Conservation Agriculture in AFRICA: Analysing and Foreseeing its Impact - Comprehending its Adoption

Final modelling report **(D3.1)**

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CA2Africa seeks to assess and learn jointly from past and on-going Conservation Agriculture (CA) experiences under which conditions and to what extent does CA strengthen the socio-economic position of landholders in Africa. This will enable the identification of knowledge gaps for future research, development and promotion of CA. The project is carried out by a consortium of 10 partners, led by CIRAD, France

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General information

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Executive summary

2 sites have been selected for the study: the lake Aoatra area, considered as CA successful and Vakinakratra/Highlands considered as CA failure.

Modeling at plot and cropping systems level

The comparison of soil loss results obtained by direct and indirect estimations showed that generally soil loss calculated from direct measures were lower than those obtained by RUSLE. Therefore, to improve and calibrate RUSLE model at Lake Alaotra, a correction factor was proposed, mainly the reduction of the P factor by making the amount of soil loss by simulation closer to the direct measurement on field. So, extrapolation or modeling of soil loss depending on the soil management mode appeared valid for rice and maize crops, by using for CA systems different types of mulch the most used in the region at Lake Alaotra such as mulch of rice, maize+dolichos and stylosanthes.

The DSSAT experiment was realized on two experimental fields that had been installed by the URP SCRiD at Andranomanelatra. From these studies, it was impossible to use the cropping model to assess the weight of water factor in the variability of inter-annual yield in these regions. It was demonstrated that in the Vakinankaratra, the part of yield variability due to stress water in conditions of study was not important, but at Lake Alaotra, it is responsible for a significant inter-annual variability of yields. The study also highlighted the big differences between achievable yields to the yields observed in field, even under controlled conditions, demonstrating the impact of other limiting factors for both regions.

These studies allowed us in isolating the weight of climate and water factor on the variability of rainfed rice yields. Thus, it appears that plant health problems including weeds are similarly responsible of some differences between observed and achievable yields and the difference between treatments in the test, but there is probably also an important problem of nutrition mineral crops, contributing strongly to the differences between observed and achievable yields, and to the differences between treatments. The models tested can be used for the prediction of the potential and achievable yields with the available water in the soil conditions and the climates in which they were calibrated. Some potential advantages of CA for cropping rainfed rice (improvement of water balance, and control on water erosion) have been efficiently tested with the models f But for taking into account other potential effects of CA (weeds control, P availability, improvement of Soil organic matter stocks…) the crop models need still to be improved.

Modelling at farm level

GANESH

The model used was called GANESH (Goals oriented Approach to use No till for a better Economic and environmental sustainability for SmallHolders). The full model and output is described in Naudin (2012). Our study is the first, to our knowledge, that models the impact of practicing CA, with various degrees of biomass export, on integration with livestock and farm income for smallholders. Optimization was a useful method as it allows exploration among millions of combination of potential production systems that represent the numerous constraints and goals of the farm. It further allowed an objective comparison of the production activities, based on quantitative data and taking into account the complexity of the interactions between theses production activities at farm level. This kind of ex ante study can be useful for guiding a CA design approach to explore impacts of a possible change in the context (inputs, forage, workforce, crop animal products prices); to understand which changes and trade-offs are associated with CA systems at farm level and which types of CA systems are more suitable for different types of farm.

OLYMPE

Vakinankaratra as a "Current CA failure case study"

The main contraints to CA adoption in the highlands are the following:
The main technical reasons are the following:

- ***1 Growth delay of rice in CA system:*** delay in soil biological activity and plant growth : soils remains cold due to the mulch, if mulch is existing (in experimental conditions with soybean maize and Maize Bracharia) (Julie 2012) if a graminae is present in the rotation : delay in rice production (not seen with maize).Rice is a plant more difficult to associate with others compared to maize for instance. Phenomena of "nitrogen deficiency due to mulch" due to Bracharia in the system. Rice roots grows more rapidly with tillage.
- ***2 Coldness***: we observe a real difficulty to produce biomass in counter season and to keep it dur to coldness during 2 to 3 months.
- ***3 Competition biomass mulch/animal feeding.*** There is effectively in this area, called "the dairy triangle" a very strong competition for the use of biomass between livestock requirements and mulch for CA croppig systems.
- ***4 Complexity of current CA cropping system.*** Existing and suggested CA cropping systems are effectively relatively complex to implement with respect to specific agronomic requirements but local people are quite used to complex cropping systems with up to 4 associated or successive plants a year.
- ***5 Difficulty to control weeds compared to tillage .***CA systems implies a full control of weeds regarding their complexity and it is even more complex to control if linked with dry seeding technique for instance or rice : it has been proved that to control weeds need an almost perfect 100 % covering mulch (K Naudin, 2011).

The main social and economic reasons are the following:

- ***1 Small cropping area with priority to food security.*** Farms have a very small cropped area, between 0.4 and 0.6 ha in average. Therefore modifying rotation to include CA is a potential risk for food security: there is in fact no possibilty to do unproductive fallow or period/plot with no production.
- ***2 Global farmers'priority to upland rice :*** Farmers always give priority to rice, whatsoever , in particular since several years to upland rice with even rice on rice rotation pattern. We observe a double phenomena : increase of upland rice area in general and new rice /rice rotation on upland that will lead very rapidly to fertility

problems as rice is a relatively exigent crop in terms of soils fertility. It is therefore a real difficulty to suggest CA complete rotation that could be compatible to farmers 's objectives or priorities.

Lake Alaotra as a "success story"

The Alaotra lake area can be consider as a success in term of real CA systems adoption (CA systems "stricto sensu") : 410 hectares of CA systems with 600 farmers have been identified in 2010 : probably 600 hectares with 700 farmers in 2012.If we carefully look at statistics in some other countries claiming 100 ,000 ha of CA (Zambia, Zimbabwe , Tunisia etc …) : most of what is declared as CA is not : most of them are "light or limited tillage systems " or systems which include 2 but not 3 of the main Ca principles as described by FAO (2008).

In fact, Madagascar is probably the only country there CA systems "stricto sensu" have been effectively adopted by smallholders (we are talking of small family farms). North Cameroon, Laos and Cambodia have probably as well some limited area with real CA systems (less than 1000 ha). But the lake Alaotra area see clearly a critical mass of farmers and a relatively locally significant area under CA to built up a sufficient and sustainable "heart" od CA adoption. This is the results of 14 years of Research presence and 10 years of Development efforts (with the projects BV(lac). But the question is now: what next after the end of the current BV-lac project ?

We do observe a real technical demand from farmers on whatever type of practices or technological package that can provide production stability. Meanwhile, If CA systems have been effectively adopted, we do observe that they are not spontaneously adopted by non project surrounding farmers. In other words : NO CA outside development project which raise the question of CA diffusion when project ended up. One of the constraints to such no outside project diffusion could be: i) 5 years or learning process, ii) no immediate and visible results (results appears after several years).

Positive aspects are the following: i) a real basquet of technology: many CA available cropping systems with 5 families and over 130 cropping systems to cover many situations, ii) freedom of choice as farmers have never been constrained to a specific technique, iii) easy adoption and importation of covercrops , iv) real positive outputs after 5 years …v) a real expansion trend on upland when irrigated rice area is limited and saturated

The first CA introduction has been historically made in Vakinankaratra, in the high lands, but too much existing constraints leave to no adoption. The highlands have extreme constraints when Lake Alaotra still has potential areas of development and far less severe constraints. CA success eventually linked with very specific situation. Therefore, it seems to be very difficult to extrapolate CA success to another region if not similar.

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1. Brief description of the case studies

1.1. The lake Alaotra case study

The Alaotra lake region is located in the Toamasina province 250 km north from the capital city, Antananarivo. The Alaotra lake plain covers an area of 180,000 ha at an altitude of 750 m. It is surrounded by high ferralitic hills raised on a granite-gneissic platform. The basin formation is due to tectonic and erosive phenomena. The plain center is occupied by a 25,000 ha shallow lake (2 to 4 m depth). This Alaotra lake region is characterized by a humid tropical altitude climate with a mean annual temperature of 20°C. The climatic year is divided in 2 seasons: the rain season from November to March and the dry season. Mean annual rainfall reaches 1046 mm on the east shore of the lake. Currently, the Alaotra lake region is composed of almost 30,000 ha of IPF and 72,000 ha of PWC (MAEP 2004). Despite yield saturation, irrigation channels non-maintenance and positive population growth, the region remains productive on a national scale. Indeed, it produced 300,000 tons of paddy rice in 2004 which represents 9% of the country production. Every year, about 80,000 tons of white rice is exported to Toamasina and the capital city. Thus, the Alaotra lake region is the main Antananarivo food supplier (MAEP 2004). At the Alaotra Lake region, three evaluations of socio-economic impacts were realized: the first one was realized by Beauval *et al.* in 2003 but wasn’t validated by the BV/Lac project (); the second study was made by Freud in 2005 and the last study was conducted by Fabre in 2010. Both Beauval and Freud studies underline the lack of means to achieve properly the evaluation. The country has suffered economic troubles that currently continue with the last politic crisis; and smallholders are particularly affected. But most of disseminated crop management techniques are based on an intensification of the use of inputs. The cost of herbicide is prohibitive for farmers. This overinvestment combined with the financial overinvestment related to the increase of labor needs (for some systems requiring a straw collection) make the systems become very risky (Beauval & Leval 2003). According to their low capacity of investment, small farmers would rather adopt an “extensive logic” that guarantees a short-term income than bet on the “productivity challenge” that they have no insurance to win and which is expensive (Freud 2005).

1.2. The Vakinankaratra case study

The Vakinankaratra region is located between 18°59’-20°03’ south and 46°17’-47°19’ east. It is mainly characterized by volcanic soils and a high-altitude tropical climate (over 1100m) with a mean annual rainfall of around 1000 mm/year and a mean temperature of 17°C (Nandibiniaina, 2008). This climatic condition is convenient for dairy farming and forage production. However, temperature drop-off during dry season leads to a significant decrease of biomass production, mostly between June and August (Kasprzyk, 2008). The climatic year is divided into 3 distinct seasons: i) November to March: the rain season with a mean temperature of 19.4°C, ii) May to September: the dry season with a mean temperature of 14.2°C. During this season, temperature can drop off to 0°C and iii) April and October: the intermediate season with a mean temperature of 17.8°C. The are selected as a case study for CA2AFRICA concerns the "highlands" of Vakinankaratra (The eastern part called "Middle west", with an altitude between 800-1100 m. is not concerned).

Heart of the "Dairy triangle", the Vakinankaratra is the main dairy production zone of Madagascar. The early set up of food industries (STAR brewery, TIKO dairy and KOBAMA flour mill) has turned this region into a central agricultural and agro-industrial area. Thus, farm production is oriented toward cereals, fruits, vegetables and dairy production. More than 80% of Madagascar dairy production is provided by this region (DUBA, 2010). A population density is very high with in addition a population growth dramatically high in the region (2.4% per year) and mean farmable area is estimated around 0.8ha per farm in 2005. With this growth, available farmable lands keep on decreasing year by year. These lands are either paddy fields and irrigated crops or rain field crops on hillsides. The population pressure leads to a complete saturation of paddy fields that increases more and more the agricultural land use of hills, already saturated as well in most areas. Added to the current political and consequent economical crisis, population income becomes truly low when off farm opportunities significantly decrease as well as global employment in main towns.

Thus fallow periods are disappearing in traditional cropping systems and farmers diminish the use of manure. Subsequently, soils fertility decreases. Plus, traditional tillage techniques increase the erosion phenomenon. That is directly related to low lands silting-up which participates to the farmable land loss. These 2 agro-ecological constraints have a direct influence on smallholders' standards of living.

Financed by the AFD[1], BVPI-SEHP project has been set up since 2006. It covers 4 regions including the region of Vakinankaratra. The main project challenge is to develop and enhance the management of watersheds, considering them as a coherent geomorphologic entity, low lands and high lands gathered (Rakotondramanana et al., 2010).

2. Modelling analysis at field level

2.1. Modeling erosion: RUSLE

2.1.1. Model presentation

To evaluate soil loss, the RUSLE or *Revised Universal Soil Loss Equation* was chosen as a model of prediction that can quantify soil erosion. It's an American empiric model created by Wischmeier in April, 1985. Among the models of prediction of erosion, it has been the most widely used equation especially for developing countries, among other, it is easier to adapt to the climatic conditions in tropical countries.

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[1] AFD: Agence Française de Développement (French Agency for Development)

RUSLE model includes all the five factors that govern the phenomenon of erosion, and simulations represent annual values of soil loss. Indeed, erosion is a function of (i) the erosivity of rainfall and runoff; the susceptibility of soils to erosion, (iii) the land topography; (iv) the vegetal cover and (v) the conservation practices.

The general equation by Wischmeier and Smith (1978) is as follows:

$$\mathbf{A = R\,.\,K\,.\,LS\,.\,C\,.\,P}$$

Where:
- A = soil loss ($t.ha^{-1}.an^{-1}$),
- R = rainfall erosivity factor,
- K = soil erodibility factor,
- L et S = topographical factor intégrating the length and angle slope,
- C = factor of soil protection by the cover-management,
- P = factor expressing the soil protection by agricultural practices

a) Rainfall erosivity factor (R)

The R factor represents the erosive effect of raindrop impact on the soil and is expressed in $MJ.mm.ha^{-1}.h^{-1}$. It is defined from rainfall data collected over 4 years (2006 -2010) in the automatic weather stations (CIMEL) of BV-Lake and CRR-ME in the center of Ambohitsilaozana. Yearly rainfalls are considered in the beginning of the summer (September) until the end of the winter (August). As the data available are daily rains the formula used was regression equation of daily rainfall (Yu, 1998) based on the effective rainfall (daily rainfall more than 12.7 mm) and the climatic coefficients model which vary depending on the study area.

According to Van Hulst, 2011, the climate of the region of Lake Alaotra is characterized by a Climate Code or CC=5, Rainfall Seasonality Index or RSI =0.90 and Mean Annual Rainfall or MAR=985 mm. Thus, these characteristics are closed to those of tropical Australia (CC=5, RSI=0.97 et MAR=939) and the suitable coefficients of the model are:

$\alpha = 7.61$, $\beta = 1\pm0,05$ et $\eta = 0,280\pm0,135$.

$$Rj= \alpha\,(1+\eta \cos(2\pi fj - \omega))\sum_{k=1}^{N} P_k^{6}$$

where :
- Rj: rainfall erosivity during months j;
- α, β, η et ω: coefficients of the model ($\omega = \pi/6$: higher erosivity in January;
- P_k: effective precipitation;
- fj: frequency (1/12) to explain the seasonal variation.

b) Soil erodibility factor (K)

The erodibility factor (K), expressed in t.h.MJ-1.mm-1, represents the influence of soil properties facing erosion (splash effect and runoff). Values are obtained experimentally by measurement plots of standardized size, directed on bare soil and slope. Soil erodibility is an intrinsic characteristic of the soil linked to its physical and chemical properties. Indeed, it's especially depending on the studied soil texture. According to Roose (1996), ferruginous and especially iron-bearing soils, are relatively tough compared to those temperate regions, but they are more eroded due to heavy rainfall. The texture used came from TAFA's plots site at Lake Alaotra. In this context, the following regression equation of global soil texture given by Renard and al., 1997 is used to calculate the K factor:

$$K = 0.1317 * 7.594\left\{0.0034 + 0.04\exp\left[-\frac{1}{2}\left(\frac{\log(D_g)+1.659}{0.7101}\right)^2\right\}$$

$$D_g = \exp\left(0.01\sum f_i \ln m_i\right)$$

Where :

- Dg : average particle diameter (mm),
- f_i : percentage of the fundamental particle
- m_i : arithmetic mean of the limits of the particle size

c) Topographical factor: slope length and steepness (LS)

The factor LS is a combination of the effect of slope length L, angle S and slope complexity over the erosion. For the Unit Plot, slope is 9% and the slope length is 22.13m. These are standard size whose Unit LS=1. In this present study, the slope characteristics ranging from 20 to 40 m long and 5 to 22 % slopes. Thus, LS is calculated by the formula by Arnoldus (1980):

$$LS = \left(\frac{\lambda}{22{,}13}\right)^{0{,}5}(0{,}0065 + 0{,}045\ S + 0{,}0065\ S^2)$$

Where λ: slope length (m), S : slope steepness (%).

The topographical factor LS is a function of the considered slope length and steepness. The more the slope is long and/or with a higher intensity, the more the LS value is important.

d) Factor of soil protection by vegetal cover (C)

C value mainly depends on the percentage of vegetal cover and growth phase (Kalman, 1967). To assess the cover rate, measures and visual estimates was made every 15 days since the seeding until the crop. Factor C is obtained from monthly data measuring the cover rate evolution whether is alive (main farming, weed…) or dead (mulch or residue). Thus, it is divided into C factor for alive cover or plant (Cp) and into C factor for dead cover or mulch (Cm). So, it is calculated by the following formula:

$$\mathbf{C_i = Cp_i \times Cm_i}$$

With : $\mathbf{Cp_i = 1 - V/100}$

$$\mathbf{Cm_i = exp\ (-b} \times \mathrm{M)}$$

where:

- C_i: C factor for period i
- Cp_i: C factor for plant
- Cm_i: C factor for mulch
- V: Alive cover rate (plant)
- M: Dead cover rate (mulch)
- b: detemination coefficient of mulch effect (b rice =0,027, b maize = 0,031, b dolichos = 0,035 and b stylo = 0,044 (Van Hulst, 2011).
-

e) Factor expressing soil protection by agricultural practices (P)

P factor considers purely erosion control practices such as tilling or ridging on curve level that modify the transport capacity of the water and on strip or terrace crop reducing sediments. It varies between 1 in bare soil without any erosion control arrangement to about 0.1, when on low slope, we practice compartmented ridging (Roose, 1996).The minimum or zero labor is considered in the factor P.

This table 1 below illustrates the different values of soil protection factor by the conservation practices (P) according to the considered soil management.

Table 1 : P factor value per type of soil management

	Conventional system	**CA System**
Mechanical tillage (reference)	1	1
Tillage (non mechanical)	0,7	
No tillage		0,2
Vegetation borders	0,6	0,6
P	**0,42**	**0,12**

Source : Van Hulst, 2011

2.1.2. Cropping systems modeled

This study has been led also in the region of Lake Alaotra for four years (2006-2010). It is based on the comparison of simulated soil loss on four different treatments:

- « **Conventional** » with two-year rotation of upland rice (*Oriza sp* L.) and maize (*Zea mays* L.) under conventional manual tillage of the soil,
- « **stylo 1**» or three-year CA rotation fallow (first year), growing stylo (*Stylosanthes guianensis* : second year) and upland rice plots cultivated with direct seeding on a mulch of stylo (third year),
- « **stylo 2** » similar to « stylo 1 » CA system but the difference is based on the seeding density and a Stylo growth less efficient,
- « **dolichos** » or two-year CA rotation of upland rice and maize plots with mulch of dolichos (*Dolichos la lab*) (Van Hulst,2011).

