CA2AFRICA Peoject

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IMPACT OF CA ADOPTION 'CONSERVATION AGRICULTURE ON FARMING SYSTEMS IN THE REGION OF LAKE ALAOTRA, MADAGASCAR

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INTRODUCTION

The Lake Alaotra basin, surounded by high hills, is one of Madagascar's primary rice producing regions, with over 100,000 hectares of rice fields. The region, is known as the "Malagasy rice granary". It produces an annual surplus of rice, and plays an important role in inter-regional trade, serving as a critical supplier of rice for the country's capital Antananarivo, and largest port city, Tamatave. Rice production of the Alaotra was greatly enhanced through the hydro-agricultural schemes managed by SOMALAC (Société Malgache d'Aménagement du Lac Alaotra) in the 1960s and 1970s (Devèze, 2007).
For 40 years, the demographics of the region have been marked by the high rates of immigration of farming families attracted to the wealth of the region. High population growth,has tripled the population since 1960 (and is doubling it every 18 years) leading to land tenure saturation and an increasing pressure on natural resources (Durand et Nave, 2007). Land tenure is saturated in low land areas (Irrigated Paddy Fields (IPF), Poor Water Control Paddy Fields (PWCPF) and *baiboho*). Therefore, when seeking new land for cultivation, farmers tend to expand onto uplands, the *tanety* (hills), previously under-developed or reserved for grazing herds (Domas et al., 2009). Deforestation, repeated burning, and the exclusion of fallow periods have accelerated natural erosion processes in these degraded and fragile soils,, resulting in an alarming loss of soil fertility, siltation of downstream irrigation canals, and declining yields to fisheries. Today, on 30, 000 hectares of rice fields developed by the SOMALAC, between 10,000 and 15,000 hectares are currently under good water control (Durand and Nave, 2007).
In the context of increasing degradation of natural resources, research and development programs (both Malagasy national and French) have set up projects for the extension of agro-ecological techniques, based on the principles of conservation agriculture (CA). Direct mulch cropping (DMC) is one of these techniques, introduced in the Lake Alaotra region in the 1990's, with the objective of introducing new cropping systems to improve yields while preserving natural resources.
Having encountered many problems (constrained access to inputs, technical complexity that is overwhelming for small farms), the adoption of CA grew significantly since 2000 with the launch of the project "*Mise en valeur et protection des Bassins Versants du Lac Alaotra* » (BVLac). The project, started in 2003 and was conducted in two phases over a period of five years each, from technical advisory at the field scale, to a holistic approach at the farm scale.

In 2009, the EU-project CA2AFRICA was launched for a period of 3 years. The overall project goal is to assess and learn jointly from past and on-going CA experiences. This includes understanding the conditions of the region, and to what extent does CA strengthen the socio-economic position of landholders in Africa (CA2AFRICA, 2009). The project uses three scales to analyse: field, farm/village and regional. It aims to work across Africa with contrasting case studies in 5 regions: East-Africa (Kenya and Tanzania), West Africa (Burkina Faso and Mali), Southern Africa (Zimbabwe, Zambia, Mozambique, and Malawi), North Africa (Morocco and Tunisia) and Madagascar.

In order to meet these objectives, this study, based partly on the methodology EVALINOV (Faure et al., 2010), makes an *ex-post* evaluation of the technical and economic introduction of CA on farms in the region of Lake Alaotra. Eleven years after the extension of CA began in the Lake Alaotra project by BV-Lac, this prject will examine the outcomes of the introduction of CA on farm income. And will ask whether the implementation if these systems improved the incomes of these farms and if so, under what conditions.

The Lake Alaotra: a crucible of innovation in the context of land tenure pressure

The Lake Alaotra is located in the mid east, 250 km north of Antananarivo (see Figure 1). It is a lowland area located 750 meters above sea level surrounded by rugged and eroded mountains up to 1500 meters.

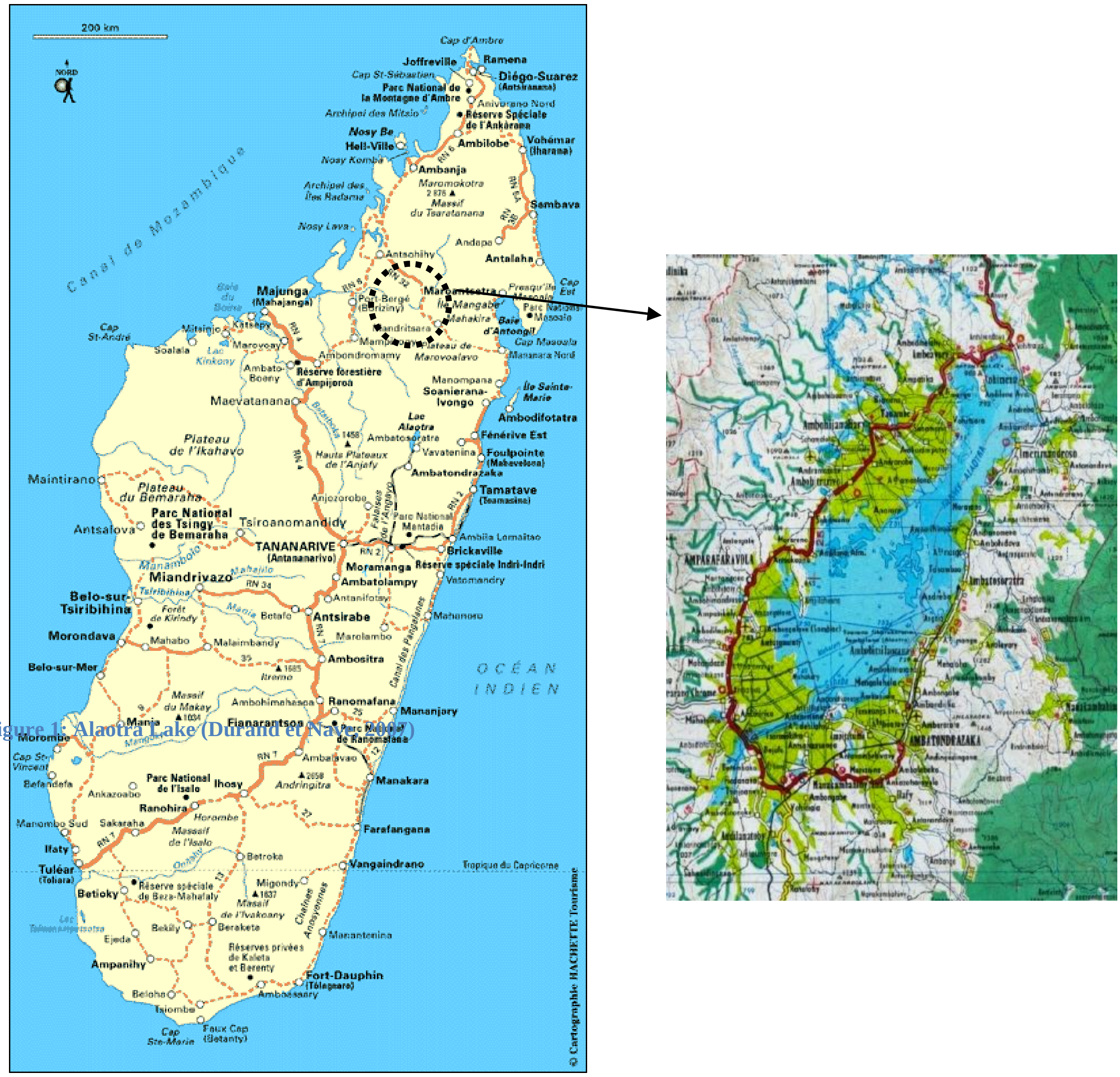

Figure 1: Alaotra Lake (Durand et Nave 2007)

According to the thesis work of Geography Garin (1998) and Teyssier (1994).

In the fifteenth century, the *Sihanaka* tribe, forced into exile from the Highlands colonized the Alaotra region. The lake is surrounded by wetlands where the main vegetation is composed of *Cyperaceae*. Marshes to the east of the lake were gradually exploited for rice cultivation by slash-and-burn followed by puddling with zebu cattle. Rice was hand sown, with low yields in areas where the lake's water level drops. Gradually, the *baiboho* and hills are cultivated with rainfed crops on very small areas. This is simmilar to homegardening, plowed with the *angady* (a Malagasy spade), around living areas. Lake Alaotra came to be increasingly developed especially following the nineteenth century, migration wave of Merina (a Malagasy ethnic group) from the highlands to the region of Alaotra.

The extensive breeding of cattle moved through the Great Plains west of the lake. The traditional rice cultivation system (on mud during rainy season followed by fallow), including the pastoral activity is set up. New technologies are emerging to reduce work at harvest (the use of the sickle replaces the tooth knife), and threshing rice (trampled by the zebu rather than beat with a scythe). While Sihanaka grow local varieties of red rice, the Merina introduce varieties of white rice grains.
French colonization of the region began in 1896, attracted by the high agricultural potential of vast plains. The first colonisation perimiters (PC : *périmètre de colonisation*) are created. Concessions of one hundred hectares are finaly poorly developed, the colonial government invests more in agricultural research to develop more intensive farming techniques such as transplanting, already practiced by the *Merina* or new rice varieties for export. Transplanting will be widespread from 1950 on. The plow and animal traction spread quickly in the 1920s and is widely adopted since the 1960s. They can split the time of plowing by 5 compared to conventional tillage with *angady*. In 1923 the first industrialised development work began with the opening up the region, through the construction of a railway line, Tamatave-Antananarivo, creation of the road Antananarivo-Lake Alaotra, and settlement of PC. Migration to the Lake Alaotra accelerates. Rainfed crops appear in the southeast, where the land begins to saturate. Pig breeding, *fady* for Sihanaka is introduced by migrants. Traditonal and family aviculture is widespread. Almost every family has at least a few chickens, geese ducks, or turkeys (Ministère de l'Agriculture, 2001). French colonists introduced the *Eucalyptus robusta*, which after the end of construction will continue to be heavily exploited by the farmers of the Alaotra as firewood, timber and coal, constitute one of the best sources of income. In 1940, the rice sector for export is growing due to water projects, and construction of drainage canals in the marshes and irrigation canals on the PC 15 and 23. Large farmers (often European settlers) introduce the first tractors for the cultivation of irrigated rice. In 1957 the eastern part of Alaotra is the first area of production and export of rice. To the west are the cash crops (groundnuts, cassava) that develop on the low lands. After the proclamation of independence in 1960, starch and oil mills are closed and exports stop. The settlers leave the area whilst waves of new arrivals migrate in from the from large cities. This is the beginning of the saturation of the rice fields and marshes. Colonisation is from then on included in the evolution of the agrarian system.

The Malagasy government, since independence (1960), made the Lake Alaotra area a focus for development projects destined for family farming (PDR, projet *Imamba Ivakaka*), land tenure project, development of irrigated rice (SOMALAC), mechanization of agriculture and later with the project BVLac the development of rainfed crops on *tanety* with the diffusion of CA pratices (Penot, 2009).
The region's population has exploded since 1897 with the arrival of many migrants attracted by the richness of the basin, looking for land to cultivate (Penot, 2009). The population has almost doubled in 20 years to now over 670 000 inhabitants, 80% of farmers (Devèze, 2007). Gradually, there is a saturation of lowland rice-growing areas (irrigated rice fields and lowlands), which brings farmers to the colonization of *tanety* for food subsistence. The slopes and *plateau* of *tanety*, susceptible to erosion are gradually colonized and settled rainfed. In *baiboho* (alluvial plains and lowlands) fallow periods tends to be reduced to cope with the progressive fragmentation of holdings (Garin, 1998). The emphasis of the erosion phenomena on *tanety* combined with the gradual withdrawal of the state (lack of maintenance of irrigation schemes since the closure of SOMALAC in 1990) are causing significant damage to irrigated rice fields downstream. Irrigated rice fields gradually become rice fields with poor water control (PWCPF), representing now about 70% of rice fields of the area (Devèze, 2007). In addition to the gradual degradation of natural resources, there is a sharp drop in yields of

upland crops. In parallel rice availabity per family dropped from 290 kg/year in 1970 to 113 kg/year in 2008, due to the doubling of the population every 20 years (Penot, 2009). In this context, aggravated by multiple successive political crises, scientific research (CIRAD and FOFIFA) revived since the 2000s, attempts to spread new agricultural techniques at lake Alaotra to concile intensification and resource conservation. The main issue is to increase the production of lowland and develop sustainabily the uplands to an interesting agronomic potential (Domas et al., 2009). Through the project BVLac diffuse the issues of land security, diversification, intensification, small mechanization (development already begun in 1990), the crop-livestock integration, and finally a new paradigm: Conservation Agriculture.
The alternative agricultural practices that are being developed were by the Food and Agriculture Organisation of the United Nations (FAO, 2010) considered as a package, and labelled as ‘Conservation Agriculture’. These practices are:

1. Continuous minimum mechanical soil disturbance.
2. Permanent organic soil cover.
3. Diversification of crop species grown in sequence or associations.

CA was introduced in the Lake Alaotra in response to three major challenges: reducing poverty, feeding people, and reversing the degradation of the biophysical environment, more generally to develop a sustainable agriculture in opposition to traditional rainfed agriculture.
CA practices range from minimum tillage (*TCS*: a plow every two cycles of culture and direct seeding followed by conventional weeding) to more sophisticated techniques such as strict notill. There are two main types of CA systems on dead mulch and with a cover crop (Faure et al. 2009).
In tropical conditions, the agronomic and ecological effectiveness of these systems have been highlighted by numerous studies at cultivated plot scale. Findings are: a significant reduction of water runoff (Findeling et al. 2003) and erosion (Lal, 2007 quoted by Penot, 2009) through permanent soil cover, resulting in an improved water balance (Scopel et al. 2004 quoted by Penot, 2009). Cover crops and no-tillage allow an enrichment of the topsoil carbon and organic matter to maintain soil fertility in the long term (Bernoux et al. 2006, Corbeels et al. 2006 quoted by Penot, 2009). There is also an activation of the micro and soil macrofauna in favor of recycling carbon and soil structure (Brévault et al 2007, quoted by al.2004 Blanchart and Penot, 2009). The cover crop also helps control weeds (Seguy et al. 2006 quoted by Penot, 2009). However, these results remain to be qualified, the benefits of these systems vary according to their conditions of application. The ecological balance is sometimes mitigated by: the frequent use of pesticides, need to adapt crop technical pathways to practices and local interests, management of soil-animal competition for biomass, constraints on small family farms ; manual family labor or animal traction, low monetary means (Serpentié, 2009).

CA has been promoted in the context of a “slow pioneer front”[1] (Penot, 2009) at Lake Alaotra in a double objective: intensify production to increase farmers' income and preserve natural resources. It is therefore to develop diverse and locally adapted cropping systems allowing a regular and sustainable production (Domas et al., 2009). It should however be remembered that the CA systems require an investment more or less consequent (chemical inputs, mineral fertilizers, herbicides, insecticides, equipment, cane planter, seeder) (Bolliger, 2006, 2001 Ribeiro, quoted by Penot 2009). The use of these investments is often essential to deal with hazards (weeds, mulch failures, parasites...). The implementation of innovative systems of

[1] The region of Alaotra lake has been definied by Penot as a “slow pioneer front” that has seen repetitive waves of migration since the XIX century. From 1897 the population exploded forcing the expansion of cropping systems from the flooded lowland to the uplands.

varying complexity, must meet the objectives and constraints of farmers to minimize risk, and requires a network of adapted agricultural (technical advice) and financial (credit) services.
The majority of current CA surfaces of Madagascar are at Lake Alaotra. Indeed, their development has been facilitated by its specific context, predisposed for agriculture "rice granary" and has long been a dynamic receptacle of innovations (Serpentié, 2009).
Gradually, since 2004, the extension is done in a system approach,taking into account watershed scale, livestock, socio-economic dimension, and management of natural resources. Technical advice is adapted to farmers to form integrated actions (theoretical and practical training, development of monitoring and evaluation). CA extension is done at wider scale by the *"projet de mise en valeur et protection des bassins versants"*[2] (BVLac). BVLac project is a pilot project for the phase I (2003-2008) whose objectives are: 1) To increase and secure the incomes of agricultural producers, 2) Preserving natural resources and secure investments for irrigation downstream, 3) Aid to producer organizations and rural communities to become the architect of their development.

At the launch of the project BVLac the following year (2003) the first technical and economic constraints began to emerge. The NGO TAFA diffuses the first systems cover crops-based (cereal/legume), systems with high input and therefore high levels of investment for small farmers. Input are still paid in advance, but the rates of non repayment rise, while the quality of seeds recovered (for the following season) is poor. The project then opts for a redirection toward micro-credits granted by the Bank of Africa (BOA). The number of adopters and surfaces of CA is growing, the project promotes the creation of producer organisations (*OP*), also known as *groupements semis-direct* (GSD) in order to spread the "technical message" more directly and to obtain loans with joint guarantee. In parallel, the project increases the number of technicians including the use of AVB (base extension agent), chosen among the most motivated smallholders. The operator BEST helps the GSD and other OP initially for loans, and they then deal directly with banks. The project is phasing out its functions relating to access to credit.
Extension operators keep track of plots and the results are compiled in a database. The information collected on yields, crop management and key practices. The exploitation of this database to better understand the process of local innovation (adaptation and transformation of knowledge and expertise diffused) against the real paradigm shift for farmers (Domas et al., 2009). In 2008, operators find that most of the loans taken are "credits pots ", that is to say, the original budget for CA plots are in fact used on plots without CA including rice fields and for consumer goods. The approach of framing to the plot seems inadequate, so the project adopts quickly a system approach at its second phase.
The field approach soon showed its limits in terms of efficiency given the high dropout rate from one year to another (35%) (Domas et al. 2009). A system approach taking into account all factors of production and constraints that guide the choices of farmers is adopted since 2007. This approach also incorporates the notion of acticity systems in which co-exist a farm and a household with activities; farm and off-farm incomes. A range of new CA systems are developed and disseminated: systems with high biomass production, based on improved fallow of *Stylosanthes guianensis* and *Bracharia sp.* of 3 years and the rotation rice/vetch (Fabre, 2010). Inputs are not provided by the project, transfer activity was done to the PO. Only the transfer of seed of certain cover crops are difficult to obtain is done by the project (collected from farmers and packaged in a kit that the project provides).

[2] Development and protection project of watersheds

The extension of CA techniques by the extension operators is achieved through the implementation of the following tools. In 2007 is created (adopted in 2008) a typology of farms based on the characterization of farms in the area (Domas et al., 2009). Then followed by the creation of a “farming system reference monitoring network” (FSRMN), representative of the target areas to observe, describe, and analyze the developments related to farming. The economic farm modeling tool Olympe is based in particular on that network through prospective analysis in order to offer to different categories of farmers’ improvements of their farm. API Session[3] (Accelerated Propagation of Innovation) of self-assessment of farmers are also set in place to better understand the processes of innovation (Domas et al. 2009). In this second phase of the project the systems approach includes a monitoring of adoptions/drop outs to highlight the constraints of adoption. The second and final phase of the project BVLac aims: to the progressive autonomisation of PO (Peasant Organisation) through transferring skills and tools.

Conservation Agriculture systems diffused at Lake Alaotra

According to Naudin et al. (2007), there are two different ways to make CA systems: 1) import biomass from neighboring plots: simple systems but labor intensive and the improvement of soil fertility and structure remains limited. 2) Produce the mulch on the plot (cleared of natural vegetation, crop residue, cover crop in association with the main crop): simple techniques to more complex ones where you have to control the cover crop to avoid competition with the main crop. Various cropping systems adapted to different morphopedological units with crops selected by farmers were identified and proposed (Domas et al. 2009):

- On moderately fertile *tanety*: CA systems with low-input because the risk is high at this level of topo-sequence (including drought)
- On fertile *tanety* systems with simple CA practices’; annual rainfed crops or perennial semi perennial (fruit) focusing on systems with low-input but can lead to greater intensification
- On lowlands (*baiboho* and poor water control paddy fields (PWCPF)) with more intensive systems due to a much lower risk; rice during the season (flexible rice SEBOTA in particular) and secondary-season crops have been developed to increase farmers income and biomass production for coverage and/or forage during the dry season.

CA systems are not applicable to irrigated rice fields. Development of *tanety* can be done with forest systems (*eucalyptus*) or forage (*Brachiaria sp.*) and undemanding multiyear diversification crops (pineapple). On irrigated rice fields are disseminated improved techniques, relatively known and controlled by producers *systèmes de riziculture intensive et améliorée* (SRA) derived from partial SRI (Systèmes de riziculture intensive) techniques.
On areas of significant risk (drought, flooding, silting, etc.) only systems with low level of inputs will be applied. In contrast in areas with low climate risk (*baiboho*), the level of investment will be higher as likely to generate significant gains with less risk and return on investment particularly interesting. The final criterion for the selection of cropping systems and crop management is the integration of various activities on the farm (crop-livestock). This integration allows you to increase the available forage for the animals to install forage and

[3] API : Exchange meeting between farmers of a same groupment, of different groupments or of individual farmers; where they share informations on innovations of a particular crop or technical pathways

associated crops on uncultived areas, and also to use animal by-products fertilizers on areas with high potential of production, while reducing costs in chemical fertilizers which have with fluctuating prices.

The systems producing little biomass (on imported dead mulch or residue from the previous crop)

- **Upland rice on dead mulch**

Rice is the priority cereal for Malagasy farmers. At farm scale, upland rice on soil cover with short-season varieties is of major interest by the fact that the production of irrigated rice is often inadequate or non-existent in some areas supervised by the project. Harvesting is carried out during the lean period during the months of March to April, with higher selling prices.

- **Vegetable growing and ground legumes on mulch**

The gardening in the secondary-season or legume on mulch usually produce very good results in CA sytems. The gains in time of work provided by mulching (little or no weeding, no watering) can generate high margins. A full range of garden plants is thus offered to adopters.

Systems producing large quantities of biomass

Systems based on imported biomass are difficult to put in place by some farmers: difficult access to biomass, lack of availability of labor for mowing and transport, high cost of bales. These systems are not distributed in the region. An interesting alternative is to set up live coverage in the first year (that brings an income if possible) which will have two main purposes: restructuring and enriching the soil and creating biomass for the next crop, alternating with systems *Gramineae* based mainly.

- **Legumes in pure culture or in association with maize or sorghum**

This technical pathway involves the installation of a legume with high invasiveness type *tsiasisa* (*Vigna umbellata*), *Dolichos Lablab* and mucuna (*Mucuna pruriens* var. *itilis*). These long-cycle plants (5 to 6 months) can create a very large amount of biomass that can be used as mulch for the next crop with also significant amounts of nitrogen fixed by nodules. This technical pathway is recommended on all levels of the toposequence with consistent organic fertilisation on the soil less fertile. The association with maize can combine food production (maize and legume if it produces edible seeds) to a biomass production on the plot. The rotation “maize + legume/upland rice” is the most common.

- ***Stylosanthes guianensis* based systems**

Stylosanthes guianensis is a perennial plant, particularly suited to improve the fallow because with a powerful root system it can deposit large amounts of nitrogen. It is also a very good fodder for the zebu. Unlike *Brachiaria* sp. a simple etching allows its destruction, with no use of herbicides required. Upland rice yields obtained after 1 to 2 years of *Stylosanthes guianensis*-based fallow are excellent, even at low doses of fertilizer. *Stylosanthes guianensis* can be set up in pure culture or in combination with cereals, cassava, bombara nut etc. to generate income while producing the coverage.

