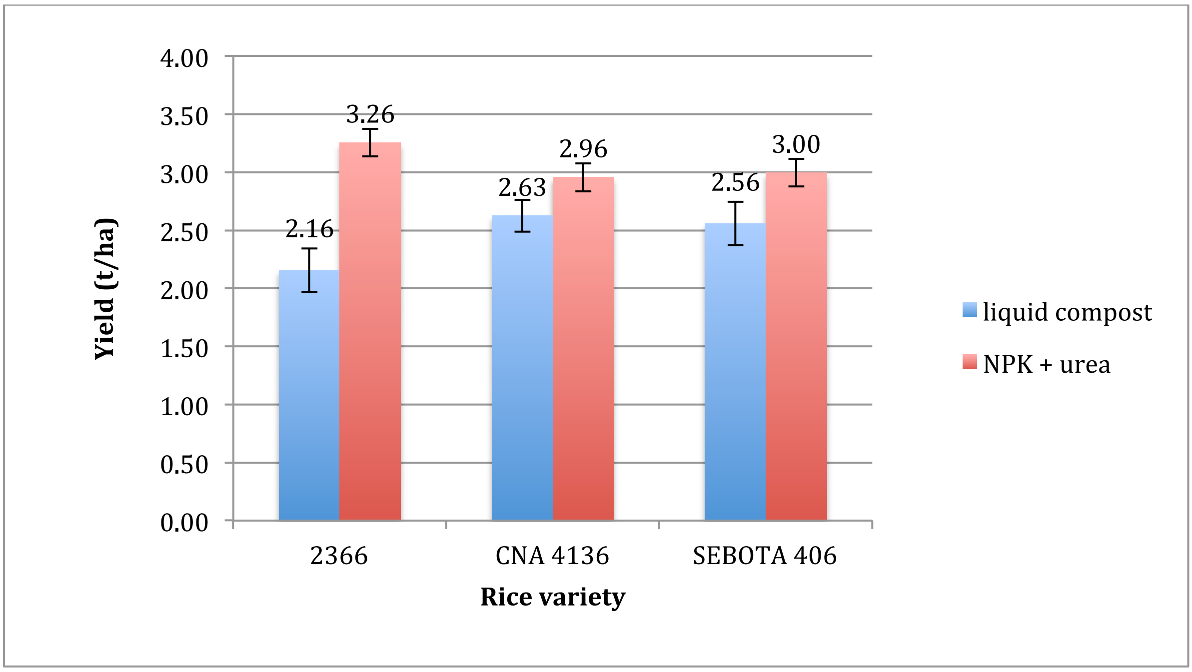

Figure 14. Rice yield (t/ha) per fertilization treatment and variety in experiment 1 north of the ABACO project 2012-13, Lake Alaotra. Data labels are rice yield values. Vertical bars denote standard error.

Farmers had the chance to **compare development and yield of a crop grown on fields with and without mulched residues** in one experiment: 5 south (sandy lower slope).

Greener leaves and moister soil were observed in the field with mulch, leading farmers to anticipate better yields from the field. Bambara groundnut yield from the mulched field was approximately double that of the field without mulch (Table 6). In the mulched field, the average seed size was larger and seeds were located closer to the soil surface. Although farmers were impressed before and after learning the yield results, it was not one of the fields they volunteered to discuss during individual or small group conversations about the experiments. It seems that few farmers in the groups grow Bambara groundnuts regularly, and were therefore less interested in the experiment because it lacked applicability to their own farming practices.

Table 6. Bambara groundnut yield (t/ha) (experiment 5 south of the ABACO project 2012-13, Lake Alaotra).

Treatment	Yield (t/ha)
Mulch	4.24
No mulch	1.90

Objectives concerning rice production

Farmers were able to **compare yields between different upland rice varieties** on CA managed plots in two of two experiments: 1 north and 3 north (both on lower slopes).

Beyond general comments that the rice grew well in both experiments, there was no general consensus on yield expectations per variety. In 1 north, yields were similar with no significant difference. In 3 north, CNA 4136 produced more rice than 2366, although the 2366 yield was affected by low production of one sub-plot for unknown reasons (see Figure 15) for results of both experiments). The diversity of farmer opinions about yields in 1 north seem to have been supported by the lack of significant difference between variety yields. Several farmers, including field owners, expressed interest in growing CNA 4136 as it was a new variety that produced approximately equal or higher yields.

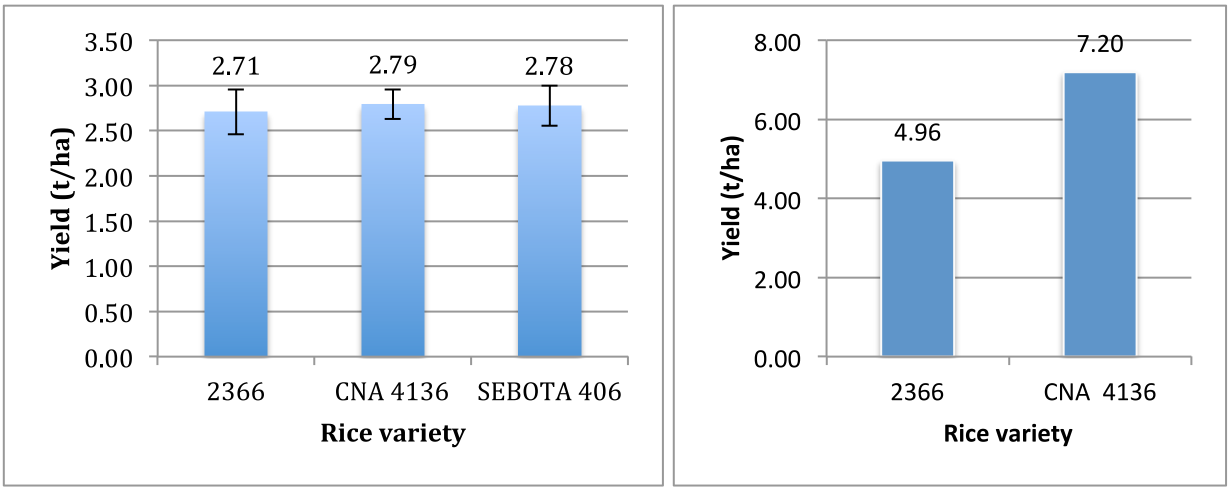

Figure 15. Rice yield (t/ha) per variety for two experiments (left: 1 north; right: 3 north) of the ABACO project 2012-13, Lake Alaotra. Data labels are rice yield values. Vertical bars denote standard error, available only for experiment 1 north.

Farmers had the opportunity to **compare the effects of different rice sowing densities on yield and weeds** in one experiment: 1 north (lower slope). Sowing densities were 20 x 25, 20 x 30, 20 x 40.

This research plot and particular objective generated many responses during interviews. Although the perceptions were diverse, many people, including the field owner, anticipated that 20 x 25 cm would result in the highest yield due to a higher number of pockets. Yields for 20 x 25 sub-plots across rice varieties were generally lower, and there were no significant differences between the three sowing densities (Figure 16). Farmers' anticipation that 20 x 25 sowing density would produce the highest results was not verified by the results. They had assumed that the grain production would be the same per seed hole between different planting densities. They concluded that the yield difference did not justify the increased quantity of seed necessary to sow 20 x 25 cm, and therefore 20 x 40 cm may be best on fields located on lower slopes.

Weed populations were approximately equal between plots sown with 20 x 25 cm and 20 x 30 cm, and the 20 x 40 cm plots had slightly more. Assessment of weed populations was performed by the field owner and recounted verbally during conversations. No quantitative measurements were taken.

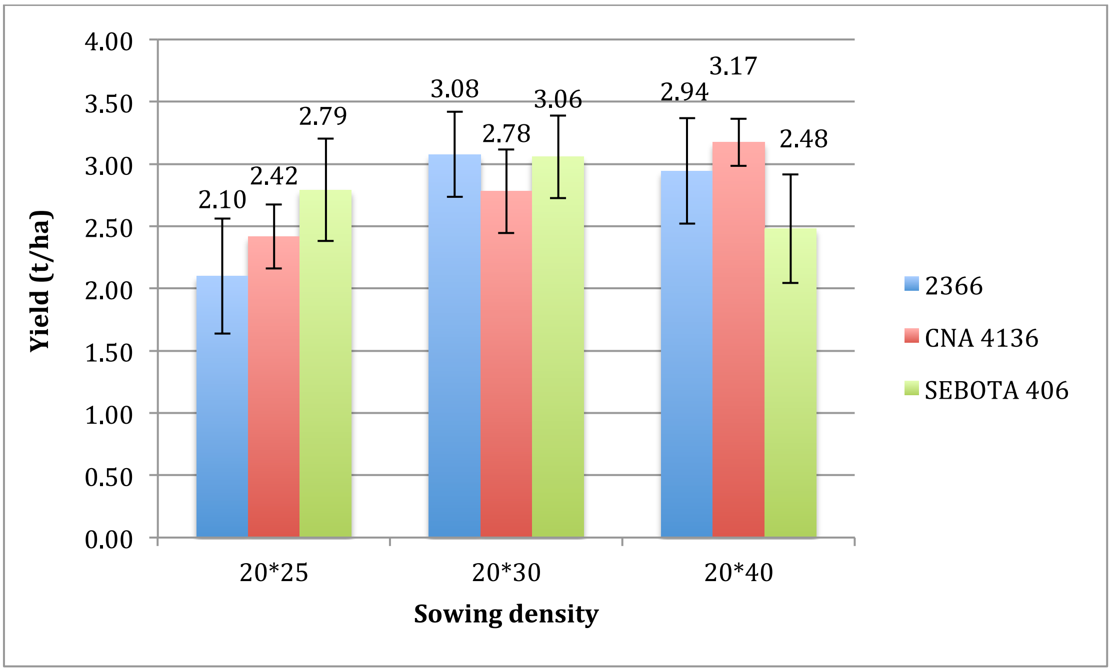

Figure 16. Rice yield (t/ha) per variety and sowing density for experiment 1 north, of the ABACO project 2012-13, Lake Alaotra. Data labels are rice yield values. Vertical bars denote standard error.

Farmers were able to partially **observe effects of relay sowing cover crops into rice in order to improve soil cover** before the end of this research. Although it will be observed in the future, comments up to early June concluded that the dry weather was principally responsible for the slow growth of both cover crop varieties, and that perhaps earlier sowing dates would have improved their development.

Some farmers had the opportunity to **observe upland rice on *tanety*** before it was stolen. An exchange visit after the harvest also offered the chance for people to make what observations they could. Farmers from Mahatsara expressed general satisfaction or even pleasure, it being the first time they had purposefully observed rice on *tanety* (rice in Mahatsara is usually produced on rice fields with varying degrees of water control, or on *baiboho* during the rainy season). Farmers from the northern *fokontany* were not particularly interested as they are accustomed to growing rice on *tanety*.

Other objectives

Farmers had the chance to **valorize use of *tanety*** in one experiment: 4 south (gently sloping *tanety*). Development of some cover crops was considered poor, blamed on dry weather conditions. Observations will continue throughout the next year, providing an opportunity to discuss use of cover and primary crops on this type of *tanety*.