2.1.3. Model outcomes

The results of the five factors that provide the soil loss per treatment are synthesized in table below:

Table 2 : Values for each RUSLE factor per treatment

	Conv.	**Stylo 1**	**Stylo 2**	**Dolichos**
R (MJ.mm.ha^{-1}.h^{-1})	8487	8487	8487	8487
K (t.h.MJ^{-1}.mm^{-1})	0,038	0,038	0,038	0,038
LS	0,6 à 4	0,6 à 4	0,6 à 4	0,6 à 4
C	0,56	0,04	0,14	0,13
P	0,42	0,12	0,12	0,12

During the four years of study, the mean rainfall erosivity factor (R) was 8487 MJ.mm.ha^{-1}.h^{-1}. For soil erodibility factor (K), the average value for the different types of studied soil was 0,038 t.h.MJ^{-1}.mm^{-1}. In terms of slopes, three situations have been considered by obtaining topographical factors (LS) approximately 0.6; 1.5; and 4 but for the potential erosion (R x K x LS), the average value (1.5) was used. In this case, the potential erosion was around 484 t.ha^{-1}.an^{-1}. As for the cover management factor C, it varied from 0.04 to 0.56 and it is the « plowed system » which had the highest value of C followed by « Stylo 2 », the « dolichos » and finally the « stylo 1 ». The more the soil cover rate is high, the more the C factor value is low. Protection factor of soil erosion control practices depends on soil management mode, it is about 0.42 for plowed system and 0.12 for the CA one.

In view of these results, multiplying the five factors including the RUSLE model, the monthly cumulative soil loss for each type of treatment is shown in this Figure 1 below:

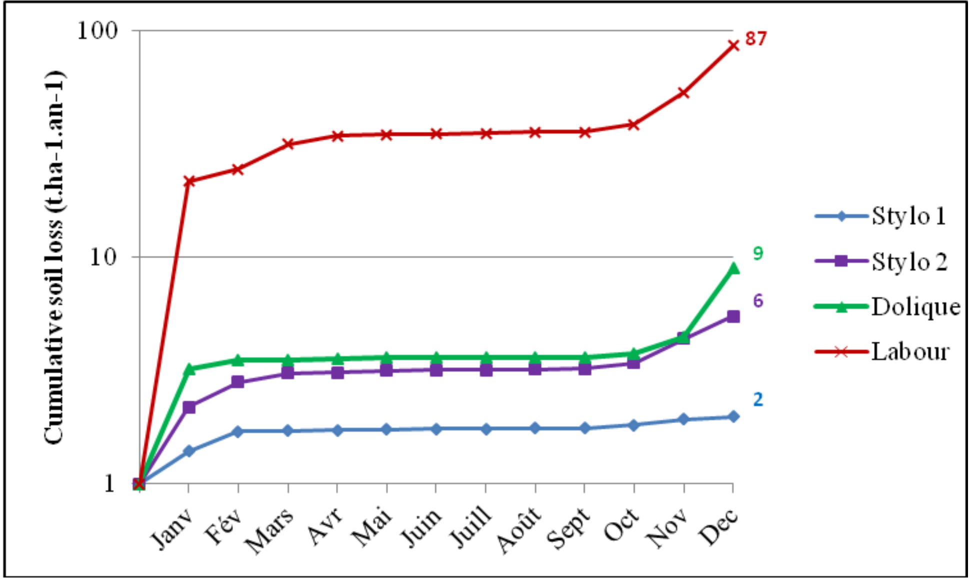


Figure 1 : Monthly cumulated dynamics of soil loss (in logarithmic scale)

The results obtained by using the prediction model RUSLE show that under plowed plots, the amount of land lost rised up to 87 t.ha^{-1}.an^{-1}. On the other hand, under CA plots, it reduced up to 9 t.ha^{-1}.an^{-1} in « dolichos », 6 t.ha^{-1}.an^{-1} in « stylo 2 » and 2 t.ha^{-1}.an^{-1} in « stylo 1 ». Hence, th is resulted in a significant difference between the plowed systems and CA system, and in order of importance of soil loss, the classification of three treatments is Labor > Dolichos > Stylo.

2.1.4. <u>Comparison of the observed and simulated soil loss</u>

The comparison focused on the 2010-2011 and 2011-2012 growing season, during which only data in soil loss observed were available for the Cala experimental station. An experimental trial based on two different slopes (7% or 25%) and the three treatments Conventional, CA of rice on maize+dolichos residue (CA-R) and CA of Maize +Dolichos on rice residue (CA-MD) was seated. Thus, the simulation was also based on these two campaigns for the local soil characteristics. The following Tables 4 and 5 summarize the values of each RUSLE factor and soil loss according to the slope and the treatment for the considered both campaigns.

Table 3 :Value for each RUSLE factor and the simulated soil loss based on the slope and the treatment during the 2010-2011 campaigns

	2010-2011					
	Low slope			**Steep slope**		
	Conv	**CA-R**	**CA-MD**	**Conv**	**CA-R**	**CA-MD**
Rainfall (mm)	637	637	637	637	637	637
R (MJ.mm.ha^{-1}.h^{-1})	4076	4076	4076	4076	4076	4076
K (t.h.MJ^{-1}.mm^{-1})	0,043	0,043	0,043	0,043	0,043	0,043
LS	0,18	0,18	0,18	1,02	1,02	1,02
C	0,624	0,205	0,185	0,663	0,225	0,222
P	0,42	0,12	0,12	0,42	0,12	0,12
Soil loss (t.ha^{-1}.an $^{-1}$)	**4,90**	**0,30**	**0,27**	**29,55**	**2,02**	**1,83**

During the 2010-2011 campaigns, a lack of rain was observed with a total height of 637 mm corresponding to a rainfall erosivity factor (R) of 4076 MJ.mm.ha^{-1}.h^{-1}. Soil erodibility factor was 0.043 t.h.MJ^{-1}.mm^{-1}. Similarly the topographical factor (LS),was about 0.18 on a low slope (8%) against 1.02 on a steep slope (24%). The cover management factor C depended on the mode of soil management; 0.6 for the plowed system and between 0.18 and 0.22 for CA. Note that the factor C on a steep slope is a little higher than on a low slope, but the difference is not significant. Concerning the protection factor of soil erosion control, (P), it has been estimated as 0.42 for tilled treatment against 0.12 for CA treatment.

The obtained results showed that for plowed systems, the cumulative amount of lost land rised up to 29.5 t.ha^{-1}.an^{-1} on the steep slope against 9 t.ha^{-1}.an^{-1} on the low slope. While under CA systems, it varied from 1.83 to 2,02 t.ha^{-1}.an^{-1} on the steep slope against 0.27 to 0.3

t.ha^{-1}.an^{-1} on the low slope and it has been the CA treatment maize+dolichos which had the lowest amount (table 4).

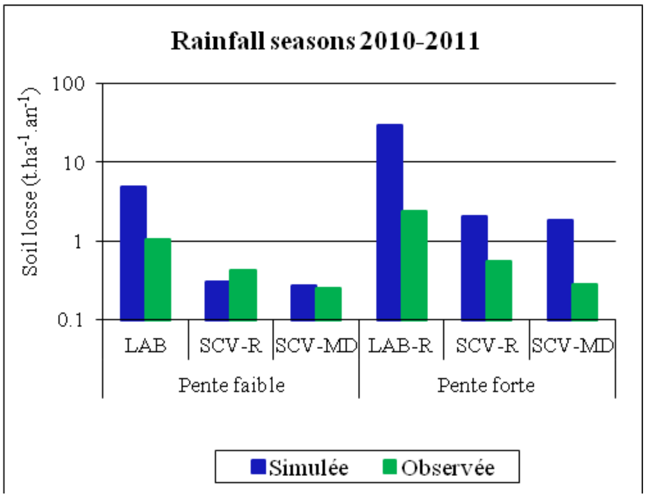
Table 4 : Value for each RUSLE factor and the simulated soil loss based on the slope and the treatment during the 2011-2012 campaigns

	2011-2012					
	Low slope			Steep slope		
	Conv	CA-R	CA-MD	Conv	CA-R	CA-MD
Rainfall (mm)	967	967	967	967	967	967
R (MJ.mm.ha^{-1}.h^{-1})	6941	6941	6941	6941	6941	6941
K (t.h.MJ^{-1}.mm^{-1})	0,043	0,043	0,043	0,043	0,043	0,043
LS	0,18	0,18	0,18	1,02	1,02	1,02
C	0,624	0,205	0,185	0,663	0,225	0,222
P	0,42	0,12	0,12	0,42	0,12	0,12
Soil loss (t.ha^{-1}.an $^{-1}$)	**9,49**	**0,61**	**0,53**	**56,98**	**3,95**	**3,64**

The total rainfall during the 2011-2012 campaign was 967 mm with a R factor of 6941 MJ.mm.ha^{-1}.h^{-1}. Others factors (K, LS, C and P) were obviously considered all similar to those of the previous campaign.

According to these results, whether on a low or steep slope, soil loss under plowed plots (9.5 and 56.9 t.ha^{-1}.an^{-1} respectively) were higher than those under CA plots (0.5 to 0.6 and 3.6 to 3.9 t.ha^{-1}.year^{-1} respectively) and these differences were highly significant (table 5). As the 2010-2011 growing season, the classification of three treatments in order of importance has been Labor > CA rice> CA maize+dolichos.

The following figure 2 shows the comparison of soil loss obtained by the RUSLE model and by direct measure during the two growing season (2010-2011 and 2011-2012).



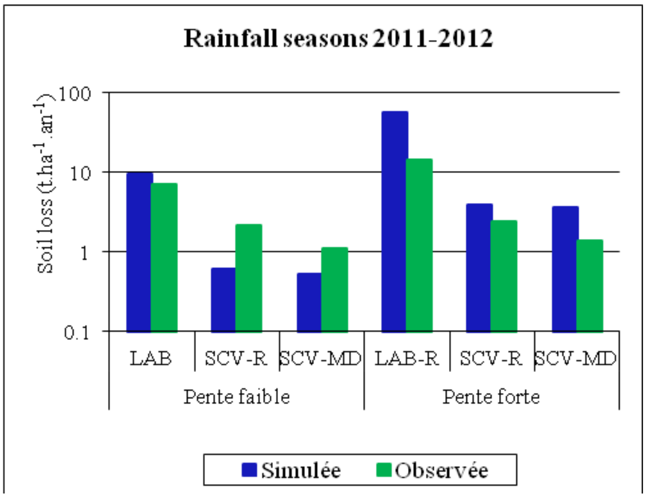


Figure 2: Comparison of observed (Observée) and simulated (Simulée) soil loss on low slope (pente faible) and steep slope (pente forte) and treatment (LAB: tillage, SCV-R: CA rice crop, SCV-MD: CA with maize and dolichos) during 2010-2011 and 2011-2012 rainy season, (logarithmic scale)

The difference between the results of direct and simulated results (RUSLE) depended on the situations (yearly precipitation and soil management mode). For plowed treatments, whether on steep or low slope, the RUSLE model overestimates soil losses. During the rainy season 2010-2011, the difference between soil loss calculated by the RUSLE model and direct measurement raised to 4 t.ha^{-1} on low slope and 27 t.ha^{-1} on steep slope. During the rainy season 2011-2012, this difference reached 2.5 t.ha^{-1} on low slope and 42.5 t.ha^{-1} on steep slope.

For the CA treatment, whatever the rainy seasons, contradictory tendencies were found on both slopes (low and steep). On low slope, the RUSLE model underestimated soil losses with a difference ranging from 0.1to 1.4 t.ha^{-1}, while on steep slope, it overestimated soil loss and the difference is between 1.5 and 2.2 t.ha^{-1}.

2.1.5. <u>Extrapolation according to soil management mode</u>

We first tried to improve the model (correction of the factor P which appeared over estimated) so that the simulated soil losses were closer to those measured directly.

For this, the P factor has been calculated from the difference between soil loss observed on land (direct measure) and those obtained from the model (by using the factor P uncorrected, see table 2). In this case, compared with the latter, the treatments considered (labor, CA-rice and CA-MD) had different P values and quite low.

Figure 3 shows the correlation between simulated and observed soil loss with a factor P « uncorrected » as well as the new factor P called « corrected ».

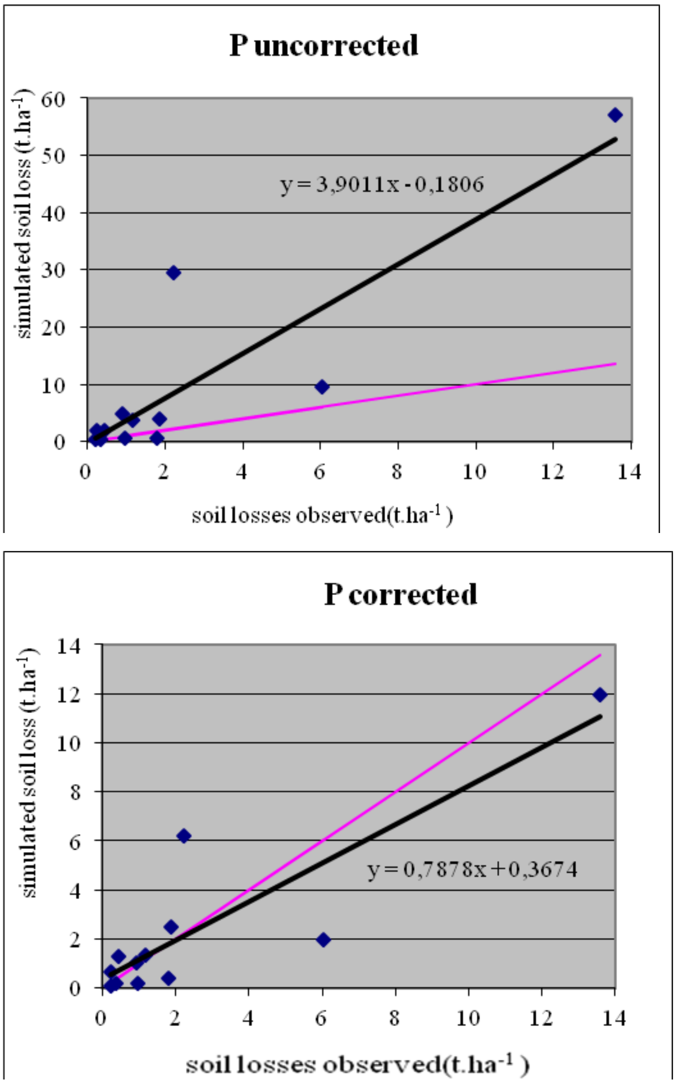


Figure 3 : comparison of the simulated and observed soil loss following the (a) uncorrected and (b) corrected P factor

To see the difference between the simulated and observed soil loss, a correlation study was made. The black line is to soil loss calculated from the model, P « uncorrected » (a) or P « corrected » (b) and the pink line for the observed soil loss. According to the results, with P corrected, simulated soil loss became closer to observed soil loss.

Then For the simulated extrapolation, R factors were calculated from rainfall data collected over 10 years (2002-2012) in automatic weather stations (CIMEL) CRR-ME in the center of Ambohitsilaozana and they varied according to the year of simulation (see appendix). The K factor remains the same as that of the previous comparison part.

Three treatments were simulated to be compared: (i) two-year rotation of upland rice (*Oriza sp*.) and maize(*Zea mays*) on plowed plots, (ii) two-year rotation of maize-dolichos association(*Dolichos lablab*) and upland rice plots with CA with dead cover mulch of rice and mulch of maize-dolichos at a rate of soil cover of 30% and (iii) two-year rotation of maize-dolichos and upland rice plots with CA with dead cover mulch of rice and mulch of maize-dolichos at a rate of soil cover of 100%. Each treatment was simulated for the two previous slope situations which low slope (8%) and steep slope (24%).

Figure below shows the extrapolation of soil loss (accumulated over 10 years) calculated from the RUSLE model based on rainfall, slope ant treatment

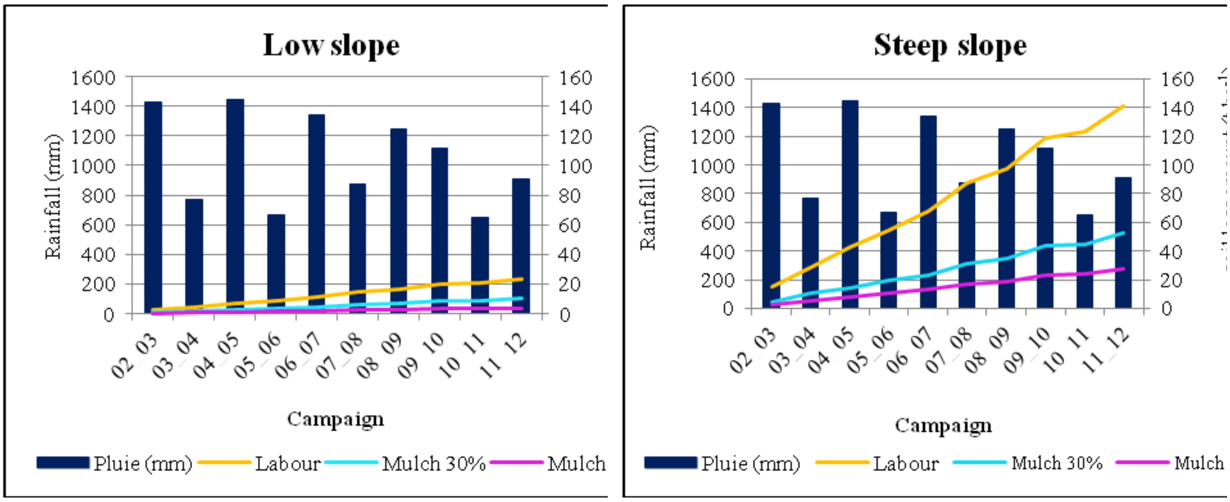


Figure 4 : Cumulative of simulated soil loss depending on rainfall and the treatment during the twelve successive years on low slope and on steep slope.

2.1.6. <u>Conclusion</u>

At the end of this study, it was concluded that soil loss on plowed plots are much more important than on CA plots. This observation is valid for low and steep slope. On low slope, compared on conventional systems of plowing (23.5 t.ha-1), the cumulative amount of soil loss over the ten years period has been two times less on CA treatment with 30% mulch (10,2 t.ha^{-1}) and six times less on CA treatment with 100% mulch(3,7 t.ha^{-1}). On steep slope, the difference became three times less on CA treatment with 30% mulch and five times less on CA treatment with 100% mulch.

The comparison of soil loss results obtained by direct and indirect estimations showed that generally soil loss calculated from direct measures were lower than those obtained by RUSLE. Therefore, to improve and calibrate RUSLE model at Lake Alaotra, a correction factor was proposed, mainly the reduction of the P factor by making the amount of soil loss by simulation closer to the direct measurement on field. So, extrapolation or modeling of soil loss depending on the soil management mode appeared valid for rice and maize crops, by using for CA systems different types of mulch the most used in the region at Lake Alaotra such as mulch of rice, maize+dolichos and stylosanthes.