- ***Brachiaria sp.* based systems**

Three species are distributed: *Brachiaria ruziziensis*, *Brachiaria brizantha* and *Brachiaria humidicola*. These grasses can provide a very large amount of biomass, even in very low fertility soils. Their ability to restructure is very important; they are much better suited than annual legumes to revegetate degraded soils of the hills. They are also excellent fodder. The

Brachiaria sp. can be implemented in pure culture or in association with cassava, bombara nuts etc.

- **Vetch based systems**

These systems are installed on *baiboho* or PWCPF. Vetch provides a large amount of biomass and higher rice yields at low input levels. Its destruction, however, requires resorting to herbicides.

The table below presents a synthesis of CA systems distributed according to the toposequence

Table 1: Opportunities for cultural pratices applicable according to the physical environments (Domas et al., 2009)

Soil type	Intensification level	Systems
Tanety rich	All levels	▪ Intensive, cereal based (rotation maïze + legumes // rice) ▪ Extensive, based on fodder plants
Tanety poor	Low	▪ Extensive, based on fodder plants (rice on a long fallow) ▪ Ground legumes on mulch
PWCPF	All levels	▪ Intensive, cereal based (rotation maïze + legumes // rice) ▪ Extensive, based on fodder plants
Baiboho	High	▪ Intensive, cereal based (rotation maïze + legumes // rice) ▪ Intensive rice production with winter vegetables (rotation legumes // rice//vegetables CS) ▪ Intensive system with one year *Stylosanthes guianensis* fallow

These systems are distributed in varying proportions in different areas of lake Alaotra. The *tanety* predominate in the north of the lake, while *baiboho* and rice fields are common in the southeast.

High *Tanety* dotted with *lavaka*. Grazing area

Cultivated *Tanety* (rainfed crops)
Maïze+ légumes//Upland rice
***Stylosanthes* or *brachiaria*//cereals**

Baiboho and PWCPF
Upland rice//vetch
Upland rice //vegetables on mulch
Maïze + leg. //upland rice

Irrigated rice fields
Improved irrageted rice grow

Figure 2 CA in the landscape of the South est valleys (Fabre, 2010)

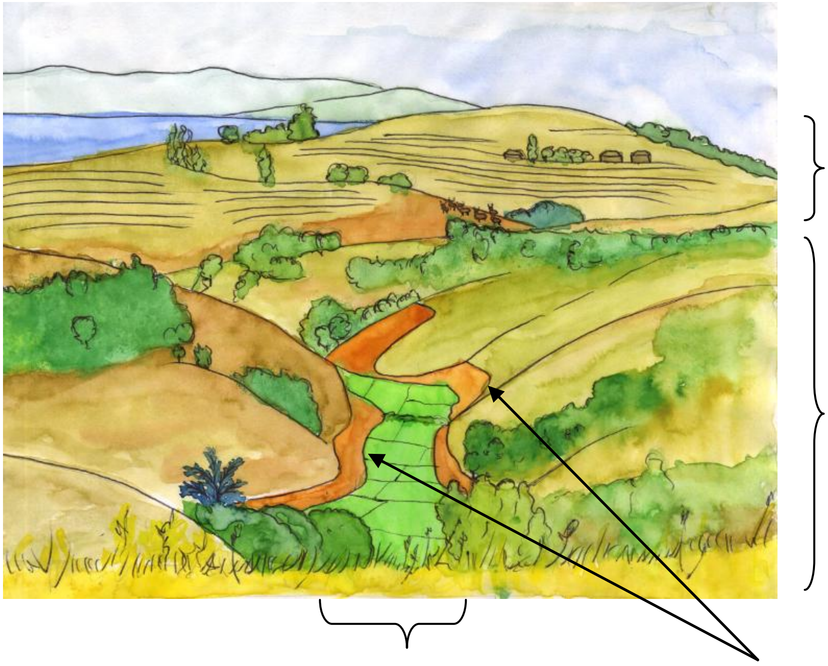

Figure 3: CA in the landscape of the South est valleys (Fabre, 2010)

The assement of the place occupied by CA at Lake Alaotra did not start until 2005. The assessment is based on the “plots” and “farm” databases filled by the operators of different areas of BVLac project after each campaign. These databases are then forwarded to GSDM, which is responsible to analyze and provide statistics on the adoption of disseminated systems. These statistics, however, have biases: forage systems, improved rice (SRA) or intensive (SRI), or surface about to be switched to CA are often recorded. The adoption rate of CA practices’ is a good indicator of the interest of farmers for these technical innovations and provides an overview of the effectiveness of diffusion. This assessment was studied in 2010 by J. Fabre.

Current state of the place of CA in farms

At Alaotra lake, the most adopted systems on alluvium (lowlands: *baiboho* and Poor Water Control Paddy Fields (PWCPF)) is an upland rice during the season and a legume (vetch) or gardening on rice straw during the dry season. On uplands cultivated only during the rainy season (*tanety*), we find the inter annual rotation maize//upland rice on mulch of crop residues, maize is associated with a twining legume (*Dolichos*, *mucuna* or *vigna*). There is also the association cassava-*bracharia* or cassava-*Stylosanthes guianensis* (Domas et al. 2008). In 2009/2010, 1,083 hectares of farmland are under CA systems in Lake Alaotra. Most CA systems are present on *tanety* especially in the area north of the lake with little *baiboho* and *vice-versa* for the southern zone. The western zone is characterized by little *baiboho* and little CA surfaces. Of these 1,083 hectares, only 83 hectares are perenised CA, that is to say, having passed the third year of implementation of CA, 336 hectares are surfaces being tested (years 1 and 2), and 666 hectares are surfaces in installation (year 0). Perennised CA among the surfaces, 80% of them are surfaces of seniority 3 to 4 years in CA system. Very few surfaces in CA are perpetuated for over 5 years (Fabre, 2010).

On average, 25 % of farm cropped areas are under CA. It varies depending on the type of farm and systems installed. Farms that have adopted CA systems intensive in labor and inputs (small to medium farms with little irrigated rice fields, and large rice farms with *tanety*), type maize+legumes or upland rice//gardening on straw mulch, have in average 50 to 75% of CA on their surfaces. The mechanized farms turned to irrigated rice cultivation, have set up CA systems extensive in labor and inputs at less than 15% of their total area for the most interested and up to 25% of the total cropped area in the case of "opportunists" smallholders (Fabre, 2010).

Causes of abandonment

The practice of CA does not necessarily make a farmer an "adoptant". Adoption is defined as the appropriation of knowledge and know-how disseminated, by the smallholders. This appropriation is built through a process of transforming the innovation. The farmer experiments the dissiminate techniques then modifies them and adapts them according to his constraints. The first year of installation of CA is described as year 0. This is the installation of the cover crop after plowing deep enough to loosen the soil. This is the final year of plowing. The first year of CA is year1. Farmers install CA culture by direct seeding. Between the first year of implementation of the CA systems (year 0) and second (year 1) the dropout rate is 60% in average among farmers but varies from 34 to 70% (data 2005-2010, analysed by Fabre, 2010). Farmers are abandoning the system without having experienced it. These smallholders are characterized as "opportunists" they did not understand the objective of direct seeding. Yields in year 0 are equivalent to the previous conventional system with the same level of intensification. Between year 1 and year 2, the dropout rate is around 45% but varies from 2 to 72% depending on the year. This is an experimental phase for farmers who mobilize much time to learn CA techniques. They must organize their time between CA practices' and conventional plots (data from 2005 to 2010, Fabre, 2010). It is important to note that in year 1, yields are often lower or equivalent than conventional yields due to the change of agricultural system and a partial management of CA techniques. In year 2, yields reach the same level as they were in the conventional system. From year 3 drop out rates are lower (around 20%). Farmers have a better control of the techniques and the first effects of CA practices' appear, yields increase slightly compared to conventional systems. These farmers have integrated CA systems; they are the adopters of the innovation. However, in year 6 the dropout rate increases sharply, 75%. In year 7 the dropout rate drops to 35% (data from 2005 to 2010, Fabre, 2010). It can be hypothesized that adopting farmers tend to neglect weeding gradually, yields being good with low labor requirements. Over the years the weed pressure becomes too great, in year 6, farmers are forced to plow the fields, which are then considered as dropouts.

The technical and financial constraints of farmers are not the only causes involved in the abandonment of CA systems by farmers. Indeed, the land situation is also a predominant factor. At the Lake Alaotra the land situation is complex, most farmers do not have ownership title to their land and are renting or sharecropping (Freud, 2005). With a short-term rent lease, it is risky for the farmer to invest. He limits the use of inputs as much as possible. However, for a long-term rent lease, the risk is lower, the farmer will use the inputs in the early years of the lease and will stop two years before the end of the contract. In the case of sharecropping, the farmers do not use inputs because it is the farmer who invests and half the profits (half of the crop) is recovered by the owner. Also, often when the farmer gets a good crop year after year, the owner takes his plot back, to seize the opportunity to cultivate a plot apparently fertile. In this context, it is easy to understand the reluctance of farmers to invest in

sustainable CA systems, whose effects appear only after 3 years of investment (labor, technology, time, and inputs). In 2009/2010 only 11% of CA plots to the north east are rented or sharecropping and 22% in the south east. Another constraint is added to this social order; the practice of grazing the common causes damages on the mulch, and is a further obstacle to the adoption of CA techniques. According to Domas et al. (2008), 36% of dropouts are related to poor "adaptation of techniques" (failure due to non-compliance to the recommended technical pathway, peaks of work load and duplication of work time associated with a poorly distributed rainfalls, areas predominantly with irrigated rice prevailing over other crops), 32% for financial reasons (lack of cash) and 13% for land tenure reasons. Since 2008, prices of inputs and labor have increased it appears that the financial cause is increasing. Today, the surfaces said to be perpetuated, that is to say not abandoned after the first year, up about 51% of the supervised surfaces (29% in the second year, 16% in the third year and about 6% in the fourth year and above) (Domas et al. 2009).
Diffusion of CA systems at Lake Alaotra seems to work well for some categories of famers when CA techniques bring solutions to specific constaints because each year the rate of adoption is growing. The problem lies more in the sustainability of the systems as evidenced by the high dropout rates.

Evaluation of the performance of CA systems and their economic impact

The farming systems approach adopted at the second phase BVLac was preferred considering that it would be possible to compare the performance of farms that have adopted CA techniques to farms that did not adopt (control). The comparison is ultimately difficult to establish. The adoption of CA is recent on small surfaces or old on large surfaces. The comparison can only be done with systems well conducted over several years where the cumulative effect of biomass left on the ground can produce good results and more interesting than in conventional systems. It therefore appeared interesting to compare the performance of innovative cropping systems with conventional crops. The different technical pathways are compared (Domas et al. 2009). However, methods for the evaluation of results have certain biases: it is very difficult to differenciate economicaly the effect of CA techniques from the effects due to improved varieties or the level of intensification, when the plots do not have the same characteristics. However, since 2008, mineral fertilizers are generally not used, and farmers have massively adopted the improved varieties on rice fields. In addition, the databases are informed regarding the CA systems, but not in conventional systems.

MATERIALS AND METHODS

The objective of this study is to achieve a counterfactual technical and economical assessment of the introduction of CA in farms located around the lake Alaotra. The counterfactual approach is to reason as follows: what would now be cropping systems if the farmer had not adopted the innovation? The evaluation focuses on the economic performance of CA systems integrated into the operator adopts, therefore “old” CA. These cropping systems are those that guarantee the best value for agriculture? Over a 10 year period, does the adoption of an innovative system in the farm allow for an increase in farm income? Under what conditions? What are different levels of adoption of conservation agriculture at the lake Alaotra?
Assumptions about the expected effects of CA at cropping system level and of the overall farm production system have been proposed by the GT3 PAMPA (Faure et al. 2009). These assumptions will be to confirm or undermine during the study.

At the cropping system level (field level)

- Changes in the crop sequence
- Modification of cultivation practices for the conduct of the cropping system and modification of technico-economic results (reduction of working time, yield improvement, early harvests)
- Improved technical-economic performances (labor productivity, land productivity reversed)

At the production system level (farm level)

- Expected Outcomes
    - Changing the management of labor
- Reduction of working time for production plant
    - Modification of the agricultural calendar (early sowing)
    - Changes in economic performance
- Improved overall income (earnings and net operating)
- Increased productivity of land and labor

- Indirect Effects Expected
- Modification of conventional farming systems (partial transfert of CA disseminated techniques)

Analysis of the FSRMN database in the software Olympe (2007-2010) (2011 data not available) was performed in order to extract data on conventional cropping systems, crop sequences, and crop technical pathway. Data were extracted from Olympe to an Excel database and analyzed using a PivotTable. The major study areas were determined using the following criteria: 1) surfaces in CA and 2) accessibility. Areas northeast and southeast have been selected for the study.

Southeast valley	Northeast
Lots of *tanety* but of poor quality, lots of *baiboho* and PWCPF. Close to irrigated peremiters	Lots of *tanety* of good quality, few *baiboho* and few irrigated rice fields but vast areas of PWCPF
Good connection to the local market	Relative remotness
Mainly irrigated rice	Rainfed and irrigated crops in equivalent proportion
Early extension (2000)	Late extension (2003)

The technico-economic evaluation is performed on selected farms with “old” CA followed every year since their adoption by operators; FSRMN farms. These farms are located in the *fokontany* of Ambaniala and Amparihitsokatra to the northeast (commune of Imerimandroso and Amparihitsokatra) and Ambohipasika, Ilafy, Mahatsara for the area southeast (communes of Ilafy and Ambohitsilaozana).

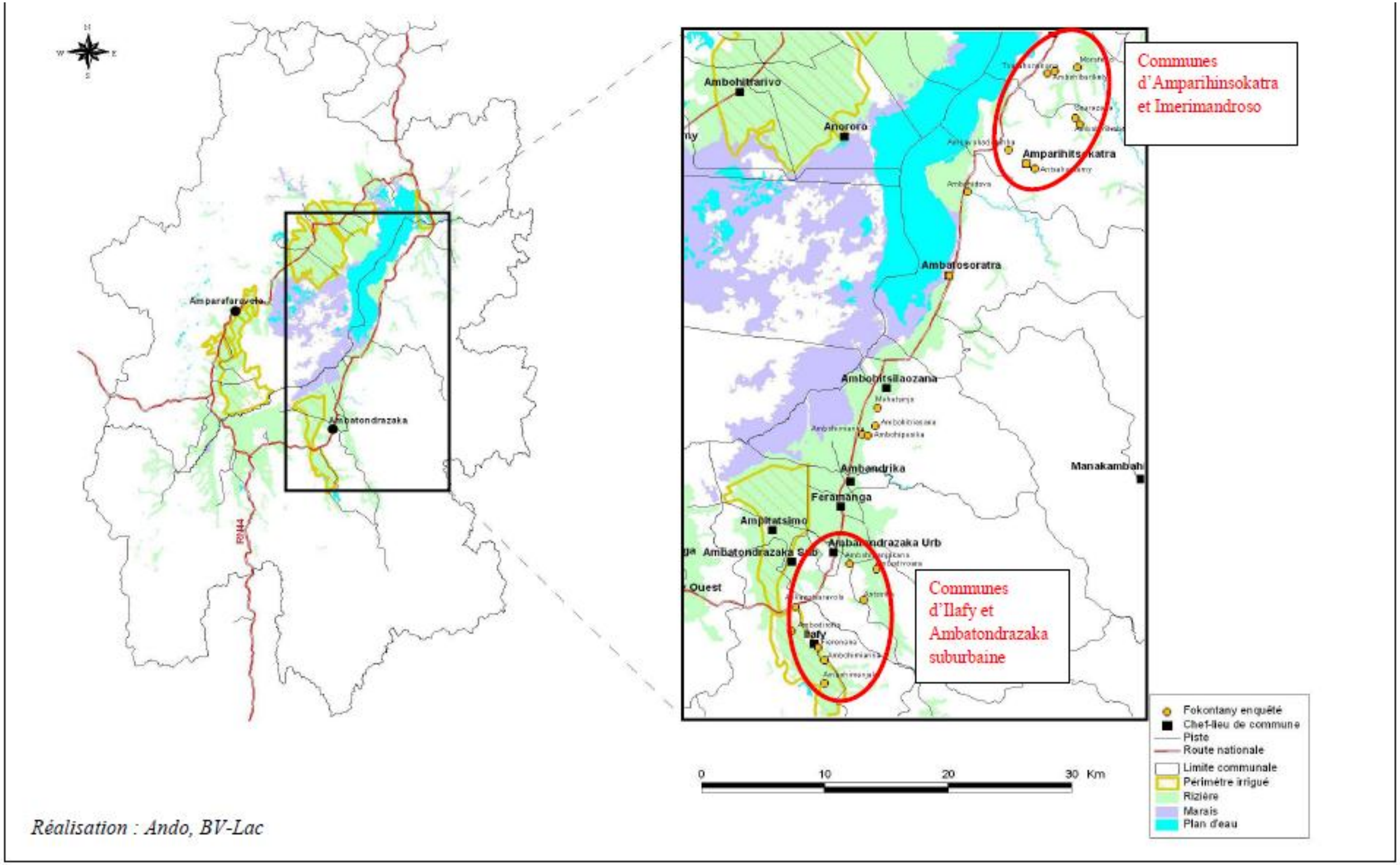

Figure 4 : Localistion of study areas (Fabre, 2010)

The farms in the northeast, isolated between the *tanety* and the Alaotra lake

The communes of Amparihintsokatra and Imerimandroso are located northeast of Lake Alaotra. The nearest urban center is the small town of Imerimandroso.

- ❖ Production systems organized around the rainfed crops

Irrigated rice fields are rare in the northeast of the lake, and extend into the lowlands between *tanety*, or on the shores of Lake Alaotra. Some rice fields are cultivated only during the low water period of the lake, with recession rice. The lowland paddy fields are fed by perennial or temporary water sources, such as small lakes or ponds. Some rice fields located near sources of water supply can be grown during the dry season with secondary-season rice.

The *tanety*, very numerous, are composed of basic soils relatively fertile (Raunet, 1984). Drought is the main risk of these units where irrigation is impossible. The *baiboho* are virtually non-existent in the area. Production systems are organized around the rainfed crops. Since the 90s, upland rice is grown with the development of new varieties (B22). The ability to produce rice on *tanety* was an important innovation for farms. Small family farms (pigs, poultry...) are well developed due to the high production of maize and cassava on the hills. Cattle breeding is employed with small herds. The isolation of the area makes it very susceptible to armed attacks and theft of zebu. The pressure on forage resources is important during the dry season, given the limited availability of rice straw and paddy fields.

- ❖ Poor market integration

Tanety hills area is isolated with poor communication acess (**Erreur ! Source du renvoi introuvable.**), making travels difficult, especially during the rainy season. The different communities suffer a gradient isolation as they move away from the main trail that connects Ambatondrazaka to Imerimandroso. The relative isolation of the area has an impact on production in place. Cereals and non-perishable legumes that can easily be transported are preferred to perishable products. Isolation implies poor access to markets as well as poor input supply

Work opportunities outside the farm are reduced. The proximity of Lake Alaotra can supplement farm income by selling fish. *Eucalyptus* plantations also help diversify income through logging.

- ❖ A *terroir* of later extension than the southeast

CA techniques are disseminated (directly with cover crops) in *fokontany* surveyed since 2003 (with the exception of a few test plots). Despite the later start of the extension, CA practices' are well distributed in the area.

Figure 5: Picture of the fokontany of Amparihintsokatra (source: Ando, BV Lac)

The valleys of the southeast: a landscape of irrigated paddy fields

The communes of Ilafy and Ambohitsilaozana are located in a vast rice plain in irrigated areas, on the left bank irrigated perimeter of the valley *Marianina* and the irrigated peremiter PC15 (**Erreur ! Source du renvoi introuvable.**). The landscape is open and marked by rice cultivation.

- ❖ The well-integrated rice farms to markets

Rice fields are varied ranging from irrigated low land paddy field (IPF) to poor water control paddy field (PWCPF) well represented. The *baiboho* are numerous and cultivated during the rainy season with upland rice followed by vegetable crops in the dry season. The *tanety*, with low fertility are less numerous in the area and are sensitive to the geological process of erosion *lavaka* (Raunet, 1996). They are extensively cultivated with maize, legumes, cassava or extensively grazed (forage).
Cattle breeding is well developed, it is complementary to rice crops. In season, the zebu is used for the settlement of crops (tillage, puddling). At the end of the season and during the dry season zebu graze in rice fields. Rice straw is the main source of fodder. The grazing of zebu in rice fields is an important source of manure.

The areas economy is thus based on rice and secondary season crops. Proximity to markets of the city of Ambatondrazaka encourages vegetable production. The area is also fairly well served by grain collectors or garden crops that feed the markets of Antananarivo and Tamatave. The city of Ambatondrazaka also offers significant opportunities for off-farm (trade, transport, services ...).

- ❖ A *terroir* of older extension than the North East

The commune of Ilafy was among the first "test" areas of the project for the extension of CA (2000). CA systems on dead mulch, "écobuage" and cover crops were disseminated. The diversity of disseminated systems in this region is not necessarily perceived as an advantage over the northern area.

Both study areas have different constraints and opportunities in terms of adoption of CA systems. Supervision is provided in both areas by BRL.

Figure 6: Picture of the commune of Ilafy and the irrigated peremiter in the Marianina valley (source: Ando, BV-Lac)

1.1 Method of socio-economic assessment

The methodology adopted in the economic assessment of CA systems is partially based on the methodology Evalinnov (Faure et al. 2009). The initial goal was to achieve an *ex-post* evaluation based on a counterfactual approach. We will see later how and why the methodology has to evolve towards a prospective analysis.

Evaluating the effects of the introduction of an innovation in farm holding is done by comparing a reference situation to the current situation in which is the farm. The baseline here adopted and validated by farmers (Fabre, 2010) is the initial situation before the adoption of the CA system. The effects of CA will be measured against the cropping system the farms were doing before adopting the innovation. When the information is not available, neighbours adopters and non adopters are a valuable source of information. The study takes place over six months; it is not possible to obtain follow-up indicators in real time. The assessment is however possible in a counterfactual approach. The reference situations on the functioning of the farm are reconstructed from the oral reports of experts (farmers). This reconstruction is based largely on the memory of the farmers, who often do not have a logbook; the BRL databases do not have the information on non-CA cropping systems. The comparison that we will adopt in this study is the current situation “with project” with the one “before adoption of innovation”. Therefore note that before the adoption of innovation, farmers may have changed their practices by observing the neighbours, this is innovation processes is due to spontaneous diffusion of technolohies or techniques .

Sample Selection

The evaluation is done on farms with “old” CA, followed since their adoption, the farms of the FSRMN, in order to assess the economic impact of the technical change (Penot et al. 2004). Of these farms were selected those whoses types are the most representative of each study area (from the analysis of BVLac “farm” databases). The farms of FSRMN in practice are not really representative of each zone (Terrier, 2008). Each selected farm of the FSRMN was surveyed on the basis of crops technical pathway; cropping situation and results of 2011, and then the non-CA cropping systems practiced before the arrival of the projects supervision. Information on non-CA crops collected from these surveys can be incomplete. In fact, if memory allows farmers to track the rotations, it is not enough information on technical pathways and even less on yields. A selection of farms neighboring each farm of the FSRMN has been performed.