3.3. Farmer suggestions for next year's field experiments

Farmers proposed the following ideas for next year's round of field experiments. They were discussed during individual and group interviews, and during meetings.

Strategic use of the ABACO project

- There should be more experiments, but on larger (full) field plots. In other words, all the interested ABACO members should now try to implement a cropping system that interests them on an entire field plot, and then share the results with others afterwards. It is the next step in the innovation process because people need to "do" in order to learn. The risk of being discouraged by poor cropping system performance (due to lack of knowledge or good management) should be tempered by the fact that people have already seen encouraging and positive results during the field experiments. Many people would like ABACO to be an intermediary seed supplier to support this next step, seeing as it can be difficult to source cover crop seeds.
- The best time to discuss experiments and other ideas with farmers is just before the beginning of the agricultural season.
- There was not enough discussion and exchange between farmers, especially between those from the two different regions. The aims of the exchange visits were to observe experiments, rather than to create time for farmers to discuss amongst themselves. There should be more people present at the meetings before and after the experiments in order to facilitate more discussion.
- Future experiments should implement ideas discussed for how to control cover crop growth on maize.
- Experiments should be repeated on different land types, and in different villages. This would reduce the need for people to travel to see fields, test the innovations on a wider variety of soil and land types, encourage local interest for people who are interested in CA practices but not ABACO participants, increase the number of people practicing the techniques rather than just observing.
- There should be some kind of rule put in place to discourage *tondra-boly* (a cultural practice that grants common grazing rights in fields after harvests)
- More assistance from technicians would be appreciated. They could monitor crop growth in field plots and make sure farmers use sound agronomic practices in the field studies, although the technicians do not need to give strict instruction to farmers.

These suggestions and recommendations imply that farmers would like to make use of the material and other support offered by ABACO while it exists, even if they were also contributing constructive criticism about how the participative research project functions. The opportunity to discuss between farmers from different *fokontany*, for example, was made possible because the project organizes and bears costs for transportation and a meal, as well as being the catalyst for people from different social networks to come together. Similarly, interest in expanding the number and location of experiments (as well as the informal, larger “real field” experiments), which all occur on farmer-owned and managed fields, may also have been encouraged by the expectation of input support (ABACO provides seeds, some fertilizers, and insecticides for the field experiments). Assistance from technicians (technicians being any outsider with agronomic knowledge) and foreigners (such as researchers) may also contribute to this interest. Almost every farmer discussed the need to be “made aware”, “encouraged”, or “led” towards “improvement” – not only, but often, by outsiders with different technical knowledge. Association with outsiders also brings advantages related to authority, such as the weight of their presence through a painted sign post banning *tondra-boly*.

The region has a long history of development projects. The most recent situated technicians in different villages to promote CA ended during the first year of the field experiments (in May 2013). This reality, in addition to the constant reminders during meetings and interviews that support from ABACO would terminate in the near future, may have further encouraged farmers to take advantage of the time-limited resources. Strategic consumption of development projects has been discussed as a smallholder strategy (Michener, 1998), and seems to have played a role in this case. Nonetheless, the proposals above may simultaneously be interpreted as genuine interest in innovation development, with the support of a project entity.

Continuation of exchange in the future

- The two ABACO groups should create a type of headquarters, with representatives from each region. They could facilitate communication between the communities (e.g. to take orders for vetch seeds, organize meetings) and perhaps coordinate visits to share knowledge and innovations. Farmers were aware that this organization would require self-generated funding. Members from Mahatsara proposed the idea, but initial interest spread and each group has already chosen four representatives.
- Farmers from Mahatsara proposed that their group should have one common field, donated by somebody, worked by everybody interested, close to the village. It would serve several purposes: (1) demonstration field (2) production of seeds that could be sold to finance the bureau (3) a central place to gather that would offer the opportunity for people to exchange information.
- In the future even after ABACO project terminates, some farmers from Mahatsara hope the group will continue to exchange knowledge amongst members. They proposed that it should be open to everybody to join, though there should be some kind of informal training by existing members first in order to encourage group cohesiveness by establishing common objectives.

These proposals give the impression that some farmers would like to continue information exchange, within and between groups. It is possible that the Mahatsara group seemed most interested as they were least experienced with CA techniques, implying that they would most benefit from information exchange, as well as other potential advantage of being in contact with the northern group. For instance, this year some farmers in the north had an excess of vetch seeds that they were willing to sell to farmers from the southern group. Whether the groups continue to exist, and whether they see mutual benefits from an exchange remains to be seen.

3.4. On-farm use of zero-tillage and soil cover techniques over time

This section presents farmers' use of zero tillage and soil cover across time. Soil cover refers to purposeful use of mulched residues – *ex-situ* or *in-situ* residual mulch (Erenstein, 2003) - or live leguminous cover crops. Observations included past and current practises up to the 2012-13 growing season and future refers to planned activities starting from the 2013-14 cropping season. What farmers said they will do in the future was interpreted as an expression of intent or interest. The data comes from interviews with 44 farmers, all participants to some degree in the field experiments. Interviews addressed characteristics and management decisions of each land field, as well as certain farm and household characteristics. Therefore, all statements by farmers and trends presented in this section refers only to these 44 farmers and is based on direct communication and information collected during interviews.

First, a brief list of typical practices gives some background context with which to compare any use of zero-tillage or use of soil cover. Second, the 44 farmers are described in three groups according to how their use of zero-tillage and soil cover may have evolved over time. Those in the group A, have used one or both of the two practices at least once in the past. People in group B tried at least one of the two practices in the current agricultural year (2012-13). Farmers in group C verbally expressed trying zero-tillage or soil cover, or both, for the first time in the near future. Third, other farm or household characteristics such as interviewee age, number of zebu, farm area per toposequence, and off-farm activities are also presented per group in Table 7. Conclusions drawn from these results are discussed later.

Typical practices

Typical practices described by farmers during interviews and conversations include the following: annual tillage and occasional use of a fallow year (there were very few fields left intentionally fallow, and further questioning revealed that it was often because the field was too infertile or flooded). In terms of fertility management, zebu manure was commonly used, while there is little to no use of chemical inputs (NPK, urea, phytosanitary products), and there appears to be a preference for organic fertilizers[11]. There is no specific use of cover crops or mulching. In terms of food and cash crops, rice production is prioritized when possible for both home consumption and cash. Rotation practices were not discussed in detail due to time limitations, but in the majority of fields most farmers grew less than three crops, either in succession or at the same time in different parts of the field. Few are practicing crop associations aside from maize and beans, but this may have been due to the limited time spent on the subject.

Past history of zero-tillage, soil cover, or both (Group A)

31 farmers (14 from the south and 17 from the north), group A, have tried zero-tillage or cover crop/residues in at least one field prior to the current agricultural year (2012-2013). Within this group, there is an overall expression of intent to increase incidence of practicing zero-tillage and soil cover techniques.

More people tested a soil cover technique in the past other than zero tillage. Those from Mahatsara were more likely to try either in this agricultural year or the future than their northern colleagues. This may be because those in the north have already experimented more with CA techniques. For example, in Mahatsara, an average of 15% of fields per farm used zero tillage, and 23% cover crops or residues at least once in the past while the respective numbers for farmers from the north were 36 and 52%, respectively.

Once farmers started using zero tillage, they tended to continue its use for that specific field : 18 farmers who started zero- tillage in the past continued into the current year, and anticipated to be continuing it in the future as well. Farmers also increasingly used zero tillage in the current year, either on additional fields or on their farm for the first time. They expressed intention to continue

[11] Several farmers expressed a clear dislike for chemical fertilizers, saying they "burn" the soil, resulting in hardened and "dead" earth. Unfortunately, there was not adequate time to discuss the subject further. See Vanlauwe and Giller (2006) who address this so-called myth, which they have heard in both public and academic domains.

with this practice in the future (11 anticipate expanding their use of zero tillage to more fields in the future, and four intended to use it for the first time). Some people did resume tillage on field due to cover crop failure, flooding, or dry conditions. In the rare case of zero tillage of more than five years, the owners said they had or will practice opportunistic tillage to reduce soil compaction, weed pressure, or both.

Similarly, once farmers started with a cover crop or residues, they tended continue in the same fields: 26 who started in the past continued into the current year and anticipate doing so in the future. Farmers also increased use of soil cover techniques in the current year, either on additional fields or on their farm for the first time. They expressed intention to continue with this practice in the future (11 farmers anticipate adding soil cover to fields next year). Almost half of the group also added, or anticipate adding, a cover crop variety that they have not yet tried before. If expressions of intent are realised, then all members will be using either cover crops or residues on at least one of their fields next year.

First time use of zero-tillage , soil cover, or both in the current agricultural year (Group B)

Five farmers (four from the south, and 1 from the north) used cover crops for the first time in the current agricultural year (2012-13). All plan to continue with cover crops in the future, as well as diversifying the species of cover crops used. None tested zero-tillage in the past or this year, but all five express intent to begin in the near future.

First time use of zero-tillage , soil cover, or both, in the future (Group C)

Five farmers, all from the Mahatsara *fokontany*, anticipate trying zero-tillage , cover crops, or both for the first time next year (2013-14), or if not possible, in the near future.

Three farmers, all from the Mahatsara *fokontany,* expressed no intention to try zero-tillage or soil cover practices in the near future.

Other farm and household characteristics

Results from farm and household characteristics are presented in a table format (Table 7) and discussed later on in the report.

Table 7. Farm and household characteristics of interviewed farmers who participated in the 2012-13 ABACO field experiments in the Lake Alaotra region. Data is from interviews with 41 farmers about first use of zero-tillage or soil cover practices in the past (group A), current year 2012-13 (group B,), or future (group C). Headings "North" and "South" under Group A refer to farmer groups from the two study sites. Group B included four farmers from the south, and one from the north. Group C consisted of farmers from the south, only. Off-farm activities included market intermediaries, small shop, weaving, fishing, labour on other farms, masonry, and animal husbandry.

	Group A		**Group B**	**Group C**
	North	*South*		
N˚ farmers	14	17	5	5
Land area (ha)				
Total used	3.60	3.50	2.20	3.84
Rice fields	2.27	0.79	0.44	2.40
Baiboho	0.54	0.46	0.36	1.29
Lower slope	0.03	0.13	0.02	0.00
Tanety	1.92	0.61	0.56	0.14
Let	0.12	0.56	0.00	0.80
Rented	0.25	0.62	0.00	0.35
Other characteristics				
Interviewee age	Evenly distributed across 30s, 40s, 50s, and 60s		Evenly distributed across 40s, 50s and 60s	All in 30s except one in 60s
N˚ zebu	Relatively evenly distributed between 0-15, one person had 20		0-20	0-16
N˚ of housenolds that are/not rice self-sufficient	15 reported no, 9 yes, 3 sometimes.		4 no, 1 said sometimes	4 no, 1 yes
N˚ who participated in former trainings	5		0	2
N˚ households that conduct off-farm activities	20		4	2
N˚ households paying for a child in high school, past/ present	14		1	1

4. Results and Discussion: Part II

This section triangulates data from field experiments, interviews, and personal observations during project meetings and village visits. The purpose is to broaden the perspective of previous analysis by building upon subjects in the previous section while adding other insights, some of which are contextualized with other related studies. Although domains do overlap, it may be helpful to see the following sub-sections as related more closely to either technical or social components. Technical: perceptions of cover crops, perceptions of constraints and advantages of CA techniques, high-impact experiments, on-farm use of zero-tillage and soil cover techniques over time, and land use - preferences for CA practices. Social: land use – tenure, motivation to participate in field tests, social networks and sharing knowledge amongst farmers, gender and CA, and comprehension of experimental procedures. Limitations of this study are also discussed at the end of this section.

