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Using Sustainable Rural Livelihoods framework to analyze the determinants of adoption and disadoption of conservation agriculture in Western Madagascar.

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Abstract

Conservation agriculture (CA) is known as a potentially efficient technique to address land degradation issues. CA has been promoted in Western Madagascar where farmers' livelihood is weakened by soil fertility. However, the low adoption rate of CA raises the question of its suitability to smallholder farming systems. The aim of this study is to assess, through an econometric analysis, the determinants of CA adoption and disadoption. Drawing on primary data collected in 2015, we conclude that financial and natural capitals are the main factors explaining CA adoption among farmers. More specifically, the findings show that the ownership of upland areas, the access to credit and the total income per capita does not influence significantly the probability to be a disadopters but affects the probability to be still adopters with respect to that to be a non-adopter.

Keywords: Technology, Conservation agriculture, Livelihood, *Vakinankaratra*, Madagascar

JEL: Q12, O13, D13

1. Introduction

Land degradation is a critical issue in Africa (Drechsel et al., 2001). As an agroecological technology, Conservation Agriculture (thereafter, CA) is a potentially efficient technology to address land degradation issues (Husson et al., 2008). In fact, CA implies minimal soil disturbance, permanent soil cover and crop rotation or association (FAO, 2014). Beyond the fact that CA addresses land degradation issues, it is expected that it sustains food security and enhances livelihoods of farmers in different ways. The adoption level of CA is however found to be low: farmers appear to be reluctant to adopt such a costly technique and/or to maintain its adoption overtime, specifically in Sub-Saharan Africa (thereafter, SSA) (Hove et al., 2011). To improve the efficiency of CA programs' design and implementation, understanding the factors influencing farmers' adoption has received attention of several researchers.

In this paper, we analyses the determinants of adoption and disadoption of CA by using the *Sustainable Rural Livelihood*s (thereafter SRL) framework and by focusing on the role of the access to livelihood assets in Western Madagascar.

Since the original work of Bebbington (1999); Chambers and Conway (1992); Ellis (1998); or Scoones (1998), the SRL framework is commonly used by different international organizations and non-governmental organizations (NGOs) to understand the structure and functioning of farms among other actors. Technological innovations is seen as a key determinant of the agricultural developments, the improvement of rural livelihoods and poverty reduction (FAO, 2014, PNUD, 2014). Then, the SRL framework can help to understand the different relationships between the adoption of technologies and the livelihoods of farmers in rural area. But, the use of this framework to analyze the adoption and the impact of technology is an ongoing debate. Dorward and al. (2003); Adato and Meinzen-Dick (2003) and Duncombe (2014) point out that there is a lack of application of the SRL framework to analyze the technologies. However, some studies link the different elements of the SRL framework to do so: vulnerability contexts and adoption of technology (Hossain et al., 2007), livelihood assets and adoption of technology (Belay and Bewket, 2013), adoption of technology and livelihood strategy (Hossain and al.,2007), adoption of technology and livelihood outcomes characterized by yields or poverty (Duncombe, 2014; Mago and Mago, 2015). According to these studies, we can suppose that the analysis of technology can fit into this SRL framework.

The contribution of this paper is twofold. First, it contributes to the existing empirical studies using SRL framework to analyze determinants of the adoption as well as the disadoption of CA in Western Madagascar. In fact, Pannell et al., (2014) noticed that there is a few published economic studies about CA in Africa. And the published studies present a set of heterogeneous and inconclusive results about the determinants of CA adoption (Knowler and Bradshaw, 2007) due to the fact that the factors influencing the adoption of CA are highly context specific. Second, the study contributes empirically to a large literature, in order to enhance knowledge about innovation processes and targeting development actions, specifically for Western Madagascar.

The rest of the paper is organized as follows. The first section presents the methodology of data collection and studies the determinants of CA adoption and disadoption by farmers. The second section discusses the results. The last section draws some conclusions of these results.