2.2. Water balance: DSSAT and ad hoc modelling

2.2.1. Region of Vakinankaratra

a) Materials and methods

Experimental setup

The experiment was realized on two experimental fields that had been installed by the URP SCRiD at Andranomanelatra. The first field, also called « matrix » is a split-plot with 4 repetitions and extended on four agricultural campaigns, 2003 to 2007. Two biennial rotations on upland rice were compared, including 2 soil management methods, a conventional tillage with residue removal of the previous harvest (LAB) and a no tillage system with previous crop residue maintenance on soil surface (CA). In the secondary treatment, two types of fertilization have been compared: an organic fertilization of 5 T.ha^{-1} of cattle manure (FU) and an organo-mineral fertilization (FM) with 5 T.ha^{-1} of manure, 300 kg.ha^{-1} of NPK fertilizer (11% N, 22 % P_2O_5, 16 % K_2O), 500 kg.ha^{-1} of dolomite provide at seeding, and urea (46 % N) at 50 kg.ha^{-1}provided at tillering time. The two years of the rotation were represented at the same time on the field.

The second experimental field was cultivated during the 2009-2010 rainy season essentially on tillage and received the same dose of organo-mineral fertilization (FM) than the field 1. This field has been used to assess the cultivar parameters of models needed to simulate phenology, biomass and yield.

Table 5 : The different cropping systems studied

System	Rotation	Number of Years	Field
T	Rice – vetch* <--> Been - oats– vetch*	4	1
R3	Rice <--> Maize / brachiaria ruzisiensis*	4	1
R4	Rice – vetch* <--> Maize / soya – vetch*	4	1
Rp	Rice <--> Crotalaria / cajanus / eleusine	1	2

/ Association, - succession (concealed), <--> rotation, * cover plant (alive)

Daily values of temperature, relative humidity, rainfall, radiation and wind intensity have been measured from a weather station brand CIMEL placed on the site.

Modeling

Cropping models are used to predict the development, growth and crop yield in different conditions of climates, soils characteristics and cultural practices. For this present study, two models have been used of which the first one specific based on an ad hoc approach of modelling (called here the ad hoc model) and the other one more generic was the DSSAT model. The ad hoc model is built from the Visual Basic programming language. Inputs and outputs data of the model are organized in an Access database which is linked to the model. In DSSAT, it is CERES-Rice that is used for the study and has been already tested in many situations. Both models have functions modulating the development and growth of the plant. They differ in the setting of equations but they both describe how the plant behaves and reacts to its environment. Thus, they calculate the potential yield, soil water, phenology, produced biomass, LAI (Leaf Area Index), and simulate the development and growth of the crop. In CERES-Rice, biomass is distributed among leaves, stems and seeds depending on the stage of plant development. While in ad hoc model, yield on seed is calculated from a harvest index and a biomass. For hydric balance calculation the soil is assimilated to a single reservoir limited by root depth. Assessment of upland rice were realised during the crop cycle. On each trial, LAI and biomass were made at intervals of 30 days over 6 seeds holes in each plot. Phenology was studied considering the appearance of each stage of plant development. A new stage is considered as achieved when 50% of the population has reached this stage. Particular emphasis has been put on the flowering and maturity. Yield component at the harvest date were assessed over 1 to 3 squares of 1 m² according to the size of the plots. At the end of cycle, the variables measured were: number of plants/m^2, number of tillers and panicles /plant, number of spikelets/m^2, percentage of full seeds and average weight of seed. On the field n°2, yield components were measured over the 8 better holes of the plot.

Calibration and simulation

Calibration consisted in adjusting the model parameters so that the simulated values corresponded well with the measured values. Plots of the experiment n° 2 considered as non limiting water and nutritive parts were used to calibrate the phenology, the LAI, the biomass and the yield.

CERES-Rice

For phenology, LAI, biomass, yield, CERES-Rice calibration has been done by modifying the coefficient of genetic factors that control first the vegetative stage(P1, P2O, et P2R) then those linked to the reproductive stage (P5, G1, G2, G3, and G4) of the crop. The estimation of these stages allowed determining particularly in the phenology the number of flowering and maturity days. Once the calibration of phenology completed, coefficients linked to growth, and to yield components were adjusted to correctly represent the LAI, the above ground biomass, the number of grains per m^2, the grains ‘weight and the final yield. Hydric balance module CERES-Rice calculated on a daily basis all the process that affected the stocked water in all soil profile during the period of simulation (Ritchie and *al*., 1998).

AD hoc model

For phenology, the model simulates the development of the plant by considering that a stage *i* is achieved at *n* day. The LAI is a key variable of the model. Each day, a LAI difference is calculated depending on the phenological stage of the plant and the density of the crop. However, it can be affected by the stress of water and/or nitrogen in the two first stages of development if the crop conditions were limited for one and/or both of these factors. For biomass, the model links the production of dry material to the interception of an active photosynthetical radiation of the crop cover (efficiency interception) (Monteith, 1977). The intercepted radiation by the leaves is transformed into biomass with an efficiency which depends on species and the presence or absence of water or nitrogen stresses . The grain crop yield estimation is carried on determining the number of grains, that is determined during a fixed number of days preceding the start of the filling grains, and the weight of each grain. The calculation of water balance model is the same than from the model "Sarra-Millet" (Affholder, 2001), changed to consider the effect of mulch on evaporation and runoff by introducing proposed relations by Scopel *et al,* (1998). The calibration parameters of this model are empirical parameters of decomposition speed of mulch, of its equivalent soil cover, water storage capacity, and the threshold setting of water of the soil from which the transcription and the evaporation is reduced. The amount of mulch present on soil increases with the contributions of previous crops, but decomposes along the periods. The runoff was considered as insignificant at these sites and it has not been modelized in this study.

b) Results and discussions

Calibration

Calibration of CERES-Rice

The observed and simulated number of days to flowering and maturity are shown in figure 5.

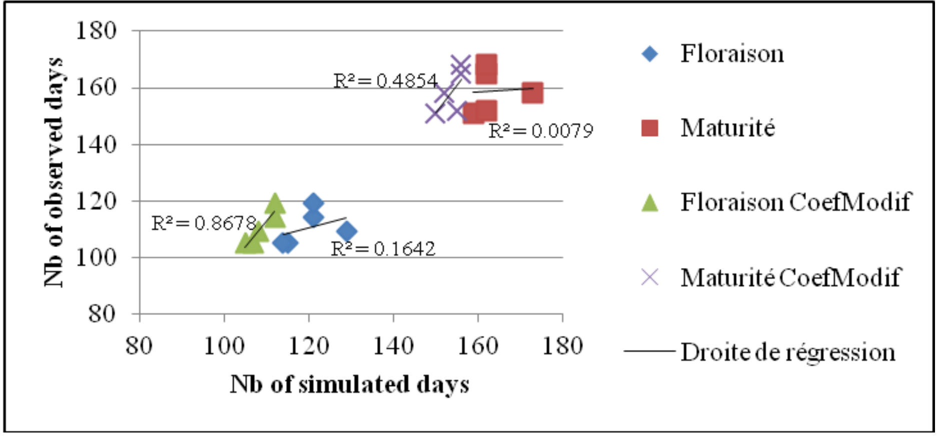


Figure 5 : Regression analysis for the simulated and observed values of number of days to flowering and maturity. (Floraison: florewing, Maturité: maturity with or without modification in model coefficient)

The comparison of observed and simulated grain yields and biomass by the CERES-Rice model is summarized in table below.

Table 6 : Variables used for the calibration of the CERES-Rice model. RMSE and number of observations used

Variable	Observed (T/ha)	Simulated (T/ha)	RMSE	n
Biomass	16.25 ± 2.46	22.35 ± 2.2	6.31	8
Yield	7.26 ± 1.4	8.74 ± 0.52	1.85	8

n : Numbers of observations that are used in the genetic of coefficient calibration.
The numbers after the ± sign are the standard deviations

The first calibration of CERES-Rice was done from genetic coefficients obtained for variety FOFIFA 161 by Gerardeaux *et al.*, (2011). By introducing those values as a test in the model, more or less large differences have been observed between the number of simulated days and those at flowering and maturity (Fig.5). New values of coefficients estimated by using Hunt *et al*. (1993) were included in the model and have reduced the difference to flowering from 9 days to 1 day.

The model was able to simulate values very close to those observed for the phenology of rice in particular the number of days to flowering and maturity. The simulated values and observed biomass and yield were in good agreement. However, there was a slight overestimation of biomass. The RMSE were 6.31 and 1.85 respectively for biomass and yield.

Calibration of ad hoc model

The table below shows the comparison between observed and simulated yields by the ad hoc model for both grains and biomass.

Table 7 : Variables used for the modeling calibration ad hoc. RMSE and number of observations used

Variable	Observed (T.ha^{-1})	Simulated (T.ha^{-1})	RMSE	N
Biomass	16.27 ± 2.46	18.34 ± 1.14	3.57	8
Yield	7.04 ± 1.49	8.32 ± 0.29	1.90	8

n : Number of observations that are used in the calibration
The numbers after the ± sign are the standard deviations

The ad hoc model was able to simulate values very close to those observed for the phenology of rice in particular the number of days to flowering and maturity. Similarly, the simulated and observed LAI and yield were in good agreement. The RMSE were 0.68; 3.57 and 1.90 for respectively the LAI, biomass and yield.

c) Simulation

- **Potential yield and achievable yield**

The following table summarize for each agricultural campaign, the simulation of potential yield and achievable yield.

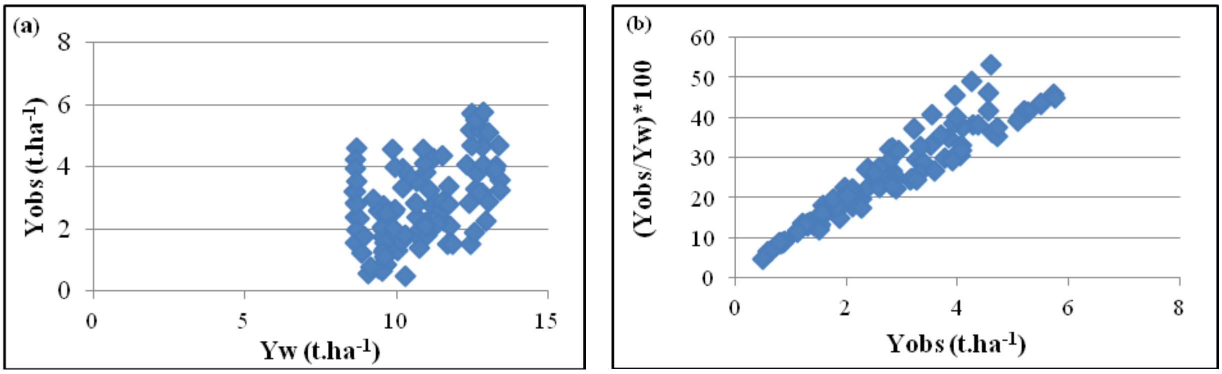
Table 8 : Potential and achievable yields obtained by simulations with the cropping ad hoc model.

Growing season	Potential Yield (T.ha^{-1})	Achievable Yield (T.ha^{-1})	Yield loss portion due to water deficit (%)
2003-2004	12.20 ± 0.12	11.14 ± 0.21	8.65
2004-2005	15.16 ± 0.20	12.70 ± 0.89	16.13
2005-2006	14.80 ± 0.16	9.22 ± 0.47	37.64
2006-2007	13.76 ± 0.19	9.76 ± 0.16	29.08
2009-2010	10.92 ± 0.56	8.51 ± 0.44	22.11

Potential yields simulated were around 10 to 15 t.ha^{-1}, while those achievable were around 8 to 13 t.ha^{-1}. The simulations results showed that water was responsible for 8% to 37% of yield losses depending on the years (Table 9). Comparing the observed yields to achievable yields (Yobs to Yw) and the achievable yields to potential yields (Yw to Y0), water stress, and to a lesser radiation and temperature, were generally responsible of the inter-annual variability of the matrix yields.

- **Observed yields with their differences in achievable performance**

The analysis focused on the percentage of achievable performance (relative yield) in each plot and defined by the ratio Yobs/Yw, where Yobs is the measured yield and YW, the simulated yield under water stress.



a) b)

Figure 6 : a) Observed yields depending on the achievable yields of the matrix. b) Percentage of achievable yield obtained on the matrix plots depending on the observed yields.

The results showed that observed yields were below 60% of the achievable yield (Fig 6b).This means that considerable losses in productivity might be attributed to other constraints than those linked to climate and water balance.

Table 9 shows the different values of observed yields and percentage of achievable yield depending in soil management method, rotation systems and different types of fertilization.

Table 9 : Observed yields (T.ha-1) and percentage of achievable yields (Yobs/Yw, in percent)

Management	Cropping system	F0	FM	FU
Conv.	R4	2.06 (19)	2.86 (26)	3.14 (29)
Conv.	T	-	3.82 (36)	3.10 (29)
CA	R3	1.31 (11)	1.98 (17)	1.83 (15)
CA	R4	1.69 (14)	2.22 (19)	2.52 (21)
CA	T	-	3.00 (26)	2.37 (21)

Conv. : Conventional soil tillage, CA: Direct seeding on cover crops F0 : None fertilization, FM : Fertilization organo-mineral, Fu : Organic Fertilization, the numbers without brackets : Observed yield and the numbers between brackets. : Percentage of achievable yield.

The results of variance analysis have shown that there was a significant effect of the year (at 1% threshold) and soil management and the system (at 0.5% threshold) on the percentage of achievable yield. On the other hand, the ANOVA showed that there was no interaction between the different factors at 10%.

Table 10 : Results of the variance analysis for the percentage of achievable yields

		Sum of the squares	Ddl	average square	F	Probability
Percentage of achievable yield	A :Agricultural year	994.89	3	331.63	4.45	0.0075*
	B : Management	1142.43	1	1142.43	15.34	0.0003*
	C : System	1258.58	1	1258.58	16.90	0.0001*
	Interactions					
	AB	232.21	3	77.4047	1.04	0.3832
	AC	211.11	3	70.37	0.94	0.4260
	BC	28.95	1	28.9521	0.39	0.5358
	Residue	3798.89	51	74.488		
	Total (crib)	7667.07	63			

All F are based on residual average quadratic and indicate that the difference is significant.

Table 11 : Average two-by-two test comparison (student test)

Main factors	Sub-factors	Percentage of the achievable yield
Year	2003-2004	25.36 ± 6.78a
	2004-2005	33.72 ± 4.01b
	2005-2006	27.53 ± 10.28a
	2006-2007	23.15 ± 9.24a
Management	Tillage	31.66 ± 7.39a
	CA	23.21 ± 6.97b
System	R4	23.08 ± 7.07a
	T	31.87 ± 7.01b

NB: The equality of variances has been checked with Barlett test. The student test has been used to compare the averages at 5%.

Comparing the percentage of achievable yield two-by-two with the student test for the different studied factors; 2004-2005 has a higher percentage of an achievable yield than other years. While, there are no differences between other years that are statistically the same. The percentage of the obtained achievable yield from T system is higher than the one from R4 system. Finally, tillage showed percentages of achievable yield superior to CA (Table 11)

We still have done an analysis variance non balanced for all the treatments with data, using the year as repetition. (Since there is no interaction with the soil management system), and we obtained the same effects with R3<R4 and F0<Fu<FM. We saw as well that Yw CA>tillage (maize around 10%) and then the depressive effect of CA on the Yobs pass by a harder depressive effect on the Yw (including possible differences in population density).

Finally we have seen that both models adequately simulate the development and growth of the rice cropping in our test conditions. We have seen that potential effect of CA on Water balance slightly influence rainfed rice production. In many cases other limiting factors may deplete observed grain yields.

Region of lake Alaotra

a) Materials and methods

Experimental fields

The tests have been conducted on different treatments of a controlled trial at the experimental station of FOFIFA at Ambohitsilaozana in partenership with the CIRAD. They consisted in 4 blocks of 30 individual plots of 100 m² observed in 2009-2011 cropping season. The Upland rice (*Oryza sativa)* was there in rotation with the stylo (*Stylosanthes guianensis)* every two years. The rice cropping was cultivated with CA techniques (no tillage, seeding on the residue of the previous year, about 5t.ha^{-1}) or plowing with incorporation of the residue (the previous residues depend on the plot before the tillage, about 5t.ha^{-1}). Thus, two levels of fertilization were applied. The F1 level was an application of 5 t.ha^{-1} of cattle manure a week before the seeding. The F2 level consisted in applying the F1 level plus an application of 150 kg.ha^{-1} of NPK (7% N, 33% P_2O_5, 16% K_2O), a week before the seeding and an applcation of urea (46% N) 50 kg.ha^{-1}, two months after seeding. Fertilizers have been applied directly into seeding holes. The data used for the calibration of the model came from plots conducted under tillage, while plots with CA were used to validate the calibration. The DSSAT software that was previously explained has been used for this study.

Calibration and validation

The data used for the calibration of the model came from the conventional treatments during the 2009 to 2011 seasons. The procedure consisted in simulating rice growthfor those two seasons and then adjusting genetical parameters of the model to minimize differences between simulated and observed variables. Variables taken into account were the date of flowering, maturity, yield and biomass.

A iterative manual approach (Godwin, 1989) was used as a first stage to adjust the different genetical parameters. Physiological parameters (settling the development of plant) have been adjusted first to wedge the phonological stages. Then, growth parameters (settling the productivity) had been adjusted to fit yields. The goal of each step was to minimize the RMSE (Table 11) between the simulated and observed variables.

Table 12 :Values of RMSE obtained for the variables used at the time of the parametization

Variable	RMSE (%)	
	Calibration	Validation
Date of flowering	9	11
Date of maturity	6	7
Grain Yield	19	17
Total biomass	26	24

To refine the manual calibration software GLUE (Generalized Likelihood Uncertainty Analysis), present in DSSAT, has been used to adjust more precisely genetical parameters A new set varying around 4% from those obtained by manual calibration has then beeb obtained.

The data used for the model validation came from plots conducted with CA for the same 2009 to 2011 seasons. Parameters were the same than those obtained from the phase of parametization, it has been incorporated to the model that these simulations were made for situations without tillage. So the seeding was directly carried out into the residues that were not incorporated. The simulations were then launched to check the correlation of output variables to those observed. In case of bad RMSE (30% threshold), the phase of parametization has been improved so as to get a better adjustment to the next validation

b) Simulation of scenarios

Two types of simulations were undertaken: one for comparing direct seeding and tillage management on a climatic serie of 11 years (2001 to 2012); the other realized on the same climatic series but in which precipitations were reduced by 10% for each event to improve the potential effect of water stress.

The model parameters for the soil and genetical coefficients for these simulations were those obtained during the parametization process. The model management part allowed to distinguish both tested factors: cropping system (direct seeding or plowing with restitution of residues) and level of fertilization (F1 or F2 corresponding to the fertilization levels of testing plots). Climate data corresponded with the climatic set of 11 basic years or to the one reduced by 10% per day for the rainfall.

We therefore compared CA for F1 or F2 to tillage on F1 or F2 on a basic climatic set or on a dryness scenario.