4.1. Perceptions of cover crops

Mucuna, dolichos and vetch were the cover crops most cited to be planted in the future, despite challenges such as inputs required to produce seeds and climbing behavior. Of 44 people, 24 indicated wanting to try vetch on *baiboho* and rice fields, 21 anticipated growing dolichos or mucuna, 16 planned to grow stylosanthes, 11 wanted to grow brachiaria, and just 9 planned for *tsiasisa*. Farmers planned to plant dolichos, mucuna, sylosanthes, brachiaria and *tsiasisa* on *baiboho* and *tanety.*

Although vigorous cover crop growth was positively perceived in terms of its ability to control weeds and contribute to soil fertility, the species that produced the most biomass (measured during flowering) was not necessarily farmers' preferred choice. Biomass produced over time and physical qualities seemed to be considered more important. In two of the three experiments where cover crop biomass was measured, *tsiasisa* produced the most biomass compared to two other cover crops. In the third experiment, *tsiasisa* produced the second highest biomass compared to the other two treatments. Nevertheless, most discussions revealed that farmers preferred mucuna and dolichos for cover crops if the goal was to fertilize the soil, because they continued to produce leaves after grain harvest (unlike *tsiasisa*). If it were a priority to consume the seeds as well, they said, then *tsiasisa* was the logical choice. One farmer, who tried growing mucuna once in the past but otherwise observed the leguminous crops in other people's fields, described dolichos leaves as slightly oily, and therefore better at retaining soil humidity when they layer on the soil. Several farmers described *tsiasisa* leaves and stems as "softer" than those of mucuna or dolichos, and therefore decompose faster and provide less soil cover. Fieldwork ended just after the flowering period of most cover crops, but discussions about soil cover seed production can be held later in 2013-14.

Mucuna and dolichos were perceived by most farmers to be functionally interchangeable due to their similar characteristics (e.g. climbing behavior, similar leaves, seeds are not considered edible) that distinguished them from the most similar cover crop *tsiasisa* (climbs to a lesser extent, seeds are valued as food). This results from their observations in the field experiments and in fields of neighbouring farmers, as well as their personal, but limited, experience with the crops. Even some who have grown one or both of the crops, such as field owners of field experiments, admitted having trouble to distinguish the two.

Vetch was not part of the experiments, but after both groups had a tour of a rice field grown with vetch, farmers showed great interest (see “high impact experiments” for more discussion of reactions to the vetch-rice system). A total of 24 farmers anticipate growing vetch next year, ten for the first time. Several of these farmers were from Mahatsara, and bought vetch seeds from their northern colleagues. Their positive impressions of the field grown with vetch seem to have influenced their intentions to plant vetch in their own rice fields next year.

Few farmers aside from the field owners volunteered opinions about stylosanthes in the experiments, so it was unexpected when many more expressed interest to grow it in the future. They were generally vague about why, the overall comment being that it seems to grow well in the experiments and so they were curious to try. It may also be that that they had observed it growing well in neighbouring fields, seeing as a couple of people referred to such plots as potential sources of seedlings.

Brachiaria may be used as fodder, and seemed most interesting for farmers with zebu. Of the 44 farmers interviewed, 25 reported owning zebu. Although fifteen zebu owners had never and do not intend to grow brachiaria, ten zebu owners said they had tried or will try in the future. Only one farmer who owned no zebu grew brachiaria.

The relatively low interest in *tsiasisa* appeared to be due to its earlier termination following seed production (therefore less organic matter contributed to the soil), as well as the difficulties in producing enough seeds for consumption (due to dry weather and insect damage).

Farmers described the required insecticide treatments to produce cover crop seeds (for consumption or for seed production) as a constraint, but many still expressed intention to grow them in the future. Depending on the farmer, perhaps this implies their relative confidence in being able to acquire and apply pesticides effectively, possibly expecting or hoping that the project would assist. They said the likelihood of sourcing adequate agrochemicals increased if they started with relatively small fields or sections of fields (e.g. 0.01 - 0.02 ha). It may also imply that the perceived potential benefits of the cover crops are more important than being able to harvest seeds despite the cost of acquiring them again. At the end of the experiments, *tsiasisa* was described as requiring spraying in order to produce seeds. While farmers described *tsiasisa*’s softer leaves (than dolichos or mucuna), as well as its thick growth observed in some fields (attractive to host insects) as possible reasons.

Concerns about the vertical climbing behavior of mucuna and dolichos reducing maize yields were generally supported by biophysical results, which showed overall slightly lower maize yields with mucuna and dolichos intercrops compared to *tsiasisa* and first year stylosanthes. This led to several practical discussions about how to control the cover crop growth in the future. Methods discussed included sowing the cover crops after the maize, lightly trampling or cutting cover crop stems as they start to grow too high, or choosing appropriate land types. (e.g. less aggressive growth on *tanety* than *baiboho* due to differences in soil fertility). Farmers seemed confident in these techniques, saying that the experiments were just the first year and that results will improve as they gain experience. In future field experiments, it would be useful to demonstrate and test the different methods discussed above. Asked how the climbing behavior and thick growth might affect the (increased) presence of rats, the general opinion seemed that they were present with or without cover crops.

Farmers generally did not attribute value to additional uses of mucuna and dolichos beyond soil fertility. Calls for attention to multiple uses of cover crops beyond soil fertility are aimed to improve their attractiveness by increasing their usability in other dimensions of the farming system (e.g. cash, fodder, home consumption) (Mureithi *et al*., 2003; Schulz *et al*., 2003). However, farmers interviewed seemed to be satisfied with mucuna and dolichos as green manure alone, and the potential use of the edible seeds for consumption did not seem to be of interest. The beans are consumed in certain regions of Madagascar but are not part of the cultural diet in the Alaotra region. Only one person reported having tried dolichos seeds, reporting them to be very "fatty"[12]. It raises the question, would be advantageous to promote the edibility of these cover crops as an additional use? However, this seems unlikely considering that insecticide treatments required to produce grains of *tsiasisa* and mucuna were already cited as a constraint. In addition, proposing changes to such deeply embedded cultural norms such as diet may be extremely challenging.

4.2. Perception of constraints and advantages of CA techniques

Farmers of different experience levels were generally optimistic about the potential benefits of CA techniques, despite their awareness of constraints (see Ranaivoson, 2012 for constraints described by farmers in the two research sites, many who later participated in the field experiments). This could be due to several reasons, depending on the farmer, including: initial confidence in the techniques based on observations of personal experience, field experiments, neighbouring fields, or all; initial confidence in the techniques introduced by outsiders (perceived to bring new ideas, knowledge); few personal opportunities to grapple with potential constraints that may have been discouraging; and hopefulness and willingness to find solutions to their real and immediate agricultural challenges. Farmers cited advantages such as reduced costs due to zero-tillage (paid labour, zebu and plough rental), increased soil moisture, increased yield, and generally improved soil conditions. When farmers were asked what might stop them carrying out the techniques they described trying next year, they mentioned constraints such as lack of access to seeds, cost of buying seeds, and costs for treatments for cover crops.

Only those who had practiced CA for several years mentioned the potential constraint of increases in weed populations. Those experienced farmers still practiced CA techniques, but recommended opportunistic tilling every five years or so to reduce the slowly increasing weed populations and compaction. When asked what caused the increase in weed populations, they described inadequate soil cover, whether by live cover crops or straw residues. Even those who used rice straw mulch under the guidance of BRL reported that adequate quantities of straw were usually unavailable, even

[12] This farmer also happens to have been one of the poorest overall, according to discussions about her land holdings, off-farm activities and overall quality of life. She explained that her situation pushed her to be creative and try new ideas to gain cash or food. It raises the question whether this played a role in her curiosity to try the beans.

if one was willing to invest the time and costs (labour, use of zebu and wagon) of transporting straw between fields. For these reasons, several people who had used residues at some point in the past later discontinued. This was despite their observations of small weed populations and higher yields. Only one person clearly stated that he preferred dead mulch to live plants because he is concerned about competition with cover crops.

Discussion of constraints is limited in this study as most farmers have yet to test CA techniques themselves. For studies on CA and constraints in the Lake Alaotra region see: Penot and Andriatsitohaina, (2011b) for constraints and opportunities; Penot *et al*., (2013a) for economic and political constraints; Penot *et al*., (2013b) for technical constraints; and Chabierski *et al*., (2009), Durand *et al*., (2012), Fabre (2011) Penot *et al*., (2012b) for general discussion.

4.3. High impact experiments

The most influential experiments showed dramatic performance of crops and land types that farmers wished to valorize on their own farms. Impressive differences in primary crop yields alone were not enough to convince farmers to anticipate using the cropping systems in the future. Four examples are useful to illustrate this point.

Farmers were most impressed with experiments 1 (sandy *baiboho*) and 3 (*tanety* with a steep slope) in the southern region, where they observed good plant development on what they usually consider relatively infertile soils. Referring to the steeply sloped field, one farmer from Amparihitsokatra said the good cover crop and maize growth pleased him because he had (unused) land like that, and after the experiment he saw that it had potential to be productive. The second example comes from experiment 2 in the same region. Upon observing the field and yield results, people from Mahatsara (and one from Madiorano) also expressed pleasure and some surprise at seeing rice grow on *tanety*, as it is usually only grown on rice fields in the region. A third example comes not from an experiment, but a field with a rice-vetch rotation managed by a participating farmer from Ambalakondro village. Both northern and southern groups had the opportunity to view the field during an exchange visit, and their observations of the rice during maturation, which they perceived to grow better than in some of surrounding fields, inspired a number of people from Mahatsara to buy vetch seeds to sow in their rice fields next year.

The previous three examples are interesting to compare with that of bambara groundnuts grown on mulched and non-mulched fields (5 south). The field was also on a sandy soil with low yields. He ascribed the poor fertility to soil excavation some years ago for construction of the nearby dam. In the experiment, the yield difference was dramatic, the mulched field producing twice as much, and people noted the differences in the appearance of above ground biomass (colour, dryness). Farmers who usually covered the plants with soil to encourage seed production saw that mulching could replace that time consuming practice (although acquiring and applying mulch also takes time and may imply other costs). Nevertheless, people spoke about this field only when directly asked, unlike the previous examples. Further questions revealed that only a few of the farmers interviewed regularly grow bambara groundnuts (or anticipated growing them in the future after seeing the benefits of the mulch), suggesting that their interest was diminished by the lack of applicability of this system to their own farms. As mentioned above in the brief discussion about constraints, mulch was generally an unpopular choice of soil cover due to time and labour costs, which may have contributed to the low interest in applying practices from this experiment on farms.