The survey is semi-directive; it is divided into three main parts. The first part covers the general characteristics of the farm, name of the farmer, village name, status of supervision by the project, operators name, zone, plots (number of plots per toposequence, area and type of tenure), self-sufficiency in rice, number of zebu, pigs, and off-farm income. The second part deals with rotations per plot. Are indicated by year and plot cropping systems (rainy season and dry season) varieties, the total production, self-consumed production, the sale price. We only focus on *baiboho* and *tanety*; also provides information on the type of *tanety* (plateau, slope or low slope) and *baiboho* (sandy or fertile) based on the farmers expertise. During the interview we try to know what are the reasons why the farmer opted for a crop rotation or sequence. There are also varieties, production, self-consumed production, selling price, quantities of seeds and cultivation techniques for rice. For farms that are part of the FSRMN seeks to track the information only for 2 years (ie. the campaigns 2009/2010 and 2010/2011), to make the connection between this year and last year. These farms are monitored every year, so the information is already available. For selected farms, we try to gather information as far as the memory of the farmer allows it, usually until the 2005/2006 season. The third part deals with the non-CA Crop Technical Pathways (CTP) only in the case of selected farms and all CA and non-CA crops for FSRMN. We are only interested here in *tanety* and *baiboho* for the campaign 2010/2011. The crop technical pathway requires the following information: cultural operation, date, type of input, amount used, costs, family labor and employment, cost of labor. In total 37 farmers were surveyed on two areas northeast and southeast. The data collected in surveys is processed in an Excel database.

Identification of non CA standardized technical pathways

Initially, the study of the database is intended to highlight the different levels of adoption of innovation among farmers surveyed. These different levels of adoption are based on the following indicators: i) Reconstruction of crop rotations and ii) Technical pathways of cropping systems

We hypothesize that there are four levels of adoption of CA systems in the study areas:

- Level 0: traditional farming system, now assumed a very limited presence in rural areas. Cropping systems incorporate some of the current technical introductions since the 1930s
- Level 1: conventional cropping system, the system is supposed to be the most common among surveyed farmers. It corresponds to all the innovations brought during the colonization and after the independance
- Level 2: Innovative Cropping Systems (ICS); it is the result of a partial spontaneous diffusion of techniques disseminated by BVLac and previous projects. This system is difficult to distinguish between levels 1 and 3. It is likely that it can be found in some of the FSRMN farms.
- Level 3: CA cultivation systems, popularized techniques are adopted and implemented fully or almost; it is assumed that these systems are those found in the FSRMN farms and with some supervised and motivated farmers.

These different levels of adoption will be quantified on the basis of the sample of surveyed farms and described precisely according to the indicators mentioned above. They will be defined for each major study area: northeast and southeast, the survey sample is not large enough to allow a detailed analysis across *fokontany*. In addition, it is unlikely that the practices are really very different at this scale. For the first two levels of innovation adoption (level 0 and level 1) will be determined:

- Standardized Crop Technical Pathways (std CTP) per year
- Average yields for each crop per year
- Standardized crop rotations or sequence

The standard CTP are created from calculations of average monthly labor requirements for each cropping system and amount of inputs (seeds, pesticides, mineral and organic fertilizers). The analysis is carried by pivot tables on the database. For CA systems operators determine the standard CTP, standard rotations and average yields for each cropping system. Each cropping system is processed with the software Olympe.

Modeling the selected farm sample with Olympe

Modeling of the selected farms of the FSRMN is performed with Olympe. Different sccnarios based on levels of adoption of innovation are tested. We adopt a “counterfactual approach”;

we simulate a farm with no adoption of CA where CA systems are replaces by convetionnal systems . Simulated non-CA farms are compared to current farms with CA The modeling period selected for the analysis is a 10 years period. Climatic effects are taken into account. Modelling is done with yields according to the last 5 climatic years. We initially determine, the current level of adoption of CA techniques in each farm of the FSRMN, it is the current scenario. For each farm there can be a total of four different scenarios. These scenarios are changed only at the cropping system level of *tanety* and *baiboho* (crop rotations, std CTP, yields). Irrigated or poor water control paddy fields, remain unchanged, as are other parameters of the farm (number of animals, number of people to feed in the family, off-farm...). Olympe allows the comparison between CA and non CA farms on, the following item : i) the farm income: to evaluate the economic performance of farming system and ii) the cash balance: it represents the theoretical capacity of investment (actual balance after subtraction of all farm and family expenses) and iii) cumulated cash balance over 10 years: to assess capital building capability in the medium term.

Economic analysis of CA system performance

The performance evaluation of CA systems is first carried out at plot level. We assess economic performance at the cropping system level. Secondly, impact evaluation focuses on farming system and thirdly on extension effect. The activity system a définir àplus haut is defenied as a farming system + a household (including off farm) The effect of extension is to provide general technical advice to farmers. Apart from the extension of CA techniques, technicians also provide advice to farmers on their rice fields (planting plans younger, line drilling), new varieties (depending on soil type) etc. The extension impact needs to be evaluated. Some farmers practice CA on a very small area in order only to maintain a link with the project through the extension agent. A revoir

Analysis at plot level is based on the following economic indicators

- Gross margin for productivity measurement of the systems
- Return to labour to measure labour productivity
- The return to capital and the intensificavation ratio to assess the level of intensification of the system and therefore the degree of risk

Analysis at the farm level based on the following indicators :

- Net farm income (calculated before auto-consumption)
- Real agricultural income (non-calculated after auto-consumptions: to create an indicator in Olympe, after consumption)
- Total income (after consumption, and with off-farm)
- Cash balance (⇔theoretical capacity of investment) after household expences and self-consumption

Economic evaluation of the performance of innovative systems is based on models constructed from information of experts, farmers. The counterfactual approach leads us to obtain more or less inaccurate unverifiable data. The economic analysis therefore provides results with a margin of error that can not be quantified.

The farm typology

It s presented in table 2.

TYPES	***CRITERION 1*** *Self-sufficiency in rice depending on the type of rice fields*	***CRITERION 2*** *level of diversification with other productions*	***CRITERION 3*** *type labour and off-farm*
A : Big Rice growers	**Irrigated paddy fields Selfsufficient in rice + sale**	**Surfaces of *tanety* above 4 ha little to not cultivates Extensives crops**	**Temporary labour> 300 M.d** (man x day)
A1 : Irrigated paddy fields ≥ 6 ha			
A2 : 3 ha ≤IPF<6 ha	A21 : > 4 ha of upland surfacesmore or less cultivated A22 : ≤ 4 ha of upland surfaces		
B : Rice growers with random yields	**IPF < 3 ha PWCPF or RR** ≥ 7,5 ha **Selfsufficient in rice + sale**	**upland sufaces not irrigated (≥ 2-3 ha) entierely cultivated in a more or less intensive way, with an objective to sell**	**Temporary labour > 200 M.d**
B1 IPF < 3ha PWCPF ≥ 7,5ha	B11 : *baiboho* (rich upland soils) and/or *tanety* ≥ 1 ha B12 : *tanety* only		
C : Selfsufficient farmers	**1ha ≤IPF<3ha PWCPF <7,5ha Medium Risk Selfsufficient in rice**	**Upland surfaces < 3ha and entierly cultivated intensively in a sales objective**	**Temporary labour ~ 100 M.d Off-farm = services**
D : Farmers diversifing their productions	**IPF < 1ha PWCPF<2 Important risk Selfsufficient but not every year**	**Sales Objectives Présence of breeding activities**	**Temporary labour ~ 100 M.d**
D1 : **Paddy fields Ratio ≥ 2**	D11 : *baiboho* ≥ 1ha D12 : *baiboho* <1ha and *tanety* ≥ 7,5ha D13 : *baiboho* <1ha and *tanety* <7,5ha		
D2 : **Paddy fields Ratio <2**	D21 : *baiboho* ≥1ha D22 : *baiboho* <1ha and *tanety* ≥ 7,5ha D231 : *baiboho* <1ha and 3 ≤ *tanety* <7,5ha D232 : *baiboho* <1ha and *tanety* <3 ha		
E : Non Selfsufficient , agricultural workers	**Paddy fields Ratio <2** IPF<0,5, PWCPF<2 **Very important Risk Non Selfsufficient**	**Upland surfaces < 1 ha cultivated very intensively in a sales objective**	**Temporary labour ~ 0 Off-farm activities : agricultural worker**
F : Fisherman and farmer	**Paddy fields Ratio <1** RI<0,5 , PWCPF<0,5 **Non selfsufficient**	**Upland surfaces < 0,5 cultivated very intensively in a sales objective and selfconsumption**	**Temporary labour ~ 0 Off-farm activities : Fishing**
G : Landless fisherman, no farming activity →Could become a type F	**Landless Non selfsufficient**	**Landless**	**Agricultural worker: provide other types with labour**

An irrigated rice field produces in avergae 3500 kg/ha of paddy rice per year. The PWCPF

Table 2 : Typologie of farms at lake Alaotra revisited (Durand C. et Nave S., 2007 ; Penot E. and operators, 2008 ; Domas R., 2011)

The updating of the database provides the actual proportions of each type of farms for each study area. The results are presented in the graphs below. G type farms are not represented, they are landless farmers who by definition do not have a farm.

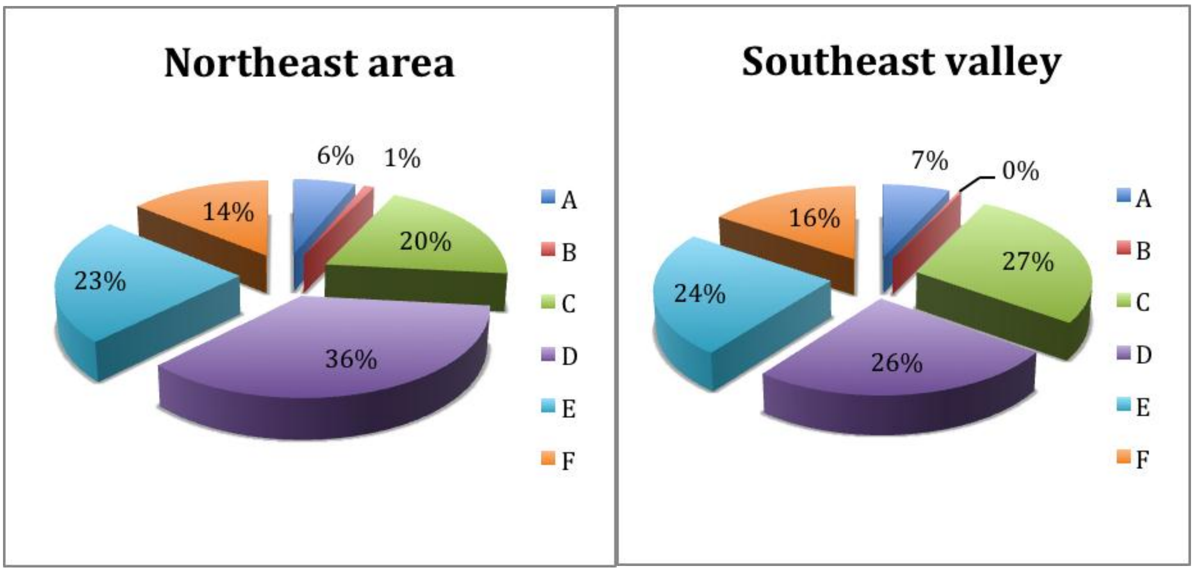

Figure 7 : Distribution of main types of farms in areas northeast and southeast of Lake Alaotra

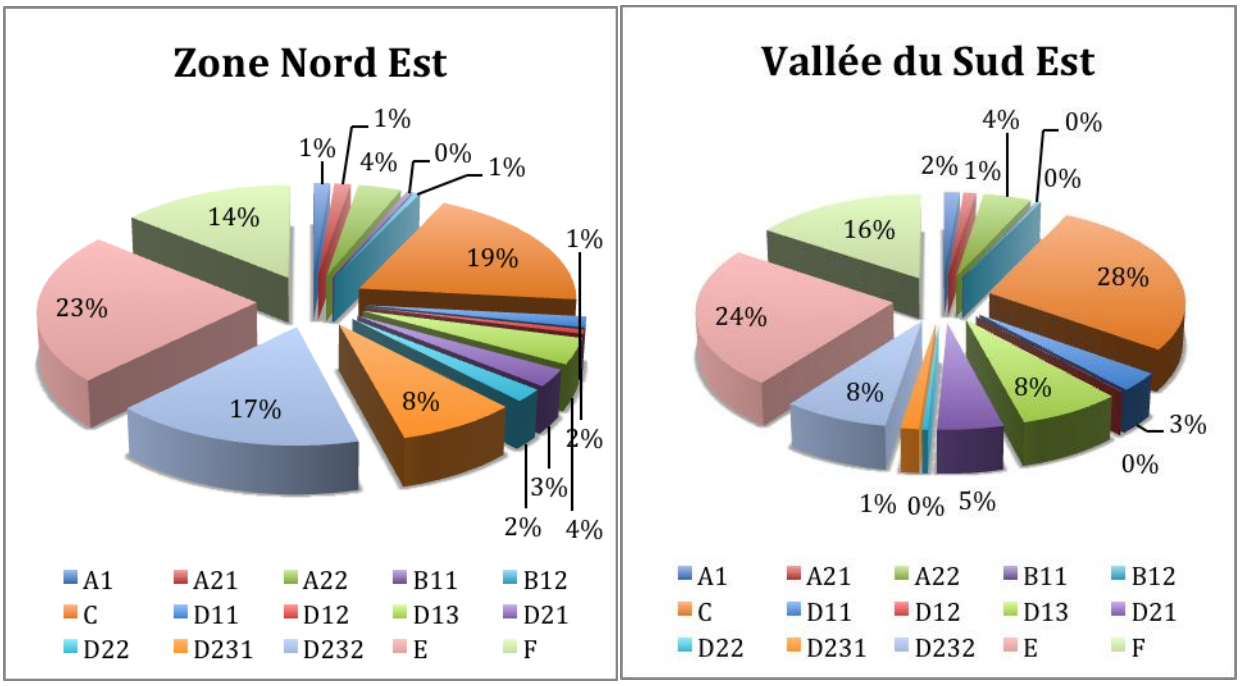

Figure 8 : Distribution of detailed types of farms in areas northeast and southeast of Lake Alaotra

In the northeast the most represented farm holdings monitored by the operator for the 2009-2010 campagnain are the type D (36%), E (23%) and C (20%). In the southeast valley it is the type C (27%), D (26%) and E (24%).

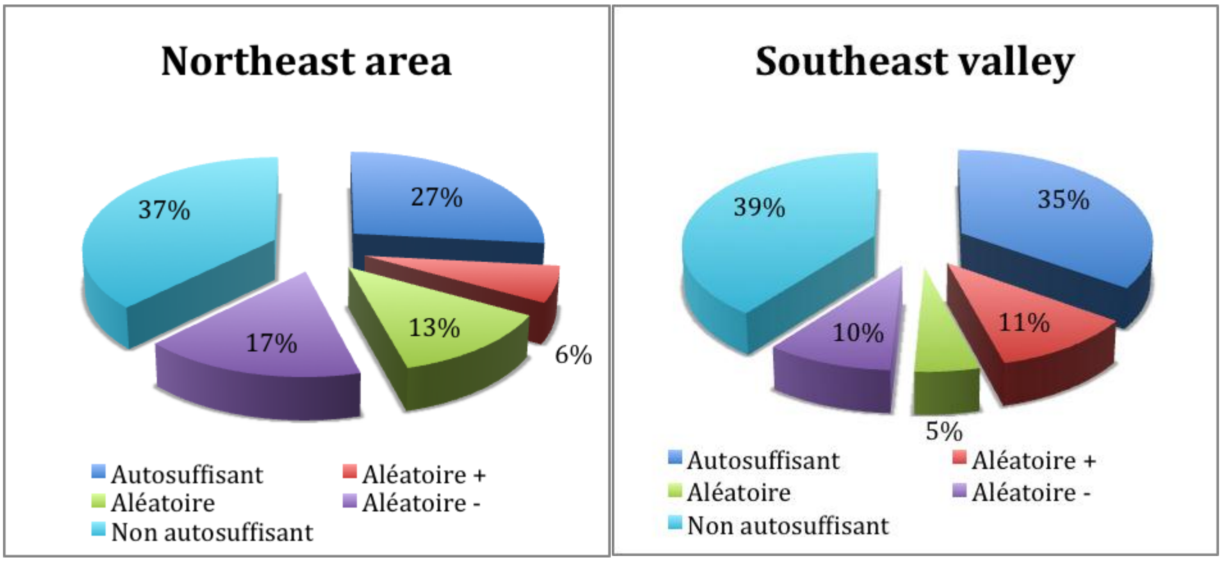

Figure 9 : Distribution of farms in the northeast and southeast according to the self-sufficiancy in rice critirion

Types A, B and C are self-sufficient in rice every year, with a minimum of 3500 kg of paddy per year, this is 27% of the supervised farms. The type D have a random rice self-sufficiency. To the southeast, farm types D11, D12, and D13 (random +) can reduce their deficit in rice by the cultivation of upland rice on their upland surfaces more important than for the D2 type. D21 type (random), D22, D231, D232 (random-) cannot compensate for their rice deficit in bad years, they are not self-sufficient. In the northeast types D11, D12, D13 (random +), D21, D22, D231 (random), are not self-sufficient in bad years, but can reduce the risk through production of upland surfaces more important than the type D232 (random-), which is rarely self-sufficient. In both zones random + types tend to be self-sufficient in years when rainfall is sufficient and well distributed; through their upland surfaces between 4 and 8.5 ha. They tend to get closer to the type C. The random - types have less than 4 ha of upland surfaces. They are rarely self-sufficient and tend to type E. Farms of type E and F are never self-sufficient in rice. These farms have less than one hectare of rice and less than one hectare of upland fields for the type E and less than 0.5 ha for type F.

In the northeast the proportion of non-self-sufficient in rice farm is slightly higher than in the southeast. Among the farms self-sufficient and random in rice, 60% are self-sufficient in the northeast against 70% in the southeast.

In conclusion, the farm database was, on the one hand, inadequately completed by operators, and also the basic typology of 2007 did not allow to discriminate fully farms. The surveyed sample conducted in 2007 by Durand and Nave was not balanced between the three areas of extension of the project, the majority of the sample is located in the southeast. This results in smoothing the differences between farms in the same area. In addition, three areas have very different characteristics: large irrigated areas in the southeast, large flood-recession rice in the northeast and large plateau of *tanety* on the west bank.

The analysis of the actual proportions of types of farms provides for modeling, detailed design types of farms representative of the study areas. Farms in the FSRMN then are always representative of the type revisited?

To assess the impact of CA systems on farm income is necessary to use a model. It raises the question; are the farms of the FSRMN good models? Are they truly representative of agricultural areas of study? These two issues also raise a third question; do we really know the farm areas of study?

Field surveys were used to compare the information in the "farm" database from BEST (2009/2010) with reality. Discrepancies were observed between the farm database and field surveys. Indeed, after investigation, the structure of most farms surveyed does not reflect the type specified in the database. We can then make several assumptions:

- The FRSMN database was inadequately completed
- The farms have evolved over time and have not been updated
- Farms are not representative of the type (they do not fit into any "box"). Is the typology then really representative of the entire population of farm at Alaotra lake? Is it sufficiently discriminating?
- The 2007 typology (Appendix 2) is partially out of date (built in 2007 by Durand and Nave) and requires an up to date through detailing some specific types in particular C, D and E.

The updating of FSRMN farm types shows that some farme types have evolved over time.

Table 3 : The FSRMN farms selected for this study

Zone	*Farms of FSRMN*	*Type to DB*	*Actual type*	*Evolution of the structure since 2007*
Zone NE	Randriamiarintsaina Zakamarosoa	D	**C**	Yes
	Rabemanantsoa Edmond	C	**C**	No
	Heranamanjaka	F	**C**	Yes
Zone SE	Rakotoary Ernest	D	**C**	Yes
	Rakotoarimanana Sylvain	E	**E**	No
	Randriamahasoa Jules	D	**B**	Yes

It is noted that the majority of farms in the FSRMN have evolved to a "superior" type. The majority of farms of FSRMN are types C. There is also a B and E. All farms except one are self-sufficient in rice. The most represented types on both study areas are D, C and E, the FSRMN farms can only be good models for the type C. Type E farm within the network is not an interesting case, the farmer has only one plot of 0.5 ha of PWCPF and functionning of his farm is not understandable from the information provided by the farmer. In conclusion the FSRMN farms are not really representative of the all the study areas. However, they can be good models for modeling type C. The types C will be chosen among a farm of the study area, the most interesting in terms of allocation of plots on the toposequence (diversified).
The situation of reference is not reconstructed from the words of farmers only, but will be a model based on standard rotations and non-CA technical pathways (built for each toposequence and area).

Standardized CA and non-CA technical pathways

The methodology for determining non-CA rotations and cropping patterns remains unchanged leading to standard rotations and standard crop sequences are determined by toposequence for each study area according to the surveys. Modeled CA systems are those proposed by the project and those defined by Fabre, J. from the 2010 surveys. The recommended CA practices

effectively adopted and promoted are multiples according to a wide range of situations. Farmers seem to adopt only some of these systems and modify them in part. Modelling systems actually adopted by farmers provides standard cropping systems closer to field reality than with diffused systems. CA standard technical pathways used for modeling were built by toposequence for each area by BRL for the 2007-2008 campaign; as it is the only campaign to have detailed standard technical pathways for the main crops. However, these existing standard technical pathways will not be used as is. An analysis of the raw data from the previous campaigns will help to assess changes in yields depending on the age of the CA system. This should be confirmed by the analysis of trend curves on the results of BRL (annual report on yields per crop). An analysis of the workload will be performed on this database, depending on the age of the CA system. The quantities of fertilizer are considered as stable for the modelisatoion; since 2007 the amount of fertilizer applied by farmers are below the recommendations of BRL (the amount of fertilizer applied to cover exports). The evolution of yields does not seem to be directly related to the evolution of fertilizer applied, because of the very low intensification level.
The lack of reliable actual data on non-CA systems does not allow to analyze the evolution of yield in non-CA systems or changes in the level of intensification by crop on several campaigns. We then consider the yields and crop technical pathway stable over 10 years.

Modeling of the FSRMN sample under Olympe

Modeling is done by keeping the structure of the farms: plots and type of crops on IPF and PWCPF. Indeed in this study we focus on upland plots with CA cropping systems. Rice cultivation on IPF and PWCPF are modeled using information gathered from surveys and entered into the database Olympe in 2007. We consider these systems stable over 10 years for IPF. In PWCPF yields vary every year depending on the level and repartition of rainfalls. Original crops on *tanety* and *baiboho* are replaced by standard non-CA and CA systems (standard rotations or crop sequences, standard crop technical pathway). The choice of crop sequences or rotations of non-CA and CA type is done from the information available on systems grown by the farmer in order to be the most representative of reality.
For each modelled farm we created a CA variant with standard CA technical pathway with tillage in the first year, followed by CA technical pathway in year 1 or more, with no-tillage for the folling years. Then a non-CA variant with a standard non-CA technical pathway, stable over ten years.
The farm general data (off farm, number of labor units, selfconsumption, household expenditures) remain unchanged between the types. Indeed the farms D and E for each study area are derived from a type C farm. We will keep the general data of this type C farm in order to be able to compare the cropping systems on the same farm basis. The cost of expenses (fertilizer, seeds, pesticides, labor) and the selling prices of products are similar over 10 years (real prices based from the 2007-2008 campaign).
Due to the low intensification of all non-CA systems, the climate remains the main factor limiting yields. According to climate data over the last 5 campaigns, we can assume as an hypothesis that the yields of non-CA systems vary over 10 years. However, it is assumed that the yields of CA systems evolve according to the age of the plot in CA as CA systems are less sensitive to climate (buffer effect of CA prooven by yields evolution from the projet database). It is also assumed that these systems are more resilient to climatic hazards. These assumptions will be processed in Olympe through the module hazards or “delta”. The module “production hazards” allows us to: test the robustness of technical choices in a farm, draw up prospective scenarios base on prices or production, etc.
In conclusion, the modeling of standardized farms will take into account the diversity of data in order to remain the closest to average situations.