2.2.2. Results and discussion

In this study we considere that the rice cropping is not limited by diseases, pests or weeds. No more climatic event desecrate such as hail, strong winds or cyclons are taken into account. This means that the following results can not be extrapolated to these kind of extreme conditions.

a) Calibration and validation

The model calibration allows fixing the value of genetic parameters (Table below) which behave been used in the model for this simulation.

Table 13 :Values of genetic parameters obtained after model parametization

Physiological Parameters		Parameters of growth	
P1 (°.j^{-1})	270	**G1**	75
P2O (h)	13	**G2 (g)**	0,0267
P2R (°.j^{-1})	30	**G3 (%)**	0,90
P5 (°.j^{-1})	350	**G4**	1,00

Values of the observed and simulated variables by the model were compared. Graphically the correlation was acceptable for the phenological stages and yields (Figure 7). The differences of simulated phenoligical stages to those observed have been already observed in other parts of the world and should correspond to the thermical variations (Yun, 2003; Sarkar and Kar, 2008). The accuracy of the model has been statistically confirmed by

RMSE values which indicates that calibration set of parameters allowed to a good simulation of the rice cropping with tillage or with CA (direct seeding with mulch).

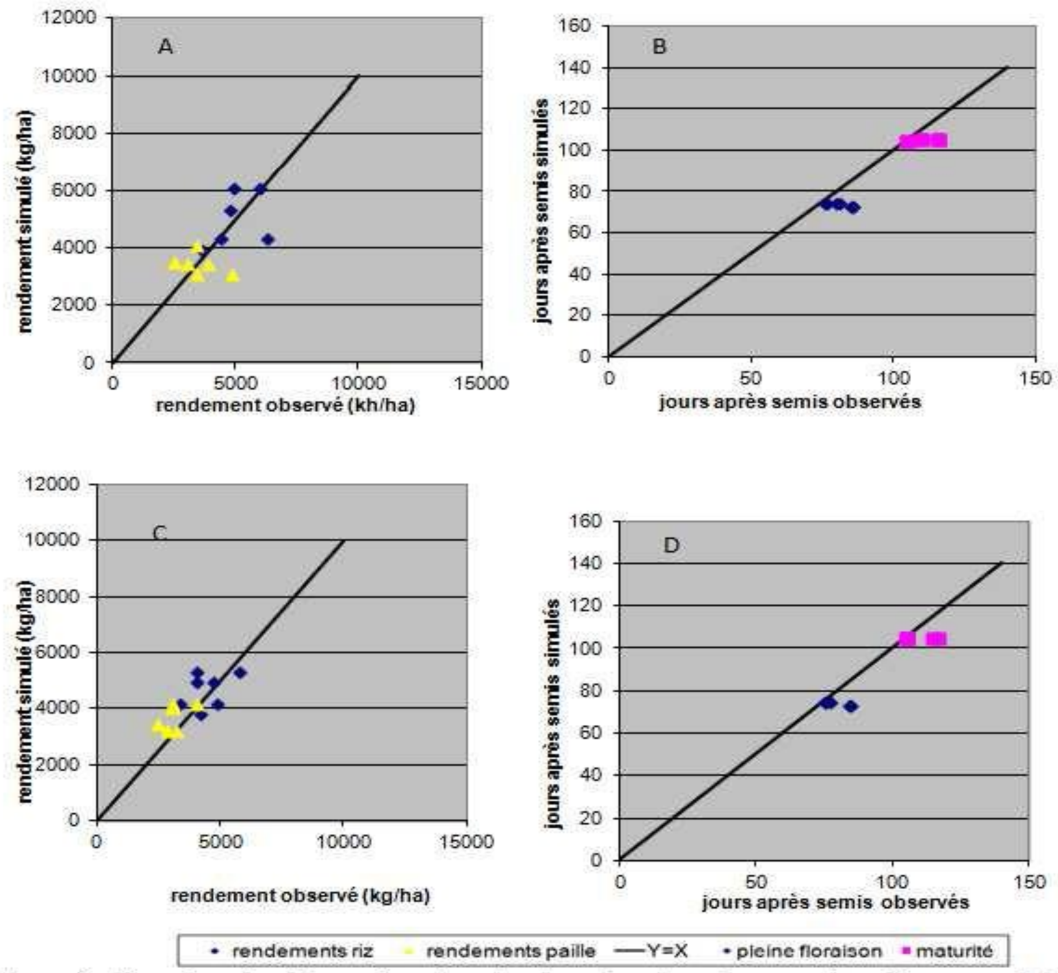


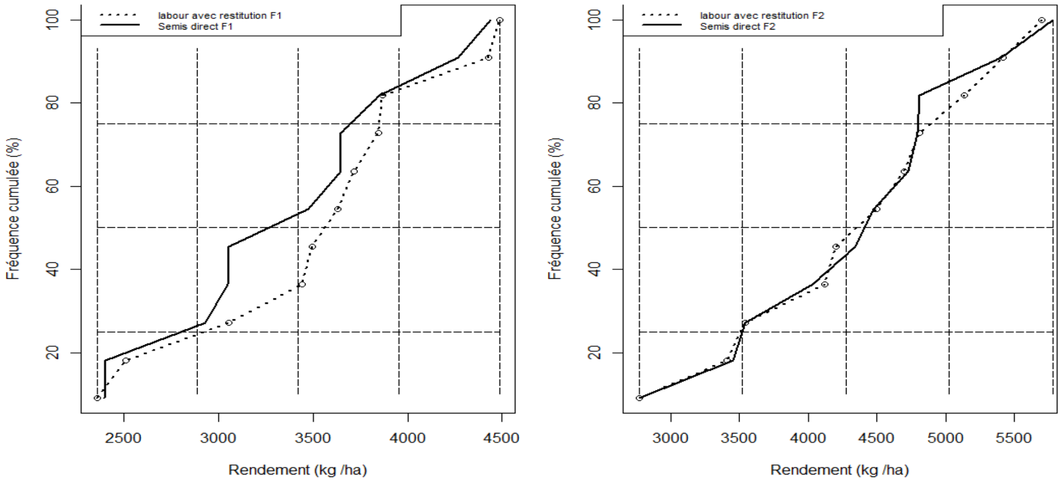
Figure 7: Simulated data depending on the observed data for A calibration (yield, y: simulated, x: observed yield) and B (days after sowing, y: simulated, x: simulated) and for C validation (yield, y: simulated, x: observed yield) and D (days after sowing, y: simulated, x: simulated).

b) Simulation

- **Comparison tillage and direct seeding**

a) *Comparison of yields*

The rice yields with CA were compared to those with plowing with restitution of residues on a climatic set of data from 2001 to 2012. To verify too a supposed effect of the level of fertilization, the influence of this level (F1 (Low) or F2 (High)) has tested as well.



a) **b)**

Figure 8: Distribution of the simulated yields by DSSAT of rice cropping with CA (black line) or conventional tillage (dash line) on a climatic serie of 11 years (2001-2012). In a): simulations with low level of fertilization F1 and b) with high level of fertilization F2

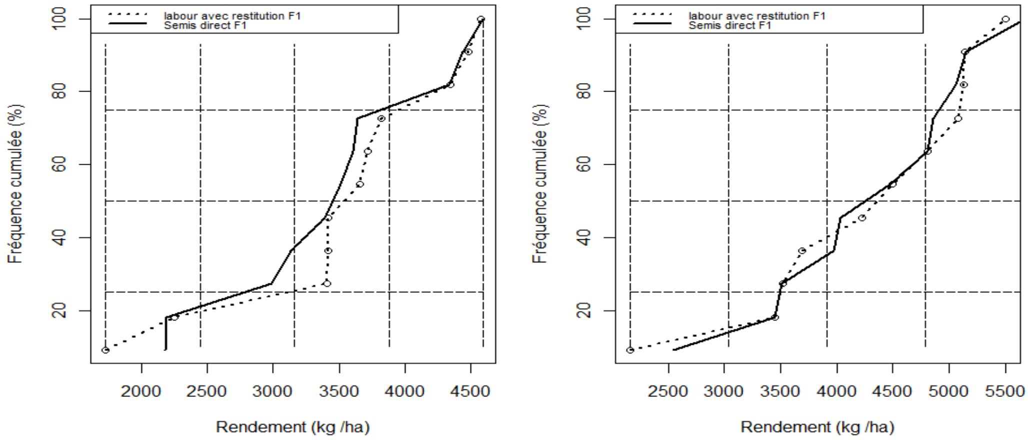
In both cases, the level of fertilization improves the yields. (Figure 8 B). Its effect is more marked in CA system because for F1, the yields on conventional tillage are better but for F2 yields of both systems are in the same order. Therefore, it seems that agronomic performance of tillage is higher than CA in the Lake Alaotra conditions. Nevertheless a sufficient fertilization greatly improved rice yield in direct seeding. On plowing with restitution, residues are incorporated into the soil and are decomposed more quickly, thus freeing mineral contribution. With CA the residues are not spread in soil so as the decomposition is very lower. The interest of fertilization in CA makes up this lack of decomposition of minerals. In case of low fertilization, the yields are very close for the both systems for the extreme values (around 2500 and 4500 kg.ha^{-1}).

However it is necessary to verify if the speed of residue mineralization on surface and of the buried residues used on the model well corresponded to the observed dynamic in that region. Additionaly it is necessary to simulate some scenarios of exportation of part of the biomass before tillage as it is often practiced by the farmers. So maybe the weight residue mineralization has been over-represented in comparison to the water factor in these simulations.

Some conditions apart from the fertilization seem to improve yields under direct seeding. It has been demonstrated that the direct seeding improves the balance of soil water (Scopel, 2005) but Ca advantage depends on the rainfall characteristics. A main components analysis on the yields, has allowed to show that in general, yields were higher on CA when cumulated precipitations per season are very low (less than 650 mm per year). It appeared too that with this calibration, the influence of the fertilization level is more important than the cumulative of precipitations. So direct seeding would be more efficient in extreme rainfalls conditions.

- **Tillage and CA comparison on pessimistic scenario**

The yields of rainfed rice under CA and under plowing with restitution of residues were compared under pessimistic scenario of lower precipitation.



a) b)

Figure 9: Distribution of the simulated yields by DSSAT of rice cropping on CA or conventional tillage on a climatic serie of 11 years (2001-2012). in which precipitations have been reduced 10 % each day. In a) : simulations with low level of fertilization F1 and in b) with high level of fertilization F2..

The two kinds of fertilization have been distinguished again. It seems that comparing to the basic scenario (fig 8) the difference of yield between the two systems is less important (fig 9). On another part, in case of strong fertilization, the yields on CA appeared to be higher to those under tilage for a few situations. Therefore, compared to basic scenario, the pessimistone highlights an additional interest of CA in the case of low rainfall situation. This result is in agreement with previous work done in this region (Gerardeaux et al., 2011) where A gain in yield stability comparing to climatically risks has been also demonstrated with CA in the context of the Region of Lake Alaotra. So CA can be adapted to this region with high climatic variability and allows to the farmers to stabilize their yields over time.

2.2.3. Conclusion and perspectives

From these studies, it was impossible to use the cropping model to assess the weight of water factor in the variability of inter-annual yield in these regions. It was demonstrated that in the Vakinankaratra, the part of yield variability due to stress water in conditions of study was not important, but at Lake Alaotra, it is responsible for a significant inter-annual variability of yields. The study also highlighted the big differences between achievable yields to the yields observed in field, even under controlled conditions, demonstrating the impact of other limitng factors for both regions.

These studies allowed us in isolating the weight of climate and water factor on the variability of rainfed rice yields. Thus, it appears that plant health problems including weeds are similarly responsible of some differences between observed and achievable yields and the difference between treatments in the test, but there is probably also an important problem of nutrition mineral crops, contributing strongly to the differences between observed and achievable yields, and to the differences between treatments.

The models tested can be used for the prediction of the potential and achievable yields with the available water in the soil conditions and the climates in which they were calibrated. Some potential advantages of CA for cropping rainfed rice (improvement of water balance, and control on water erosion) have been efficiently tested with the models f But for taking into account other potential effects of CA (weeds control, P availability, improvement of Soil organic matter stocks…) the crop models need still to be improved.

3. Modelling analysis at farm level

3.1. Optimization with linear programming : GANESH

Model used

The model used was called GANESH (Goals oriented Approach to use No till for a better Economic and environmental sustainability for SmallHolders). The full model and output is described in Naudin (2012).

The model includes three main components: i) the farm, ii) the crops, iii) the cattle herd. External factors taken into account in the model were: input price (pesticide, fertilizer, hired labor, forage), output price (milk manure, crop production) and volume of milk marketable. GANESH optimizes the total net income of the farm (from crop and livestock activities) over a three year period, by choosing: i) the crop succession to be implemented on each farm fields, by selecting among 28 crop production activities which can be combined in different ways for the three-year period; ii) the quantity of forage to be purchased from outside the farm; iii) the quantity of above-ground biomass exported from the field for cattle feeding; iv) the quantity of hired labor. Constraints applied to the optimization are: i) the size of the workforce available in the family and the labor which can be hired taking into account available cash; ii) a minimum soil cover % at the end of each year for CA fields. This value can be set between 30 to 95 %; In this study, the minimum was set to 30 % of soil cover, a value commonly accepted to be the minimum for effective organic mulching. If the biomass exported for cattle feeding leads to a soil cover lower than the chosen value, then the following crop production activities must be conventional and not CA; iii) a minimum net income to cover basic needs of the farm (including household requirements); iv) a maximum volume of milk marketable per day.

Model outcomes

After an optimization on three years it is possible to see where the model chose to select CA systems in function of the different scenarios. In our study only conventional systems were possible for irrigated paddy fields. The model chose CA systems for the whole area of poor water control paddy fields and alluvial soils, because CA was more productive in terms of grain and biomass and more flexible in terms of the cropping calendar Only for hillsides did the proportion of CA selected by the model vary according to the different parameters, such as the soil cover constraint (30 or 95 %) and the price of forage purchased from the market (Fig. 10). With 12 cows to feed and a forage market price of 0.15 kAr /kg, which is only 50 % more than the actual (2011) price in the Lake Alaotra region, it appears almost impossible to implement CA while maintaining more than 80 % of soil cover. Above a threshold forage price of 0.2 kAr/kg, it becomes cheaper to use biomass produced on the farm through CA than to purchase it from outside for all kinds of farm.

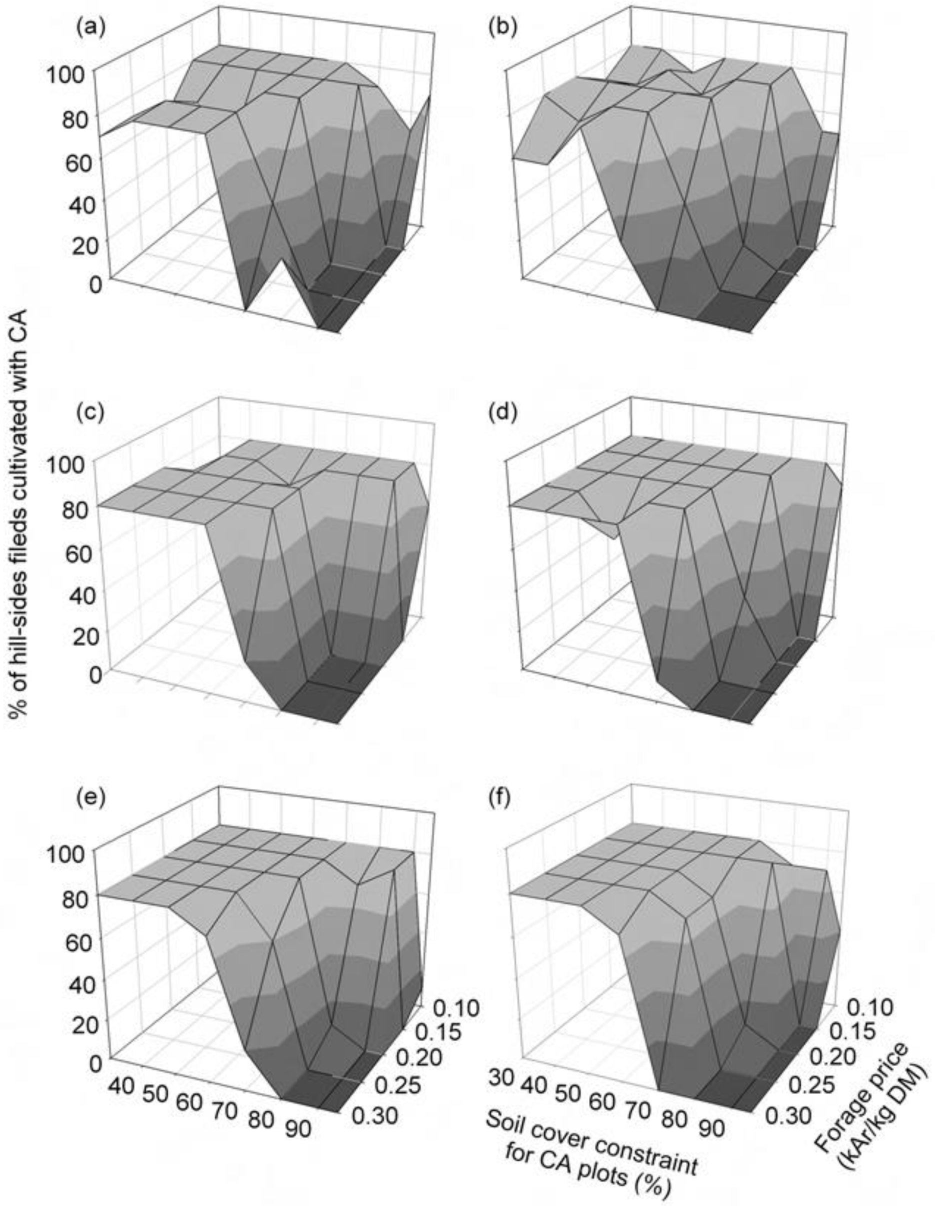


Figure 10: Percentage of hillsides fields covered by CA cropping systems, the third year: a,b medium-sized with hillsides, c,d medium-sized with irrigated paddy fields and e,f small-sized with hillsides fields as a function of an increasing constraint for soil cover of CA fields (30 to 95 %); forage. Two scenarios of milk market are explored: a,c,e open or b,d,f limited milk market. Simulations are made for farms with 12 cows.

Discussion

By using data from fields' surveys in a farm model we could explore some facets of integration of CA at farm level on small farms in the Alaotra lake in Madagascar. Setting a more or less strong constraint on the degree of soil cover to be retained on CA plots did not significantly modify the total farm net income. It was possible to maintain > 50 % of cover on hillsides for CA fields even on a farm with twelve cows. By contrast, it was impossible to keep 95 % of soil cover on these fields due to the great demand for biomass and the high price of forage. If there is less demand for crop residues, CA is a technically and economically interesting solution to increase biomass production. In conclusion, we find that CA and livestock can be compatible and even mutually beneficial. Even when there is a strong biomass demand for fodder it could be more profitable to practice CA on some fields and to purchase forage to compensate the biomass retention in the field. CA and livestock are mutually beneficial when the pressure on biomass is less intense. In this case, CA can be an efficient way to increase forage production at farm level while maintaining the major agroecological functions of mulch. Our study is the first, to our knowledge, that models the impact of practicing CA, with various degrees of biomass export, on integration with livestock and farm income for smallholders. Optimization was a useful method as it allows exploration among millions of combination of potential production systems that represent the numerous constraints and goals of the farm. It further allowed an objective comparison of the production activities, based on quantitative data and taking into account the complexity of the interactions between theses production activities at farm level. This kind of ex ante study can be useful for guiding a CA design approach to explore impacts of a possible change in the context (inputs, forage, workforce, crop animal products prices); to understand which changes and trade-offs are associated with CA systems at farm level and which types of CA systems are more suitable for different types of farm.