These four examples suggest that even if CA practices produce dramatic yields, this alone is unlikely to change primary crop preferences. Use of CA techniques applied to crops and land types that were applicable to other farmers' situations (e.g. vetch and rice), and valorised land usually considered less fertile (e.g. maize on sandy *baiboho* and steep *tanety*), however, may be well appreciated by farmers. Kessler (2006) working with soil and water conservation practices in Bolivia concluded that focusing on short-term impact and success was necessary to inspire farmers to experiment. Although the geo-cultural setting differs, this may be a lesson applicable to the Lake Alaotra region.

4.4. Use of zero-tillage and soil cover over time

This section refers to the three groups identified according to their first use of zero-tillage and soil cover techniques. Group A describes farmers who used either one or both of the practices in the past for the first time, group B are farmers who started in the current year, and group C are those who anticipate trying them in the future.

There were no identifiable patterns between groups A, B and C regarding other farm and household characteristics discussed during interviews: zebu ownership, age, rice self-sufficiency, participation in previous trainings, off-farm activities, and children in high school. Although the sample size was small and the research was not designed to predict potential adoption, this seems to agree with the widely acknowledged observation that technology adoption by small holders is difficult to predict (Knowler and Bradshaw, 2007).

Farmers' selective use of CA techniques corresponds to other studies that document similar behavior (see Penot *et al*., 2012a for mention of innovative cropping systems in the Lake Alaotra region). Although the vast majority of farmers said they need to be "made aware", led, and encouraged by outsiders[13], many clearly stated that they don't always listen to technicians. This was also evident during the development of experimental plans where farmers sometimes decided against technicians' advice. As one farmers explained, he likes to listen to the ideas and then decide for himself which aspects to implement. In general, farmers tried 0–till, live cover crops, or residues as individual or paired techniques. They were more likely to start use of cover crops with tillage, and then stop ploughing when the cover crops had performed well for about three years. They were more likely to try or consistently use live cover crops than residues. This was usually because the quantity of residues (*in-situ* and *ex-situ*) were inadequate, and transporting *ex-situ* residues required too much work, even if farmers did notice positive results (low weed population, improved soil conditions).

There seemed to be a general confidence in the use of zero-tillage and soil cover techniques, evidenced by the actual or intention of increased use, which may be the beginning of a common trend already observed with CA in the region: initial implementation followed by a sharp drop in

[13] Outsiders refer to people who are not part of their village communities. This includes not only foreign researchers, but Malagasy project staff (technicians, translators) as well.

subsequent use (Penot *et al*., 2011a). Farmers most likely to begin using zero-tillage or soil cover techniques in the current year or in the future tended to be from the Mahatsara group, which had the least CA experience overall. They expressed having done so (or intending to) as a direct result of being involved in the field experiments. Of the 44 farmers interviewed, they tended to continue, and even increase, use of zero-tillage and soil cover practices. Increasing numbers of people tried this year for the first time, and more anticipate trying for the first time in the future. Use of CA techniques usually continued in the fields where it began. Most farmers did, or showed intention to, apply similar management to additional fields and try different cover crop species (all of which were used or discussed during the field tests). It should also be added here that some farmers conducted their own unpublicized tests of cover crops during the 2012-13 year. These consisted of *in-situ* residue mulch or live cover crops on small fields, usually very close to the village. They were not presented to the ABACO groups, and were discovered during interviews, informal conversations, or walks with the field owners. The farmers preferred to wait to observe their tests throughout the year before evaluating their results, and certainly before sharing their efforts with other farmers in the wider groups.

It may also be possible that farmers expressed interest during interviews in an effort to be polite (culturally very important) or supportive of a project that might result in tangible benefits. To reduce this pressure, every interview was prefaced with an introduction (a culturally expected and appropriate way to begin a meeting) that stressed the importance of hearing their opinions about how to adapt CA techniques, and what could be done differently in the next year of the project. Consultation with the translator and variation in responses gave confidence that this step had some impact, even if it was difficult to measure.

4.5. Land use - preferences for CA practices

Asked what type of land they saw most fit for (adapted) CA practices, farmers almost invariably proposed *baiboho* and *tanety*. Interestingly, none mentioned rice fields (of any degree of water control), though they were obviously interested in using the vetch-rice system. This omission may have been due to the context of the question (speaking about the experiments, of which the vetch field was not a part) or perhaps the wording of the question itself.

Asked to explain the motivation to try zero-tillage or soil cover in their chosen fields, farmers often indicated that the fields were “used” and that the soils were not very fertile. This explanation was echoed by the ABACO project staff, who added that farmers tended to prioritize land that was underperforming when using CA practices, rather than maintaining fertility in fields that already performed adequately. However, this was not always the case. For instance, several farmers were explicit about their interest in maintaining or even improving performance of fields that were considered to have decent or good fertility. Also, several fields seem to have been selected for cover crop “tests” because they were close to the village. Farmers said that it gave them the chance to observe the cover crop development, while proximity to frequently travelled paths reduced chances of *tondra-boly*.

4.6. Land use - tenure

Insecure land tenure is one of the constraints identified to CA adoption in Madagascar

(Rakotondramanana *et al*., 2010), including the lake Alaotra region (Penot *et al*, 2012a). This was not a focus of interviews, but farmers were asked about it when they were observed to have used (or intend to use) zero-tillage or soil cover techniques on rented land. A few said they did not care whether the land was rented or not – if it brought benefits to them in the short term they didn't mind the investment (some farmers attributed good cover crop and maize growth in some experiments to the cover crops). Some others said they knew the land-owner, and either they had already asked and were granted permission, or were planning to. In some cases, the land owners were so-called CA practitioners, making it acceptable for the renters to follow similar choices. As this study came across these accounts as side details, little more can be concluded beyond recognition of their divergence from the apparent norm.

4.7. Motivation for participation in field experiments

Farmers indicated that they participated in the field experiments for a variety of reasons: 1) To improve upon what they already know; to learn something new in a proactive attempt to "develop"; 2) They were previously interested in the technique but need "awareness training", therefore ABACO's approach of sending people to interview them and follow the field experiments was appealing; 3) They did not have much land and want to increase yield on what they have; 4) Climatic risk (unpredictable and inadequate rain) force them to improve their agricultural techniques; 5) Being part of a social network or formal group (e.g. groups formed several years ago to access credit) and just followed their colleagues even without knowing much about the project; 6) To them CA techniques seem attractive because they can reduce inputs; 7) The project provided seeds and technical advice; 8) Working with *vahaza* (foreigners) and outsiders has various, if undefined, advantages (e.g. signs in fields to discourage *tondra-boly* may carry more weight as they suggest involvement with projects, implying institutional power and the increased capability to implement punishment).

Perhaps in the beginning people were attracted to the project in hopes of gaining access to free or subsidized inputs, but it generally did not seem to be the case with interviewees. There was just one farmer who categorically stated that he joined in hopes of receiving cover crop seeds to improve soil on several infertile fields.

4.8. Social networks and sharing knowledge amongst farmers

Social networks

This study found evidence to suggest that bounded social networks play a role in sharing knowledge and thereby potentially encouraging agricultural innovation. This is stated cautiously. Firstly, because it was far beyond the scope of this research to conduct an anthropological study into the possibilities and implications of such social structures. Secondly, because the observations seem contrary to what is understood by researchers who are familiar with agricultural innovations in the region (personal communications). In addition, Fauroux and Blanc-Pamard (2004), writing about Madagascar - but not necessarily the Lake Alaotra region - also warn severely against misinterpretations of farmer group dynamics in their discussion of "*l'illusion participative*" (the participative illusion). Nonetheless, it seems worthwhile to look into this tentative observation for several reasons. First, there has been very little attention to socio-cultural aspects of agricultural innovation in the region. There have been few, if any, extended stays in villages by people likely to document their experiences and observations. Lastly, informal conversations about farmer social networks pointed to differing perceptions amongst researchers and various personnel who worked with local projects[14]. Unfortunately, timing did not permit additional discussions with key project staff who could have helped develop this point further.

The aim here is not to argue a case for the existence of bounded social networks and their prominence in diffusing knowledge and agricultural innovation. It is rather to describe what was observed during fieldwork, in case it may contribute to what currently seems a relatively anemic discourse about the socio-cultural context of agricultural innovation in the Lake Alaotra region.

Farmers who were more dynamic and progressive[15] tended to be part of social networks that shared information and experiences related to improving agricultural practices. These so-called networks included a core of approximately five people, all women, from Ambavahadiromba village (northern region); a core of six people, all men, from Ambalakondro village (northern region); and a core of people (number unknown, but believed to be around ten) that included two interviewed farmers from Ambohimanjaka village (southern region). Each had its own history and socio-political dynamics.

However, it is important, to note that all of these networks were formalized in some way due to the formation of groups for access to financial credit. This was organized through BRL several years ago (around 2005, but the start year varied for different groups). Many of the credit groups were dysfunctional or dissolved due to various internal tensions, mainly related to reimbursement problems. Other credit-access groups continued working together on agricultural interests (no longer only related to credit access), associated with BRL technicians. In an attempt to better understand within the limited time available, farmers from each group were asked what originally created the group, and what maintained it. They responded that they were based on a combination of kinship, friendship, and similar work objectives, varying per network. The group with farmers from Ambohimanjaka seemed to be united more by similar work objectives than kinship, for example. As one farmer said, they try to ensure that those who enter have the same ideas, objectives, and ways of working. Although it was beyond the scope of this research to investigate these social networks further, it seems that they were likely to have had some form of existence prior to formation of the credit groups.

Identification of these social networks came about during interviews, where their presence at first seemed evident. First, people were specifically asked from where they gained certain knowledge (e.g. if somebody said they tried mucuna for the first time last year, they were asked from where the idea emerged, who they asked, where they obtained the seeds, etc.). Certain farmers consistently

[14] Conversations about the subject were brief, and not wanting to misinterpret or misrepresent people's ideas details don't seem worth describing.

[15] "Dynamic and progressive" refers to farmers who had a high level of participation during interviews (individual or group), or who indicated that they try new agricultural practices (including but not only zero-tillage or soil cover techniques) and other farm or household activities, or a combination of both.

referred to each other, whereas other were vague or did not refer to an identifiable social network. Second, group interviews were organized per village in an attempt to make it easier for people to participate (e.g. distance, familiarity with each other). It was obvious that some people within the groups were more comfortable with each other (relaxed body language, joking around, less formality, comfortable expressing contradicting opinions), and when asked about this dynamic they explained that they were used to each other and often work together. Follow up conversations revealed that they often shared information pertaining to agricultural innovations and jointly reviewed their performance on their respective fields. For example, a group of farmers from Ambalakondro all started experimenting with vetch and rice rotations around the same time. Certain members had received training in the technique through BRL, and shared what they learned with others.

Other, less formal networks were also influential. These were also recognized during interviews as well as informal interactions during village stays. In one experiment that included mucuna and dolichos, for instance, people close to the field owner mentioned their intention to source cover crop seeds from her. For another example, when asked how they might find more information about about CA techniques in the absence of technicians, individuals in Mahatsara referred to M. Réné Gilbert, considered the most experienced CA practitioner in the southern group. Those with closer connections to him (but not part of one of the more formal social networks) also indicated they felt comfortable asking him for brachiaria or stylosanthes seedlings to transplant in their own fields.