2. Methodology

2.1. Study area

The Western area of Madagascar covered a dozen regions (of a total of 22) between the Central Highlands and the West coast. This area is characterized by an average altitude of around 1000 m, and an average rainfall of about 1100 mm per year. The temperature is relatively high all year round, marked by a long dry period from April to October. The landscape is dominated by uplands, known as "*tanety*", potentially suitable to rainfed crops. The lowlands ("*Bas fonds*") are often narrow, which limits the creation of irrigated rice fields.

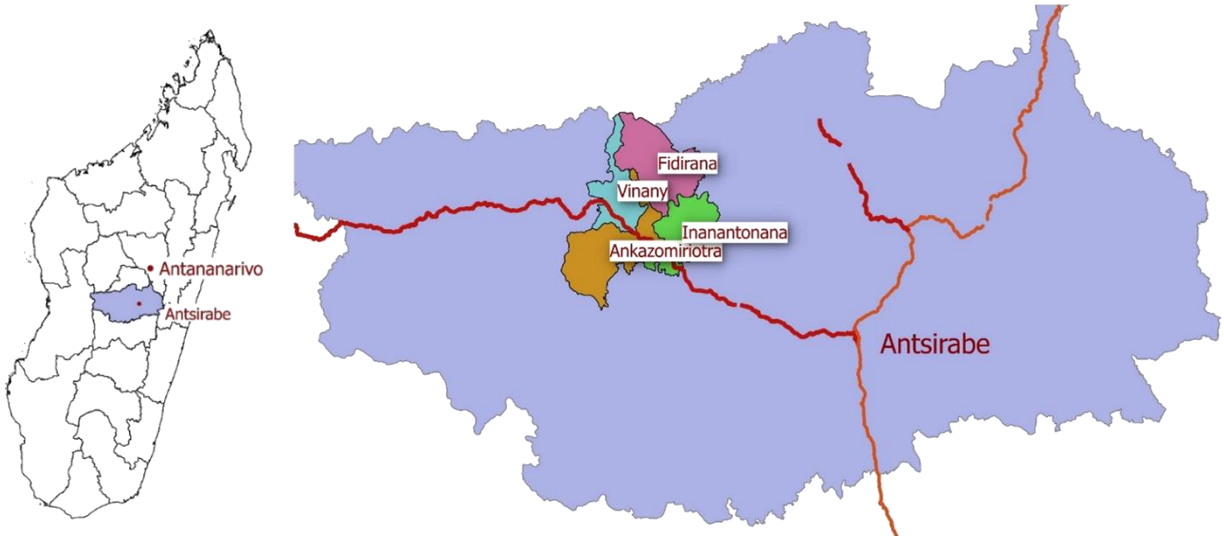

Figure 1 : Study area in Western of the region of *Vakinankaratra* in Madagascar

The study area is located in the Western area of the region of *Vakinankaratra*, one region of Madagascar, whose regional capital is *Antsirabe*. CA among smallholders has been disseminated in this region since 1995 through different development projects. In this study, data were collected in four municipalities (*Ankazomiriotra, Vinany. Inanantonana and Fidirana)* located in the area of intervention covered by *Bassins-Versants et Périmètres Irrigués* (thereafter BVPI) in *Vakinankaratra* (see Figure 1).

BVPI is a large-scale program implemented at national level aiming at promoting and protecting watershed and irrigated areas. As such, it is part of the national agricultural Malagasy policy. Financial supports of different international donors allowed the Malagasy government to implement the program in different regions in Madagascar. Both the improvement of the agricultural production and of farmers' incomes were promoted. The fields of action in the implementation are large: development and rehabilitation of irrigated areas, land tenure security, access to credit, improvement of agricultural (in upland and lowland) and livestock practices. The dissemination of CA from 2006 to 2013, is one component of the BVPI