3.2. CA adoption in highlands of vakinankaratra : an exemple of failure

3.2.1. Introduction

In the Vakinankaratra region, several CA cropping systems has been identified to fit with the different agronomic units because of their interesting characteristics. Though, the diffusion of these technologies is quite new and the economic evaluation of these systems has to be deepened. The use of biomass as forage or as a mulch is an important trade-off that depends on milk market price which continuously fluctuates. Consequently, the optimal required time to improve a field soil (closely related to the mulch quantity) depends on market conditions. It can be quickly improved when market prices are low. On the contrary, it can be slower when market prices are high. Indeed, in this last case the mulch regeneration becomes less paying on a short-term. Thus, proposal and diffusion of CA cropping systems have to take in account the "livestock requirement" and performances. Because of the important pressure on farmable land use in the region, the easiest diffusion approach is to "add" cover plants to the farmer already existing systems. In such way, total biomass production is increased and as much biomass as possible can be returned to the soil

3.2.2. The main results on CA adoption

Several studies have been done on CA adoption since historical introduction or CA in the area in 1995 with the NGO TAFA. In 2006, RAZAFIMANDIMBY Andriatiana Jean William released a thesis on CA adoption contraints in Antsapanimahazo, Ampandrotrarana et d'Ivory (Vakinakaratra) showing severe constraints to preliminary CA tentative of adoption according to a survey of 73 local farms. In 2008, Narilala Randrianarison study the diagnosis of the same area using a cohort method to understand CA abandon in Antsapanimahazo. Maiike Hartog implement a survey for CA2AFRICA in 2010, as a Master thesis Land Degradation and Development Group submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands named " Constraints and opportunities for the implementation of Conservation Agriculture in the highlands of Vakinankaratra. The idea of CA does not raise high expectations with regard to production. This is mainly due to a lack of confidence in a no-tillage system; *´labour toujours´* seems to be the device in the studied zones. People who applied CA mention this low production level as the main economic disadvantage. Farmers without experience with CA are more inclined to decide on the basis of subsidised inputs they can get through the project.

The social threshold they need to take to get involved in the project is their weakest link towards CA. This shows that the local context involves more than 'just' climatic circumstances and financial possibilities. Changing an agricultural practice requires strong support systems that provide inputs and equipment (Corbeels *et al.*, 2011), and above all a social environment that incites and stimulates this change. Elaborating on the notion of change - the meaning of this concept depends highly on a person's circumstances. While a Dutch student may find moving to another country a big change, for a farmer in Fitakimerina a change in crop rotation has much more influence on the income of the family and issues like food security. So, one of the reasons why farmers are 'hesitant' to apply CA practices, could be that they simply have no choice. Several of the families we encountered during the survey had no capital to invest in whatever better system.

While they are the ones that can use innovation of agricultural practices, they are caught in the poverty-trap and do not have any power to choose. 'Development' in this sense means that they themselves create a way to raise their production or income. The project BVPI SE/HP has recently started the introduction of CA practices at the study locations. The CA systems that are currently used by farmers who are part of the project (table 14):

Fitakimerina	**Iandratsay**
Beans + Oats	
Maize + Beans +Oats (Iandratsay: + Potato)	
Beans + Brachiaria	Potato +oats
Cassava + Brachiaria	Potato + Wheat
Pois de terre+Brachiaria	Potato +Vetch (low part)
Pluvial/non-irrigated Rice + Crotalaire	Ray-grass + Vetch
Soja + Brachiaria	Barley + Vetch
Soja + Crotalaire	Beans + Vetch (mainly C2/C3)
Brachiaria/Oats pure	Wheat + Vetch

Table 14; CA systems that are currently used by farmers

- In the zone of Fitakimerina, the dissemination of CA practices has not been successful until now. Since the beginning of the project, the cover crops have been removed from the fields; often not with a direct purpose for fodder but to sell the crop residues or exchange it for fertilizers. This happens because the farmers cannot afford chemical fertilizers and also do not own enough cattle. Farmers also prioritize the rice paddies above the *tanety*. According to BVPI SE/HP reporting, adoption of CA practices cannot be expected in this zone (Raharison & Andrianaivolala, 2009).
- In Iandratsay, the pressure on crop residues is also high. The stalks of the maize are for example used as firewood. But there is a potential for systems that improve the 3-cropping system that is practiced on the *tanety*. In this rotation, oats can be added to provide extra biomass. It will be explained in the next paragraph (Raharison & Andrianaivolala, 2009).

Overall, CA has not been adopted in Vakinankaratra due a very high level of technical and socio-economical constraints. In 2011/12 Hanitriniaina Rrazafimahatratra E Penot and C Mc Dowall and did implement a modeling of potential promising CA and comparison with current situation (farm with no CA) integrating recent results from research (SCRID). This suggests that there might be potentially some possibilities of further CA dévelopment if some conditions change.

New rotations with crops have been tested :

Table 15: Crop rotations suggested per location

Location	A0 year 0	A1 year 1	A2 year 2
Fitakimerina	Rice + crotalaria	Crotalaria alone	rice + crotalarae
Fitakimerina	Rice	Maïze + crotalaria	Rice
Ikobona	Rice	Maïz + Common Bean → Oat	Rice
Iandratsay	Maïze + Common Bean / Potato + at	Maïze + Common Bean / Wheat + Vetsch	Maïze + Common Bean / Potato + Oat

The scenarios are suggested as displayed in this table 16:

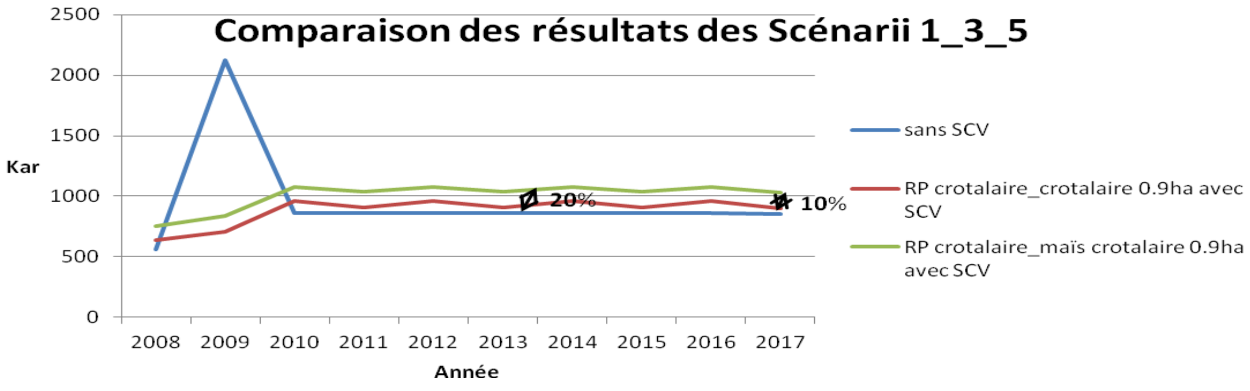
Type of scénario		Area (ha)				Notes
			CA cropping systems			
		conventionnel cropping systems	Rice crotalaria// Crotalaria alone	Rice crotalaria// maïze crotalaria	Other CA systems	
No CA	**Scénario 1**	**1.2**	**0**	**0**	**0**	**100% conventionnel**
With CA	**Scénario 2**	**0.3**	**0.4**	**0**	**0.5**	**75% CA with :** **33% rice crotalaria/crotalaria** **42% with other CA systems**
	Scénario 3	**0.3**	**0.9**	**0**	**0**	**75% CA with rice crotalaria//crotalaria**
	Scénario 4	**0.3**	**0**	**0.4**	**0.5**	**75% CA with:** **33% rice crotalaria//Maïze crotalaria** **42% with other CA systems**
	Scénario 5	**0.3**	**0**	**0.9**	**0**	**75% CA with rice crotalaria//Maïze crotalaria**

Table 16 Différents scénarii tested with the farmer RAHAINGOXXXXXXXX_ (périmètre fitakimerina)

The CA scenario is the witness. For CA scenarii CA plot area with rice/crotalaria alone move progressively from 0.4 ha to 0.9ha.

Figure 11. Example : Scenario 3 et 5 with CA: 0.90ha rice rotalaria//crotalaria. Comparison of farm net agriculturel income with and without VA

Résultats_ compte des résultats

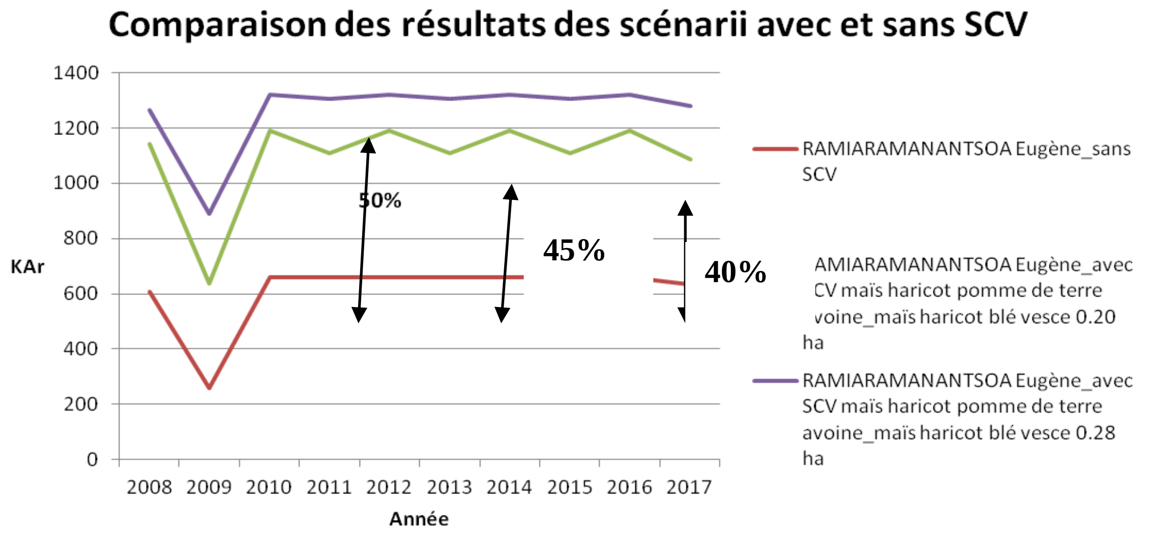


Sans SCV = No CA
RP crotalaire = rice with crotalaria

The system rice crotalaria // crotalaria alone is inferior as there is one year of improved fallow with crotalaria alone. But with Maize, the net agricultural income increases of 10% compared to the precedent CA system and 20% with no CA.

Scénario 3 with CA based on Maïze common beant/potato Oat //maïze common bean/wheat vetsch on 0.28ha

Figure 12 : Résultats_ compte des résultats



In red : NO CA
In green : Maïze common beant/potato Oat //maïze common bean/wheat vetsch on 0.2ha
In purple : Maïze common beant/potato Oat //maïze common bean/wheat vetsch on 0.28ha

CA potentially may increases farm net income of 45 % with 0.20ha of CA and 50 % with an area of 0.28ha compared to non CA farm. Eventually, Julie Dussere and colleagues from SCRID released a paper called ‘Upland rice production under conservation agriculture cropping systems in cold conditions of tropical highlands (Julie Dusserrea, Jean-Louis Choparta, Jean-Marie Douzeta, Jacqueline Rakotoarisoab, Eric Scopela in Field Crops Research 138 (2012) 33–41. In response to the extensive development of upland rice on the hillsides of the Malagasy highlands, alter-native cropping systems based on conservation agriculture have been recommended to halt loss of soil fertility. To assess the yield performances of these cropping systems, an experiment was set up in 2003 at Andranomanelatra (1640 m asl) in the Malagasy highlands. Grain yield, yield components, biomass accumulation and nitrogen uptake of upland rice were analyzed in the 2004–2005, 2006–2006, and 2006–2007 seasons, and root length density was measured in the 2007–2008 season. The rice crop was planted every second year following two different crops: maize intercropped with soybean (M + S, with both conventional tillage and no tillage) and maize intercropped with Brachiaria ruziziensis (M + B only with no tillage). For each cropping system, two levels of fertilization were used: no fertilizer or applica-tion of organic inputs and mineral fertilizer. The season, cropping system, and fertilization treatment had significant effects on rice grain yields. Higher yields were associated with a greater number of plants per m2, which decreased significantly over the three seasons, probably due to the highly variable beginning of the rains, and in the final season, with attacks by soil insects. The rice yield with conventional tillage was the highest and differed significantly from rice yield when maize was intercropped with Brachiaria under the no-till system, but not when the maize was intercropped with soybean with no tillage. In all three seasons, grain yields were closely linked to crop N at harvest. Differences in N uptake between treatments appeared very early in the crop cycle. Under conventional tillage, root length density at 68 days after sow-ing was higher between 0 and 30 cm depth than with no tillage. In these cold highlands conditions, plant establishment appeared to be more difficult with no tillage and resulted in reduced plant development and plant N uptake, particularly when rice was planted after maize intercropped with Brachiaria.

3.2.3. <u>The main contraints to CA adoption in the highlands</u>

The main technical reasons are the following

1 Growth delay of rice in CA system

- delay in soil biological activity and plant growth : soils remains cold due to the mulch, if mulch is existing (in experimental conditions with soybean maize and Maize Bracharia) (Julie 2012) if a graminae is present in the rotation : delay in rice production (not seen with maize).
- Rice is a plant more difficult to associate with others compared to maize for instance
- Phenomena of “nitrogen deficiency due to mulch” due to Bracharia in the system.
- Rice roots grows more rapidly with tillage

2 Coldness :

We observe a real difficulty to produce biomass in counter season and to keep it dur to coldness during 2 to 3 months.

3 Competition biomass mulch/animal feeding

There is effectively in this area, called “the dairy triangle” a very strong competition for the use of biomass between livestock requirements and mulch for CA croppig systems.

4 Complexity of current CA cropping system

Existing and suggested CA cropping systems are effectively relatively complex to implement with respect to specific agronomic requirements but local people are quite used to complex cropping systems with up to 4 associated or successive plants a year.

5 Difficulty to control weeds compared to tillage

CA systems implies a full control of weeds regarding their complexity and it is even more complex to control if linked with dry seeding technique for instance or rice : it has been proved that to control weeds need an almost perfect 100 % covering mulch (K Naudin, 2011).

The main social and economic reasons are the following :

1 Small cropping area with priority to food security

Farms have a very small cropped area, between 0.4 and 0.6 ha in average. Therefore modifying rotation to include CA is a potential risk for food security: there is in fact no possibilty to do unproductive fallow or period/plot with no production

2 Global farmers'priority to upland rice

Farmers always give priority to rice, whatsoever , in particular since several years to upland rice with even rice on rice rotation pattern. We observe a double phenomena : increase of upland rice area in general and new rice /rice rotation on upland that will lead very rapidly to fertility problems as rice is a relatively exigent crop in terms of soils fertility. It is therefore a real difficulty to suggest CA complete rotation that could be compatible to farmers 's objectives or priorities.

3.2.4. Conclusion

New CA cropping possibilities from SCRID do exists :

- Systems maize with crotalaria seems to be prominsing ; no need of herbicids to control weeds and crotalaria cannot be used as forage. Crotalaria has a negative effect on white grubs.
- Mais + crotalaria, + cajanus and Eleusine finger millet //rice in year 1 (A1): technically could be feasible work BUT does not fit farmers global strategies.

But still these systems are not yet adopted as BVPI-SEHP, the main local development project ended in octobre 2012. The only CA Systems rice // maize + common bean/ oat currently used by less than 30 farmers in BVPI development project is even not stable: oat does not generally provide sufficient biomass for mulch. Rice being the priority crop : TAFA has proposed in the past maize and legumes based CA cropping systems : maize with Desmodium, common beans with Kikuyu (*Pennisetum clandestinum*) : but no adoption has been observed as most systems were without rice, rice being farmers' priority. Rice is i) the stapple food that contributes mainly to self sufficiency and ii) sales of rice are valuable as rice price is high compared to maize for instance.

Priority is given as well to livestock and dairy production as soon as farmers can afford it. Therefore, competition for biomass remains one of the most powerful constraints. Dairy production is the main potential output for farmers who have sufficient land to feed their animals. The second global trend is the explosion of upland rice cropping. Such trend will lead very rapidly to a real problem or soil fertility management by farmers: how to maintain upland rice in systems with such conditions?

Farmers will have to take in to account both on erosion and fertility management. That will required:

- Introduction of plants to regenerate fertility , compatible with local demand, probably linked with CA systems
- Integration with livestock : better efficiency of manure (currently the only fertilizer used by farmers as mineral fertilizers are not anymore used since 2008). .

Farmers that have never tried to implement CA, are often under informed about the system. Witnessing other people abandon CA is also a reason to stay away from it. In cases where people have tried CA but abandoned it after some time, the organization of the dissemination turned out to be problematic. Credit can only be obtained when one is a member of a farmer's association (*association d'agriculteurs*). There is a lot of critique on these organizations. Complaints are about the delivery of inputs and material, that is often late. (Randrianarison et al., 2007). TAFA offers no assurance if the harvest is lost, which can happen through natural causes. Razafimandimby (2007:32) concludes that the credit system should become less rigid, to enable more farmers to profit from it.
In conclusion, the Vakinankaratra highland area suffers from major technical constraints linked with major socio-economic lead to a a situation where CA does not provide a solution acceptable for local farmers. The do observe a new situation with the recent boom on upland rice on *tanety* , opening a new field or research to propose solutions for soil fertility maintenance with rice based cropping systems.

3.3. Lac Alaotra : an example of a relative success - Farming systems level modelling using the tool Olympe

3.3.1. Introduction

CIRAD has developed (with INRA and IAMM) a software called « Olympe » that enable the modelling of farming systems in order to characterise them, to identify typologies (and potentially recommendations domains) and enable prospective analysis according to price and yields evolution.. There is also a module that permit the analysis at the level of farms groups (regional level). Positive or negative externalities can be integrated. With "Olympe," it is possible to build several scenarios according to price, climatic events or various types of risks. It is also possible to calculate impact at the regional level on various groups of farms (according to a typology). Building scenarios allows a prospective analysis. One of the main outputs of such approach is to assess impact of technical alternatives or choices at the farming systems level, on the economic point of view as well as on the environmental point of view. Olympe is feed with data from adapted farming systems surveys and will provide key information in terms of diagnosis and, further on, in term of prospective analysis.
Tools for the comprehension of farming systems based on simulation and modelling such as the software "Olympe" (INRA/CIRAD) allow a comprehensive understanding of how a given farming system functions, as well as provide a tool to model prospective technical choices, price scenarios, and even ecological scenarios (for example taking into account the impact of El Nino in given years to test the robustness of technical choices and their adaptability in new conditions or environments). These tools have been validated by experiments and activities in

the field. In addition to the Participatory approach and on-farm experimentation, tools for decision-making aid such as SIG,

Olympe has been widely used during the training periods of Joana Fabre, Colomban Mac Dowall and Lionnel Cottet to test a wide range of scenarios. A synthesis in french is available to identify all scenarios effectively done (By José H Andriarimalala , Eric Penot, 2012).