It is expected that social networks of some sort exist amongst Malagasy farmers (Fauroux and Blanc-Pamard, 2004), but the question is from what origins, in what form, and for what purpose. A better understanding of how farmers are socially connected, and how they share information, seems crucial to the effort of encouraging dissemination of agricultural technologies. This since it may speed up the diffusion and enhance the transfer efficiency. An ethnographic study aiming to understand social networks and knowledge transfer would have been of use to previous work attempting to diffuse CA practices in the region, and is recommended to compliment future projects. Working with the sixteen or so groups that have already been created (originally for credit-access, e.g. VONONA, VATSISOA), a better understanding of their structure and internal relationships, and why some seem to be more unified and active than others may reveal insights that could be applied to future efforts to support farmer innovation.

Sharing knowledge between farmers

There was an interesting ongoing discussion throughout interviews about whether people, who are not necessarily connected by a particular social network, ask each other directly for advice regarding agricultural innovations (e.g. in this case, use of cover crops). This question deserves more attention, but an initial conclusion is that the varied answers reflected a range of personalities. Some said "no" because: 1) people are too shy; 2) people are afraid that the field owner will be too selfish to share their knowledge (and the person seeking advice would then feel embarrassed by a lack of response); 3) those in need of advice were the same people who initially laughed at the innovation, and only later were curious after observing the results. Others said "yes" because of course people are curious, not shy, and want to learn. One respected practitioner replied that people do ask him questions and he is pleased to reply. Other times, he believes people are too shy to ask, but they observe his fields and try to implement the same technology on theirs. He noted that sometimes they fail due to lack of technical mastery, and are disappointed.

Opportunities for farmers from different regions to meet and exchange knowledge were highly valued, partly because they presented a setting were asking questions was formally encouraged. Many farmers described them as one of the highlights of participating in the field experiments. The example of vetch viewed in Madiorano, for instance, was quite striking. Following the field visit during which Mahatsara members showed visible interest, ABACO staff coordinated the transport of vetch seeds to fill orders by group members in Mahatsara. Vetch and rice rotations are also practiced in Mahatsara, and members are surely acquainted with those farmers in one way or another. That people showed such immediate action following the field visit suggests that the opportunity to have direct social connections result in more tangible exchanges.

Regarding participation in the two ABACO groups, the social dynamics tended towards group inclusiveness. Discussions with the group from Mahatsara, for example, revealed that they were in favour of keeping the group open for other farmers to join. This would be on the condition that the newcomers were given a training (by existing members) on the activities and expectations of the group, in order to encourage group solidarity. Non-participation by behavior interpreted as laziness or lack of interest was perceived negatively. This is in contrast to respectful acceptance of absence from meetings due to work responsibilities.

4.9. Gender and CA

Gender did not seem to influence interpretations of experiments or perceptions of CA. This may be because agricultural work is not as strictly separated by gender as it may be in other contexts. For example, the often cited story of decreased labour for men without use of the plough, and increased labour for women to manage the higher weed populations (Giller, 2009) did not seem to have any parallels amongst the farmers studied. Although men and women do hold responsibility for different tasks, there was also evidence of flexibility. For instance, men typically operate the plough and transport heavy loads from the fields while women generally transplant and thresh rice. However, men were also observed to transplant rice, and women held typically male jobs such as security guard. Weeding was performed by both men and women. During meetings, women seemed as free to speak as men, and in one village it was clear that the women were the leaders of agricultural decision-making.

4.10. Comprehension of experimental procedures

Some aspects of the experimental procedures may have been too unfamiliar for many farmers to follow, whereas others were easily understood. The experiments were still valuable as platforms to simultaneously test and demonstrate CA techniques, providing an opportunity to build upon observations with discussion and exchange between farmers, technical staff and researchers.

Synthesizing observations across repetitions (1 north) and interpreting results presented in numbers (except for yields) were among the most challenging aspects for farmers to follow. This is based on observations during interviews. For instance, experiment 1 north with replicated field plots in a single field was clearly difficult for most people to follow, judging by their apparent difficulty in generalizing across treatments. Some people also said that they were not able to observe all of the sub-plots, so it was difficult to generalize. Other impressions were made during biophysical measurements. For example, field owners showed varying levels of comprehension of why yields from separate fields should be kept separate before being weighed.

Visual observations in the field were easier to interpret and clearly carried great weight, although most farmers were very interested to know yield results. The lack of repetitions (except for experiment 1 north) kept the experiments simple (and manageable for available ABACO staff), but required care in what conclusions could be drawn from a single test. Most farmers, though, were aware that one experiment served as just one example that could have different outcomes depending on management decisions as well as starting conditions. For instance, if they commented that mucuna grew too thickly on the maize in one experiment, they usually followed up by saying that it was just one test and that it might not happen each time, especially if techniques to control the cover crop were to be applied. Discussion of different soil conditions to explain yield differences within one field also highlighted knowledge of contextual details.

The contrast between perceptions and yield results in experiments 1 north and 2 south demonstrate the value of complimentary methods of observation. In 1 north, many farmers anticipated the yield of 20 x 25 rice sowing density to be higher compared to 20 x 30 and 20 x 40 sowing densities, but yield measurements showed otherwise. In 2 south, farmers expected rice grains from the year 5 field to be fuller (and perhaps more per panicle) than the adjacent year 0 field, but results showed the contrary. Precise yield and yield component measurements are usually impossible for the farmers to carry out. As in these cases, co-observation of experiments with outsiders who have access to different types of measurement and analysis can be complimentary.

Overall, it may not be important that the majority of participants followed the details of the experiment, because those more dynamic and innovative individuals who did follow tended to speak often, serving as interpreters for the rest. They were the ones who raised questions, proposed answers and suggestions during meetings, and what they said was often repeated during interviews.

4.11. Limitations of this research

Biophysical data

Measurements of maize stover biomass were not included in this study. However, they would have been useful to indicate the potential contribution of organic matter to the soil. Using a harvest index of 0.4 (see Hay and Gilbert, 2001), estimates of maize stover ranged between 335 to 6661 kg/ha amongst different sub-plots of four field experiments (Figure 17).

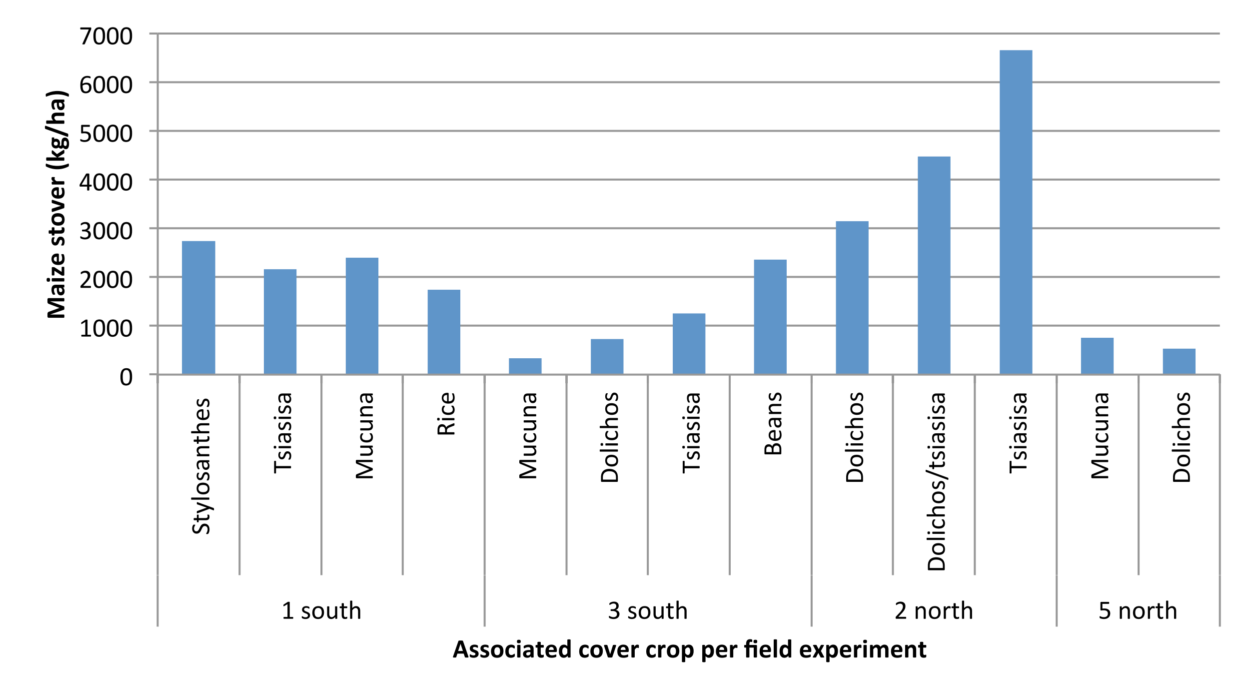

Figure 17. Maize stover estimates (kg/ha) in experiments with maize associated with a cover crop. Estimates were calculated based on a harvest index of 0.4 (see Hay and Gilbert, 2001).

Interviews

Most of the qualitative information for this research came from individual interviews. The technique was useful to hear from different farmers, for the limited time available for fieldwork, and having focused subjects to discuss. However, differences in underlying culturally-informed logic and working through translations, however, were amongst the key difficulties encountered.

One general problem with interviews is the assumption that the interviewee shares the interviewer's sense of logic, and will communicate with similar ideological structures. This may be the case even between interlocutors of the same cultural background, but the challenge can be significant in situations such as this study where cultures and languages are very different. Communicating perceptions when translated through two (Malagasy-French) or three (Malagasy-French-English) languages adds layers to the interpretation of results, which already requires careful attention to words chosen. Despite the utmost confidence in a translator's abilities, accurate interpretation and representation of farmers' ideas may be rightfully questioned. Future studies of farmer perceptions may do well to apply linguistic analysis to Malagasy words (e.g. Blanc-Pamard and Rakoto-Ramiarantsoa, 2006 for such an example).

Contrasting notions of participation

The increase in projects using participatory approaches in agricultural innovation and research are a response to critiques of the top-down style that has prevailed in many projects. Recognition of farmer agency, local knowledge, strategies, and heterogeneity and complexity within a population certainly is progress when viewed through the lens of social science. However, the assumptions underlying the concept of participation and use of the term may be questioned (Chambers, 1995; White, 1996; Blanc-Pamard and Fauroux, 2004;). Fauroux and Blanc-Pamard (2004) argue that western interpretations of participation may result in seriously misguided, if well-intentioned, development efforts. They refer specifically to the (western) misconception that participation must be democratic, a critique shared by several others (see for example, Roncoli *et al*., 2010 for a similar argument based on linguistic analysis amongst Ugandan smallholders). Briefly summarizing from this short fieldwork period and from others with more experience: socio-cultural norms in rural parts of Madagascar's highlands decree that those with higher status (age, leadership position, experience, wealth) may exercise the right to speak first, and even if others of lower status may have different opinions they will not voice them in order to be polite and respectful; those who have the real say may not be present at so-called participatory meetings (Blanc-Pamard and Fauroux, 2004); and it is difficult for outsiders to identify those who have such authority because their status may not be evident (Blanc-Pamard and Fauroux, 2004).