project actions, funded by the French Development Agency, in the district of *Mandoto* in Western of *Vakinankaratra*. Six municipalities were selected out of the eight municipalities across the district. The selection of the intervention zone is based on the presence of irrigated area at municipality level. The dissemination approach of CA among farmers was implemented through trained technicians and existing or newly created farmer groups. The farmer group facilitates as well credit access in microfinance institutions and provides services like training, input distribution (seeds or fertilizers), especially during the first years of the project. Finally, the selection of farmers was based on a voluntary participation. The predominant system under CA disseminated by BVPI project is based on *Stylosanthes guianensis*, which is : (i) an association of *Stylosanthes guianensis* and subsistence crops (rice, maize or cassava) using *Stylosanthes guianensis* as a cover crop in upland area; (ii) a rotation of one year of association of subsistence crops with the cover crop followed by two or three years of the cover crop considered as year of fallow (Husson et al., 2008). *Stylosanthes guianensis* can't be used as a human food but it can be used as a fodder for animals. This implies, for the farmer, a trade-off of the use of this plant as a cover crop or as animal feed in the case of mixed crop-livestock farming systems (Naudin et al., 2015).

In fact, we take the opportunity of the implementation of this project in order to build our sample. In each municipalities, two groups of *Fokontany* (can be related to villages, and which is the basic administrative subdivision in Madagascar) were purposively chosen, one near the administrative capital of the municipality and the other more distant. It is hypothesized that farmer near the capital would adopt CA more likely than far farmer.

2.2. Data collection

A sample of 240 farmers was randomly selected at the *Fokontany* level from two lists: (*i*) 120 households, as former beneficiaries of the BVPI development project, selected from the database of the project; (*ii*) 120 selected from the electoral lists (and not related to BVPI activities). Farmers were interviewed on a face-to-face basis in 2015. According to their availability, either the household heads and/or their spouses were interviewed. A structured questionnaire, documenting the 2013/2014 season, was designed, tested and used to collect data on farmers. A team of trained interviewers (3) and supervisor (1) was in charge of the data collection.

The data collected entails information on a socio-demographic descriptions of the household, productive and non-productive assets, on- and off-farm activities and productions or revenues, technical and agricultural practices, income generated by each activity and (dis) adoption specific question regarding CA, with recall data on the adoption of the techniques. The unit of analysis is farm or household. Due to the specificity of the field we study, the two units fully overlap and the terms farm and household are thus used interchangeably throughout the article.

2.3. Statistical analysis

The literature proposes different ways to study the adoption of technology. The adoption may referred to: (i) the first adoption which is the first time that the farmer adopts CA; (ii) the continued adoption where the farmer decides to maintain the practice of CA; (iii) or the disadoption where the farmer decides to abandon the adoption of CA. And for the analysis of CA some studies examine a part of it (one practice) or the whole bundle of practices (multiple practices) of the CA package. This paper focuses on the factors affecting the adoption and the disadoption of the whole packages of CA including minimum soil disturbance, permanent soil cover as well as crop rotations and associations (FAO, 2014 for a summary). And, the sample is split into three categories of farmers, according to CA adoption: 1) non-adopters, namely farmers who have never used CA; 2) disadopters, namely farmers who previously tried, adopted CA and have abandoned it; and 3) adopters, namely farmers who are still practicing CA in 2013/14 season and have done so for more than three years.

The methodology used to analyze the determinants of CA adoption by farmers must be chosen rigorously because it can influence significantly the results (Knowler and Bradshaw, 2007). In this paper, a multinomial logistic regression, commonly used by economist (e.g Nyanga, 2012; Grabowski et al.,2016; Van Hulst and Posthumus, 2016) is chosen to estimate the probability to belong to each category according to a marginal change of an explanatory variable. In the empirical application, the reference category will be the non-adopters. According to Greene (2012), the multinomial logistic model can be presented formally as describe above.

$$p_{ij} = Pr(y_j = i / x_j) = \begin{cases} \frac{1}{1+\sum_{m=2}^{k} e^{x_j \beta_m}}, \text{ if } i=1 \\ \frac{e^{x_j \beta_i}}{1+\sum_{m=2}^{k} e^{x_j \beta_m}}, \text{ if } i>1 \end{cases}$$

where :

p_{ij} = probability that observation j takes the modality i (i =1, n*on adopters (reference category)* ; i =2, *disadopters* ; i =3, *adopters.*

y_j : observed value of endogenous variable *y* for the j^{th} observation

x_j : observed value of explanatory variable x for the j^{th} observation

$\beta^{(i)}$: set of coefficients corresponding to each category i

In our empirical model, a set of variables standing for livelihood assets are chosen (DFID,1999) as explanatory variables.