Synthesis : Chapter II : Méthodological approach

Steps	Determine the different level of adoption of the innovation in peasant environnement	Caracterise the different farmer strategies	Assess the economic performances of innovative systems
Tools	Analysis of the survey database	Recontruction of crop rotations, determination of technical pathways, organisation of the work schedule	Modeling the FSRMN farms with the software Olympe
Research questions	What are the technical changes involved in the adoption of an innovation? What are the different levels of adoption?	For each level of adoption of the innovation which are the typical rotations, level of intensification (inputs et labour), average yields?	What economic differences are there between a traditional/conventional and innovative cropping systems?
Results	Regionalised typology of adoption of the innovation	Creation of regionalised standard rotations and technical pathways	Respond to the question; does CA allowto rise income of farmers at Alaotra lake?

The Malagasy traditional agriculture is characterized by flooded rice cultivation in lowlands. Most of the upland areas were not cultivated before colonization. Rice cultivation was effected by slash and burn of *zetra* (marsh vegetation) followed by a puddling of the soil by trampling with zebu and a hand seeding in lowland areas. Rainfed crops and tillage did not exist (the only tillage practiced was with the *angady* on upland soils for small gardening plots).
Traditional farming practices around Lake Alaotra therefore only concern flooded rice on the lakes marshes. We consider that there is currently almost no traditionnal upland farming practices. Current upland cropping practices includes many techniques introduced from the 1950 (around Imerimandrosso), later in the 1980 and more recently in the 2000 defined as conventionnal systems.

Conventionnal practices

Rice cultivation is therefore mainly irrigated originaly from colonial peremiters and lowland Sihanaka rice fields. Transplanting, already practiced by the Merina ethnic group, has been transferred after the 1930 and widely adopted in the 1960. Mechanical and animals tillage appear after 1930. The first rainfed crops are introduced in the 1950's as cash crops in the north east (groundnuts, cassava). Since the independence, intensification has been promoted in response to increasing population and land tenure pressure. Pesticides and fertilizers have been introduced around the 1960 by Somalac and in the 1980 on upland by the RD research project. The lining out, and new techniques of irrigated rice SRI (System of Rice Intensification), SRA (System of improved Rice cultivation) appear later in the 1980's. Conventional practices in the lake are characterized by surfaces of rainfed crops on uplands. Rainfed crops are plowed and sown randomly in the wake of the plow. They are mostly grown in monoculture. On the irrigated rice field conventional pratices are caracterised by intensive irrigated rice fields.

Innovative practices Erreur ! Source du renvoi introuvable.)

We will distinguish the CA practises' from ICS (Innovative Cropping Systems). The ICS were first definied by Fabre in 2010. It is the result of the adoption of part of the CA techniques, integrated with conventional cropping systems.

Table 4 : Synthesis of cropping system types

Cropping system type	Concerned toposéquence	Pratice
Traditionnal	Concerns floded rice cultivation	Slash and burn of *zetra*, hand sowing
Conventionnal	Irrigated rice in irrigated peremiters Culture de rente (groundnuts, casava) Introduction rainfed crops on *baiboho* and *tanety* (rice, maize)	SRI SRA Mecanised and animal tillage Line drilling Monocultures or pseudo-rotation Fertilisers, phytosanitary
ICS	Hybrid Systems on uplands	Partial introduction of CA pratices'

CA	Direct sowing on mulch cover, concerns rainfed crops mainly on uplands	No tillage Cover crops Agronomic Rotations

Adoption and innovations by farmers of Lake Alaotra: a wide range of practices

The analysis of the cultural practices of farmers deals only with rainfed crops. The surveys were conducted with farmers supervised by a project operator with at least one CA plot. These supervised CA plots were excluded from our sample. A total of 109 plots were surveyed and 80 technical crop pathways and rotations practiced for rainfed crops were collected. The distribution of cultivation was analyzed from the 80 plots where the crop management and rotation performed has been documented in 2011surveys. It should be noted that the practice of plowing is assessed on the 2010-2011 campaign practices contrary to the rotation and cover that they are evaluated on the last five campaigns.

This analysis focuses on the non-monitored plots plots in farms with extension plots monitored by the project. The criteria used are as follows: tillage or no tillage, rotation, pseudo-rotation or monoculture, absence or presence of mulch or produced *in situ* on the plot.

Table 5 : Discriminant criteria for the typology of behaviours toward the adoption of CA practices

1st criterion : Soil tillage	→ tillage → No tillage
2nd criterion: crop succession	→ Rotation → Pseudo rotation → No rotation
3rd criterion: soil cover	→ Dead mulch → Use of a cover crop

The result of the surveys show a wide diversity of situations as shown in the next figure.

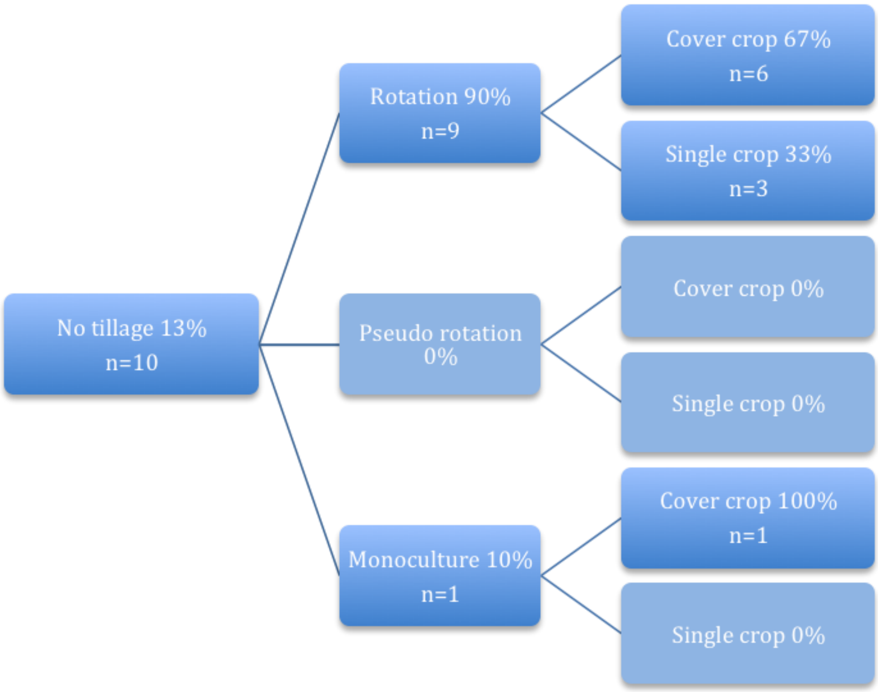

Figure 10 : Distribution and combination of cultural practices associated to no-tillage (n=10)

Of the 80 identified technical pathways 10 only are with no-tillage in 2011 among which 6 combine the three principles of the CA namely, no-tillage, permanent soil cover and rotation.
For 3 technical pathways with an agronomic rotation, the principle of permanent soil cover is not applied.
The mulch identified are mostly rice straw in the secondary-season for vegetable growing. Indeed, mulching *baiboho* in the secondary season (straw of previous upland rice crop) is a common practice at Alaotra lake (Fabre, 2010). Few cover crops were identified. These are mainly associations maize + legume (Vigna, Dolichos, cowpea), and beans + vetch. Technicians recommend the use of fertilizers to form a cover crop with sufficient biomass (150 kg NPK and 100 kg of urea). These recommendations may be an obstacle to the establishment of a permanent soil cover. CA systems with low-input (*Stylosanthes guianensis* or *Brachiaria sp.*-based systems) are also available but were not observed, they are not practiced spontaneously by farmers. One technical pathway was identified, applying the principle of no-tillage and permanent soil cover, as a maize+Dolichos//maize +Dolichos).

The possible reasons for the non-adoption of low input CA (*Stylosanthes guianensis* or *Brachiaria sp.*-based systems) systems are:

- The "learning requirements" from knowlege to practices to control the system (more complex than the covers to high-input)
- Requires years of improved fallows (*Stylosanthes guianensis* or *Brachiaria sp.)* in the rotation

However, farmers want to grow food crops each year. Indeed, the CA systems adopted by most farmers are systems based on maize+*Dolichos*//upland rice on *tanety* (40% of the CA plots surveyed by Fabre, 2010) and upland rice-seconcdary season of vegetable growing on *baiboho* (20% of the CA plots surveyed by Fabre, 2010).

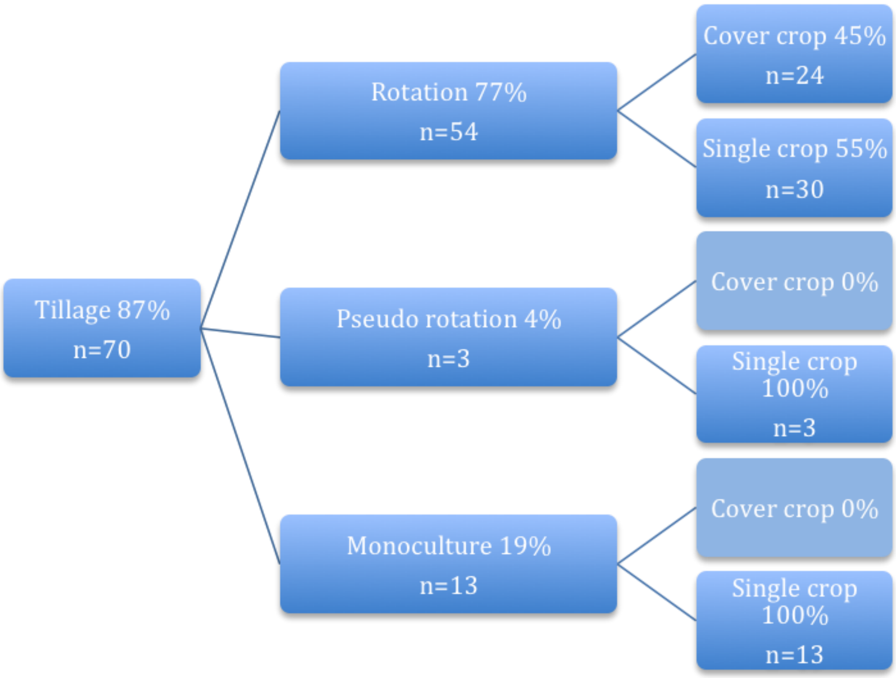

Figure 11 : Distribution and combination of cultural practices associated to tillage (n=70)

Most technical pathways with tillage have a rotation of (77% against 19% of monoculture). About half of these technical pathways combine agronomic rotations and soil cover. The covers are mostly covers of dead mulch on *baiboho*. Technical pathways with a monoculture or pseudo-rotation (two consecutive years with the same culture and a different culture for two years) are most nearly in pure culture (no cover or combination of culture).
In conclusion, farmers most often use the principle of rotation whether in tillage or no tillage. The principle of permanent soil cover is applied mostly in no-tillage, but only 50% in tillage system. Tillage is still widely practiced by farmers at the Alaotra lake. According to the farmers tilling is a necessary intervention to limit soil compaction and control weeds (ie surveys 2011). No tillage seems to be the determining limiting factor in the adoption of the entire CA « package ». In our study a combination of these practices is not related to either study area or the toposequence (except for land cover) or the mode of land tenure or type of farm.

Cropping systems adopted by farmers

None of surveyed farmers has preserved traditional farming practices on irrigated rice fields. It was observed that the majority of rice fields are managed in a conventional system. Indeed, the improved varieties recommended by the operators are widely used on irrigated rice fileds and PWCPF but also for rainfed rice. All Farmers use transplanting, tillage and fertilizer. However, some farmers south of Lake Alaotra still cultivate their rice fields in the traditional system, they clear the *zetra* by burning during the period of decline of the lake and the rice is hand sown.

The above results on upland cropping system practices showed that crop rotations is widely used on the unmonitored upland plots, whether in tillage or no tillage. The observed rotations are very diverse. They are sometimes the result of opportunistic behavior; farmers will choose to sow a crop based on seed availability and prices (seeds and sale of the product). There were also plots cultivated with groundnut, cassava and maize for at least four consecutive years

until there is a crop change. The explanation given by farmers for this change is most often “the ground was tired”, “less fertile”. In the 1950’s the main crops on *tanety* were groundnut or cassava monoculture, the change was to take place after some years for the same reasons. This type of rotation is qualified as the “pseudo-rotation”. These rotations with an opportunistic logic, are definied as conventional cropping system. In contrast, rotations with an agronomic logic promoted by the project, were also observed. They are of the cereal//legume, cereal//cereal, and cereal//tuber. These are the most observed rotations. They are definied as Innovative Cropping Systems (ICS).
The cover crop is the second principle of CA more spontaneously adopted by farmers on their unmonitored plots. According to our results, the ground covers in place are mainly dead mulch of rice straw on *baiboho* with vegetables during dry season. This technique was already used before the project started, but on very small areas. The project encourged the upscaling of this technique. Cover crops, or associated cropping, are rarely performed. Operators promote them as part of the extension of CA and aiming at the permanent soil cover. However, we must distinguish the cover crop from the association of maize+food crop. Indeed, maize in another food crop is a common practice in Lake Alaotra (maize + beans, maize + cassava, maize + upland rice etc.). Farm workers at harvest consume maize. It is to be planted within the culture, or on the edge of the field. Farmers do not always mention this practice. The ground cover is all qualified as an innovative cropping system. Based on these results, it is possible to define from the different combinations of practices what are the systems (conventional, ICS, CA) practiced by most farmers.

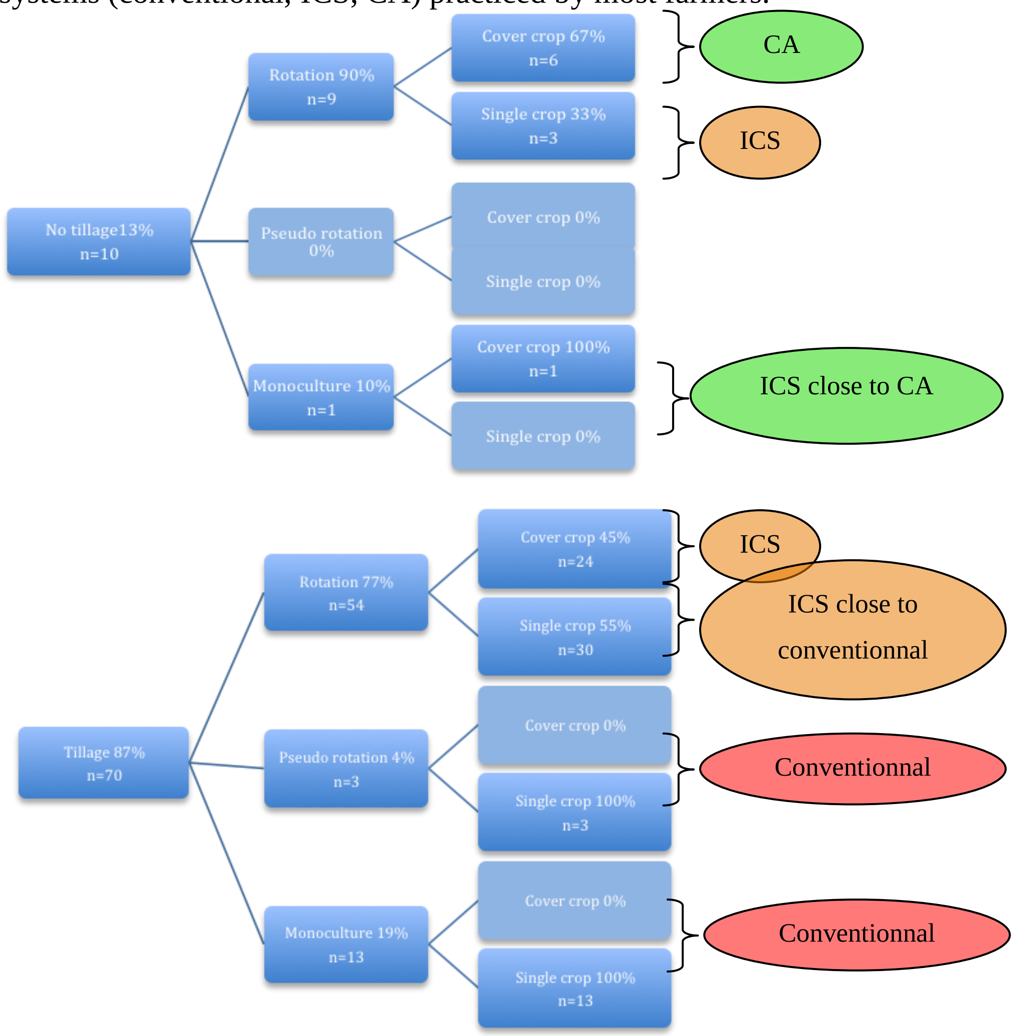

Figure 12 : Cropping systems definied according to the combinaisons of practices

Technical pathways combining the three principles of CA simultaneously are defined as CA systems. Technical pathways combining the practices of tillage, monoculture, and the pure culture are defined as conventional systems. Other Technical pathways are the result of a variety of combinations between the two previous systems; these systems are defined as ICS.
These results show that beside monitored plots, CA techniques spread spontaneously on the farm holdings on a low range but the sample is only project farmers. However, the majority of project farmers adopt voluntarily a part of the CA technical package, rarely entirely.

Typology of the adoption of CA practices

The above results show that the majority of surveyed plots are carried out spontaneously in hybrid systems, the ICS. Conventional cropping systems have been profoundly altered by the arrival of the development projects in Lake Aloatra. However, farmers do not spontaneously adopt entirely the innovative techniques on their unmonitored plots.

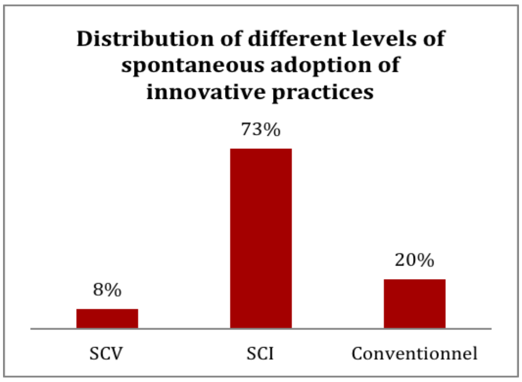

Figure 13: Ratios of plots based on the level of adoption of CA practices (n=80)

The typology based on the levels of adoption of CA practices is not discriminating. Indeed, the criteria for adoption of the three principles of the CA package cannot discriminate the sample investigated. It will not be used in the remainder of the study. To refine this typology, it would be interesting to use more technical criteria associated with each innovation mode drilling (in line, randomly, hole), fertilization (fertilizer type, amount used), use of phytosanitary products (seed treatment, chemical weed control or *angady*) etc.

In conclusion, in the investigated sample there is a strong mix of cultural practices borrowed from the successive intrduction of techniques including CA in the region of Alaotra. This is observed both at plot level but also at farm level, The constraints that limit the scale of extension of the techniques are often technical and financial (problems of labor, insufficient cash flow, low technical knowledge etc.). The technical constraints depend on the situation, and their are as many constraints as situations. The field surveys were not detailed enough to address the complexity of technical contraints. The economic factor is often a significant change in the adoption and innovation processes. For example, the rising prices of herbicides have led to a return to manual control of weeds in CA system instead of chemical herbicides.
Ultimately, the vast majority of current cropping systems are ICS, farmers are appropriating the innovations and are then mixing them according to their own constraints. Very few farmers spontaneously adopt the entire CA package whether on one or all of their plots. Only half of the FSRMN farms (farms left out of this sample) apply the entire CA package on their plots.

Standard rotations

From the surveys the rotations were determined for each toposequence by study area. Project experts and researchers validated these results. For each zone, and each toposequence were firstly identified the crops most represented by tables, constructed from pivot tables. These numbers represent the number of times a crop appears in one year. Ratio (%) was calculated to indicate the proportion of one crop over the entire crops identified by year. Detailed quantitative analysis of crop sequences in the database 2011 survey helped to define the standard rotations. The table below shows the standard rotations or crop sequence established from different rotations observed during surveys in 2011.

Table 6: Synthesis of disseminated CA systems and standard innovative systems per toposequence and per year

Toposequence	CA practices recommed by the project	Farmer ICS (Fabre,2010)	Spontaneous ICS (Enquêtes 2011)	Conventionnal (enquêtes 2011)
Tanety	Maize+leg.//upland rice (VSE, ZNE) Maize+leg.//upland rice // Maize+leg. //Groundnut (VSE, ZNE)	Maize + leg // maize + leg (ZNE) Maize+leg.//upland rice // Groundnut (VSE, ZNE)	Maize//maize// Groundnut (ZNE) Maize//maize// Groundnut //cassava (VSE)	Groundnut Cassava Maize Beans Tobacco (ZNE)
Tanety BP	Maize+leg.//upland rice // Maize+leg. //groundnut (VSE, ZNE) Maize+leg.// upland rice (VSE, ZNE)	Maize + leg // upland rice // groundnut (VSE, ZNE)	Upland rice//maize// groundnut (ZNE) groundnut//cassava//beans (VSE)	
Baiboho	Upland rice+vetch – veg growing on mulch in dry season (VSE, ZNE)		Upland rice – veg growing on mulch in dry season (VSE, ZNE)	Upland rice – dry season veg. (VSE, ZNE)

We observe from the table above that the intra-annual rotation on *baiboho* does not really change from the conventional systems, spontaneous ICS and disseminated CA. The innovative system provides dead mulch in the dry season compared to the conventional system. The CA system provides extra green manure during the main season on upland rice: vetch. On *tanety* in the conventional system can be found monocultures or pseudo-rotations, groundnut, cassava, maize, beans or tobacco marginally in the northeast. In spontaneous ICS in both study areas, the evolution of the system results in the introduction of one or two crops in the rotation after two consecutive years of maize. Maize is favored in the rotation with ground leguminous and/or tubers. Upland rice is absent from the rotation. The standard farmer ICS system in the northeast, is maize monoculture associated with legumes. For both areas, there is an integration of upland rice in the rotation between maize and groundnuts. CA systems separate into two distinct CA systems from the three-year rotation maize//upland rice//groundnut. On the one hand the cultivation of groundnuts is removed from the three-year rotation and secondly maize + legume is part of the rotation between rice and groundnuts.
On low slope, no conventional system could be identified. In spontaneous ICS, there is in the northeast a standard three-year rotation with upland rice followed by a cereal and a ground legume. In the southeast, upland rice is absent from the rotation; groundnut is placed in the

head rotation and followed by a ground and climbing legume. Farmers ICS in the rotation is the same as spontaneous ICS in the northeast but organized differently. Maize is placed at the beginning of rotation associated with cover crop and followed by maize. The reversal in position between the maize and rice between the two systems is dictated by the principle of soil coverage in CA for the next crop. This system is not considered as CA since this principle is not observed between the cultivation of upland rice and groundnuts (there is no cover). This rotation is changed to CA system by introducing a maize + legume crops between rice and groundnut to the principle of permanent soil cover. There is also a second standard CA rotation system where the groundnut was removed from the rotation like on *tanety*.
In the southeast, conventional crop sequences as we have defined it above were not observed. One can speculate that this is related to the fact that this area is the subject of an earlier diffusion than the northeast. This system will therefore be modeled in the area ZNE. To the northeast, according to survey results in 2011 (Appendix 8), the most represented conventional crop succession is maize//maize.