It is the first point (about voicing opinions) that most concerns the current study, which was aware of such dynamics from the beginning, but was susceptible to democratic notions of participation, nonetheless. For instance, one of the principal goals of this research was to ascertain farmers' perceptions of the field experiments, including any variation in opinions. Mindful that it would be difficult to measure individual perceptions during group discussions and group meetings aimed to collectively discuss experiments, individual interviews were designed to address this as well as possible. The assumption was that without the physical presence of others, people may feel more comfortable to express different opinions, if they existed. It is not clear whether this assumption was correct or not, but it may be that using multiple styles of participation did enable people to exercise both individual and collective agency (Roncoli *et al*., 2010).

Verbal expressions of field experiment perceptions

Discussions centering around field experiments were frequently superficial. Attempts to encourage discussion were tempered by concerns of the use of leading questions, or influencing responses. Upon reflection with the translator, whose cultural interpretations were valued significantly, explanations for superficial discussions may be:

- It was the first time a farmer was required to think about the subject with the intention to communicate their explicitly idea to others.
- The discussion was based on a certain (scientific) logic that may not be intuitive. In other words, the interviewer was not aware of, and did not accommodate to, their logic, and they did not manage to accommodate to that of the interviewer. For instance, results (yields, biomass) were presented to people written on paper and explained verbally. However, many people had little to no comments related to the figures (except for yields), and only when photos were added to the presentation did the discussion develop further.
- Self-consciousness and the pressure of performing (which could initiate a lengthy discourse about power dynamics, colonialism, etc., and in turn be related to fear of expressing conflicting opinions to the interlocutor – see discussion above). For example, people often gave answers in the form of a question, voicing concerns that they did not know the correct answer, although of course there were no correct answers. Several times, people had almost nothing to share about the experiments until the interviewers offered some thoughts for their reaction, which were immediately agreed with and only occasionally expanded upon. However, without implying that they are unable to form their own opinions, it seems unfair to expect that every person had developed their own perceptions of the experiments. It may be possible that some were waiting for leaders to express theirs, in order to follow.

Confidence in farmers' perceptions

Perceptions attributed to farmers throughout this report tend to be generalized. Firstly because the interpretations may have been quite similar between farmers, and secondly, despite conscious attempts to make place for potentially different opinions, it may be that the socio-cultural norms described channel opinions in the same direction. It should be made clear, though, that some farmers were very articulate in their opinions, even if they differed from their neighbours, who were sometimes present during the discussion. This was not limited to so-called dynamic and progressive farmers, suggesting the individual interviews did have some value in the attempt to understand variations ad nuances in experiment or CA perceptions, after all.

Judging by anticipated use of zero-tillage and soil cover techniques in the future, farmers were generally quite enthusiastic to test aspects of CA. Only three out of 44 farmers interviewed did not plan to use either technique. Did farmers give positive responses thinking it would please the interviewers? Were they signs of initial interest in an introduced technology? There is no clear answer to these questions, though the second hypothesis seems most likely (see following paragraph). What farmers actually do may only be observed in the future.

Nevertheless, there is still cause to have reasonable confidence in the results. Firstly, questions were repeated in different ways to crosscheck responses, and responses were collectively triangulated and discussed again during group interviews or in-depth discussions. Secondly, collaboration with a very competent translator enabled progressive modifications to the structure and general performance of the interview.

Looking at performance

A long-term study to follow these farmers and their future practices might offer insight into use of CA innovations in their particular context. Borrowing further from technography, it would be interesting to explore notions of embodied knowledge, situated action and performance to better understand the gradual adaptation of CA to local contexts. Jansen and Vellema (2011) argue the distinction between "knowing that" and "knowing how". The first is the type of knowledge that can be communicated in an interview. For example, what crops were grown in a certain field last year, and how they were managed. The second is intuitive knowledge, information that is difficult to explain theoretically, and may be so second nature that it may not even occur to the person to verbally articulate it. For example, after the harvest of maize intercropped with mucuna, an experienced CA farmer was observed to bend the maize stems towards the ground after the harvest. After about fifteen minutes of discussing the logic, a clear reason hadn't yet emerged. When it was proposed that perhaps it increased the chances of soil cover and therefore discouraged weed growth (by cover crops growing a thicker horizontal layer, rather than growing up the stems), he agreed as if it was what he meant to communicate. We were then able to continue a conversation about the advantages and disadvantages of leaving the maize stems upright. This specific example is an attempt to illustrate why observing performance can be crucial to understanding innovations (although it may also point out challenges with translation, individual personalities and reasoning abilities). Rather than expecting to understand knowledge through verbally recounted information in interviews, which rely on assumptions of shared logic, it seems valuable to spend cycles of time observing and participating in the same activities as those one wishes to understand.

5. Synthesis

This section integrates results and insights to respond to research questions and initial hypotheses. It then places research findings within the broader context of innovation development in the Lake Alaotra area. See Table 8, at the end of this section, for an overview.

This study contributes to a four-year pilot project (ABACO) that aims to engage farmers in designing and implementing locally adapted CA practices as part of a long-term soil rehabilitation strategy in semi-arid areas. Based on ten field experiments co-designed by farmers and agricultural technicians in the Lake Alaotra region, this study has two general aims: one, to develop a better understanding of farmer perceptions of CA; and two, to suggest recommendations for future co-innovation endeavors. To that end, three research questions were developed. The first, directly related to the field experiments, is concerned with their biophysical results, farmers' interpretations, and their potential impact on future tests and on-farm decisions. The second question asks how perceptions of CA compare amongst farmers, how they share knowledge of CA, and how those factors, amongst others, might influence farmer participation in the project. The third broadly questions how gender might interact with the first two questions.

It should be made clear that the so-called field experiments were primarily designed by farmers, and therefore do not have the usual features required in experiments designed by scientists (e.g. repetitions, control). They were not intended to produce agronomic data about CA practices. Rather, they were used as platforms for demonstration and potential co-innovation engagement with farmers. This gave them an opportunity to decide what aspects of CA they wanted to test, and gave technical staff and researchers an opportunity to learn more about farmers' priorities and perceptions of trade-offs in terms of CA practices.

5.1. Field experiments: biophysical results, farmers' interpretations, and their potential impact on future (ABACO) experiments and on-farm decisions

Biophysical results and corresponding farmer expectations

As expected, the biophysical results did vary depending on the experiments and objectives. There were three general categories of objectives: 1, comparing effects of different cover crops and sowing dates; 2, comparing crop performance with different soil management; 3, those concerning rice production. Additional objectives included production of dolichos seeds, and valorize use of *tanety* (hillsides). Some objectives were not met, either intentionally (results are expected next year) or due to unforeseen reasons (e.g. theft of rice).

The following is a summary of key results and any corresponding farmer perceptions (if farmer opinions are not mentioned it was due to few to no responses). In three experiments: *V. umbellata* (*tsiasisa,* or rice bean) produced the highest or second highest biomass compared to mucuna and dolichos; maize yields within experiments tended to be lower when associated with mucuna or dolichos, which corresponded to farmer concerns about the cover crops' potential to reduce maize yields due to their climbing behaviour; maize yields varied between experiments, the lowest being on fields attributed with lower fertility (sandy *baiboho* and steep *tanety*); weed populations on fields grown with mucuna, dolichos, *tsiasisa* and stylosanthes were approximately equal according to field owners (there were no measurements taken).

In one experiment that compared crop performance between year 0 and year 5 management under CA: bean yields varied but relevance was considered to be small and there was little discussion due to dry weather and insect damage; rice showed higher yield in the year 0 field, as the farmers expected. However, they pointed out that the potential long term soil health (associated with CA practices) was equally if not more important than yield alone. The grain weight was lower for the well-established field, which was in contrast with farmer expectations that rice grains would be "fuller" in this field.

In one experiment, rice yields were lower for fields treated with liquid compost compared to NPK + urea but showed no significant differences. This was likely due to inadequate applications of the liquid compost compared to the amount of NPK + urea used.

In one experiment, bambara groundnut yield in a mulched field was approximately twice that of the field without mulch. This corresponded to farmers' expectations of better crop performance (though they did not expect such a dramatic difference in yield), formed by their observations of greener leaves and more soil moisture in the mulched field.

Rice yields of different upland varieties were compared in two experiments: in one, SEBOTA 401, CNA 4136, and 2366 had no significant differences in yields; in the other, CNA 4136 produced a noticeably higher yield compared to 2366, but it may have been due to poor performance for unknown reasons in one part of the 2366 field.

In one experiment, weed populations were comparable between different sowing densities. According to the field owner (as no measurements were taken), sowing densities of 20 x 25 cm and 20 x 30 cm had similar weed populations, but slightly less weeds than sowing density 20 x 40 cm. In the same experiment, yields between sowing densities showed no significant difference. Farmers had many different opinions, but most said they expected the 20 x 25 sowing density to produce the highest yield due to a higher number of seed holes.

Interpretation of field experiments by stakeholders

In an attempt to mitigate challenges in understanding farmer interpretations of experiments, they were approached from two perspectives. One directly addressed experiment results, using written and orally presented figures, photographs, and questions to encourage responses (part III of individual interviews, see Appendix XI). These interpretations of experiments and results were generally similar between stakeholders (different farmers, technicians, project staff, researchers) for most experiments. Two exceptions, 1 north and 2 south, involved different expectations regarding rice yield and yield components. The second approach to understanding farmer interpretations indirectly addressed field experiments by asking farmers about their on-farm preferences regarding crop and cover crop choices, live cover crops vs. residues, and use of zero-tillage (Part I of individual interviews). Responses did show varying preferences, but they were generally similar amongst farmers. These preferences were considered part of field experiment interpretations because prior to the project, the overwhelming majority of farmers had very limited experience with CA, locally adapted or not. Many of their opinions were therefore developed throughout the duration of the experiments. Nevertheless, other influences certainly played a role, too. They were difficult to identify due to the relatively shallow comprehension of socio-cultural dynamics, but based on conversations during interviews it appears that they include individual personalities, observations of neighbours' fields (with varying CA practices and levels of technical mastery), and dynamics within their local social networks as well as the ABACO groups.

Experiments with the highest impact (judged by number and quality of responses during interviews) combined crops and land types that were applicable to other farmers' situations (e.g. vetch and rice), and valorised land usually considered less fertile (e.g. maize on sandy *baiboho* and steep *tanety*).

Impact of farmer interpretation of experiments on future field experiments and on-farm decisions: Farmers made two types of suggestions for the next year of experiments. One type implied that they would like to make use of the material and other support offered by ABACO while it remains operative in the region, regardless of their perception of how the project functions. For example, several people suggested that all participating farmers who were able to should experiment on a complete fields (rather than on a small subsection of a field as was now used in the field studies). On one hand, this seems to show genuine interest in testing CA adaptions with increased autonomy. On the other, it may not have been suggested if farmers did not expect ABACO to play the role of intermediary (cover crop) seed supplier. It is possible that some people also hoped for free seeds without voicing the wish; it was repeated many times by project staff that ABACO is not a project that distributes free materials. The other type of suggestion for next year's experiments gave the impression that some farmers would like to continue information exchange regarding CA practices, within and between the northern and southern groups.