2.4. Presentation of the explanatory variables

Knowler and Bradshaw (2007), in their worldwide review of the literature, show that farm and household characteristics are factors influencing CA adoption. By referring to SRL framework, farm characteristics correspond to the livelihood assets of farmers (human, natural, financial, physical and social assets or capitals). Table 1 shows the expected relationships between the

explanatory variables (livelihood assets) and CA adoption as presented in the literature (e.g Feder et al., 1985; Knowler and Bradshaw, 2007; Belay and Bewket, 2013; Mponela et al., 2016).

The human capital characterized by the number of family active workers, the age, the gender and education level of the household heads is assumed to influence CA adoption. The family active workers are adults and children working in farm and off farm activities. Penot and al. (2015) argue that CA is labor intensive. Then, an increase on the number of the family active worker is hypothesized to have a positive influence to the CA adoption by farmers. And, older household heads are presented as less concerned by soil conservation which is a long term perspective. They are thought to be less likely to adopt CA than younger household heads. The gender of the household head is a potential factor of CA adoption too (Namonje-Kapembwa and Chapoto, 2016) because access to credit and land may differ from female to male household heads. Finally, CA is a complex set of techniques (Penot et al., 2015) and a high level of education can be hypothesized as a prerequisite for CA adoption

Cattle is a relevant variable to the adoption of CA. It can be attributed to different assets according to their function in the farm. Plough oxen is considered as a *physical capital* due to use of plough oxen during the agricultural soil preparation. Cattle is also a form of saving and then a symbol of *financial capital* mobilized for expected traditional annual events or unexpected events like health issues. In this paper, cattle will be considered both as a *financial capital* and a *physical capital.* The hypothesis is that farmers having cattle in their agricultural systems may adopt more likely CA because the cover crop named *Stylosanthes* can feed animals.

The land area is a *natural capital*. The empirical literature finds in many contexts that land area, as a proxy for farm size, influences the farmers' choice regarding CA adoption (e.g., Feder et al., 1985 ; Feder et al., 1993 Srisopaporn et al., 2015 ; Namonje-Kapembwa and Chapoto, 2016 ; Grabowski et al., 2016). Moreover, it is assumed that farmers take care to their own land more than to the rented land (Knowler and Bradshaw, 2007). The explanation may linked to the land tenancy period of rented areas which is often for one or two cultural seasons. Concerning the region we study and in relation with our field surveys, we may think that the correlation between farm size (owned and cultivated area) and CA adoption is positive.

The membership to a farmer group is one form of *social capital*. Farmer groups allow their members to share knowledge, information on agricultural innovations and transfer know-how (Diagne and Pesche, 1995). It is hypothesized that the membership to a farmer group influences CA adoption.

The *financial capital* includes the access to credit and the total income per capita. The income per capita is the income generated by on-farm and off-farm activities divided to the number of household members. These variables are relevant because the financial asset is regularly assumed to have a positive impact on the adoption of CA (Knowler and Bradshaw, 2007). A

positive correlation between the financial capital and the adoption of CA is expected because farmers with high incomes or with access to credit are able to bear the costs of switching to CA practices.

Table 1 shows the expected correlation between the explanatory variables and the CA adoption and disadoption. In the literature, the determinants of CA is increasingly documented. But, not much studies analyze determinants of disadoption by focusing in farmer's characteristics. In this paper, it is assumed disadopters and adopters do not differ in their characteristics because as defined above disadopters are farmer who previously adopt CA, i.e a former adopters. Then, the expected correlation of the explanatory variables and the disadoption of CA goes in the same direction as for the adoption of CA but in lesser extent.