3.3.2. *Methodology*

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. After selecting the sample non-CA plots, yields classes were determined for each culture. The calculation of the coefficient of variation for each class in which the sample was large enough showed a high variability of the data (coefficient of variation greater than 30%). In addition, the number of plots available for each crop and class is too small (less than 10 plots) to be representative. Has therefore imposed for the remainder of the study the need to acquire information on these conventional systems mainly present at the Alaotra lake.

The major study areas were determined using the following criteria: 1) surfaces in CA and 2) accessibility. CA surfaces are low in the west (100 ha) is in contrast to the northeast areas (430 ha) and southeast (550 ha). The “old” CA surfaces (perpetuated for at least three years) in the western area count only 3,6 hectares against 34,2 hectares in the northeast and 46,1 hectares in the southeast (BRL 2010). Areas northeast and southeast have been selected for the study.

Table 17

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)

3.3.3. *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 farms were selected from the BVLac database 2009-2010 campaign processed with PivotTables. The first criterion was therefore the immediate vicinity from the farm of FSRMN concerned. It is assumed that on one restricted geographical area there is a uniformity of practices among farmers. The second criterion is the type of farms. Among the neighbouring farms, were selected the ones whose type was the same as the FSRMN farm concerned. The third criterion is the proportion of surface in CA on *tanety* and *baiboho*. The selected farms were with the lowest surface of CA on both toposequence.

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 modelling 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...).

3.3.4. Main results

a) A wide range of systems

Disseminated systems are very diverse voluntarily to be adapted to multiple cropping situations and types of farming systems. Indeed, the biophysical characteristics of an agricultural unit determines the degree of risk that the farmer is willing to take, the higher the risk, the lower the investments are. 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 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 table below presents a synthesis of CA systems distributed according to the toposequence

Table 18: 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

b) 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 interannual rotation maize//upland rice on mulch of crop residues; maize is associated with a 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).

c) 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). Moreover, despite a prohibition of sharecropping in 1975, it remains a common practice with the tenancy (oral leases). In popular culture the cultivation of land over 5 years is seen as an attempt to appropriate the land. This belief limits the term of the leases of rent or sharecropping. Because of short terms leases the cultivation of the rented or sharedcropping plots, has therefore a high risk in terms of investment as opposed to owned plots. 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 the investment made by the farmer will be partly recovered by the landowner. In sharecropping the harvested crop is split in two between the farmer and the landowner. Also, often when the farmer gets a good crop year after year, the landowner 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 northeast are rented or sharecropping and 22% in the southeast. 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.

d) 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 economic indicators (Appendix 6) following (Faure et al. 2009):

- 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 two economic indicators (Faure et al. 2009) include:

- 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 cannot be quantified.

. The database operation has been updated with this new typology (Table 19 3).

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 of 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**

Table 19: 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.

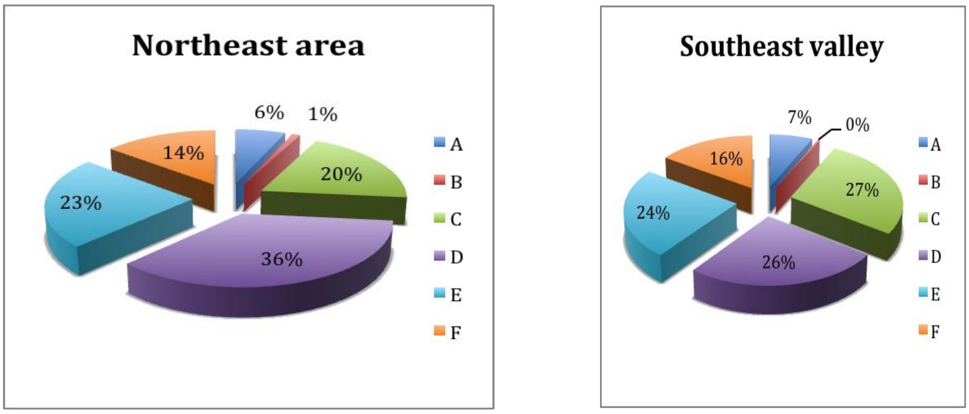
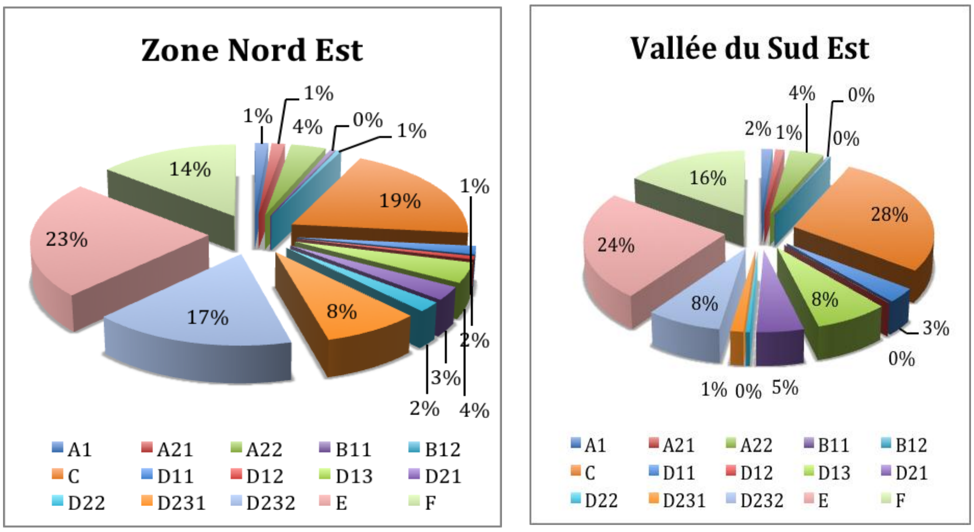


Figure 13 : Distribution of main types of farms in areas northeast and southeast of Lake Alaotra.

Figure 14 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%).

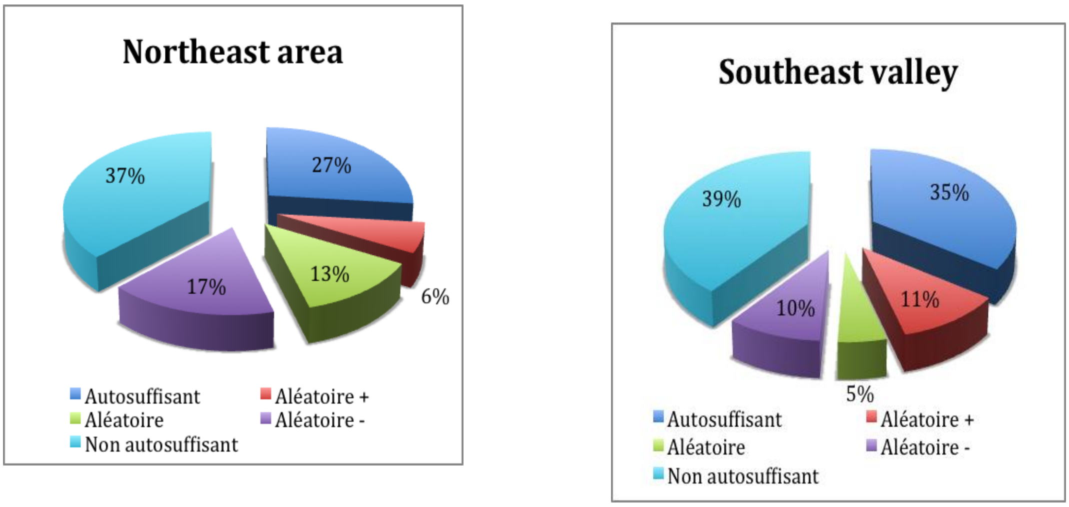


Figure 15: Distribution of farms in the northeast and southeast according to the self-sufficiancy in rice critirion

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

Table 20: 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 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).

e) 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.

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. In conclusion, the modeling of standardized farms will take into account the diversity of data in order to remain the closest to average situations.

f) Analysis of the diferent practices adopted spontanously by farmers: a mix of practices

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 21 : 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.

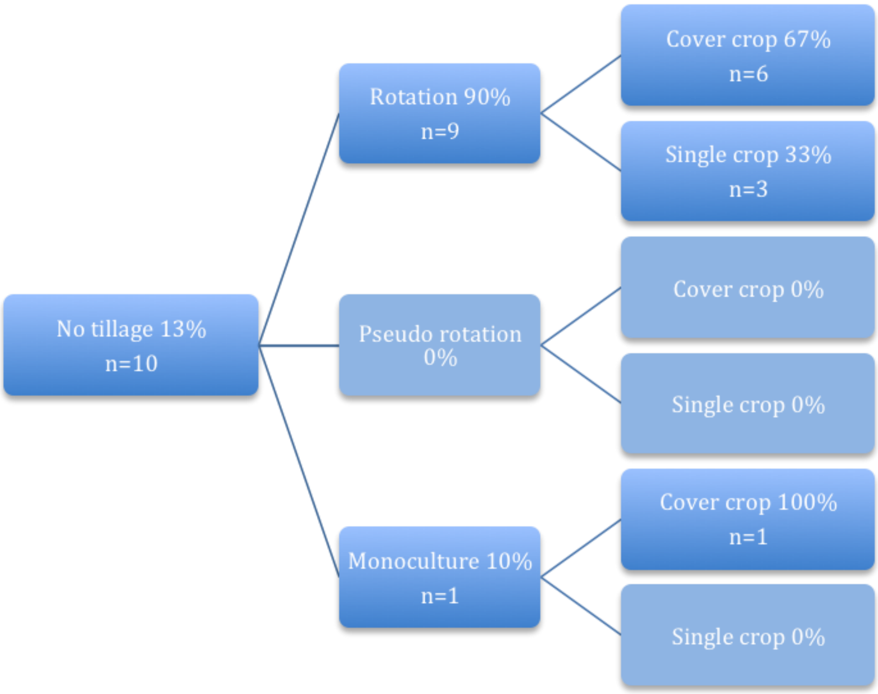


Figure 16 : Distribution and combination of cultural practices associated to no-tillage (n=10)

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).

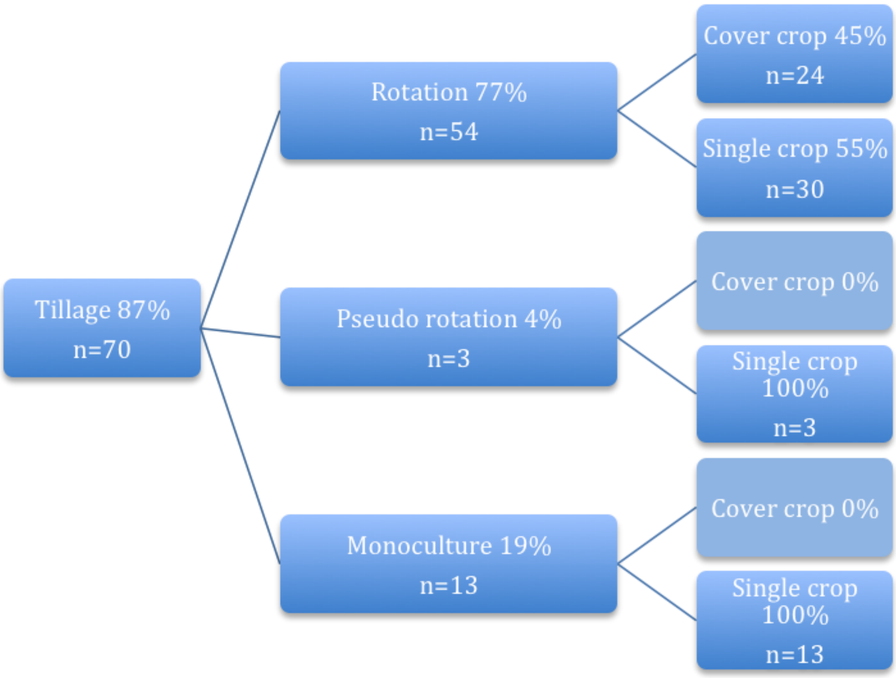


Figure 17: Distribution and combination of cultural practices associated to tillage (n=70)

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 Lake Alaotra. 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.
The above results on upland cropping system practices showed that crop rotations are 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 upscaling of this technique was encourged by the project.

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.

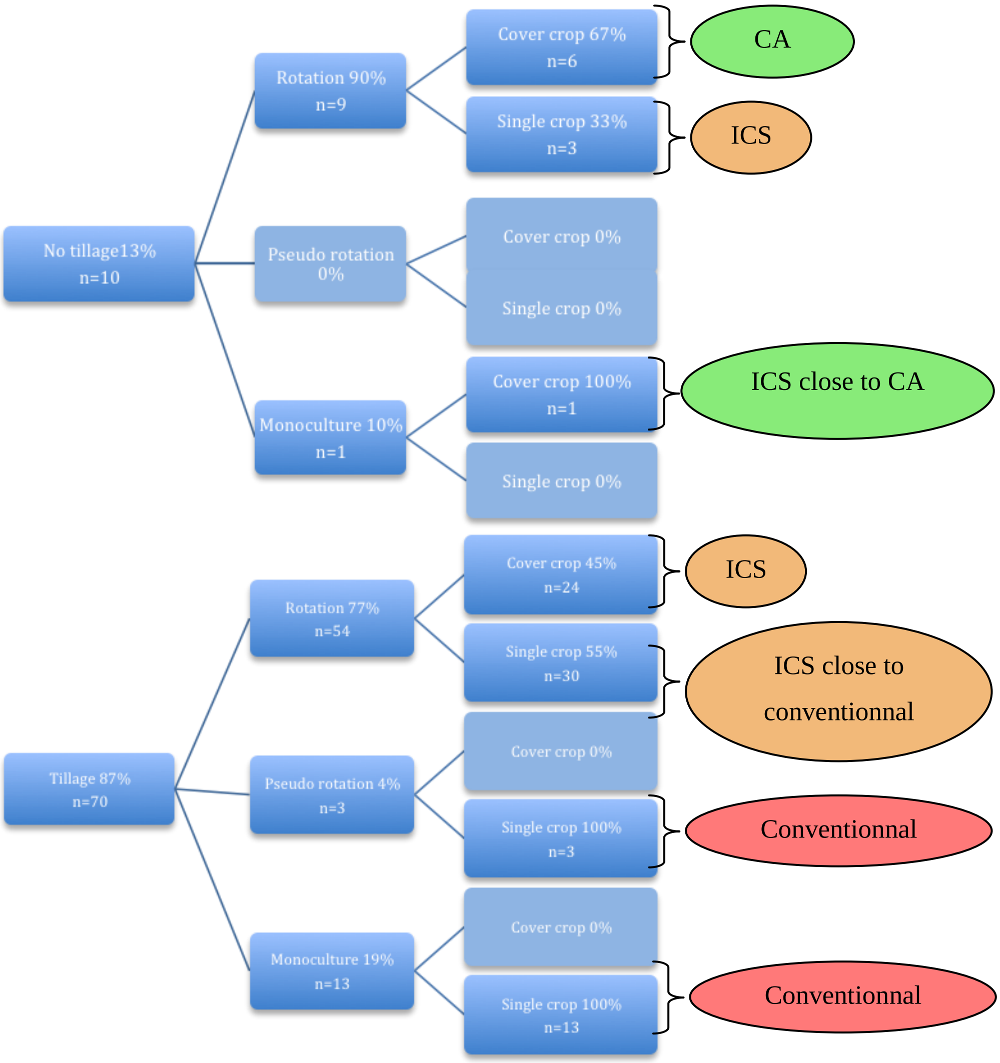


Figure 18 : Cropping systems defined according to the combinations of practices

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.

3.3.5. *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.

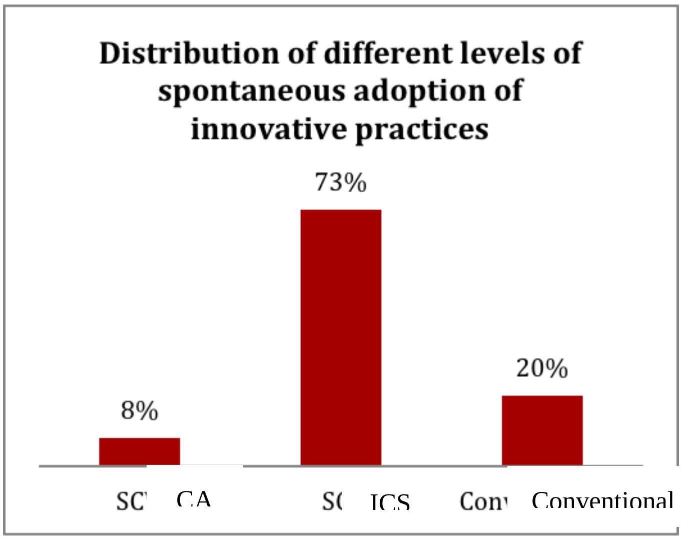


Figure 19: Ratios of plots based on the level of adoption of CA practices (n=80)

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.

The table below shows the standard rotations or crop sequence established from different rotations observed during surveys in 2011.

Table 22: 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)

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 23 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%

a) Farms in the Southeast Valley

Comparison of farm type C

Economic viability of the farm

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 (Table7). 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 the 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.

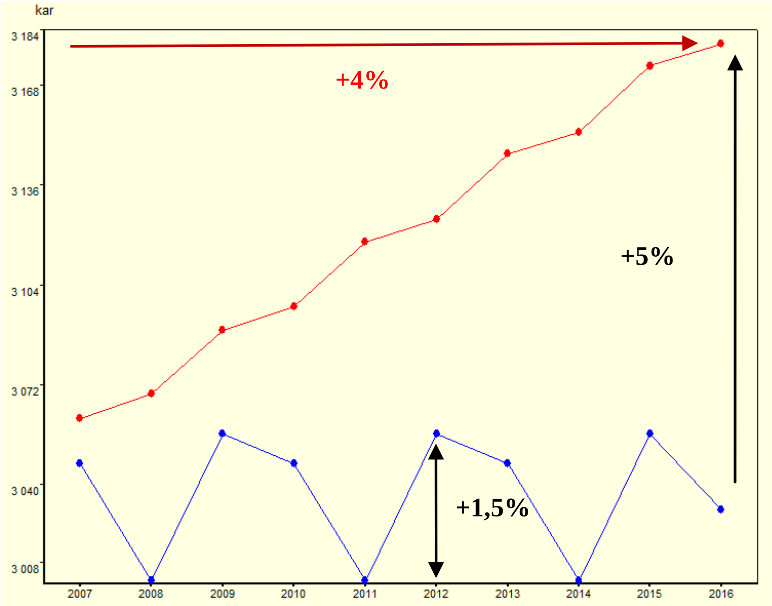


Figure 20: Comparison of farm income of CA and ICS systems of type C farm for VSE area

The cash balance (Figure 9) 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 21 : 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 10) 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.