The experiments also seemed to influence on-farm decisions, according to the actual and intention of increased use of zero tillage and soil cover techniques in the current and subsequent years. Apparently there is interest, and perhaps even a certain level of confidence, in the practices, judging from optimistic explanations during interviews. This pattern was largely attributed to active involvement in the field experiments, again due to their provision of a significant proportion of CA experience for most farmers. For instance, farmers most likely to use zero tillage or soil cover techniques now or in the near future for the first time tended to be from the Mahatsara group. Overall, this group had the least CA experience. They verbally expressed having done so (or intending to) as a direct result of having been involved in the field experiments. Overall, of the 44 farmers interviewed, the majority tended to continue (or expressed intention to continue), and even increase, use of zero tillage and soil cover practices. The majority of farmers (31) had tried a soil cover technique or zero tillage, or both at least once in the past. Many of these farmers who had stopped using either practice in the past indicated wanting to start again in the near future. They also anticipated adding different cover crop varieties, all of which were used in the field experiments. Five people tried cover crops (all of which were used in field experiments) this year for the first time, and five more anticipate trying soil cover and zero tillage for the first time in the future.

5.2. Farmer perceptions of CA, participation in the project, and knowledge sharing

Perceptions of CA

As expected, perceptions of CA did vary, according to experiment interpretations and on-farm decisions. However, some general preferences were relatively consistent amongst farmers interviewed.

Different perceptions were partly attributed to the amount of experience with CA. Most farmers (31 of 44 interviewed) had some, albeit very limited, experience with zero tillage and soil cover techniques (cover crops or residues). The remainder reported that it was the first time they were trying a cover crop this year, or zero tillage and cover crops next year. Those with more experience with CA articulated some constraints (lack of seed supply, unreliable or limited rain, lack of technical mastery, poor soil cover, need for occasional ploughing if build-up of weeds becomes problematic) even while being generally optimistic about advantages (such as enhanced soil quality, enhanced water retention and labour savings associated with land preparation). This is compared to farmers who had little to no experience (besides the field experiments) who generally recounted advantages with constraints limited to seed availability of cover crops and unfavourable rainfall conditions.

Despite some variation amongst interviewees regarding perceptions of cover crop choices, use of cover crops or residues, and zero tillage, some general preferences were clear:

- Mucuna, dolichos and vetch were preferred cover crops due to perceived advantages of greater biomass production over time (mucuna and dolichos), and perceived advantages regarding reduced labour and yield (vetch).
- Farmers were more likely to try or use live cover crops than *ex-situ* residues, due to the limited availability and work required to transport *ex-situ* residues.
- Farmers were more likely to first introduce cover crops while continue to use tillage, and then stop tilling when the cover crops had performed well for several consecutive years.
- If farmers had begun use of soil cover techniques, zero tillage, or both, on certain fields in the past, they tended to continue when possible (i.e. seed availability, field conditions, absence of *tondra-boly*). Farmers generally expressed intentions to continue, and even increase, use of zero tillage and soil cover practices in the future.

As expected, perceptions of CA also did seem to be influenced by other factors (personal character and experience, information networks, social cohesion, and motivation to gain knowledge), though to what extent was difficult to interpret. Contrary to what was expected, resource levels did not seem to necessarily influence perceptions of CA. Nor were there any identifiable patterns between household and farm characteristics (zebu ownership, age, rice self-sufficiency, participation in previous trainings, off-farm activities, and children in high school) and groups of farmers who started use of CA practices at different times (past, current year or future).

Participation in the project
Reasons to participate in the project did indeed vary among farmers. They included curiosity, motivation to improve livelihoods, potential tangible advantages, access to new technical information, potential undefined advantages of working with outsiders and foreigners, and following others in their social network. It is likely that they are influenced by both external and internal drivers that may be compelling them (push factors) to pursue CA such as, resource-limitations including land and labour, along with personality traits and positive experience with CA. Alternatively, farmers may be enticed by so-called pull factors to engage in new technologies due to their motivation to improve knowledge, natural curiosity, and potential material and immaterial gains.

Overall, farmers seemed to have genuine interest in learning more about the applicability of cover crops and implementation of zero tillage in their own fields , even if many may also have hoped for additional undefined advantages from involvement in a project. This general conclusion results from discussions with farmers during interviews (about experiments, project activities, and on-farm use) as well as the small unpublicized tests they conducted on their own fields.

Knowledge sharing
How farmers share knowledge of CA techniques remains poorly understood. It was beyond the scope of this current study to explore the complex social relationships and power dynamics that influence knowledge sharing in rural Malagasy highland culture. However, it appears that: dynamic and progressive farmers were most vocal, and seemed more prone to test innovations; and there seemed to be bounded social networks based on combinations of kinship, friendship, similar work objectives, and formalized by processes with external actors that communicated about agricultural innovations. Further research into the socio-cultural context of farmers in lake region seems necessary to gain insight on how knowledge is shared amongst farmers.

5.3. Gender

Based on interviews and personal observation, gender did not seem have a pronounced influence on experiment interpretations or perceptions of CA. Gender roles in agriculture appear to be less segregated and more flexible than in certain other sub-Saharan African regions where CA has been promoted.

5.4. Year two of ABACO experiments: reflections and suggestions

The ABACO field experiments with farmers run for two years, leaving one more round for 2013-14. The following are some thoughts and suggestions based on farmer feedback and personal observations.

Agronomic aspects of experiments next year
Experiments during the second year will continue in the same fields. According to the recommended rotation system implied by CA, rice should be the next crop for many fields. It seemed, however, that some farmers may have wanted to grow cover crops (perhaps with maize) again. The field owner of experiment 3 south on a steep slope, for example, wanted to repeat maize associated with either

mucuna or dolichos to further contribute to the soil fertility, before growing rice. Apparently, if she were to do so next year, it would no longer be followed as one of the formal experiments (according to ABACO staff). If the experiments are truly aimed at assisting farmers test ideas they are interested in, then it seems valid to permit the field owners to do so.

If the number of experiments is increased, therefore introducing new fields that would not be expected to start with rice, it would be useful to grow mucuna and dolichos associated with maize again and implement the techniques discussed to control the vertical climbing behaviour of the cover crops (cutting, trampling), which was a concern by many farmers.

The few farmers who were relatively experienced with CA (more than five years of practice) all mentioned having high weed populations after several years, and attributed it to inadequate soil cover. Next year's experiments could address the amount of mulch necessary to discourage weed growth (by adequate soil cover). This could be done by observing soil cover by live cover crops (as is already being done), and including the stage after it has been killed and during early growth of the following crop. It may be helpful to make use of visual material already created about soil cover percentage and residue quantity (Andriamandroso and Naudin, 2009), and relate it to the recommended percentages of soil cover for erosion and weed control (>30% and >90%, respectively).

Following the examples of experiments with highest impact (most reaction from farmers), fields on steep slopes or with soils considered relatively infertile would be good choices. This may also be an attractive idea for the field owners as it could valorize land they may not use.

Farmers indicated wanting to try experiments on larger fields as the next step in testing the cropping systems (see more below). The average sub-plot size of $100m^2$ was proposed by staff to avoid potential management problems such as high labour costs. If a farmer proposes a larger field and is willing to take responsibility, it would likely receive the interest of quite a few farmers.

If sub-plots are kept at a similar size ($100m^2$), including a minimal number of repetitions could offer more opportunities for farmers to observe and draw conclusions from the experiments. It was mentioned several times during interviews by a handful of farmers that the fields were small, were just one example, and that results could vary under different conditions (e.g. different fields, different management, a different year). However, based on responses to experiment 1 north (54 sub-plots with three sowing densities, two fertilization treatments, three rice varieties), it is not clear how many people would follow the concept of repetitions. Perhaps it is enough that that the farmers who do follow will voice their opinions for others to hear, as was done during the first year.

General project operation

It was heard through project staff and some farmers, that the more active group members found the unpredictable participation or late joining by some members disruptive. When this subject was raised during individual and group interviews, however, farmers seemed to favour group inclusiveness. From the southern group, there were suggestions to include newcomers, who would be taken in after a training on the objectives and operation of the group. It is unclear what farmers prefer, and it may be that the different social dynamics between groups generated different opinions. If the idea is to facilitate farmers sharing ideas and experiences, then it seems best to keep the groups open. Perhaps the more active members can propose an induction process for newcomers, which would offer a formal channel of entry.

As recommended by farmers, experiments should be more spread out. It would afford the opportunity for more people to see the field throughout the year, as it is not just the people who attend meetings who are interested in the field experiments. In fact, in several villages (e.g. Betsianjava) there were many people who wanted to join the project, but as they were too numerous some acted as "representatives". Their precise role in terms of how they communicated wasn't clear, but a local field may offer a discussion platform. If repetitions on the same field aren't possible or desirable (see above), they could be conducted in this manner, repeating the same treatments on different land types throughout *fokontany* with participating farmers.

It was observed while staying in the villages that some farmers conducted tests with cover crops, although they didn't share the development or results with the larger group (to my knowledge). A few farmers proposed that all ABACO members should perform tests on their own fields, on full-sized fields if possible, as a next step of testing the innovations. It seems that this should be appreciated, but without free material support as it may encourage opportunistic participants (if not for this project, which ends soon, then for those in the future). For instance, staff could create a way for farmers who conduct tests on their own land to share their observations with the others during meetings or perhaps even in the field.

It was noticed during the individual and group interviews, even if people did understand the written or orally presented results, it was photographs that seemed to stimulate more conversation. During result presentation meetings, it is therefore recommended to continue posting labeled photographs where people can gather to look and discuss informally, as was done this year. This should be in addition to the more formal oral presentation of results. These two practices provide at least two ways for farmers to interact with the result presentations, and may give those who don't speak during the meetings the opportunity to do so in smaller groups.

If possible, more time should be created for discussion. Farmers recommended this for next year, and the same thought occurred to me, as well. There was some time to discuss during meetings and field visits, but most of the time was spent presenting results or explaining aspects of the experiments. It seems that the best moments to discuss were during field visits, and especially during the exchange visits that brought the two groups together. For instance, when there was time, a field owner's presentation evolved into questions back and forth involving the whole group. Although creating more time for discussion would be ideal, it could be difficult to organize considering current staff resources. It would require either more meetings, or extending the meeting time into the whole day, which implies lunch provided by ABACO. Not wanting to perpetuate the association of development projects with free benefits, perhaps the first would be a better option.

Staff could play a limited role to encourage of the "headquarters" initiated by a few farmers. The aim of the so-called headquarters would be to facilitate communication (e.g. share innovations, buy cover crop seeds) between the northern and southern groups through four elected representatives, who have already been selected. Being aware they would need at least minimal funding, there were proposals to maintain a field in each of the study sites. They were imagined as innovation demonstrations and social gathering points for discussion, as well as a source of cash by producing and selling cover crop seeds. Whether farmers actually manage to create and maintain this structure is up to them and remains to be seen. ABACO could encourage the idea, however, by creating time during meetings for farmers to discuss it (e.g. demonstration plot).

Several of these last points raise questions regarding power dynamics in participatory research (which are beyond the scope of this research to address in depth). How much of a leadership role can or should a development project play? Must there always be an external catalyst for people to come together?