- **Impact on the methodology**

As part of the counterfactual approach, the reference for comparison between different farming systems corresponds to CA systems disseminated by the BVLac project. The comparison between project CA systems and conventional systems and ICS refers to spontaneous counterfactual approach (reminder, the cultural practices of farmers before adopting CA systems). However, the comparison of CA with farmers ICS; or spontaneous ICS with farmers ICS is not strictly speaking a counterfactual approach in the first case since it is an appropriation by the farmers of the CA technique and in the second case parallel innovations from two different systems, conventional and CA. Farmers ICS identified by Fabre (2010) will not be modeled. For the study we have used ICS said to be close to conventional systems. This shows the strong innovative capacity of local farmers, especially in our sample with 86% followed by the project on at least one plot. This also shows that the technology percolates through into cropping systems but not the CA technique as a whole.

Table 7: Synthesis of cropping systems to be compared by modelling

Reference system	Système à comparer
CA recommended by the project	Conventionnal (ZNE)
CA recommended by the project	Spontaneous ICS (Survey 2011)
CA recommended by the project	Farmer ICS (Fabre, 2010)
Farmer ICS (Fabre, 2010)	Spontaneous ICS (Survey 2011)

Standard crop management

The standard crop technical pathway constructed for this study are based standards technical pathway built by Domas, Penot, BRL, AVSF for the 2007-2008 campaign. All crop management collected during the monitoring framed plots, are compiled in an Excel database by BRL. The technical pathways are established by regrouping the collected technical pathways in homogeneous yield classes. For each class averages are performed on yields and expenses.

Standard innovative technical pathways

The innovative technical pathways are built from standard technical pathway BRL 2007-2008 in year 0 of CA with plowing. Data on cover crop are removed (seeds, gaucho, labour time). When data are available, these technical pathway are detailed in toposequence and area. From the analysis of climate data we assume that a year as 2010-2011 (low rainfalls) yields on *tanety* dropped by 50%. This assumption is not verifiable from the data available, but was validated by project experts and the 2011 surveys. The 2011 survey results show low yields in rainfed rice on uplands, 874 kg / ha in average, but the sample is 9 plots. The operator's database 2010-2011 is not available in detail. It was not possible either to justify the hazards of yield with the data BRL; year 0yields (with tillage) over the last five campaigns. Indeed, in Y0 are included the plots that have been in a CA for one or more consecutive years and the farmer plowed the year of the survey. The crop yield installed on resumption of tillage is generally high. The performance of these plots takes the average of yields A0on the rise and eliminates changes in climate-related yields. We can then conclude about the evolution of yields in innovative system with the BRL data.

Climatic variations over the past five campaigns indicate the following sequence: 1 good year, 2 average years, 1 very good year and 1 very bad year. We consider that this sequence is repeated twice over 10 years. A hazard on the yields of rice on PWCPF is built according to this sequence. It is assumed that a good year the yield is of 100% (2700 kg/ha), one average year of 56% (1500 kg/ha), a very good year of 129% (3500 kg/ha) and very poor years from 0% (little or no production). No data on the evolution of yields in PWCPF is currently available in order to check this hazard. This hazard has been established by an expert (Domas, Penot, 2011) by integrating the available databases.

Standard CA crop management

The standard CA crop technical pathways are detailed in appendix 9. They are based on standard technical pathways in 2007/2008 built by Domas, Penot, BRL and AVSF.

Crop technical pathways in year 0 of CA are those established by BRL. The standard yield is the same as in the innovative system in order to compare the systems on the same basis of initial yield. These systems are modeled in the implementation of the CA system in year 0, with plowing.

The crop technical pathways (CTP) in year 1 and more of CA are based on standards in year 0 of CA. CTP in the year n+1 exist but they were created by yiled classes of all n+1 year. For the sake of consistency with higher yields calculated on the basis of the age of CA system, we have kept in year 0 CA CTP , eliminating tillage time and by adjusting the labour time. Yields evolve according to the age of the plot. The analysis of changes in yields (Appendix 10) is possible only for crops of upland rice, maize and groundnuts; data about other cultures are not available.

From the available BRL databases, for each campaign there was a very gradual increase in yields in rainfed rice and maize according to the age of the CA system. For the cultivation of groundnut yields appear unaffected. The average increase in yield per year was calculated for the upland rice and maize on the basis of 4 to 5 years seniority of the CA system. The increase in yields was assessed by study area for all toposequences combined. The available data are not numerous enough to perform an analysis for each toposequence.

The percentages of yield increase per year for maize and upland rice are modeled over 10 years with a hazards.

Table 8: Annual pourcentages of yield increase per zone for upland rice and maize, all toposequences merged (source: plot database analysis, Appendix 10)

	VSE	ZNE
Upland rice	3 %	5%
Maize	4 %	3%

It was not possible to identify conventional crop sequences in the strict sense in the southeast. So there is no standard techniques conventional route for the area VSE. We therefore used the ITK SCI close to conventional techniques with plowing. To the northeast routes technical standards are the same as the innovative crop management standards except for the cropping system on which baiboho time to mulch is removed. In the absence of available data, we consider the conventional system yields stable over 10 years on selected crop sequences.

Modelised farms

Modelised farms are built from each farm type C selected in the FSRMN. Surveys of farms of type C have allowed to reconstruct the actual rotation of the farm from 2007 to 2011. This information helps establish a logical operation at the cropping system level, and build a model. From the real rotation is determined primarily by a rotation standard CA system over 10 years. Rotations or crop sequences by toposequence are chosen based on the actual rotation of the farm and its logic. The rotations in conventional and innovative system are built over 10 years from the correspondence between the different systems (Table 6). General farm information (number of zebu-off farm, number of working units…) are also used to build the model. Farms of types D and E are constructed according to the criteria of the typology (Table 2) by modifying the model farm of the FSRMN (rice field surfaces, use of external labour...). General farm information are kept between farm types modeled.

Farms of the northeast

Farms of the FSRMN modelised of type C

The modelised farm of type C in the northeast zone is located in the *fokontany* of Imerimandroso. The general farm information of the farm are presented in appendix 11.

The cultivated plots of the farm are distributed as follows:

Table 9: Plots of the type C farm in the northeast area, in hectare

	IPF	PWCPF	*Baiboho*	*TanetyBP*	*Tanety*	Total
Land tenure status	*Property*	*Property*	*Property*	*Property*	*Property*	*Property*
Nomber of hectares	1,50	0,80	0,10	0,39	0,08	2,87
Nomber of plots	3	1	1	3	1	9

- **Plots in standard CA system over 10 years**

From the actual crop rotation since 2007(appendicx 11), we determine a projected rotation of 10 years in standard CA system. On the PWCPF plot, each year the farmer grows upland rice in the season followed by secondary season rice (recession). This non-CA system is conserved over 10 years. It is the same for irrigated rice.

On the *baiboho* plot the farmer has a system Upland rice - DS gardening. The standard CA system used for modeling is Upland rice - DS bean + vetch. On the lower slope *tanety* the farmer has a Maize+legume // upland rice // groundunts or cassava. On the *tanety* plot the farmer practice monoculture maize+legume // maize + legume. The standard CA system determined the bottom of slope is the same as *tanety*. This is a Maize + legume // Upland rice // Maize + legume // groundnut.
On low-slope CA system is not modeled as a single system of 0.39 ha but three systems according to three plots. The goal is to preserve the cultural strategy implemented by the farmer on his farm. Indeed, the real rotation of the operation shows that crops of upland rice and corn are present every year in rotation on the different plots, the priority of farmers at the lake is to produce upland rice.

Table 10 : Crop rotations in standard CA system over 10 years for the farm type C in the area ZNE

	0	1	2	3	4	5	6	7	8	9	10
Irrigated rice_IPF	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50
Rainfed rice_PWCPF	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Ressesion rice PWCPF(DS)	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Maize + Dolichos_TBP	0,15		0,10	0,14	0,15		0,10	0,14	0,15		0,10
Upland rice_TBP	0,14	0,15		0,10	0,14	0,15		0,10	0,14	0,15	
Maize + Dolichos _TBP	0,10	0,14	0,15		0,10	0,14	0,15		0,10	0,14	0,15
Groundnut_TBP		0,10	0,14	0,15		0,10	0,14	0,15		0,10	0,14
Maize + Dolichos _T		0,08				0,08				0,08	
Upland Rice_T			0,08				0,08				0,08
Maize + Dolichos _T				0,08				0,08			
Groundnut_T	0,08				0,08				0,08		
Upland rice + vetch_B	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Beans on mulch _B (DS)	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10

- **Crop rotaion in standard innovative system over 10 years**

Systems on IPF and PWCPF are conducted in non-CA system and remain unchanged. The CA system on *baiboho* is replaced by the innovative system Upland rice - bean on mulch DS. CA system on lower slope is replaced by the innovative Upland rice // maize // groundnut. On *tanety* the CA system is replaced by the innovative system maize//maize//groundnut.

Tableau 11: Crop rotations in standard innovative system over 10 years for the farm type C in the area ZNE

	0	1	2	3	4	5	6	7	8	9	10
Irrigated rice_IPF	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50
Rainfed rice_PWCPF	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Ressesion rice PWCPF(DS)	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Upland rice_TBP	0,15	0,10	0,14	0,15	0,10	0,14	0,15	0,10	0,14	0,15	0,10
Maize_TBP	0,14	0,15	0,10	0,14	0,15	0,10	0,14	0,15	0,10	0,14	0,15
Groundnut_TBP	0,10	0,14	0,15	0,10	0,14	0,15	0,10	0,14	0,15	0,10	0,14
Maize _T		0,08			0,08			0,08			0,08
Maize_T			0,08			0,08			0,08		
Groundnut_T	0,08			0,08			0,08			0,08	
Upland rice_B	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Beans on mulch_B (DS)	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10

- **Cropping system in the conventional standard of 10 years**

Systems on IPF and PWCPF are unchanged. The innovative system on *baiboho* is replaced by the conventional system Upland rice - bean DS. The innovative system of low slope is replaced by the conventional system maize//maize. On *tanety* of the innovative system is replaced by the conventional system maize//maize.

Table 12: Crop rotations in standard conventionnal system over 10 years for the farm type C in the area ZNE

	0	1	2	3	4	5	6	7	8	9	10
Irrigated rice_IPF	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50	1,50
Upland rice_PWCPF	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Ressession rice_PWCPF (DS)	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Maïs_TBP	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39
Maïs _T	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
Riz pluvial_B	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Haricot_B (DS)	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10

- **General information of the farm**

The farm has 1.80 LU (labor unit) and 5.5 people to feed. Fishing is a secondary income on the farm at a rate of 400 kAr/year. Household expenses (school fees, clothing costs, home maintenance, gifts...) are 960 000 Ar per year. Self consumption, purchase of agricultural products and food animals represent 965 kAr/year. External labor is used on irrigated rice fields at 100 man.day/year.

Farm modelised type D

The farm of type D is according to the typology, selfsufficiency in rice is random. We chose to eliminate the irrigated rice fields of and keep the PWCPF plot so that the selfsuffuciency of the farm is consistent with the topology. However, the surface of this plot was increased by 0.20 ha in order for the farm to produce enough paddy rice to be selfsufficient in good years. The surfaces of upland remain unchanged.

Table 13: Plots of the type D farm in the northeast area, in hectare

	IPF	**PWCPF**	***Baiboho***	***TanetyBP***	***Tanety***	**Total**
Land tenure status	-	*Property*	*Property*	*Property*	*Property*	*Property*
Nomber of hectares	0	1	0,10	0,39	0,08	1,57
Nomber of plots	0	1	1	3	1	9

Crop rotations and cropping systems in CA and innovative systems remain unchanged.

Modelised Farm type E

E-type farms are not self-sufficient in rice according to the typology. The surface of the PWCPF plot was reduced to 0.50 ha. The technical pathway on PWCPF does not employ external labor as opposed to type D. The upland areas remain unchanged. Crop rotations and cropping systems in innovative and CA are unchanged.

Table14: Plots of the type E farm in the northeast area, in hectare

	IPF	PWCPF	*Baiboho*	*TanetyBP*	*Tanety*	Total
Land tenure status	-	*Property*	*Property*	*Property*	*Property*	*Property*
Nomber of hectares	0	0,5	0,10	0,39	0,08	1,07
Nomber of plots	0	1	1	3	1	9

Farms of the southeast

Modelised farm type C

The modelised farm type C in the valley of southeast is in the *fokontany* of Ambohipasika. Global information of the farming system are presented in Appendix 11.
The cultivated plots of the farm consists of the following:

Table 15: Plots of the type C farm in the northeast area, in hectare

	IPF	*Baiboho*		Total	
Land tenure status	*Property*	*Property*	*Rented*	*Property*	*Rented*
Nomber of hectares	1,50	0,20	0,10	1,70	0,1
Nomber of plots	1	2	1	3	1

➢ **Crop rotation in standard CA system over 10 years**

From the real rotation of the farm since 2007 (Appendix 11), we determine a projected rotation of 10 years in standard CA system. On the irrigated rice plot, the farmer grows rice every year during the season. This system is kept in non-CA over 10 years. On *baiboho* (0.17) the farmer has a system, upland rice - bean or tomato DS. The standard CA system applied is Upland rice+vetch - Bean on mulch DS. On *baiboho* (0.08 ha and 0.10 ha), the system is Upland rice - bean or tomato//Maize+ Dolichos in rotation on the two plots. The standard CA system applied is Maize+legume // Upland rice.

Table 16 : Crop rotations in standard CA system over 10 years for the farm type C in the area VSE

	0	1	2	3	4	5	6	7	8	9	10
Irrigated rice	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Maize+dolichos B	0,08	0,10	0,08	0,10	0,08	0,10	0,08	0,10	0,08	0,10	0,08
Upland rice B	0,10	0,08	0,10	0,08	0,10	0,08	0,10	0,08	0,10	0,08	0,10
Upland rice_B	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17
Beans + vetch_B (DS)	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17

➢ **Crop rotation in standard innovative system over 10 years**

The cropping system on IPF is conducted in non-CA system, it stays unchanged. CA systems on *baiboho* are replaced by innovative systems Upland rice - beans DS and Upland rice//maize//groundnut.

Table 17: Crop rotations in standard innovative system over 10 years for the farm type C in the area VSE

	0	1	2	3	4	5	6	7	8	9	10
Irrigated rice	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Upland riceB	0,08		0,10	0,08		0,10	0,08		0,10	0,08	
Maize B	0,10	0,08		0,10	0,08		0,10	0,08		0,10	0,08
Groundnut B		0,10	0,08		0,10	0,08		0,10	0,08		0,10
Upland rice_B	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17
Beans B (DS)	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17

- **General information of the farm**

The farm has 4.80 UL and 6 people to feed. Household expenses (school fees, clothing costs, home maintenance...) are 560 kAr/year, selfconsumption 1 178 kAr/year. External labor is employed in the irrigated rice field 100 man.day/year

Type D modelised farm

The type D farm is rarely selfsufficiency in rice according to the typology. We chose to remove the irrigated rice plot and replace it with a plot of 1.5 ha of PWCPF rice plot. The upland surfaces were kept.

Table 18 : : Plots of the type D farm in the southeast area, in hectare

	PWCPF	***Baiboho***		**Total**	
Land tenure status	*Property*	*Property*	*Rented*	*Property*	*Rented*
Nomber of hectares	1,5	0,20	0,10	1,2	0,1
Nomber of plots	1	2	1	3	1

External labor is employed on PWCPF rice fields at the rate of 20 m.d/year. Crop rotations and cropping systems in innovative and CA are unchanged.

Type E modelised farm

E-type farms are not self-sufficient in rice according to the typology. The surface of the PWCPF plot was reduced to 0.90 ha. The technical pathway on PWCPF rice plot does not include external labor as opposed to type D. The upland surfaces are unchanged. Crop rotations and cropping systems in innovative and CA are unchanged.

Table 19: Plots of the type E farm in the southeast area, in hectare

	PWCPF	***Baiboho***		**Total**	
Land tenure status	*Property*	*Property*	*Rented*	*Property*	*Property*
Nomber of hectares	0,9	0,20	0,10	1,7	0,1
Nomber of plots	1	2	1	3	1

Off-farm income of the farm is as farm worker jobs outside the farm. This income generates a contribution of 400 kAr/year.

Technical and economic analysis: comparing the performance of cropping systems CA, ICS and conventional

The graphs below are from the outputs of the software Olympe. They show the evolution of some economic indicators; operating income, cash balances and cumulated cash balance over 10 years (Appendix 6). The red curve corresponds to the farming systems modeled in CA, with its blue variant in spontaneous ICS, and green to the variant in conventional systems. The results of these economic indicators are presented in Appendix 12 as well as gross margin, total net income and net margin. Intensification ratios and return to capital are also presented at farm scale by type and by zone. Gross margin and return to labour at the field level are presented in a second time for the main cropping systems modeled.
These economic indicators help to assess the viability of a farm. This results of the, economic, social, environmental and institutional sustainability at farm but also regional level (Bar, 2011). Economic sustainability concerns the maintenance or improvement of living standards, linked to income levels. Maintaining a certain level of expenditure required to maintain in the long term income that supports expense. Economic sustainability occurs when a minimum level of economic well being can be maintained in the long term (Penot 2006, quoted by Bar, 2011).

Farms in the Southeast Valley

Comparison of farm type C

Farm net agricultural income is calculated (= the sum of net margins before selfconsumption with all production sold in order to assess economic efficiency of each farm) and is the total value of productions comparing the results of several farms in the same conditions (before consumption). The income (Figure 16) follows the same trend as gross margin (Appendix 12, Table 1). Indeed, the structure costs are low and stable over ten years (245 kar/year of permanent labor) and financial costs are null (no credits).
Type C farm in this area has 1.5 ha of irrigated rice fields, which provides a level of income considered locally to be high every year in both CA and ICS systems. However, we note that in the ICS system the farm income varies with the rotation upland areas: gross margins of upland rice and maize are different at equal yield level because maize is sold cheaper than rice (400 Ar/kg against 550 Ar/kg). These variations are relative, however, because the maximum variation of income is only 1.5%. In CA system the income improves every year. Indeed, the yields increase with the seniority of the system of 3% per year for rice and 4% for maize in the southeast (

Table 8). Operational costs decrease the first year (stop plowing) and then remain stable until year 10 (modeling assumption). Sale prices are considered stable over 10 years. Changes related to crop rotation system exist as in ICS but are smoothed by increasing yields on upland surfaces. However, after ten years of CA system the overall improvement of income is only 4% in total compared to year 0 (Figure 16). In year 10, the income of CA system is 5% higher than the ICS. For this farm the income is equal to the net agricultural income because there is no off-farm.

We confirmed the hypothesis that CA systems offer greater regularity of production and therefore income directly related to the gradual increase in yields depending on the seniority system.

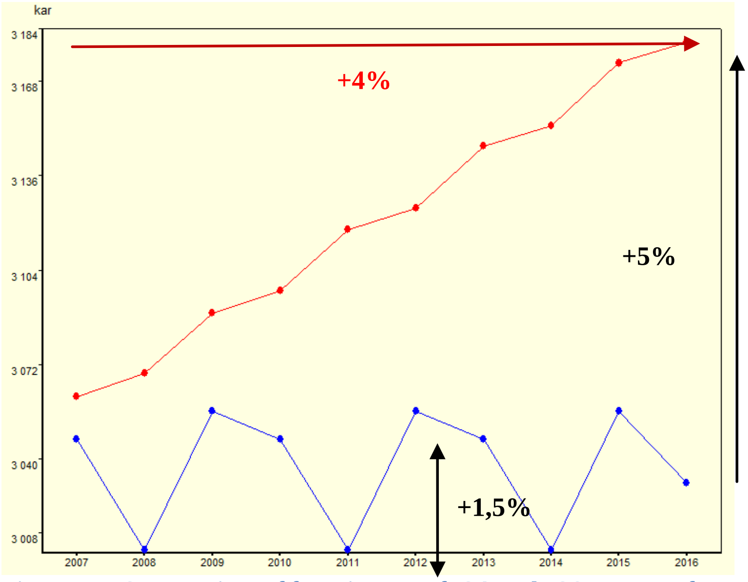

Figure 14 : Comparaison of farm income of CA and ICS systems of type C farm for VSE area

The cash balance (Figure 17) 5% drop in year 4 compared to year 3 in ICS. This is related to operational costs of setting up the crop of groundnut, more important than maize or upland rice, combined with the maize harvest less profitable than upland rice. In year 5, upland rice is absent from the rotation. Cash balance dives (-8% compared year 3) despite a harvest of groundnut and maize. Indeed, the margin provided by these two cultures did not improve the cash balance. On the other hand, operational costs related to the development of groundnut depresses even more the cash balance (groundnut is present two successive years, 5 and 6 in the rotaion). In year 6, the cash balance increases again due to the harvest of two profitable crops: upland rice and groundnut. In the CA system cash balance drop 4% in year 4 compared to year 3 because the rotation on upland surfaces is made of half of upland rice and half maize (the previous year the ratio was 2/3 rice 1/3 maize). From year 5 variations related to crop rotation are offset by the gradual increase in yields in rice and maize each year. It should be noted that the absence of groundnut in the crop rotation in CA system prevents the "yoyo" effect observed in the ICS. However no variation in the cash balance is greater than 10% between years, both in ICS and CA system.

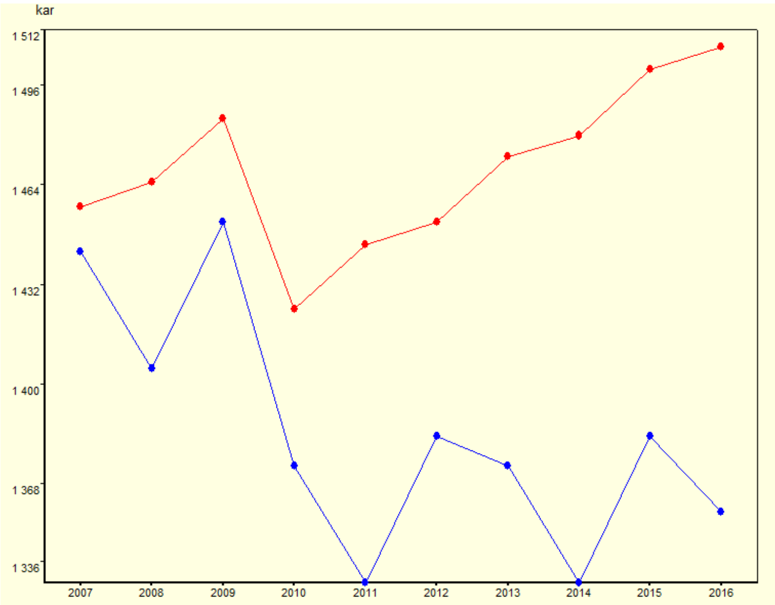

Figure 15 : Comparison of the farm cash balance in ICS and CA system for the type C farm in the VSE area

The accumulated cach balance shows that after 10 years of CA, the improvement of the system is only 6% (Figure 18) compared to the ICS. This improvement is directly related to increasing yields of upland rice and maize in CA system on upland surfaces, since the yields of IPF are equivalent in both systems.