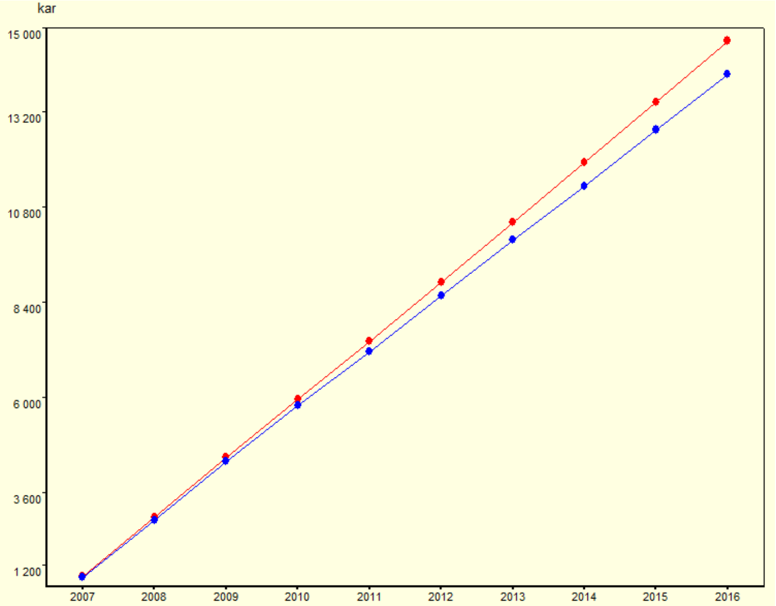


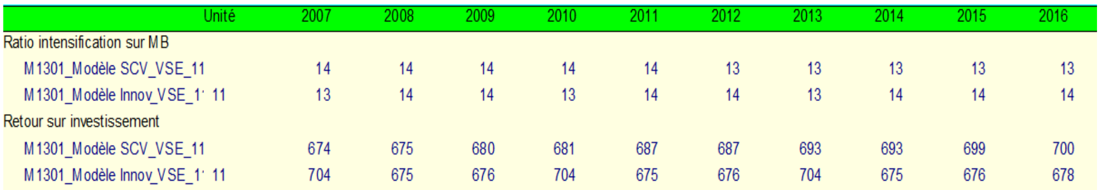
Figure 22; Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the VSE area

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

Table 24. Results of intensification ratio and return to capital over 10 years for the type 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

Economic viability of the farm

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.

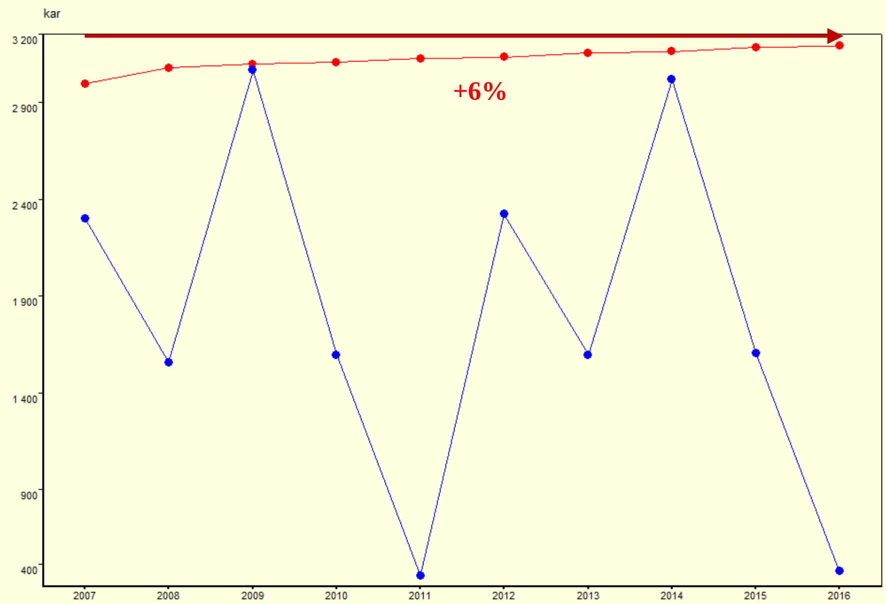


Figure 23: Comparison of farm income of CA and ICS systems of type D farm for VSE area

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 13). 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.

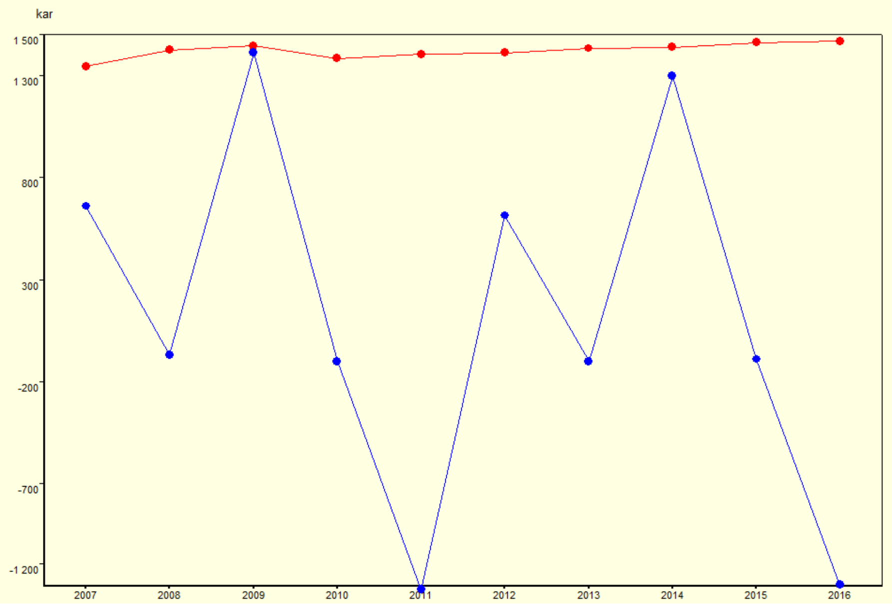


Figure 24 : Comparison of the farm cash balance in ICS and CA system for the type D farm in the VSE area

The difference in cumulated cash balance (Figure 14) 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.

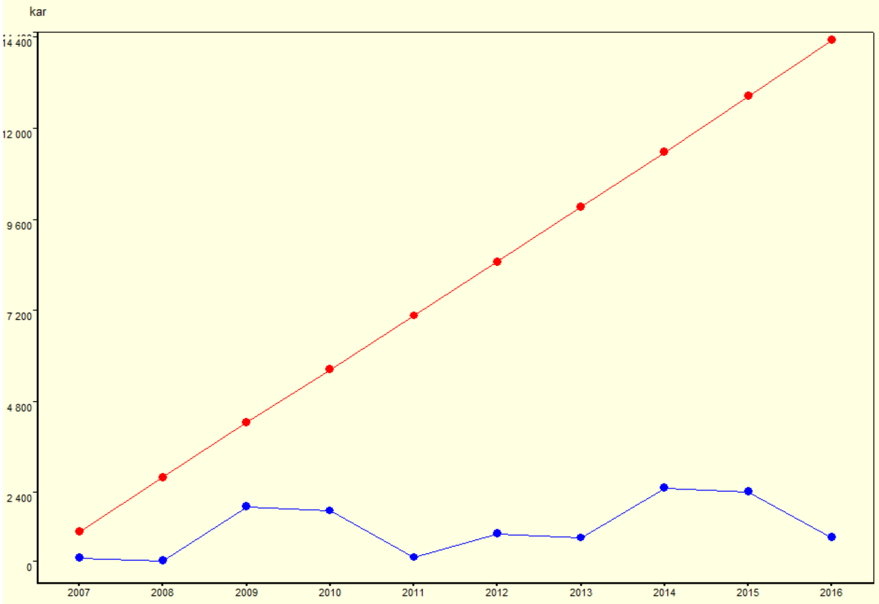
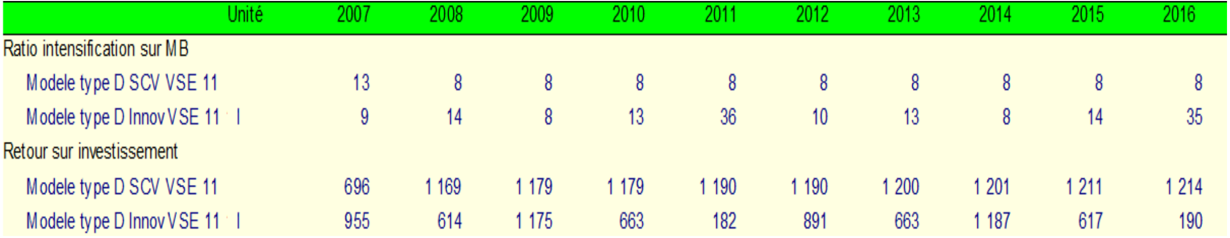


Figure 25: Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the VSE area

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.

b) 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

Table 25: Results of intensification ratio and return to capital over 10 years for the type 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 ICS is 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

Economic viability of the 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 15) 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.

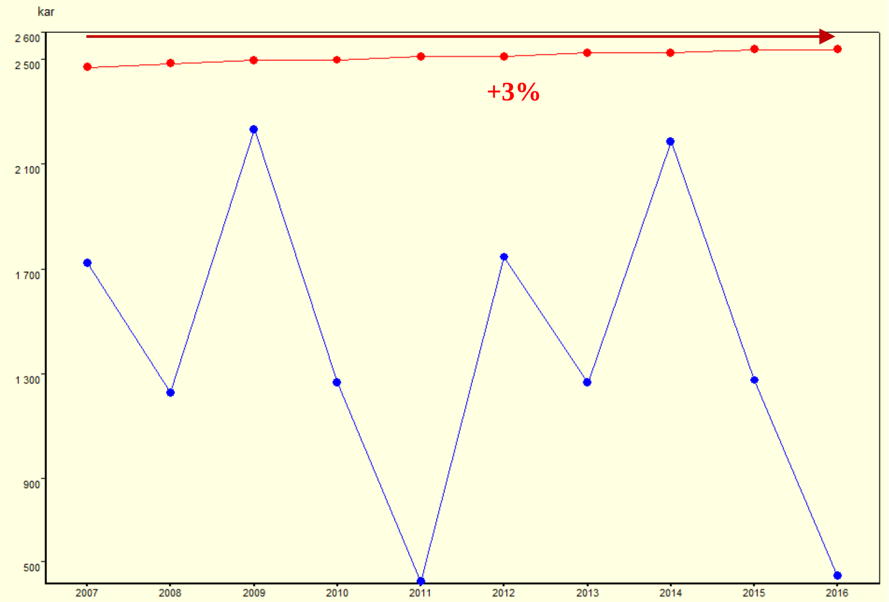


Figure 26:Comparison of farm income of CA and ICS systems of type E farm for VSE area

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 16) 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.

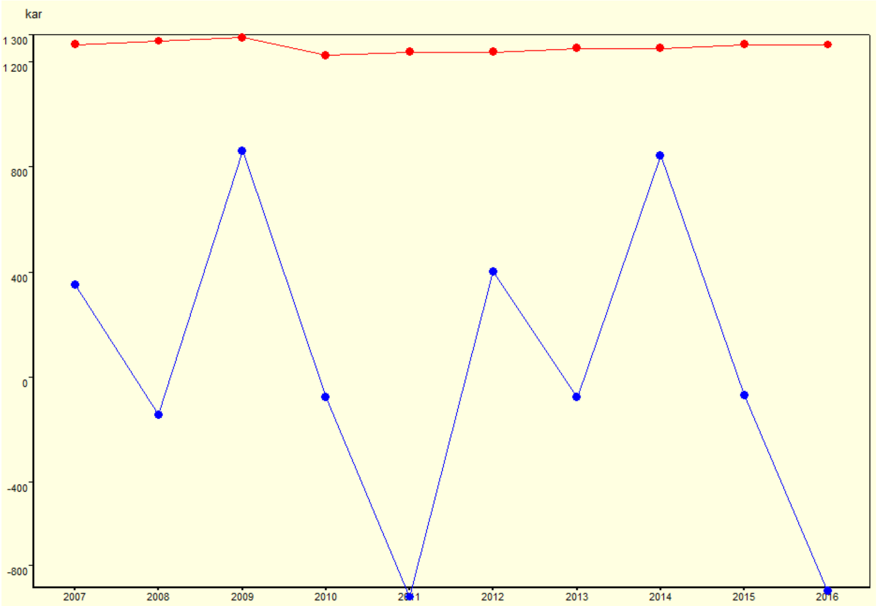


Figure 27: Comparison of the farm cash balance in ICS and CA system for the type E farm in the VSE area

The cumulated cash balance (Figure 17) 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.

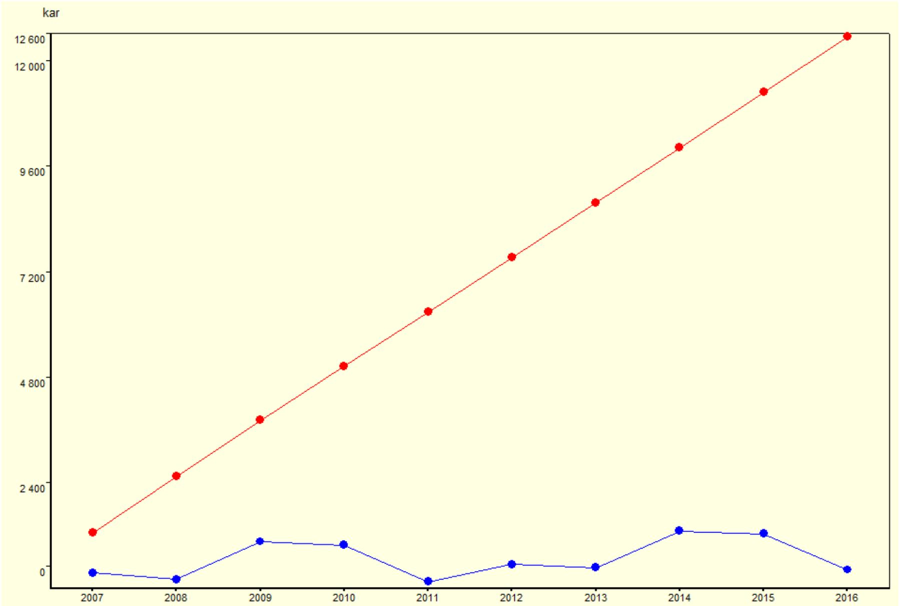


Figure 28: Comparison of the farm cumulated cash balance of ICS and CA systems for the type E farm in the VSE area

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 expenses. The farm is not really viable. CA systems allow a type E farm to secure income by more regular rice production on PWCPF, and also significantly improve rainfed productions.

Conclusion on the southeast farms

The CA systems have a lower overall economic impact on type C farms. Irrigated rice fields generate indeed most of their income. Rice production is a key factor in farm income. For type D and E farms that 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 cash in 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 does not include 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.

c) Farms in the northeast area

Comparison of farm type C

Economic viability of the farm

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.

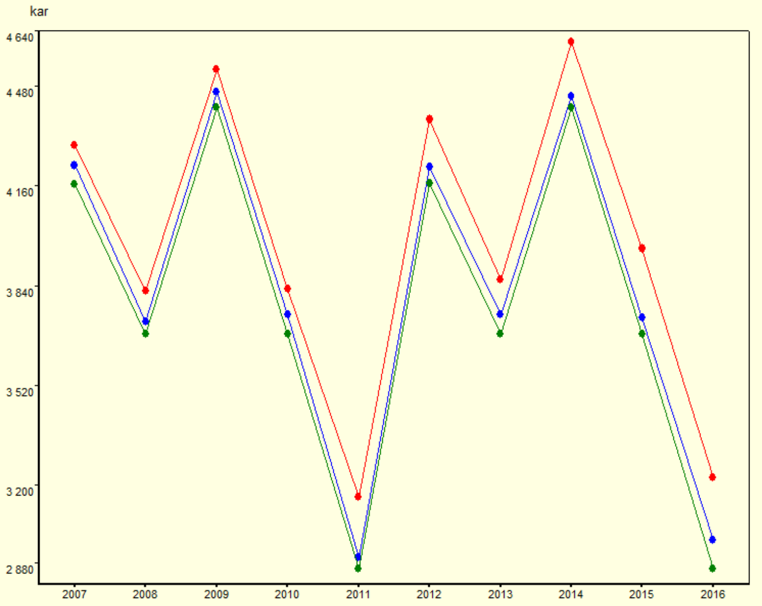


Figure 29:Comparaison of farm income of CA and ICS systems of type C farm for ZNE area

The cash balance (Figure 19) 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.

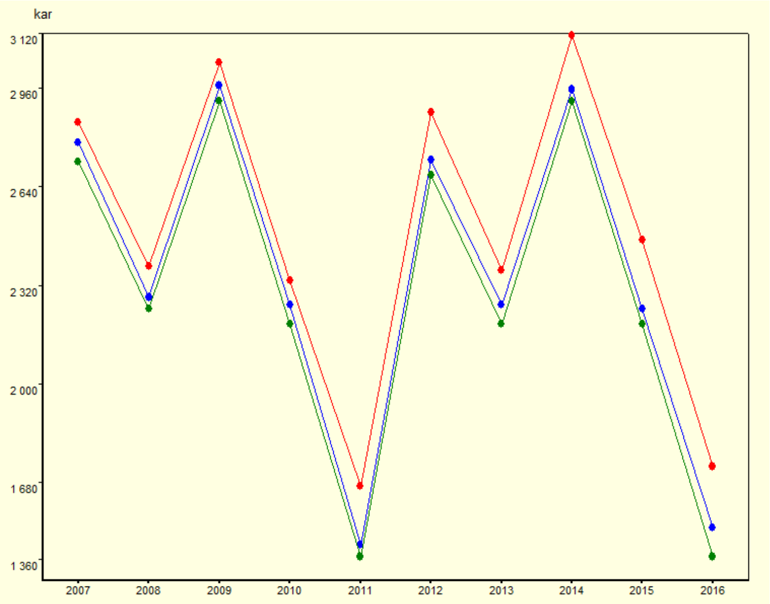


Figure 30 : Comparison of the farm cash balance in ICS and CA system for the type C farm in the ZNE area

The cumulated cash balance over 10 years (Figure 20) in CA system is greater by 5% compared to the ICS and 8% compared to the conventional system.