5.5. Research findings in the context of CA innovation development in the Lake Alaotra region

CA was introduced to the Alaotra region to elevate poverty levels, increase food production to feed the fast-growing population, and reduce land-use pressure. After more than ten years of predominantly top down promotion of CA adoption of the full technology package remains low (Penot *et al*., 2012a). However, spontaneous diffusion of some CA practices (so-called innovative cropping systems), has been observed (Penot et al., 2012a).

Throughout the interviews and informal discussions, farmers consistently referred to erratic rainfall, which was blamed for low yields and poor cover crop performance. Along with demographic pressure, farmers identified it as a factor that could encourage innovative agricultural management by means of necessity. These perceptions are consistent with research by Razakavololona (2011), in his assessment of vulnerability of farms facing climate and demographic changes in the Lake Alaotra region. He found that the majority of farmers are sensitive to the effects of climate and demographic changes on their farming systems, climate change taking precedence over demographic changes.

The ABACO pilot project in the Lake Alaotra region aims to build upon farmers' awareness of climatic and demographic changes, and their apparent interest in agricultural innovation evidenced by observations of innovative cropping systems, by involving them to develop locally adapted CA practices.

Findings from this study show that co-experimentation with CA practices (between farmers of different backgrounds, technicians, researchers) was well-received by farmers and can contribute to encouraging smallholder's apparent interest in agricultural innovations. Overall, farmers actively participated in the project activities, and tested (or expressed intention to test) techniques from experiments on their own farms. However, this optimistic conclusion about the potential of co-experimentation is tempered by historical observations of high but short-lived interest, and it is evident that participation is a complex, culturally-influenced process. For most of the promising aspects , there are counter-points that challenges use of overly optimistic and/or simplistic perception and solutions of rather complex systems:

- Farmers did play a significant role in developing experimental plans, even contradicting technicians' advice at times. After the first year of experiments, they also offered constructive feedback on what to do differently during the next round. This constructive feedback, however, also strongly suggested hopeful interest in gaining material or service benefits from the project.
- Involvement in the field experiments was thought to largely influence the actual and expected increase (diffusion) of on-farm use of cover crops and zero tillage both in space and time. However, this apparent initial enthusiasm, may be similar to what has previously y been observed with CA adoption in the Lake Alaotra area: an initial active adoption and implementation followed by a sharp drop in use within the first two years. It is also possible that farmers participate in the project in order to obtain access to tangible and non-tangible, benefits along with expectations, some of which are explicit while others may be not be readily transparent.
- Dramatic performances of crops and land types that farmers wish to valorize on their own farms seemed to have had the highest and most direct (immediate) impact. These included rice fields and vetch, and maize with cover crops on land typically considered to have poor fertility. Based on this it is evident that there is potential to valorize smallholder use of land types that are generally considered less productive and therefore a lower priority (e.g. steep *tanety,* sandy *baiboho*), while maintaining or improving those that are already a priority (e.g. rice fields). These so-called high impact field experiments provide evidence that the potential exchange of ideas during co-experimentation process with different stakeholders may indeed encourage local innovations. Whether farmers try to repeat the experiments that apparently interested them remains to be seen.

Studies in the Alaotra region that observed high levels of initial interest in CA only to be shortly followed by a sharp drop, looked at adoption of all three practices of the CA package (minimal soil disturbance, permanent soil cover, and crop rotations). The technology promoted by the ABACO project actually differs in its aim to encourage farmers to modify these practices, in order to find an operative balance between constraints and context-specific needs (innovative cropping systems). It is possible that future studies may find these so-called innovative cropping systems being more valued due to their flexibility, and more readily used by farmers. This may be not only because they encompass broader cropping system possibilities (and therefore include more farmers who use them), but also because farmers are likely to find them more appropriate and possible to implement in their farms than CA *sensu-stricto*.

Co-innovation amongst different stakeholders clearly implies a participatory approach, although this concept is fraught with different interpretations and (mis)appropriations. The result is a well-intentioned approach that is at once extremely challenging and promising. A better understanding of local cultures and their power dynamics seems crucial to appreciate how decisions are made and how knowledge is shared amongst smallholder farmers. Furthermore, recognition of different stakeholders' concepts of participation – including reflexive inquiries by project implementers – could result in complementary styles that further progress towards the ultimate goal of helping smallholder farmers develop appropriate agricultural innovations.

Table 8. Overview of hypothesis components and results.

Hypothesis components	Results
Hypothesis 1. Biophysical results of field experiments are expected to vary per experiment, with potential differences in interpretation between different stakeholders.	
Biophysical results:	As expected, the biophysical results did vary depending on the experiments and objectives.
Interpretation of field experiments between stakeholders:	Farmer interpretations of field experiments were approached from two perspectives. Both showed similar interpretations between farmers, except for experiment 1 north (effect of different sowing densities on rice yield). Interpretations between different stakeholders (different farmers, technicians, project staff, researchers) were also similar for most experiments, with the exceptions being 1 north and 2 south (both with rice).
Impact of farmer interpretation (of experiments) on future field experiments and on-farm decisions:	Farmers made two types of suggestions for the next year of experiments. One type implied that they would like to make use of the material and other support offered by ABACO while the project continues, even if their suggestions also contributed constructive criticism about how the research project functioned (e.g. larger experiment field size). The other gave the impression that some farmers would like to continue information exchange related to CA practices, within and between the northern and southern groups. The experiments did seem to influence on-farm decisions in the current year as well as the future. The general tendencies, largely attributed to involvement in the field experiments, were to continue, increase, or start use of zero-tillage and soil cover techniques.
Hypothesis 2. Farmer perceptions of CA are expected to vary depending on experience with CA. Resource-levels, personal character, information networks, social cohesion, motivation to gain knowledge and other expectations of the project may influence participation in ABACO, as well as how knowledge is shared.	

Perceptions of CA:	Perceptions of CA did vary, according to experiment interpretations and on-farm decisions, and did seem to be influenced by personal experience and other factors. To what degree other factors such as personal character, information networks, social cohesion, motivation to gain knowledge influenced perceptions of CA was difficult to interpret, though it seems that they did play a role. Contrary to what was expected, resource levels did not seem to necessarily influence perceptions of CA.
Participation in ABACO project:	Reasons to participate in the project did indeed vary among farmers. They included curiosity, motivation to improve livelihoods, potential material advantages, access to new technical information, potential undefined advantages of working with outsiders and foreigners, and following members within their social network.
Knowledge sharing amongst farmers:	How farmers share knowledge of CA techniques remains poorly understood. It was beyond the scope of this research to explore the complex social relationships and power dynamics that influence knowledge sharing in rural Malagasy highland culture. However, some insights regarding the role of more vocal farmers, social networks, and inclusion are cautiously attempted.
Hypothesis 3. Interaction of gender with questions 1 and 2 is likely to be relatively subtle	Gender did not seem to have a pronounced influence on the interpretations of experiments or perceptions of CA.

6. Conclusions

This study aimed to develop a better understanding of farmer perceptions of CA in the Lake Alaotra region through a four-month engagement with ten field experiments initiated by the ABACO pilot project. The experiments were based on CA systems, and were co-designed by farmers and technicians and managed by farmers. Results and insights from biophysical measurements, interviews and participant observation were triangulated to respond to research questions, which addressed farmer interpretations of the field experiments, how the experiments might impact future testing and on-farm decisions, and touched upon the interaction between CA and the underlying social factors of knowledge sharing and gender issues.

According to observations made during this study, as well as others in the same region, smallholders have an apparent interest in innovative cropping systems based on CA practices. This seems to result from a combination of: their awareness of local challenges (e.g. erratic rainfall, demographic pressure, limited land availability, and need to improve inherent soil fertility and crop productivity); their interest to improve their livelihoods; the presence of CA promotion in the region for more than ten years; and a receptiveness to externally introduced knowledge that they evaluate according to their own perceptions of constraints and advantages. From an optimistic perspective, this context seems to offer excellent potential to generate applicable learning outcomes through co-innovation development of CA between farmers and technicians. However, this potential is confined by the complex notion of participation, which is the very concept that facilitates co-innovation. More attention to different cultural interpretations of participation amongst stakeholders could improve the overall efficiency of work processes and the evaluation of their outcomes.

It may yet be too early to assess the impact of innovative cropping systems, but future assessments will surely respond to this optimistic perception of their potential.

6.1. Future recommendations

Related to the second year of ABACO field experiments:

1) Field-level

- Include more short-term impactful examples that valorize crops farmers typically use in combination with land often thought to be less fertile (e.g. steep *tanety* or sandy *baiboho*).
- Test management methods discussed during the first year (e.g. cutting or trampling dolichos and mucuna to control vertical climbing on maize).
- Address new aspects, such as what adequate amounts of mulch to prevent erosion or weeds look like.
- Increase the sizes of field experiments, if possible, and spread experiments throughout villages with participating farmers.

2) Social aspects and project operation

- Keep groups open to newcomers but ask farmers to propose and conduct a formal induction system.
- Find a way to value "private" tests that farmers make, perhaps by providing moments to share observations with others during meetings or perhaps even in the field.
- Continue using photographs and moments for informal discussion, in addition to orally presented results.
- More time for discussion amongst farmers, especially during exchange visits which bring the two groups together.

General ideas for future agricultural innovation in the Lake Alaotra region

1) Concerted attempts to understand more about the socio-cultural context in the region, with special attention to social networks, information sharing, and power dynamics amongst farmers. An ethnographic study, for example, could contribute to this area of research and compliment future projects in the region.

2) Employ methodologies that encourage exploring non-verbal information related to innovation choices. This could include, for example, a technographic framework that emphasizes attention to performance and embodied knowledge, complimented by an anthropological approach of long-term participant observation. This could contribute not only to a significantly improved understanding of dynamics between stakeholders, but also their interaction with other non-human elements such as the landscape, different market spheres, and (relatively) recently introduced plants.

3) Engage with critiques of participatory approaches, with specific attention to local concepts of participation and how they may be complimented by participation concepts with external origins. Lessons and information learned from point 1 and 2 above could be applied to develop improvements on participatory approaches.

Acknowledgements

My sincere thanks goes to my team of supervisors for their guidance thoughout this project: Drs. Krishna Naudin, Johannes Scholberg, Eric Penot and Hélène Brives. I would also like to extend my thanks to Dr. Pablo Tittonell for introducing the thesis topic.

I am grateful to FOFIFA and the Rhones-Alpes region for financial support that made this thesis possible.

I would also like to express my gratitude to all the farmers who shared their time, thoughts and homes with us.

To Cinderella, my translator and dear friend, you deserve special mention. It is largely thanks to your talents, work ethic , and kindness that we were able to carry out the fieldwork for this study. Misaotra betsaka for braving the caterpillars and millipedes, far too many twelve-hour work days, skipped meals, and for all the good company and laughs from the beginning to the end...until next time!

Many thanks to my colleagues and friends in Madagascar – Guillaume, Jess, Joachin, Lalaina, Monique, Rivo and Thomas, and in Wageningen and afar – Andriana, Elin, Eva, Ioanna, and Yiannis for your support and company! And to my parents and Vincenzo, thank you, as always for such consistent love and patience.

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