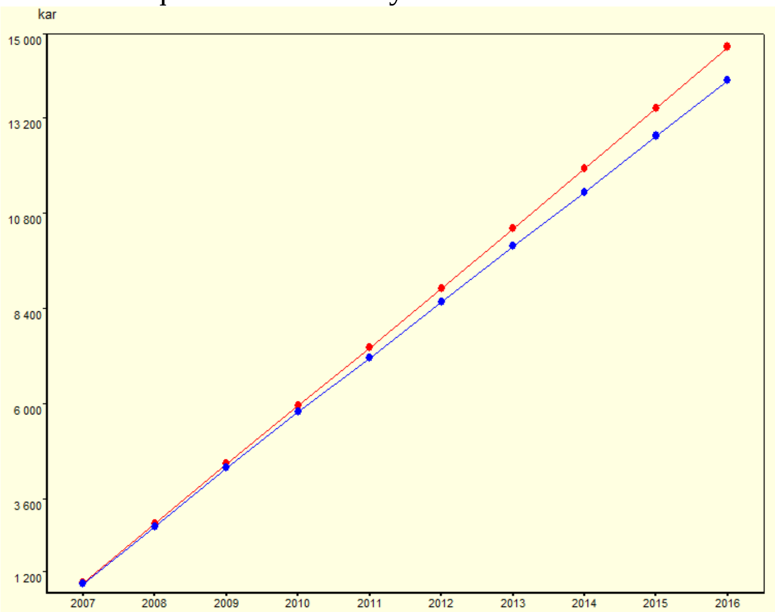

Figure 16: Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the VSE area

In conclusion, the difference in cumulated cash balance of 10 years between the ICS and CA systems is not significant (<15% view of the uncertainty of modeling in general). In addition, the CA system rotation on upland soil is biennial: Rice//maize while in ICS the three-year rotation is rice//maize//groundnut. Diversification of production can be an asset especially when the groundnut crop is better value than rice or maize, in case of health or climate accident, or in case of a hazard on the prices of agricultural products. Indeed it is technically easier to produces 1000kg of groundnut sold at 1,5 kAr/kg than 3000kg of upland rice sold at 0,55k Ar/kg. The farm type C has the required cash (thanks to income generated by irrigated rice fields) to investment in CA system (additional cost of purchasing seeds of the plant cover, time of sowing, herbicide costs etc.). on upland surfaces, but has no real interest to adopt the CA techniques.

Performance of cropping system practises at farm scale

The table below presents the intensification ratio (= operational costs / gross margin. Expressed in %, it is a good indicator of the systems intensification) and the return to capital (= net margin / operational costs. It is a good indicator of risk).

Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB										
M1301_Modèle SCV_VSE_11	14	14	14	14	14	13	13	13	13	13
M1301_Modèle Innov_VSE_1· 11	13	14	14	13	14	14	13	14	14	14
Retour sur investissement										
M1301_Modèle SCV_VSE_11	674	675	680	681	687	687	693	693	699	700
M1301_Modèle Innov_VSE_1· 11	704	675	676	704	675	676	704	675	676	678

Figure 17 : Results of intensification ratio and return to capital over 10 years for the typ C farm in the VSE area

Intensification ratio stagnates around 13% for both systems, which is very low and actually shows a very limited amount of inputs (mainly fertilizers and herbicides) in the operational costs. Most of the operational cost is indeed related to external labour. In both cases, risk-taking for the conduct of the system is low (<50%). Indeed, when the operational costs needed to produce reach 50% of the gross margin, it is risky to produce. If the harvest is divided by 2, the system wil have returned nothing, revenues will be offset by the costs. If the harvest is less than 50% of the normal harvest, then the system will make the farmer lose money. Return to capital reaches 700% in CA system and 678% in ICS in year 10. The high value of this ratio is due to very low costs in proportion to the gross margin for different cropping systems (<500 kAr/year or about 16% of the gross margin per year) on both systems.
In conclusion, the type C farm in the VSE area is economically viable with high and regular income generated by irrigated rice fields. The introduction of CA systems in the farm has little effect on the income.

Comparison of type D farms

Type D farm has 1.5 ha of PWCPF payddy fields conducted in CA system whose output is considered stable (relatively rare situation in the region with an estimated maximum of 10% of the PWCPF plots in CA supervised by the project). However, in ICS by applying a hazard on rice yield in PWCthe following sequence: a good year 2200 kg/ha, an average year 1300 kg/ha, a very good year 3000 kg/ha, an average year 1300 kg/ha and a disastrous year 0 kg/ha. There was a slight increase of 3% of the result in CA (Figure 20) between year 0 and year 1, which reflects the cessation of tillage on PWCPF (plowing is provided by external labor) combined with declining revenues due to the crop rotation (less rice and maize). Between year 1 and 10 in the CA system improved result is only 6% overall. This improvement is directly related to increasing yields of upland rice and maize in CA on upland surfaces, since the yield of CA system on PWCPF is considered stable. This increase is not significant over 10 years.
The ICS system undergoes large variations of yields on PWCPF, which explains the variability of income. Then noted that difference farm income between the two systems is mainly due to the variability of yields on PWCPF in ICS.

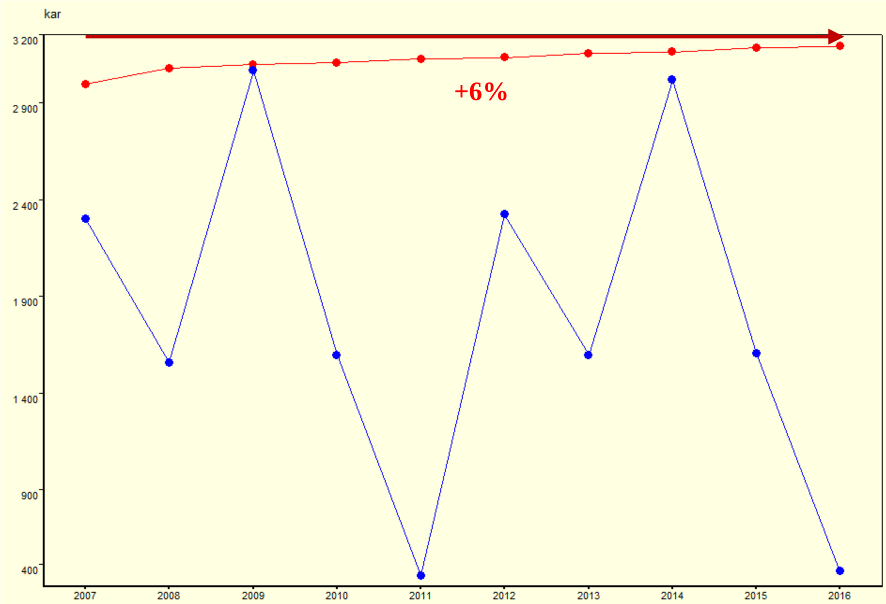

Figure 18: Comparaison of farm income of CA and ICS systems of type D farm for VSE area

In years when the yield is null on PWCPF, the farmer cannot meet his rice needs, and will have to buy which will reduce the cash balance (Figure 21). In average years his rice needs are sufficiently covered, but the sale of other products is not enough to cover the costs of setting up the crops for the following season. The farmer has a cash flow problem, despite an off-farm income of 400 kar/year.

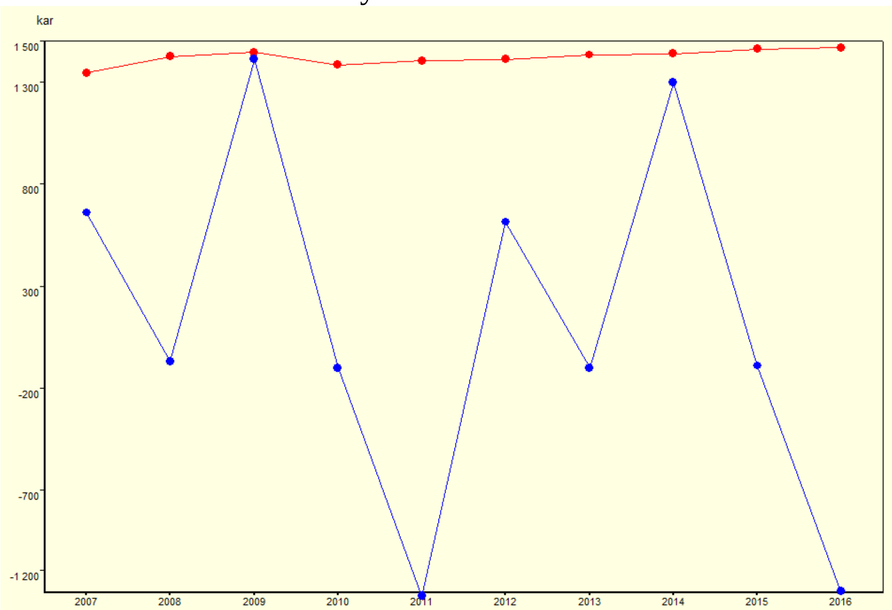

Figure 19 : Comparison of the farm cash balance in ICS and CA system for the type D farm in the VSE area

The difference in cumulated cash balance (Figure 22) between ICS and CA systems is obvious after ten years. The cumulated cash balance in the CA system is greater by 92%. However this difference is mainly due to the assumption of stable yields on PWCPF in CA and variability of these in ICS. In view of the very significant result can then ask why are PWCPF so rarely conducted in CA system. One can then hypothesize that the CA system is not as resilient to climatic hazards in reality.

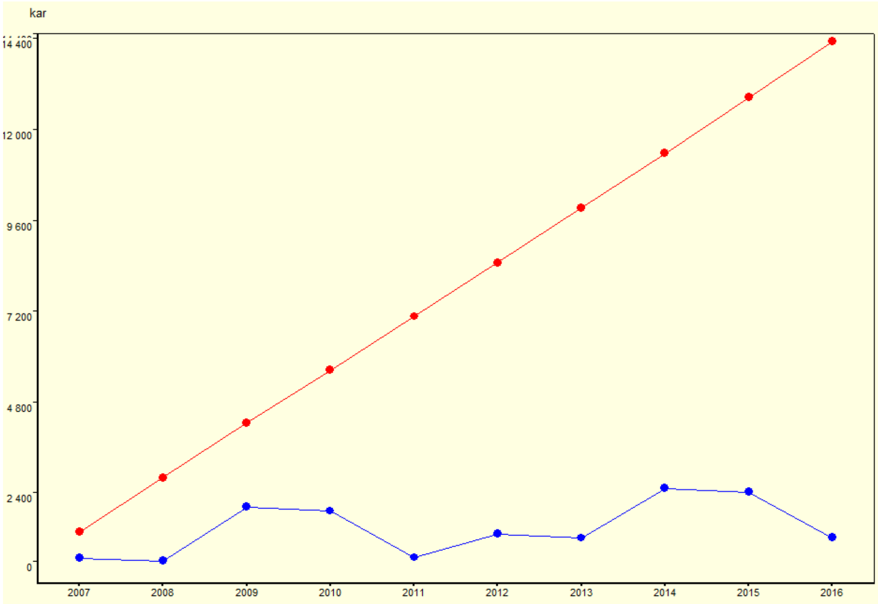

Figure 20: Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the VSE area

The PWCPF paddy field conducted in non-CA system does not allow the farmer to capitalise given the variability. In CA system, capitalization is due to higher yields on upland surfaces since yields on PWCPF are considered stable.

Performance of cropping system practises at farm scale

The table below presents the intensification ratio and the return to capital.

Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB										
Modele type D SCV VSE 11	13	8	8	8	8	8	8	8	8	8
Modele type D Innov VSE 11 I	9	14	8	13	36	10	13	8	14	35
Retour sur investissement										
Modele type D SCV VSE 11	696	1 169	1 179	1 179	1 190	1 190	1 200	1 201	1 211	1 214
Modele type D Innov VSE 11 I	955	614	1 175	663	182	891	663	1 187	617	190

Figure 21 : Results of intensification ratio and return to capital over 10 years for the typ D farm in the VSE area

The intensification ratio in CA system remains at 8%, risk-taking for the overall conduct of the system is very low. In contrast, the ratio in ICS varies greatly depending on climatic hazards. A very bad year (year 5 and 10) the ratio indicates a moderate risk for the system (>30%). This risk is strongly influenced by the randomness of rice production on PWCPF. The return to capital following these variations in ICS. However, even in years 5 and 10 it is profitable to produce in ICS.
In conclusion, the type D farm in ICSis viable even if its cash balance is negative at average to bad years. Over 10 years the cumulated cash balance increases by 55% in total. CA systems allow this type of farm to not only secure income by providing more regular rice production on PWCPF, and improving rainfed productions.

Comparison of type E farm

The type E farm has 1 ha of PWCPF in CA system. As before the production of PWCPF is considered stablein CA, whereas in ICS we apply a hazard on rice yields in the same sequence as before. The income (Figure 24) increases by 3% in total over 10 years in CA system. We observe the same variations whether in CA or ICS system as before. However, the income in both systems from starts from a baseline in year 0 500 kAr lower than in type D.

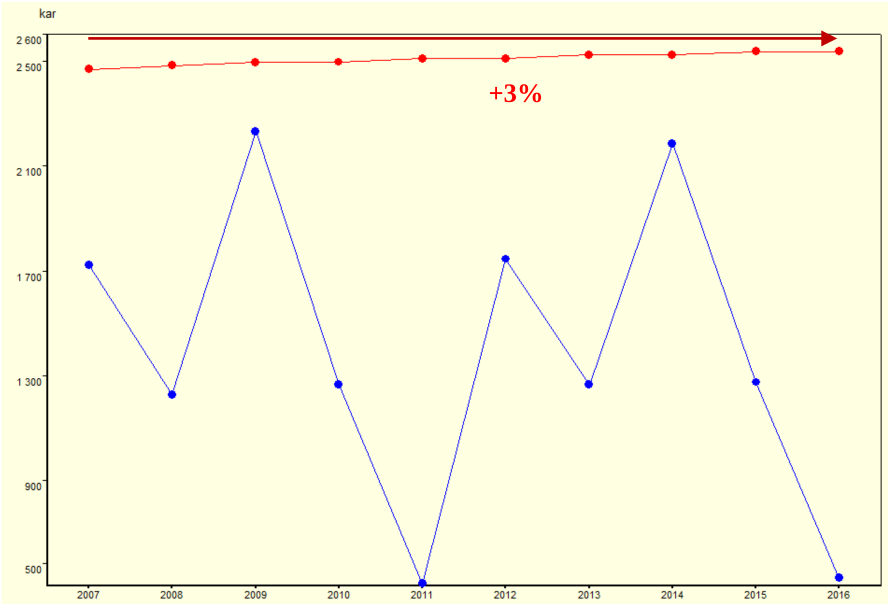

Figure 22:Comparaison of farm income of CA and ICS systems of type E farm for VSE area

The farm is not self-sufficient in rice in years when yields of PWCPF are average of (1300 kg / ha) or null. Part of the rice production is used as the liquidity to cover the needs of the household and farm costs. The cash balance (Figure 25) is negative for those years. The farmer buys the rice so that always helps to bring down more cash balances. The farm has, however, off-farm income of 400 kAr/year.

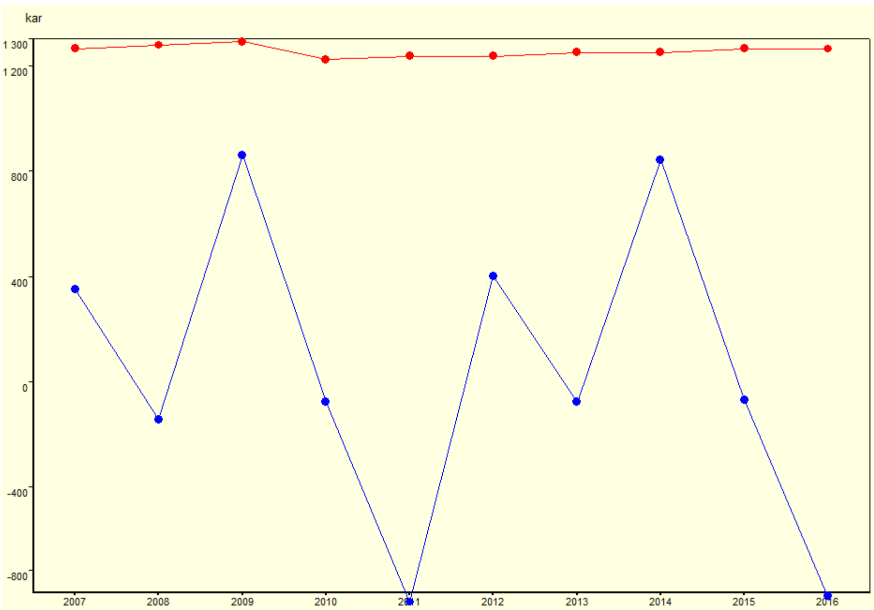

Figure 23: Comparison of the farm cash balance in ICS and CA system for the type E farm in the VSE area

The cumulated cash balance (Figure 26) over 10 years in CA system is greater than ICS by 97%. As with the previous case, this difference is directly related to yield stability of PWCPF in CA and variability of these in ICS.

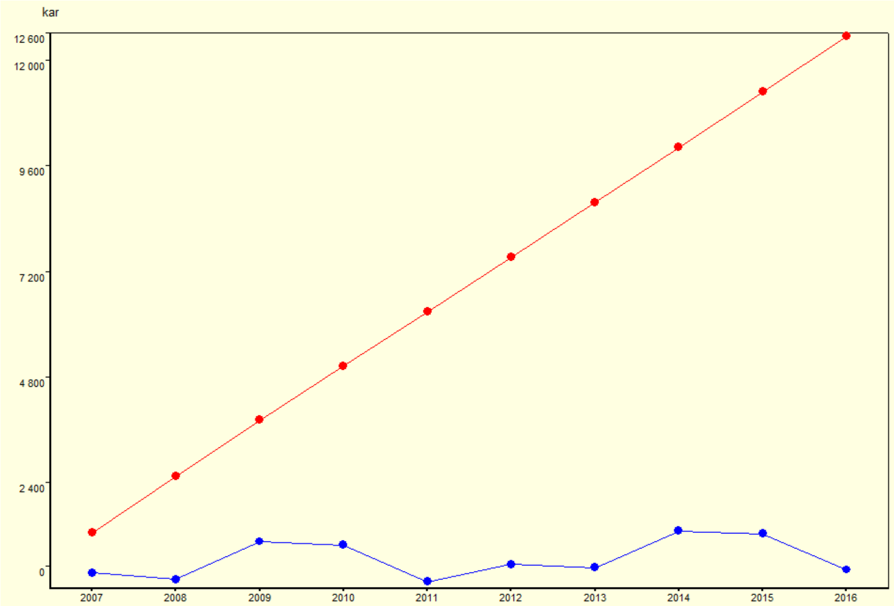

Figure 24: Comparison of the farm cumulated cash balance of ICS and CA systems for the type E farm in the VSE area

In conclusion, the type E farm in ICS is viable in theory (increasing the cumulated cash balance of 48% after 10 years). However, in reality, given the negative cash flow of 6 years over 10, the farmer would have to borrow to support household and farm expences. The farm is not really viable. CA systems allow a type E farm to secure income by more regular rice production onPWC , and also significantly improves rainfed productions.

Performance of cropping system practises at farm scale

The table below presents the intensification ratio and the return to capital.

	Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB											
Modele type E SCV VSE 11 1		10	8	8	8	8	8	8	8	8	8
Modele type E Innov VSE 11 21		9	13	8	12	25	10	12	8	13	24
Retour sur investissement											
Modele type E SCV VSE 11 1		955	1 182	1 191	1 189	1 198	1 195	1 205	1 202	1 212	1 212
Modele type E Innov VSE 11 21		923	621	1 067	689	276	842	689	1 079	625	285

Figure 25: Results of intensification ratio and return to capital over 10 years for the typ D farm in the VSE area

The intensification ratio in CA system remained stable at 8%. in ICS it increases the average to bad years. However, the farmer does not take risks by managing his PWCPF system in ICS even the bad years. The return to capital in ICS is better by 34% for a bad year compared to the type D farm. This is due to lower a intensification of the system compared to the type D farm (intensification ratio of 25% in type E against 36% in type D in year 5 of ICS). Type E has a PWCPF surface lower than the type D, the influence level overall on the farm (not clear check this) of the intensification ratio on PWCPF is lower compared to the type D farm.

Conclusion on the southeast farms

The CA systems have a lower overall economic impact on type C farms. Indeed most of their income is generated by irrigated rice fields. Rice production is a key factor in farm income. For type D and E farms who have PWCPF paddy fiels, the hazards applied to rice production

impactes heavily on the cash balance after each crop failure. It would take several years of high yields to allow the farmer’s cash balance to “recover”.
These results show that farms of type C have a relatively high cash balance (through the yield stability of irrigated rice fields) allowing them to take the risk of investing in CA systems on upland surfaces. However, the adoption of CA systems has a lesser effect on their total income. Cash in the CA system come from the sale of paddy rice produced on IPF (73% after selfconsumption of rice which is 7% of the production of irrigated rice fields).
For types D and E the total income the increase of over 10 years is provided by the adoption of CA techniques is significant relatively to other systems. CA systems secure income. However, these types of farms do not have a high cash balance and stable enough to enable them to invest consistently in upland surfaces. Indeed, the type D and E farms have little arable land and cash flow is strongly influenced by the variability of yields on PWCPF paddy fields. For the type D farm, the cashin CA system are made mainly through the sale of rice produced on PWCPF (64% after selfconsumption). For the type E farm, the PWCPF surface is lower, only 46% of cash from the sale of PWCPF rice, 33% comes from rainfed production and 21% comes from off-farm income. In innovative systems to intensify cropping to improve cash flow, the farmer must use credit as a first step to change the cropping system to CA system. However these results must be qualified by the fact that we have not applied to hazards on the yields of PWCPF in CA. Monitoring data plots by BRL on PWCPF show no changes in yields against climatic hazards, but this does not prove they do not exist. Indeed, the database processed by the operator do not inclued extreme yields such as zero, which tends to smooth the yield results. This assumption of stable yields on PWCPF in CA system must be confirmed or refuted in order to precisely quantify the impact of CA systems of rainfed crop on income.

Farms in the northeast area

Comparison of farm type C

The type C farm in the northeast has 1.5 ha of IPF and 0.8 ha of PWCPF on which he produced two crops of rice per year: one rice crop during the rainy season, and a rice recession in the dry season. The PWCPF is not conducted in CA system so it suffers the same variations of yields in the three systems CA, ICS and conventional. After 10 years, farm income (Figure 28) is higher in CA system of 6% compared to the ICS, and 9% compared to the conventional system. This is explained by the slight increase in yields on crops of upland rice and maize in CA system.
The income of ICS and conventional systems is very close, there is a difference of 3% after 10 years. The difference is explained by the diversity of cultures in ICS (maize, rice, groundnuts) while in the conventional system the only production of upland soils is maize. In conclusion, for a farm of type C, the improvement in farm income is not significant after 10 years. The result is only slightly influenced by the production of rainfed crops. It follows mainly on rice production of irrigated and PWCPF rice.