Table 1: Description of explanatory variable and hypothesized relation with CA adoption (with respect to non-adopters)

Capital	Variable descriptions (type of variable)	Unit	Expected results	
			Disadoption	Adoption
Human	Education of the household head and his spouse	Year	+	++
	Older household head	Year	-	--
	Female of household head	Yes/No	-	--
	Number of family active workers	Unit	+	++
Physical	Number of plough oxen	Unit	+	++
Natural	Owned *tanety* or upland area	Hectare	+	++
	Owned lowland area	Hectare	+	++
Social	Membership to a farmer group	Yes/No	+	++
Financial	Total income per capita	$/d	+	++
	Access to credit	Yes/No	+	++

3. Results and discussions

3.1. Adoption rate of CA

The extent of CA adoption among farmers can be measured as the area allocated to CA but it is not considered in our study: instead we focus on the number of farmers reporting to have practiced CA during the 2013/2014 season. As a result, 44% of farmers (106 farmers) have never practiced CA, 42% (101) previously adopted CA and then abandoned it and 14 % (33) are still practicing CA and did so for more than three years (Table 2).

The reasons for the low adoption rate of CA is increasingly documented in the empirical literature adoption. Multiscale analysis in seven countries in SSA provided by Corbeels et al., (2014) points out that CA is unlikely to result in the short term increase of yields and farm incomes. Andersson and D'Souza (2014), in their review studies in Zimbabwe, Malawi and Zambia, argued that the low adoption rate of CA is linked to several factors: (i) the necessity of crop rotation; (ii) weed pressure due to the low availability of the biomass of the cover crop; (iii) the investment in new equipments (e.g, specific equipment to mow the cover crop); (iv) requirement

of a higher level of input use (e.g, fertilizer, labour) and; (v) lack of monetary incentives due to low rewards of the technique by the market while the improvement in yields is low. In the context of Madagascar, Penot et al., (2015) argue that the reasons of disadoption of CA are: (i) the complexity of the set of CA technologies; (ii) the two to three years of fallow required by CA; (iii) the lack of access to seeds for cover crops, and (iv) the project completion. Table 2 shows that the intervention of the project BVPI is highly correlated to the decision to adopt CA. All the farmers in the non-adopters or adopters categories were respectively BVPI project's non-beneficiaries and beneficiaries. However, beyond the high disadoption of CA, with 101 farmers (43% of the sample) who disadopted CA, 14 % were non-beneficiaries of the BVPI project activities. This suggests that a spontaneous dissemination of CA occurred.

Table 2 : CA adoption rate during 2013 to 2015 seasons according to the intervention of BVPI

CA adoption / BVPI Project	Non-adopters	Disadopters	Adopters
Beneficiary	0%	86%	100%
Non-Beneficiary	100%	14%	0%
Number of observation	106	101	33

3.2. Descriptive statistics

Before moving to our estimates of CA adoption, it is instructive first to consider simple descriptive statistics of the explanatory and endogenous variables (Table 3).

Table 3 shows clear-cut differences of the characteristics of each category of farmers. First, the behaviors turn out to be different according to municipalities for CA adoption and disadoption rates: in particular, 55% of farmers from *Ankazomiriotra* (corresponding to 33% of the whole disadopters) report to have disadopted CA. We notice that *Ankazomiriotra* was the municipality that exhibits the highest adoption rate (with or without subsequent disadoption) with 35% of non-adopters – appendix 1 - (representing 20% of the total number of non-adopters). About 60% of farmers who still practice CA are located in *Vinany* (one half) and *Inanantonana* (one half) adopt CA. However, we should keep in mind that the number of producers who are still practicing AC in 2015 is only 33.

Moreover, Table 3 illustrates the fact that livelihood assets differ significantly between each category of farmers.