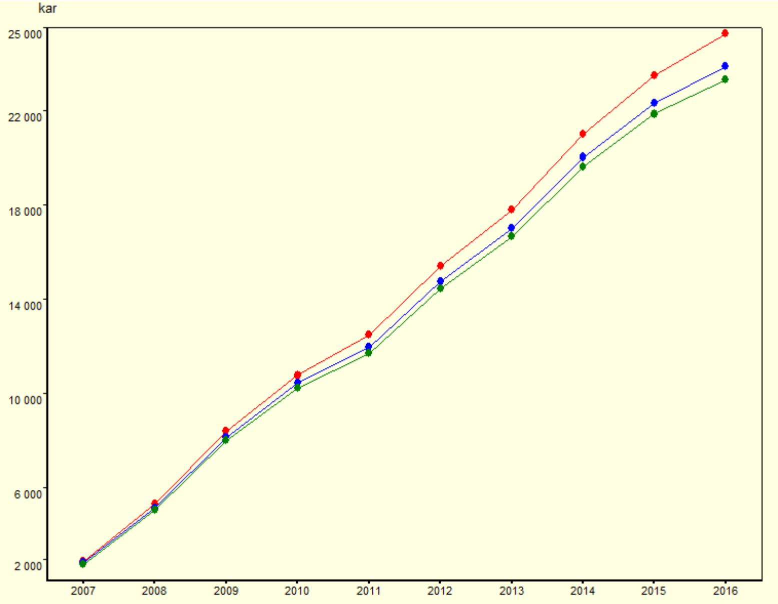
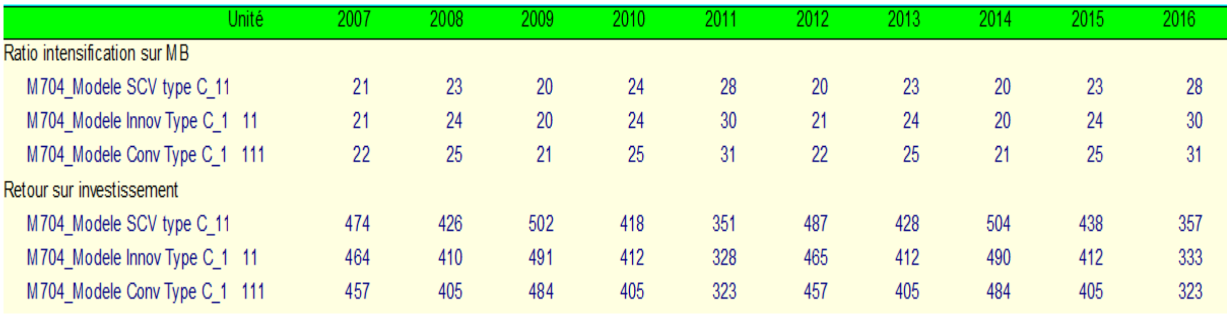


Figure 31: Comparison of the farm cumulated cash balance of ICS and CA systems for the type C farm in the ZNE area

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

Table 26 Results of intensification ratio and return to capital over 10 years for the type 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

Economic viability of the 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 variation of yield in the three systems CA, ICS and conventional.

The difference on farm income (Figure 19) 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 secure income in case of climate hazards.

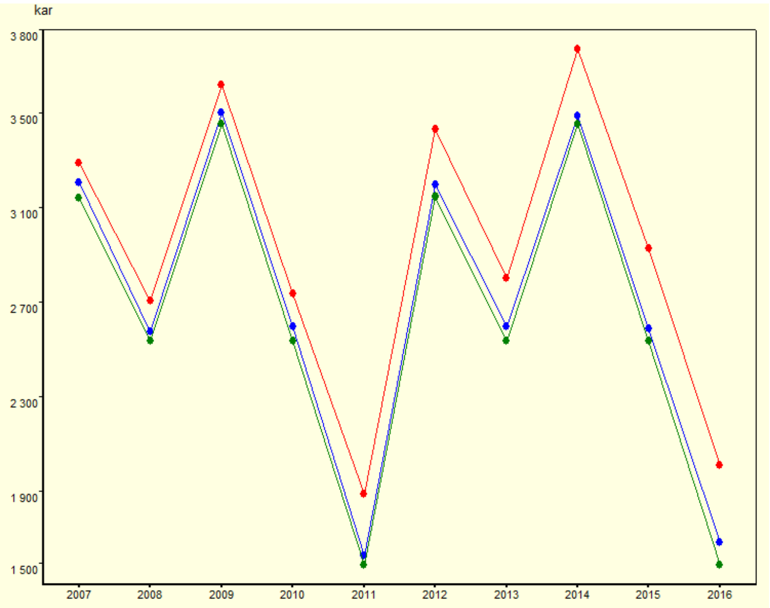


Figure 32 : Comparaison of farm income of CA and ICS systems of type D farm for ZNE area

As before the cash balance (Figure 20) follows the same variations as the operating result.

Figure 33 : Comparison of the farm cash balance in ICS and CA system for the type D farm in the ZNE area

Figure 34: 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 21) 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

Table 27 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 that 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

Economic viability of the farm

The type E farm has 0.5 ha of PWCPF. After 10 years of CA improved farm income (Figure 22) 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.

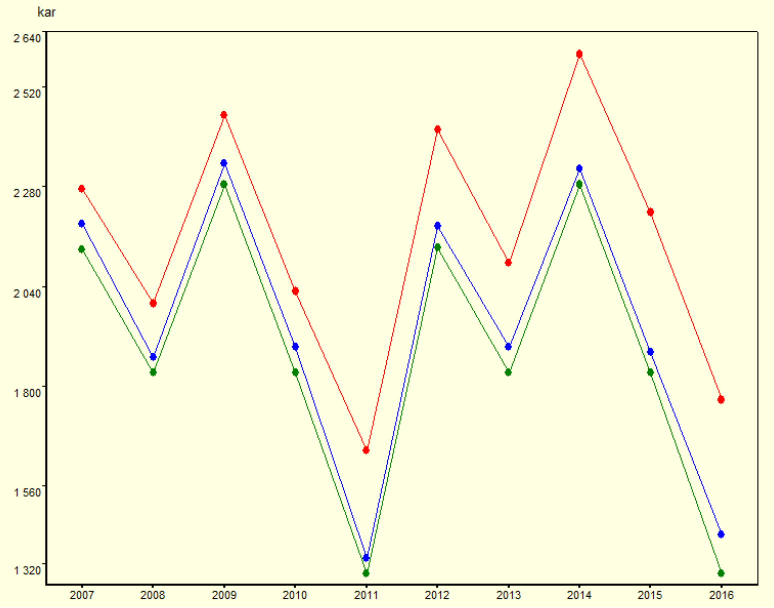


Figure 35 : Comparison of farm income of CA and ICS systems of type E farm for ZNE area

The cash balance (Figure 23) 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 secure the cash balance of the year where the harvest is zero on PWCPF.

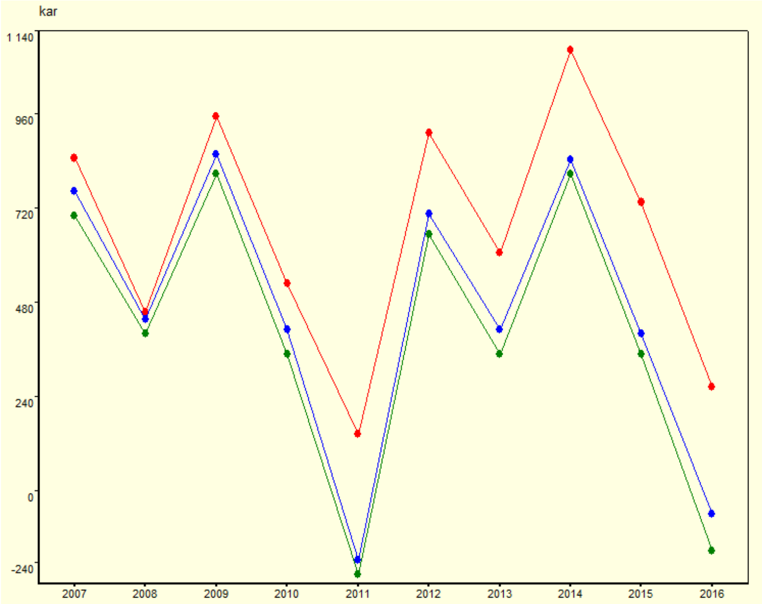


Figure 36 : Comparison of the farm cash balance in ICS and CA system for the type E farm in the ZNE area

The accumulated balance after 10 years (Figure 24) 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.

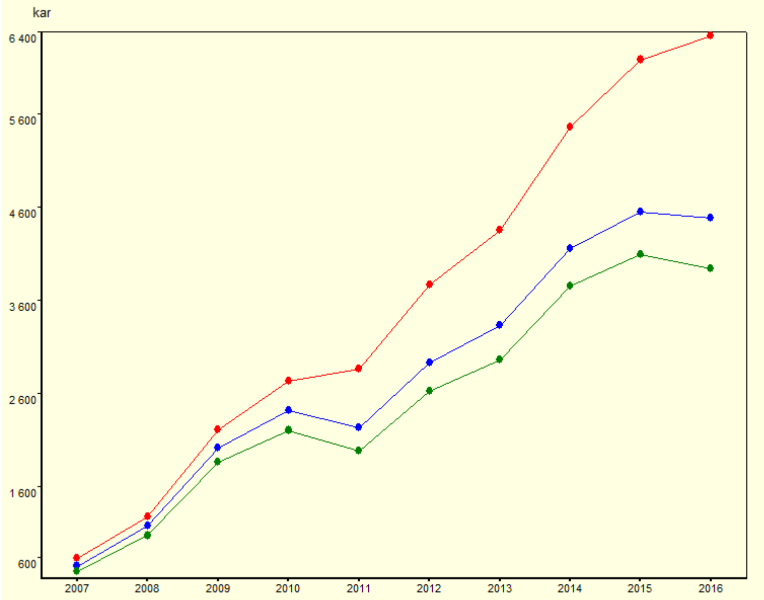
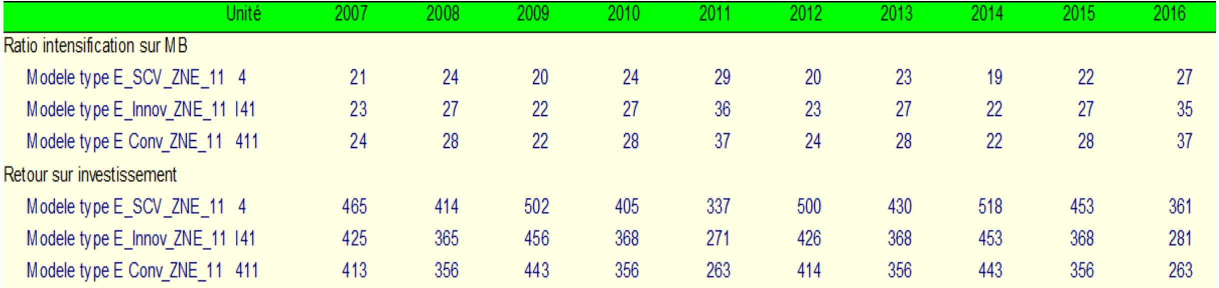


Figure 37 : Comparison of the farm cumulated cash balance of ICS and CA systems for the type E farm in the ZNE area

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

Table 28 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 improve income.

<u>Conclusion on farms of the northeast</u>

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.

3.3.6. *Conclusion on the Alaotra Lake area*

The Alaotra lake area can be consider as a success in term of real CA systems adoption (CA systems “stricto sensu”) : 410 hectares of CA systems with 600 farmers have been identified in 2010 : probably 600 hectares with 700 farmers in 2012.
If we carefully look at statistics in some other countries claiming 100 ,000 ha of CA (Zambia, Zimbabwe , Tunisia etc …) : most of what is declared as CA is not : most of them are “light or limited tillage systems “ or systems which include 2 but not 3 of the main Ca principles as described by FAO (2008).
In fact, Madagascar is probably the only country there CA systems “stricto sensu” have been effectively adopted by smallholders (we are talking of small family farms). North Cameroon, Laos and Cambodia have probably as well some limited area with real CA systems (less than 1000 ha). But the lake Alaotra area see clearly a critical mass of farmers and a relatively locally significant area under CA to built up a sufficient and sustainable “heart” of CA adoption. This is the results of 14 years of Research presence and 10 years of Development efforts (with the projects BV(lac).

But the question is now: what next after the end of the current BV-lac project ?
We do observe a real technical demand from farmers on whatever type of practices or technological package that can provide production stability ?.

Meanwhile, If CA systems have been effectively adopted, we do observe that they are not spontaneously adopted by non project surrounding farmers. In other words: NO CA outside development project which raise the question of CA diffusion when project ended up. One of the constraints to such no outside project diffusion could be: i) 5 years or learning process, ii) no immediate and visible results (results appears after several years). Positive aspects are the following: i) a real basquet of technology: many CA available cropping systems with 5 families and over 130 cropping systems to cover many situations, ii) freedom of choice as farmers have never been constrained to a specific technique, iii) easy adoption and importation of covercrops , iv) real positive outputs after 5 years …v) a real expansion trend on upland when irrigated rice area is limited and saturated

The first CA introduction has been historically made in Vakinankaratra, in the high lands, but too much existing constraints leave to no adoption. The highlands have extreme constraints when Lake Alaotra still has potential areas of development and far less severe constraints. CA success eventually linked with very specific situation. Therefore, it seems to be very difficult to extrapolate CA success to another region if not similar.

4. QAToCA: Qualitative expert Assessment Tool (QAToCA) for assessing the adoption of Conservation Agriculture

QAToCA, a Qualitative expert Assessment Tool for CA adoption in Africa, is based on the following hypotheses:

- that quantitative modelling approaches might be useful in diagnosing determinants to CA adoption at the field and farm scale, but limits of applicability of such tools become visible when it comes to the wider farming system context,
- that diffusion theories and conceptual models are useful as possible frameworks in analysing the CA adoption process at the contextual scale (CA system),
- that each diffusion theory or conceptual model might address only some aspects of the CA adoption process or CA system,
- that it is difficult to aggregate theories and conceptual models under a single generic framework which could best fit in analysing the CA adoption process as well as CA system,
- that it is difficult to obtain quantified data guided by theories and conceptual models in analysing the adoption of CA in Africa and
- that most studies explaining adoption of CA in Africa often focus on CA performance at field and farm level while leaving out the wider contextual and institutional picture with its possible influence over the likelihood of adoption.

Following the outlined hypotheses, in developing QAToCA, the authors first reviewed a cross selection of diffusion theories and conceptual models along side a literature survey on adoption of CA in Africa. The issues identified and conceptualised by these theories and concepts were translated into sets of thematic questions to form the tool. QAToCA is therefore developed on the basis of these theories and concepts, coupled with inspiration from the ScalA -Tool[2], developed by Bringe et al. (2006), tested and used by the Gesellschaft für Technische Zusammenarbeit (GTZ/GIZ)[3] (www.giz.de) and Sustainet (www.sustainet.org). It was developed for GIZ and has been tested in Germany, India, Kenya and Tanzania.

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[2] Tool for the assessment of sustainability, climate relevance and scaling-up potential of project approaches. The ScalA tool enables managers of development projects to self-assess the sustainability (covering the economic, environmental and social dimension of sustainability) of their projects along an expert-based list of criteria and questions.

[3] GTZ is a German Organisation for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit). Since January 2011, it has become part of GIZ; the German Organisation for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit), web: http://www.giz.de/en/profile.html

QAToCA specifically looks at the contextual factors not described by biophysical or economic approaches. Its thematic questions cover issues mostly at the regional level, but with some overlap with the bio-economic issues at field and farm levels. In total the tool has been tested in 13 case studies among them Madagascar.

Strengths of the tool

- The tool is easy to use and provides results instantly
- The tool is much participatory but not exhaustive
- It gives a quick overview of information on the CA status and adoption

Weaknesses of the tool

Several highlights on its weakness were raised:

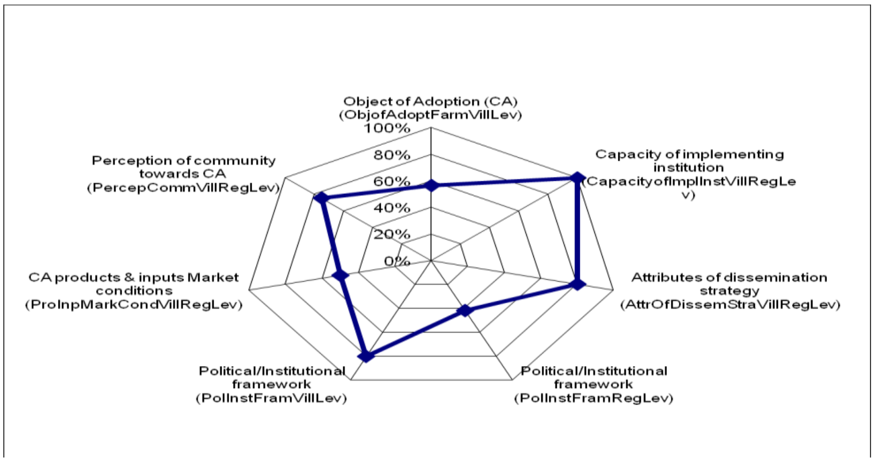
- Questions are too restrictive and evaluation scale deemed narrow, most could have preferred scale of rating or assigning scores to the statements. Responses might be too much related with the status of the person (researcher, developer, technicians etc ..)
- The tool is too compact: answers intend to be Yes/no or Black/white, Good/No good without any possibilities in between
- there is need to expand to capture all factors and opportunities and have a wider scale of evaluation : quatilative analysis is required beside the results.
- The tool benefits most from discussions of opposing views when it is possible to organise such events. It will therefore not provide an in-depth understanding of the situation if used by an individual.

Main Results

4.1. Lake Alaotra

The diagram integrates answers to CATOVA survey made with researchers and a limited number of farmers.

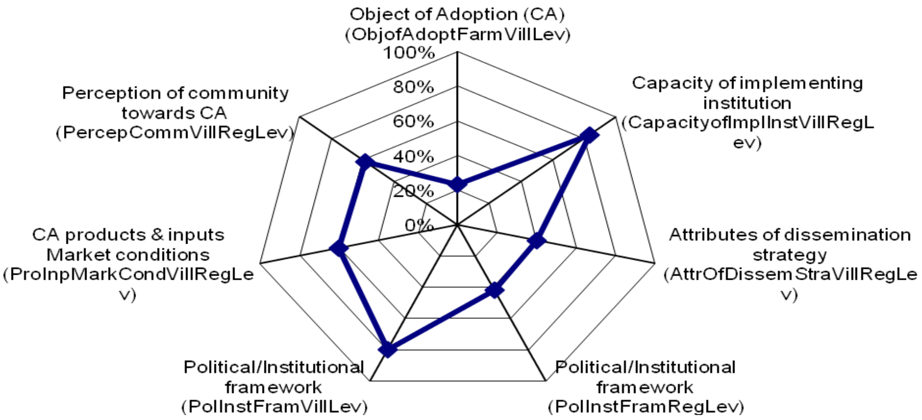
Figure 38



4.2. Vakinankaratra

The diagram integrates answers to CATOVA survey made only with researchers.

Figure 39



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