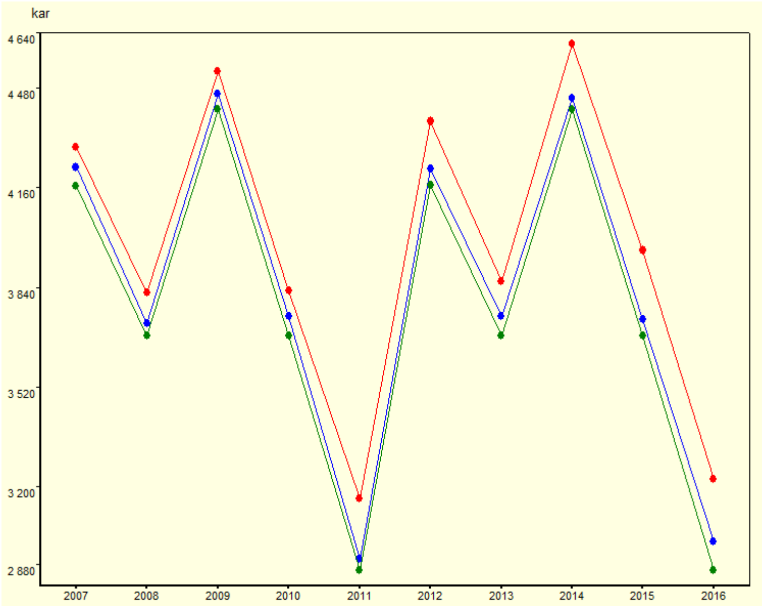

Figure 26:Comparaison of farm income of CA and ICS systems of type C farm for ZNE area

The cash balance (Figure 29) follows the same variations as the farm income. Off-farm income and family expenses are equivalent and stable over 10 years. The cash balance is influenced as the income by changes in rice yield of the season on PWCPF.

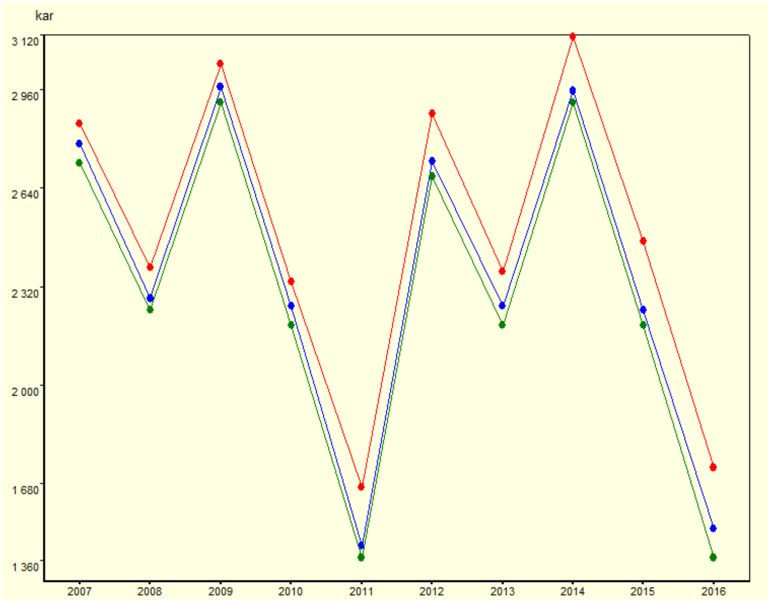

Figure 27 : Comparison of the farm cash balance in ICS and CA system for the type C farm in the ZNE area

The cumulated cash balance over 10 years (Figure 30) in CA system is greater by 5% compared to the ICS and 8% compared to the conventional system.

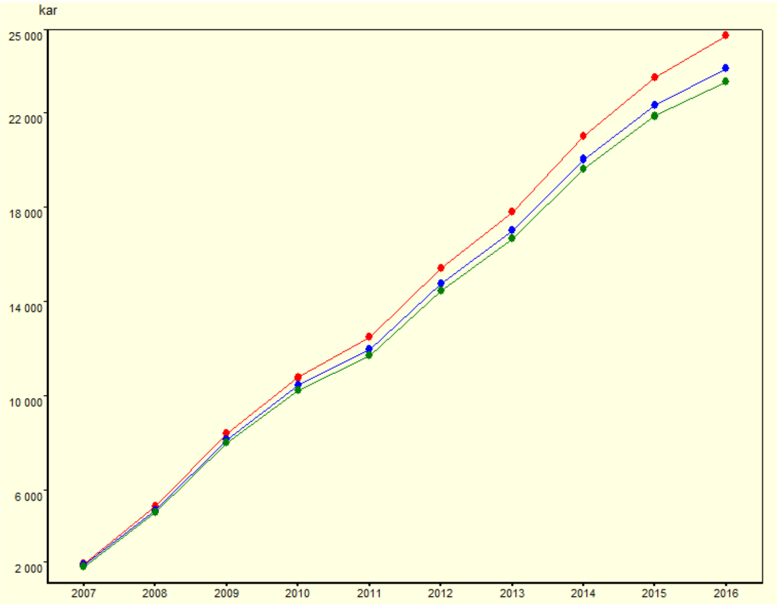

Figure 28: Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the ZNE area

Performance of cropping system practises at farm scale

The table below presents the intensification ratio and the return to capital.

Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB										
M704_Modele SCV type C_11	21	23	20	24	28	20	23	20	23	28
M704_Modele Innov Type C_1 11	21	24	20	24	30	21	24	20	24	30
M704_Modele Conv Type C_1 111	22	25	21	25	31	22	25	21	25	31
Retour sur investissement										
M704_Modele SCV type C_11	474	426	502	418	351	487	428	504	438	357
M704_Modele Innov Type C_1 11	464	410	491	412	328	465	412	490	412	333
M704_Modele Conv Type C_1 111	457	405	484	405	323	457	405	484	405	323

Figure 29 : Results of intensification ratio and return to capital over 10 years for the typ C farm in the ZNE area

The intensification ratio is around 30% in year 5 and 10 for the three systems. The higher being in the conventional system and the lowest in the CA system. None of the systems present a significant risk for the farmer. This ratio is two times higher in average than in the southeast. This reflects the crops in the secondary season cultivated on *baiboho* and PWCPF increasing the level of intensification of the system. Therefore the return to capital is almost equivalent in the three systems, although slightly higher in CA system.

In conclusion, the CA system has an impact on farm income insignificant over 10 years compared to conventional systems and ICS on a type C farm, because of the high and stable income generated by irrigated rice fields. Farms of this type are viable and have no significant interest to adopt the CA systems.

Comparison of type D farm

The type D farm has 1 ha of PWCPF and upland surfaces are equal to type C. As with the previous type PWCPF is not conducted in CA system so it suffers the same vagaries of yield in the three systems CA, ICS and conventional. The difference on farm income (Figure 32) between the CA system, ICS and conventional is only related to the effect of the techniques practiced on upland surfaces. After 10 years of CA improvement on farm income is 16% compared to the ICS system and 19% compared to the conventional system. This is due to the yield increase in CA system on upland rice and maize, whereas in ICS and conventional system yields are stable (except on *tanety* where a climate hazard is simulated, an accident every 5 years). This increase is more significant than in the previous type because of the lower proportion of paddy fields in the UAS. CA systems primarily secures income in case of climate hazards.

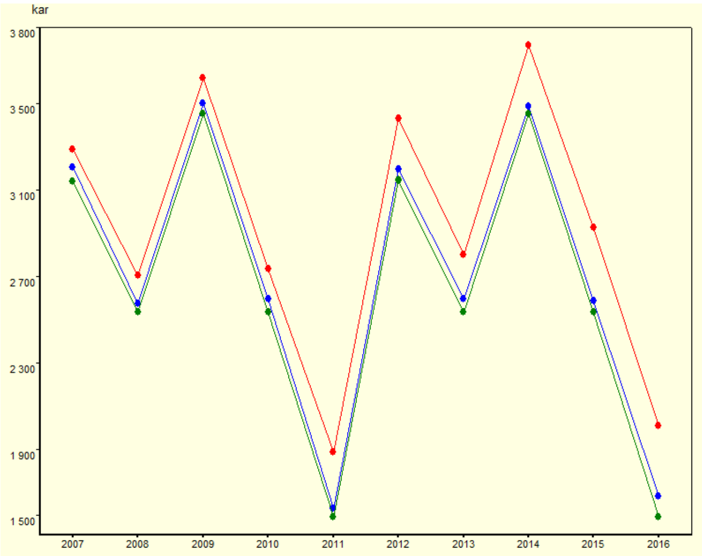

Figure 30 : Comparaison of farm income of CA and ICS systems of type D farm for ZNE area

As before the cash balance (Figure 33) follows the same variations as the operating result.

Figure 31 : Comparison of the farm cash balance in ICS and CA system for the type D farm in the ZNE area

Figure 32: Comparison of the farm cumulated cash balance of ICS and CA systems for the type D farm in the ZNE area

The cumulated cash balance over 10 years (Figure 34) in CA system is 15% higher than in ICS and 18% higher than conventional system. CA systems therefore significantly increase the farm income over 10 years for a farm of type D.

Performance of the system of farming practices across the operation

The table below presents the intensification ratio and the return to capital.

	Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB											
Modele type D_SCV_ZNE_11	2	24	28	21	29	41	22	28	21	26	38
Modele type D_Innov_ZNE_11	I21	25	31	23	31	48	25	31	23	31	47
Modele type D_Conv_ZNE_11	I211	26	32	23	32	50	26	32	23	32	50
Retour sur investissement											
Modele type D_SCV_ZNE_11	2	419	348	462	344	242	441	359	473	374	257
Modele type D_Innov_ZNE_11	I21	395	319	434	321	203	396	321	432	321	210
Modele type D_Conv_ZNE_11	I211	387	313	425	313	198	388	313	425	313	198

Figure 33 : Results of intensification ratio and return to capital over 10 years for the type D farm in the ZNE area

The intensification ratio is problematic in years 5 and 10 in both ICS and conventional systems. In ICS system it is essentially the null harvest on PWCPF which increases the ratio of overall farm intensification. In CA Systems, and also the conventional it is also the PWCPF cropping system but also the cropping system on *tanety*. The farmer takes a risk by cultivating these crops. Consequently, the return to capital is higher in CA system. Moreover, in CA system productions are more important than conventional systems and ICS.

Finally, the type D farm is viable in ICS and conventional system through large upland areas. However, CA systems enable to provide significantly higher and stable income.

Comparison of type E farm

1.1.1.1 Economic viability of the farm

The type E farm has 0.5 ha of PWCPF. After 10 years of CA improved farm income (Figure 36) by 18% compared to ICS and 23% compared to the conventional system. This increase is significant due to the lower proportion of PWCPF the UAS.

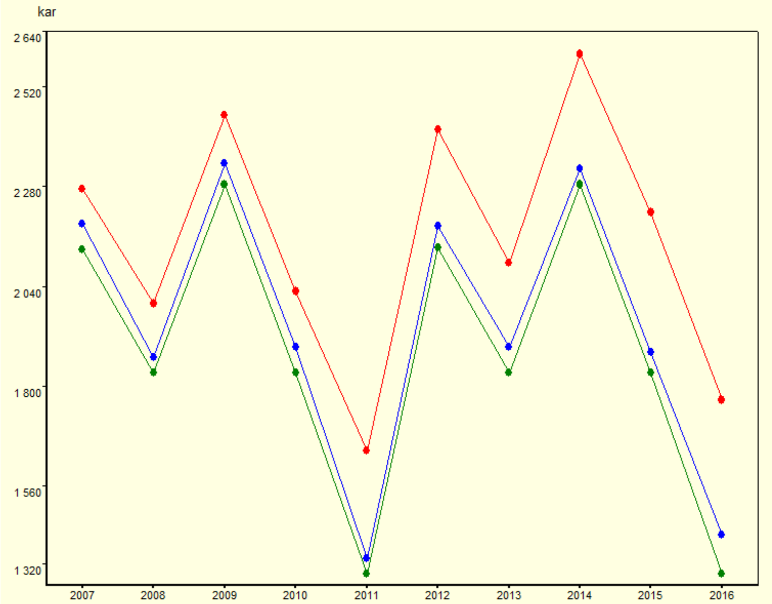

Figure 34 : Comparaison of farm income of CA and ICS systems of type E farm for ZNE area

The cash balance (Figure 37) follows the same variations as previous cases the farm income. The cash balance in year 5 and 10 is negative for conventional systems and ICS. The harvest of rice on PWCPF is zero, the farm is not self-sufficient in rice. Cash balance dives because the farm has not recovered the investment made on PWCPF, and must not only buy rice to cover household needs but also invest in the settlement of crops for the next season. Unlike in CA system, where the cash balance stays positive. CA systems secures the cash balance of the year where the harvest is zero on PWCPF.

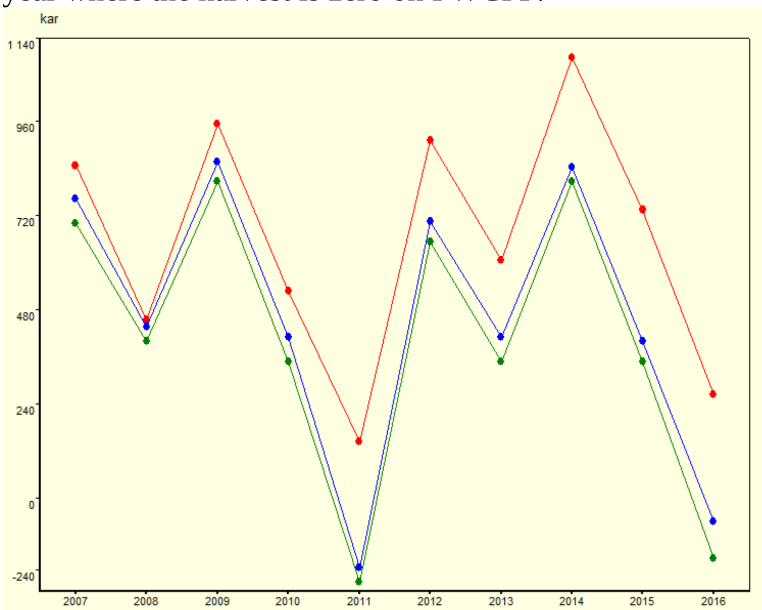

Figure 35 : Comparison of the farm cash balance in ICS and CA system for the type E farm in the ZNE area

The accumulated balance after 10 years (Figure 38) in SCV system is greater than 30% in SCI, and 39% in the conventional system. The real income of the holding type E is significantly improved by SCV systems.

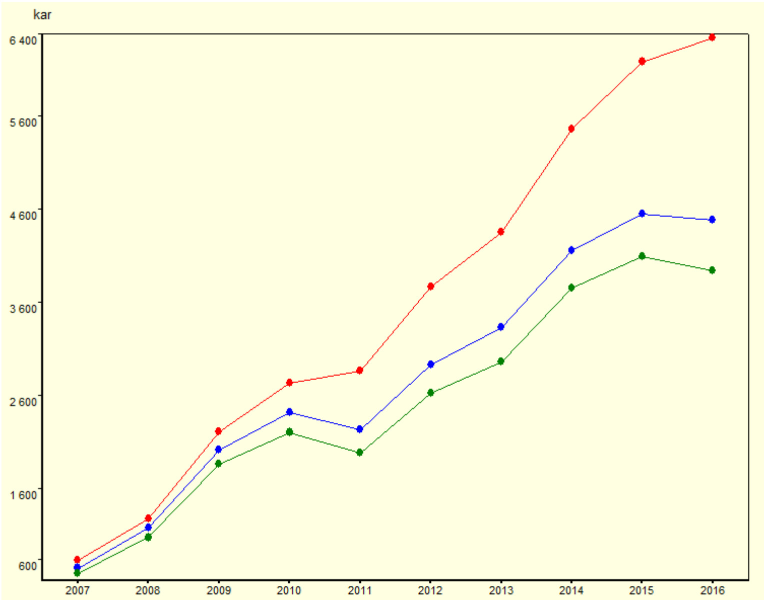

Figure 36 : Comparison of the farm cumulated cash balance of ICS and CA systems for the type E farm in the ZNE area

Performance of cropping system practises at farm scale

The table below presents the intensification ratio and the return to capital.

	Unité	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratio intensification sur MB											
Modele type E_SCV_ZNE_11	4	21	24	20	24	29	20	23	19	22	27
Modele type E_Innov_ZNE_11	I41	23	27	22	27	36	23	27	22	27	35
Modele type E Conv_ZNE_11	411	24	28	22	28	37	24	28	22	28	37
Retour sur investissement											
Modele type E_SCV_ZNE_11	4	465	414	502	405	337	500	430	518	453	361
Modele type E_Innov_ZNE_11	I41	425	365	456	368	271	426	368	453	368	281
Modele type E Conv_ZNE_11	411	413	356	443	356	263	414	356	443	356	263

Figure 37 : Results of intensification ratio and return to capital over 10 years for the type D farm in the ZNE area

The intensification ratio shows a slight increase in risk-taking for conventional system and ICS for the years 5 and 10. This risk is related to the cropping system on PWCPF. The return to capital is higher by 9% in the CA system only compared to ICS in year 5 and 22% in year 10. In CA system the increased return to capital is related to the gradual increase in upland rice yields and maize yields.

In conclusion, the type E farm in conventional system and ICS is economically viable despite a negative cash flow in bad years. CA systems on rainfed crop secure cash balance bad years and improves income.

Conclusion on farms of the northeast

CA systems, as in the southeast have less economic impact on farms of type C, because of their large proportion of income generated by the irrigated rice field and PWCPF. Rice production on these surfaces is a key factor in farm income and is also the main source of cash. For farms of types D and E increased income provided by the adoption of CA techniques is more important than the type C as in southeast. CA systems help secure income to climate hazards especially for the type E, which has only 0.5 ha of PWCPF. These types of farms in the northeast have an interest in maintaining cash balance due to the high proportion of upland surfaces on the UAA, which is not the case for the farm of the southeast. Ultimately CA techniques allows type D and E farms to secure their income, provided they have enough upland surfaces at least 0.7 ha. Type C farms with little upland surfaces have relatively little to gain by investing in CA systems on rainfed crop compared to income from their rice fields. Yet these are the farms with positive cash balance allowing the technical change and thus may take a certain level of risk by investing in upland areas.

Performance evaluation of cropping systems at plot scale

The finding of the previous analysis showed that the impact of CA introduction on income is not significant, on a farm where the income is mainly generated by the irrigated rice field. The CA did they then have a significant economic impact at plot scale. In this section we model at plot scale the different cultural practices CA, ICS and conventional freeing from the overall farm data to assess pure performance of systems. Indicators for assessing the performance of a cropping system are the gross margin/ha and return to labour. Indeed, the calculated at farm level return to labour is altered by the fact that for a large period of the year the workforce engaged in agriculture is largely unused. It is interesting to compare the return to labour by cropping systems per hectare.

Cropping system on *baiboho*

Comparison of return to labour of cropping system upland rice - DS on *baiboho* in ICS and CA system

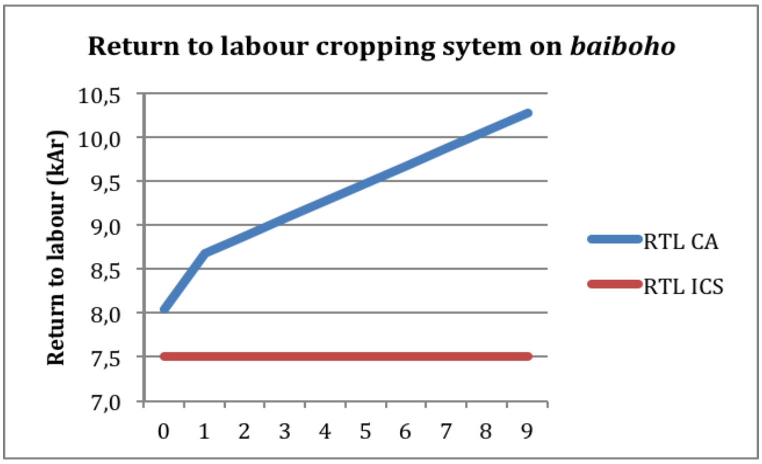

Figure 38: Return to labour of the system upland rice - DS in CA system and ICS on *baiboho*

Return to labour in ICS stagnates at 7500 Ar/day (three times the average agricultural daily wage), while in CA system it increases of 700 Ar between the year 0 and 1 and then gradually increases of about 200 Ar/year, or 22% increase in total over 10 years. The increase between year 0 and the first year of CA is due to the stopping of tillage. The increase from year 1 is due to the slight increase in the yield of upland rice each year. In reality, the time of cultivation decreases slightly as the CA system stabilises. But this reduction in working time is not significant on the one hand, and also difficult to model. One can hypothesize that the mulch is generally more effective against weeds. This technique does not significantly reduce the time worked but improves the quality of weed control, and thus indirectly allows to stabilize yields.

Comparison of the gross margin system upland rice - CS on *baiboho* in ICS and CA system

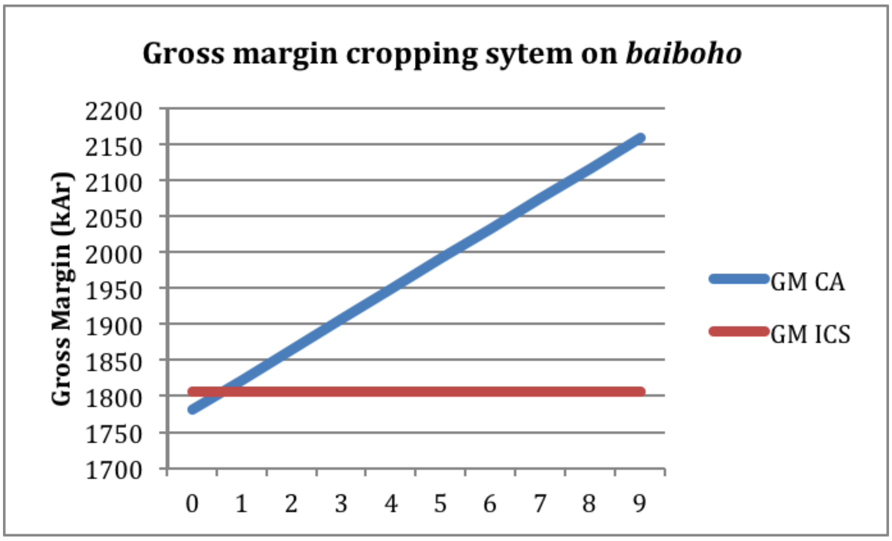

Figure 39 : Gross margin of the system Upland rice – DS in CA system and ICS

Gross margin for the CA system increases by 16% in total over 10 years. Operational costs were stable while the yield of upland rice is growing by 3% per year. In ICS the gross margin remains at 1800 kar/year, due to the stability of rice yields and the secondary growing season and the operational costs, selling prices are modeled stable and "average". We note that in year 0, the gross margin in CA system is less than 1.4% in the ICS system. This is due to higher costs associated with the cover crop (vetch) in season (seeds and planting time). Other expenses are equivalent in both systems (sowing, weeding and harvesting rice, mulching, planting, weeding and harvesting DS). In conclusion, under the assumption of stagnant yields in ICS, after 10 years, the CA system significantly improves the gross margin of 16% compared to the ICS system.