Table 3 : Characteristics of the sampled population

Assets	Variables	Sample	Non adopters (n=106)	Disadopters (n=101)	Adopters (n=33)
	Municipalities	100%	100%	100%	100%
	Ankazomiriotra	25%	20%	33%	18%
	Vinany	25%	26%	22%	30%
	Fidirana	25%	27%	24%	21%
	Inanantonana	25%	26%	22%	30%
Human	Education of the household head (year)	6 (0.2)	5 ^{A} (0,27)	7 ^{B} (0,29)	7 ^{B} (0,50)
	Out of school	4%	7%	2%	0%
	Primary school	63%	72%	57%	52%
	Secondary school (1st cycle)	24%	15%	28%	42%
	Secondary school (2nd cycle)	8%	7%	11%	6%
	University	1%	0%	2%	0%
	Age of household head (year)	49 (0.8)	46^{A} (1)	52 ^{B} (1)	52 ^{B} (1)
	Female household head (1=yes)	8%	7%	10%	3%
	Number of family active worker (unit)	3.5 (0.0)	3.6 ^{A} (0,1)	3.5 ^{A} (0,1)	3.1 ^{A} (0,2)
Natural	Owned *tanety* or upland area (ha)	1.5 (0.1)	0.9 ^{A} (1.1)	1.4 ^{B} (0.1)	3.7 ^{C} (0.6)
	More than 2ha of owned upland area	25%	13%	23%	64%
	Owned lowland area (ha)	0.5 (0.0)	0.4 ^{A} (0.0)	0.6 ^{B} (0.0)	1 ^{C} (1.1)
Financial	Total income per capita (US $1,25 per day)	730 000 (50 000)	549 500 ^{A} (70 000)	750 000 ^{B} (190 000)	1 200 000 ^{C} (150 000)
	Upper to US $1,25 per day	34%	24%	32%	76%
	Credit (Ariary)	330 000 (66 000)	88 600 ^{A} (26 000)	385 000 ^{B} (100 000)	960 000 ^{C} (300 000)
	With credit	39%	27%	43%	64%
Physical	Cattle (%) (1=yes)	64%	56%	65%	85%
Social	Membership to a farmer group (%) (1=yes)	40%	20%	50%	70%

Farmers in the non-adopters category are poorly endowed with capital compared to the two other categories of farmers (disadopters and adopters). The household heads for non-adopters are significantly younger and less educated than those in the categories of disadopters and adopters. It is illustrated that 72% of the household heads for non-adopters had attended primary school and 28% finished secondary school secondary (1st cycle). However, for adopters, 42% of the household heads achieved the secondary school level. We may thus suggest that non-adopters are less experienced and may have difficulties to apply CA than the two latter other categories of farmers. In addition, these farmers are on average less endowed with land area both in upland and in lowland. For example, in their own upland areas, non-adopters report to cultivate areas that are respectively 0.6 times smaller than those reported by disadopters and 4 times smaller for adopters. Similarly, on average, about 56% of the interviewed farmers have

cattle, and this figure rises up to 65% for disadopters and 85% for adopters. With regard to the access to credit, 27 % of non-adopters declare to have access to credit with an average amount of about 88 600 Ar per year. In comparison to the two other categories of farmers, the amount of the credit is higher and concerns about 43% of disadopters and 64% of adopters. At the same time, 20% of non-adopters state to belong to a farmer group and it is respectively 50% of disadopters and 70 % of adopters.

For farmers belonging to the disadopters' group and the adopters' group, the age and level of education of the household heads of these two categories are quite similar. But there are significant differences in terms of land and cattle allocation, access credit and membership to a farmer group. In this case, adopters are more endowed than disadopters. For example, on average, farmers in the adopters' category state to cultivate an upland area which is 2.6 times larger than that of disadopters, and to access to an amount of credit about 2.5 times higher than for farmers in the disadopters' category.