Cropping system on *tanety*

Comparison of return to labour in maize// rice//maize//groundnut in CA system, maize//maize//groundnut in ICS, and maize//maize in conventional system on *tanety*

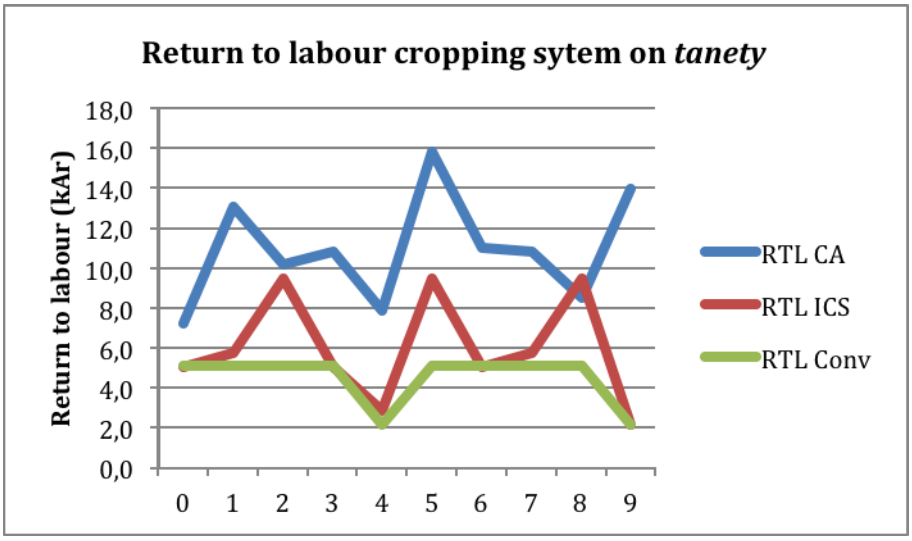

Figure 40: Return to labour on maize//rice//maize//groundnut in CA system, maize//maize//groundnut in ICS, and maize//maize in conventionnal system on *tanety*

Return to labour in the ICS system varies according to crop rotation. There is an increases up to 45% in year 2 before dropping down to 69% in year 4. This is because the first three years to maize and groundnut harvests (well valued). Then a decline in the maize crop in year 3 followed by a maize harvest cut in half because of a climate accident in year 4 combined with the operational costs of setting up the groundnut crop. In year 5, the groundnut harvest revalues the return to labour on the rise (9500 Ar / day). In conventional system, the continuous maize yields gives return to labour slightly lower (average 5000Ar/jour) than in ICS but more stable (except for 4 years and 9 where half the maize crop is lost).

In CA system, changes in return to labour are related to the crop rotation. The peaks correspond to the harvest of upland rice. Indeed, the gross margin of rice is higher than maize or groundnuts. A similar variation in the conventional system or ICS in years 4 and 9, it is the fall in maize production and therefore the gross margin due to a climatic event. However it is noted that this drop is less important than in ICS (39.7%). Overall the CA system allows better use of the work day than conventional systems and ICS through the rotation more diversified on the one hand, and the gradual increase in yields of upland rice and maize on the other. After 10 years the return to labour has doubled. In the conventional system and ICS after 10 years the return to labour has not improved.

Comparison of the gross margin maize//rice//maize//groundnut in CA system, maize//maize// groundnut in ICS, and maize//maize in conventional system on *tanety*

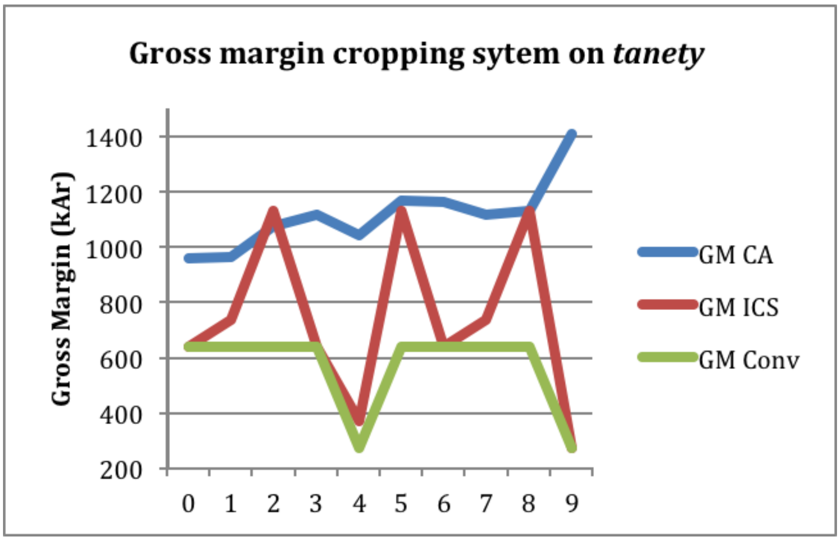

Figure 41: Gross margin maize//rice//maize//groundnut in CA system, maize//maize//groundnut in ICS, and maize//maize conventionnal system on *tanety*

In CA system the gross margin increased by 32% in total over 10 years. Variations of low amplitudes, are due to the crop sequence. It was noted that the gross margin in year 0 of CA system is higher than the other two systems due to the value of *Dolichos lablab* associated with maize. In ICS and conventional system the gross margin drops in year 4 and 9 because of the reduced yield of 50% on maize cultivation. In conventional systems gross margin remained stable due to continuous corn with no variations of operational costs or yields. In ICS, the variations are due to the crop rotation.
In conclusion in this system, the CA techniques allow to stabilize the gross margin compared to conventional systems and ICS. In addition, after 10 years, the gross margin of the system is significantly higher in CA (81%) than conventional systems and ICS, in poor climate years. It should be noted that year 8 gross margin of ICS is equivalent to the CA system through the value of groundnut crop in ICS better valued than maize in CA system. This result explains why the groundnut was introduced into the recommended CA rotation system (Fabre, 2010) and also in the ICS.

General conclusion on economic analysis of cropping systems

Based on this analysis, the more the farm type is oriented towards rainfed crop (for lack of land in IPF, and PWCPF) the more the adoption of CA techniques is interesting for the producer in terms of improving income *stricto sensu*. However, the increase in income is not very significant for the farm types C and D. The advantage of these systems is essentially the income stability to climatic hazards especially for type D farms which selfsufficiency in rice is mainly provided by the PWCPF, very random yield system. However, we can hypothesize that the farm of which cash is provided by the sale of rice grown on irrigated rice areas or PWCPF (type C and D) could significantly improve their income through the CA systems; provided that upland surfaces are sufficiently large to generate income equivalent or higher than irrigated rice.
The type E farms have a strong incentive to adopt the CA systems. However, their low cash balance forces them to use credit based on the chosen level of intensification. But the only credit to which such farms can have access to; due to lack of guarantees is the joint guarantee credit. This credit, moderately suited to agricultural activities at Aloatra Lake, is socially risky because of farmers' strategies are individualistic (Oustry, 2007). In reality, only the family-type associations of mutual liability credit scheme (ACCS: *association de crédit à caution solidaire*), so with a strong internal social cohesion, work well. Note also that in this case the

type E farm in the area northeast has the ability to repay their credit each year, especially as CA systems improve income in the first year depending on the chosen level of intensification. However the type E farm in the southeast is too economically fragile to secure the repayment of the loan.

DISCUSSION AND PERSECTIVES

Evaluation of the impact of CA adoption

The typology on the level of adoption established in this study deserve to be detailed in terms of cropping practices associated with each cropping system (seeding technique: inline, seed-hole, in the plow’s furrow; seeding density; fertilization level; time of work for each tasks etc.). The adoption of some practices is expected to be strongly related to farmers' strategies depending on local specific constraints. The type of farm is directly related to a farmer strategy. The understanding of farmers' strategies in the models requires a very detailed data collection, a qualitative approach of local interests, constraints and opportunities and a good understanding of the functioning of the small holding. It is a phase of particularly heavy work due to a complete system approach of the activty system over several years. Such an undertaking requires more than a half-day of farm survey, which is hardly applicable on a large sample. The financial and human resources to mobilize are important this led to the selection of a small sample: the FSRMN.

In this study, the agronomic effect of CA and climatic context was considered in modeling. However, the socio-economic context is difficult to reproduce. Thus, the weight of national policies and extension device to farmers should also be taken into account. The share of effects related to the pricing of agricultural products, the regulation of markets and sales opportunities for products is very important. For this study we chose a system of average prices to illustrate the situation.

The economic indicators used allowed comparison of the economic viability of production systems, but only have real meaning in a given context. It would then be considered to include in modeling the effect of socio-economic context. This would lead to a sensitivity analysis, by testing different hazards on prices.

The quantitative results of the modeling depends on the reliability of data entered into the model. Modeling results are clearly influenced by the construction of the model. Fabre (2010), indicated that the use of standards from surveys and BRL databases had resulted in a normalization of specificities of farms, which are necessary for the understanding of farmers' strategies. However, simulation can support a certain degree of standardization if the effect is to simplify and enhance the robustness of the data. The results of this study are primarily based on changes in yields in CA systems and ICS (innovative cropping systems). These variations in ICS are based on strong modeling assumptions related to climate, partially unverifiable due to unavailability of data or average reliability. In CA system these variations are related to the seniority of the system. It is assumed that the CA system are resilient to climate hazards and provide a buffer against climate variations. In non-CA system, including the majority of ICS, it is assumed that climate conditions strongly influence the yields. These modeling assumptions introduce some bias in the analysis of performance of different cropping systems.

Crop intensification is also an important determinant of yield but was not considered since farmers have stopped using mineral fertilizers since 2009 at the lake. It is difficult to measure the impact of input use for two reasons. Since the doubling of input prices (2008), farmers at the Lake Alaotra no longer use fertilizers; even if prices have now returned to the same price level as three years ago. It seems that farmers use fertilizer on the poorest *tanety* to get similar yields to rich *tanety* without fertilizer (Penot as pers., 2011). It is therefore difficult to draw conclusions due to lack of technical references on the impact of fertilizers on yields. A recent study in August 2011, highlighted the limits of use of mineral fertilizers (Reynaud-Cleyet, 2011).

Typology Durand, Nave & Penot, 2007

In 2011, at Lake Alaotra, the technical and economic analysis of cropping system performance is based on a classification made in 2007 by Durand, Nave & Penot. This typology was originally created to integrate all the diversity of farms of the various areas covered by the BV-Lac project. However, the main criterion used to discriminate different farms at the lake, is self-sufficiency in rice. Self-sufficiency in rice is a vague concept. Indeed, a holding may be self-sufficient in rice in terms of meeting the food needs of the family in rice production on the farm. This is theoretical rice self-sufficiency. But in reality, farms at the Lake are formed by a combination of agricultural production and a household interests. In many cases, rice is sold regularly in small amounts for cash to cover household expenses. Rice is thus the main source of money when required. In cases where rice production is too low to cover the needs of consumption family expenditures will necessitate that the farmer will have to buy rice. This is the real rice self-sufficiency. However, rice self-sufficiency was considered a good indicator of well being.
The typology was carried out on three major areas around Lake Alaotra, diversified in terms of socio-economic opportunities and geomorphological conditions. It would be interesting eventually to achieve a more refined typology per large area, to highlight the constraints and opportunities related to the specific context. This would help to better understand farmers' strategies and adapt the extension of CA systems

The FSRMN and modeling in real years

The network of reference farms was set up in addition to plot databases. The aim was to follow the farm evolution in actual year with a view of a prospective analysis and impact assessment of the introduction of CA in farms. However, the FSRMN has undergone many changes from 49 farms in 2007 to 15 in 2011. Crop managements in 2007, the first year of farm follow-ups are often inaccurate and yields overestimated. The actual technical pathways of the following years have not been systematically collected. They were replaced by standard CTP's. Follow-up was actually made in 2010 by Cottet. Farm cropped area is often inconsistent with data from surveys in 2011. Finally, the FSRMN farms are not representative of all farms framed.

Modeling based on “real years” on real farms is very interesting because it allows us to take into account farmers' strategies. Although this was the original purpose of our study, difficulties were encountered for the reasons mentioned above. In addition, as part of an *ex-post* evaluation of the effects of the adoption of an innovative system it is difficult to measure in the sense that there is no initial situation. Indeed, monitoring of farms was carried out after the farm had included CA practices and not before. As part of a prospective analysis we can also discuss the fact that it is difficult to know how an operation will evolve in the years following adoption of innovative practices within a short time scale (only started monitoring in 2007). Moreover, as we have shown it is a highly innovative population: 71% of surveyed plots are carried out spontaneously in innovative cropping systems. In addition, modeling in

real year is limited by the statements of actors often inaccurate or misinterpreted by the interviewer.
In conclusion, the major obstacle to modeling in real years is the reliability of data. For this reason modeling using farm models with the use of standard CTP was adopted to enhance the robustness of the data.

The software Olympe

The software Olympe is a tool that can be use for the *ex-post* and prospective analysis. At a restitution of an internship in August 2011 on the transfer of project tools to farmers' organizations, operators have decided not to stop prospective sessions, and therefore not to use the FSRMN and indirectly to stop using the software Olympe.
Indeed, data entry in the software Olympe is a particularly long step in the modeling. In addition, prospective analysis is a method difficult to understand by operators. While thinking begins on real farms; the goal is to extract theoretical references, which requires to make abstraction the specifics of the farm to generalize a model for certain types of farms. This scenarios used by Cottet in 2010, was considered too theoretical by the operators but has had an interesting pedagogic effect according to researchers.
Analysis of the farm database have highlighted some difficulties with the type of data used: operators database, data from typology and surveys, etc. The plot database is created each year, without the continuous monitoring of plots. However, it is possible to connect the plots with the software Manamura but this is a major task that has not yet been achieved. To analyze the evolution of yields depending on the seniority of CA system; continuous monitoring of the plots is necessary. The plot databases do not allow a real analysis at farm scale because only the CA plots are collected. It is therefore impossible to compare the effectiveness of practices between non-CA and CA systems from operators plots databases . In addition, in CA systems data extremes are eliminated by operators including null yield. This has the effect of reinforcing the hypothesis of CA system resilience to climate hazards. Very little data on non-CA systems are available. Data acquisition was done through surveys. Subsequently, it would be interesting to investigate the conventional cropping systems in areas where the project has no actions or influence. The farm database is not updated and its data has not been "cleaned" of inconsistent data. Yet it would be useful to follow the evolution of global farm characteristics (changing surfaces, labour units, animals) in order to understand the peasant strategy implementation and to evaluate the factors of evolution (including the development of CA systems).

This clearly illustrates the difficulty of implementong a monitoring and evaluation system, consuming in time, human and financial resources (yet begun since 2003 by Dabat, MH). The overall quality of the modeling is then limited by the lack of reliable or accurate data and available to assess the changes in yields whether in CA or no-CA systems over a long period (between 5 and 10 years). Impact measurement performed in this study therefore takes into account these constraints. For example, the plot databases do not give information on the state of mulch or plots fertility , which are essential for the analysis of results.
Although many data are available through the databases of surveys of students from 2007 to 2011, it still lacks level of detail to answer fully the questions. Indeed, CA systems do not diffuse in their entirety there is a wide range of appropriated systems, constantly changing. It would be possible to create a typology of adoption based on all the techniques disseminated by the project (preparation of the seedbed, used varieties, seeding method, seeding density, weed management and pest management, mulch and cover crops...)

External evaluation of the effects of CA

External evaluations of the effects of disseminated CA are all based on data provided by the broadcasters. The analysis of yield evolution in CA systems achieved for modeling is based on internal evaluations of the project, the analysis is not completely neutral (the annual yield survey conducted by the local cooperative Andri-ko since 2009 had too few plots to be really usable). However, internal evaluations have the advantage of being performed by people who know the context of diffusion. Strengthening external evaluation would yield results more transparent in terms of real efficiency of CA systems. The study conducted by Fabre in 2010 as part of the PAMPA project indicates that there were 419 ha of real CA considered as such and perpetuated at Lake Aloatra. Against 200 ha advanced by the GSDM (all plots combined including the plots in year 0, with tillage and other non-CA plots...).

The difficulty of collecting reliable data during investigations has been demonstrated in this study. It is a classical example of the limitations of actors statements, including over a long period: retrace cropping systems over 5 years was very complicated. The integration of farmers in the performance evaluation of CA systems both for the data collection or the verification of validity is needed. This integration is achieved in part by campaign assessments, inter-village visits and API sessions. Since 2008, the new direction is to try to promote a form of “conseil de gestion” with farmers (about 850 farms representing 30% of total framed farm in 2011). The farm book (about 150 books in total) is one of the tools developed by the project since 2008 for the “conseil de gestion”, but currently still little used by all farmers.. According to Fabre, farmers require more evaluation methods to check the performance of CA systems.

CONCLUSION

Extension of conservation agriculture techniques at Lake Aloatra really only began in 2003 through an extensive pilot project: BV-Lac, in the context of natural resource degradation and falling agricultural yields on uplands. The diffusion device has evolved from a top-down approach focused on a “plot approach” towards a "eco-socio-territorial" approach (Chabierski et al., 2005), then to an "farming systems approach" since 2007. Today this holistic approach is reinforced through the implementation of the “conseil de gestion” with groups of farmers. What is the outcomes now in terms of performance of CA system released for rainfed crops in the project on farm income?

Today the outcomes on the extension of CA are mixed from a quantitative point of view with 419 hectares of effective CA in 2010 (estimated at 450 ha in 2011), which is consistent given the complexity of the technique and the extensive time and resources invested. However, from a qualitative point of view, the results are very positive. The results of this study have shown a strong spontaneous extension (71% of the plots surveyed of farmers monitored by the project) as part of the CA technical package on plots not supervised by the project. This expresses the innovative capacity of the agricultural population of Lake Aloatra. Cropping systems practiced are described as innovative systems: the ICS. They are the result of hybridating CA techniques diffused since 2003 with the knowledge and know-hows accumulated for more than half a century of innovation at the Lake on rainfed crops.

The typology of behavior performed on the adoption of the CA showed that the technique of rotation is the most spontaneously adopted by farmers before the permanent cover of soil (especially the mulching of secondary season) and no-tillage. No-tillage clearly illustrates the paradigm shift associated with new practices, and remains a major obstacle to the sustainability of CA at the lake. Fabre in 2010 had already shown that for farms that have perpetuated CA plots; punctual plowing was a common practice. Tillage seems to be the only recourse against soil compaction and weeds if the mulch is failed or insufficient.

The study of "plots" databases of the project has shown a small but gradual increase in yields of rainfed crops in CA according to the seniority of the system, at low level of inputs since 2009. CA systems seem to be a buffer against climatic hazards as shown by the regularity of production for the main disseminated systems (rice/vetch on *baiboho*, maize+ *Dolichos lablab*//upland rice on *tanety*) but that has yet to be proved agronomically in detail. According to operators, CA conducted crops in the 2011 campaign when the rainfall was exceptionally low were "saved" in contrast to crops grown in the conventional system. Changes in yields both in the conventional system or ICS could not really be analyzed either due to a lack of reliable data, or inadequate details on the database, or due to limitations of actors statements in the investigations. One can posit the strong hypothesis that this craze for the practice of crop rotation is directly related to the progressive loss of fertility of soils and thus lower yields in conventional monocultures with low level of intensification. It should be noted that farmers today do not invest in chemical inputs anymore in the Alaotra region whether in conventional systems, ICS or CA.

Since 2008, following the doubling of prices of inputs, the process of "medium" intensification which was underway since 2003 has been stopped. This appears to be related on the one hand to changes in access to services: banning of loans to many PO (peasant organisation) due to partial non-repayments of joint guarantee credit in a context of rising input prices (Fabre, 2010). Yet in 2011 the price of mineral fertilizers has returned to the same level as in 2007 but there is a certain *inertia* of practices. One may wonder why farmers do not re-use these fertilizers on rainfed crops? According to the farmers increasing the use of organic fertilizer (zebu manure) achieves the same yields as with the use of mineral fertilizers. This may be true at first but is certainly insufficient in duration to achieve the objective of 3 tons of grain/ha/year as was set by farmers between 2003 and 2009 (observations by Chabiersky and Domas, 2007) . Current yields appear to be maintained by a "precedent effect" (strong intensification until 2008), but will probably not be stabilized in the long-term without a fertilisation offsetting the exports of nutrients.

CA systems could provide a lasting solution in moving towards an ecological intensification of rainfed agriculture through the use of cover crops in order to secure and enhance investment in fertilizer. The counterfactual analysis in *ex-post* on the results of the 5 previous years and prospective in the next 5 years, showed that impact of CA systems on farm income is rather nuanced in a medium-term. Surface types and the rotation characterising of a representative type of farm at Lake Alaotra are determining factors in the impact assessment. The impact of CA on farm income *stricto-sensu* with important irrigated rice fields or PWCPF surfaces is poorly significant. When the farm income is generated by irrigated rice for more than 80%. This type of farm has a high and stable income, ensuring its economic viability in the long term. In general the role of rainfed crops is limited, so the impact on income is low. This type of farm has *a priori* little incentive to adopt the CA systems. The gradual silting of irrigated rice fields in the southeast, however, could in the future change this situation.

The impact of CA on the income of farms having only PWCPF, whose yields are highly uncertain, is quite different. These farms according to their arable land are not always viable and face some years of problems with regard to food subsistence. Modeling over 10 years has shown that without significantly increasing the farm income, CA systems have a more qualitative impact. Indeed CA systems allows for the stabilization of yields and thereby secures farm income. More regular and higher yields than in conventional systems allow

farmers to compensate for cash imbalances in years when rice yields on PWCPF are low. The long-term, yields in CA stabilises and raises farm income, despite fluctuations in the income generated by PWCPF.
This finding, however, depends heavily on the balance between PWCPF and upland surfaces. Indeed, it was shown that the rainfed crops are an important part of the farm cropped area; the more significant the impact of CA is (quantitative). CA systems in this case significantly increases the total income over 10 years. These farms have a strong incentive to adopt these systems for their annual and long term sustainability. Fabre in 2010 showed that the installation of CA systems generates an over investment during the first fiscal year. The major problem lies in the fact that farms which have the most to gain by adopting these systems are also those whose capital bases are too weak to withstand the costs associated with installation. Their only recourse is microcredit in particular with mutual liability credit schemes. Unfortunately, these farms offer too few guarantees to access individual credit. Mutual liability credit schemes are poorly suited to the Lake and socially risky, with the possibility of effecting further the economic vulnerability of these farms.

In the short term the impact of CA is not very significant for farms already economically viable. It takes at least a decade before measuring the cumulative effects at the farm level; even if the results are significant at the plot level. This lengthy time period is what is required for farmers to learn and consolidate their knowledge and know how of these systems. The purely quantitative economic gain is part of a sustainable agriculture that is not obvious to farmers. Given the large proportion of adopters said to be opportunistic (between year 0 and the first year of CA) and the very small proportion of surfaces perpetuated for over 8 years, one might wonder what are the other benefits of these systems perceived by farmers?
Fabre in 2010 hypothesised that some farmers do not understand the basis of the principles of CA but adopt the system in a plot to keep a link with the project. The counselling from the technician is not effectively limited to rainfed and CA systems. The mind set of this farming population in the adoption of CA is an interesting topic for further research. The important development of ICS shows that if the CA techniques as a whole are difficult to manage, the partial elements of the techniques “percolates” very well in conventional systems that then evolve in ICS.

According to Fabre (2010), farmers do not intended to maximize or even optimize their production factors in the farm but rather to meet the specific demands of the family and to adapt the cropping system to local constraints and to those of the household. The continuum of combinations of ICS identified in this study reflects the plasticity of the farms. Existing techniques are probably modified to meet the objectives and constraints of each farmer. The identification of constraints and opportunities related to the adoption of ICS remains to be identified. This study, crucial to the understanding of farmers' strategies implemented, could therefore be subject to a further study in 2012.

In 2010, Fabre had already posed the question: what strategy will farmers adopt in the future, when facing lower effective yields? Will they turn to CA systems or ICS? Towards a re-intensification phase with mineral fertilizers? This study can now begin the discussion by showing that farmers have already responded spontaneously by permanently changing their conventional practices. In parallel Fabre in 2010 also showed that farmers who have adopted CA systems have also changed them to suit their own constraints. It is perhaps too early to judge the economic and ecological sustainability of these innovative systems. This trend, however, allows us to hypothesize that in the future the agricultural population of the Lake

will likely continue to innovate and will turn to an ecological intensification of its innovative systems.
Finally one of the major obstacles to the adoption of CA techniques seems to be the paradigm shift from a short-term to a long-term vision of agriculture. Given the economic and political instability of the country, few farmers take the risk of waiting 10 years to observe the effects of CA on their farm income.

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