In particular, the total incomes per capita are significantly different for all the three categories of farmers. They are ordered as follows: non-adopters with 549,500 Ariary (that is around US $1 per day), disadopters with (around US $1.7 per day) and adopters with (around US $2.2 per day). Based on the poverty line corresponding to US $1.25 per day, farmers can be categorized as poor farmers when they are below the poverty line. Poverty is thus widespread in Western Madagascar: in our sample 62.5% of the farmers are below the poverty line. Farmers above the poverty line of US $1.25 per day correspond to 27% for non-adopters, 43% for disadopters and 62% for adopters.

In summary, adopters are, on average, better endowed with livelihoods assets than non-adopters. The category of disadopters turns out to be an intermediary category.

3.3. Factors influencing adoption of CA

Table 4 presents the determinants of the adoption of CA. It reports the relative risk ratios standing for the probability of belonging to the adoption and disadoption categories rather than to the non-adoption category (reference). If the coefficient is significantly higher than 1, 1 being excluded, (resp. lower) than, a change in the variable influences positively (resp. negatively) the probability to belong to the category under consideration.

Following to the Sustainable Rural Livelihood framework, we propose to proxy the diverse livelihood assets like access to credit and income per capita (financial capitals), a high level of education, the age and female household heads, number of family active workers (human capital), access to owned upland and lowland for cultivation (natural capital), use of cattle (physical capital) and membership to a farmer group (social capital). The endowment in assets highly influences the probability of being an adopter (or having been an adopter) or not.

Table 4: Multinomial logistic model of the farmers (dis)adoption of CA in Western Madagascar

Explanatory variables		Multinomial logistic regression	
	Variables	Disadopters vs non-adopters	Adopters vs non-adopters
Municipalities	*Vinany (reference)*	Ref	Ref
	Ankazomiriotra	3.0 (1.6)**	Ns
	Inanantonana	2.3 (1.2)*	Ns
	Fidirana	2.2 (1.1)*	Ns
Human assets	Education of the household head (year)	1.1 (0.0)**	Ns
	Age of the household head (year)	1.0 (0.0) ***	1.0 (0.0) ***
	Female household head (1 if yes)	Ns	Ns
	Number of family active workers (unit)	Ns	0.6 (0.2)*
Physical asset	Cattle (1 if yes)	1.8 (0.6)*	3.8 (2.7)*
Natural assets	Owned *tanety* or upland areas more than 2ha (1 if yes)	Ns	4.9 (3.0)***
	Owned lowland areas (ha)	Ns	Ns
Social asset	Membership to a farmer group (1 if yes)	5.3 (2.0) ***	5.7 (3.5) ***
Financial assets	Total income per capita more than US $1,25 per day (1 if yes)	Ns	7.6 (5.3)***
	Access to credit (1 if yes)	Ns	5.2 (3.1)***
	Constant	0.0 (0.0) ***	0.0 (0.0) ***
Pseudo R^2 : 0.277 Nb of obs = 240			

[TO BE COMPLETED AS REGARDS ENDOGENITY QUESTIONS]

The results (Table 4) confirm the assumptions that financial assets influence positively the farmers' decisions to the adoption of CA. In comparison to farmer below the poverty line of US $1.25 per day, farmers above the poverty line are about 7 times more likely to be adopters than non-adopters. Grabowsky (2015) shows similar results and argues that poverty constraints, measured by land under-cultivation, low equipment ownership, low fertilizer use and being male-headed, hinder the adoption of CA. Wealth indexes give similar results (Arslan et al., 2014). Poverty turns out to be a constraint to the adoption because the CA system requires additional costs compared to the conventional one. The predominant CA system disseminated in Western Madagascar uses *Stylosanthes guianensis* as cover crop. Managing this plant under CA is labor intensive or requires new equipment (Penot and *al*., 2015). Furthermore, the relation between poverty and the adoption of CA by farmer can be linked to uncertainty related to the use of new technologies under the assumption of farmers' risk aversion (Marra and *al*. (2003)

;Ghadim et al. (2005). Poorer farmers are generally presented as more risk-averse (Pannell et al., 2014) and less tolerant to the uncertainty related to CA (Grabowski et al., 2016) than wealthier farmers. Moreover, the access to credit significantly influences CA adoption: in fact, credit allows to face up-front investments due to the technology adoption and annual costs related to CA. Therefore, it can alleviate the poverty or cash constraint.

The area cultivated on uplands affects the adoption of CA. In fact, CA system based on *Stylosanthes* requires two to three years of fallow after harvest. However, the increasing demographic pressure in the region leads farmers, who are faced to land scarcity, to reduce the fallow periods on their plots (Jouve, 1991). Farmers with more owned land can practice fallow and adopt CA.

The membership to a farmer group is a form of social asset described as "*an important livelihood asset for enhancement of sustainability of livelihoods*" OECD (2001). The results show a significant influence of membership on the adoption of CA by farmers. This is obviously due to the fact that the development project BVPI associated regularly farmer groups as agents of dissemination of CA in a very top-down way. In fact, farmer groups hold a high quality of information (Llewellyn, 2007) and promote an efficient information flows about innovation adoption (Fischer and Qaim, 2012). That's why, co-conception of agricultural technologies combining researchers, farmer groups and farmers have moreover recently re-gained popularity (Vall et al., 2016) to be more efficient.

3.4. Factors influencing disadoption of CA

The disadoption of CA differs significantly across municipalities. The farmers in the municipalities of *Inanantonana, Ankazomiriotra and Fidirana* are more likely to disadopt CA compared to those in *Vinany*, suggesting that the CA dissemination approach of the project BVPI was successful in *Vinany*. The explanation may be related to the fact that another development project had been operated in *Vinany* to disseminate CA well before the BVPI project itself.

Similarly to the case of CA adoption, the age of education of the household head, having cattle of plough oxen and the membership to a farmer group are factors positively affecting the disadoption of CA by farmers, relatively to non-adopters. This finding indicates that farmers are in a dynamic learning phase (Nelson, 1995) of the functioning of CA. The adoption and the disadoption is occurring over time. Furthermore, yield response is a key criteria of adoption of CA by farmers. But an increase on soil fertility and on yield responses occurs in the long run which may take up to 15 years Corbeels et al., 2014; Thierfelder et al., 2013, 2015). There is no consensus in the definition of the period of time designed by this long term view because yield responses to CA is crop, soil and site specific.

Last, the total income per capita does not influence significantly the probability to be a disadopters with respect to that to be a non-adopter but affects the probability to be still adopters. Income flows play thus an important role in the choice to abandon CA practices.

4. Conclusion

The paper proposes to study the adoption of innovative agricultural technologies from the perspective of Sustainable Rural Livelihoods. It thus focuses on aspects related to financial obstacles and low level of assets. We use original primary data collected in Western Madagascar in 2015. The results show that, CA do not match to the resource endowments of all farmers in rural area.

Due to investment costs (e.g. shortfall due to fallows and new equipment), CA is more probably adopted by wealthier households who can stand the cost of conversion towards this agricultural system and ensure its sustainability. In the view of the issue of land degradation in this area, the results put forward questions about targeting development actions. The diversity of farmers' livelihood assets and outcomes, agricultural situations should be considered in the design of development projects and public interventions. The farmer group vehicles information about adoption of technology. Associating farmer groups in the design of agricultural innovations and not just in the dissemination can facilitate adoption of CA and other new technologies.

Spontaneous dissemination of CA exists. However, the data show that farmers who adopted CA without technical supervision by the development project have all disadopted. This suggests that technical change and innovation of farmers need to be better accompanied.

The next version of the paper should take into account the suspicion of endogeneity and multicollinearity for some of the variables. To tackle this issue, the timing in adoption / disadoption, and investment in capital will be assessed with the recall data and qualitative data collected in the survey and open questions asked at the end of the questionnaire.

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Appendix 1.1: Descriptive statistics according to the CA adoption status (continued) municipality level

	Non adopters	Disadopters	Adopters	Total
Ankazomiriotra	35%	56%	9%	100%
Vinany	46%	36%	18%	100%
Fidirana	48%	43%	10%	100%
Inanantonana	46%	37%	17%	100%