Remittances, food security and resilience to rainfall variability: the case of rural Mali.

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Abstract

In this paper, we rely on the CFSVA survey of 2005 to assess both the impact of rainfall variability on the food security of rural households in Mali, and the role of remittances in their adaptive capacity. There are two stages to our analysis: first, we design a composite food security index which enables us to divide households into three categories. Then, we estimate a partial proportional odds logistic model (Peterson and Harrell, 1990) in order to find the main determinants leading to a switch from one category to the other. We further show that inter-annual and seasonal rainfall variability have a negative impact on food security, especially in southern Mali. Agro-ecological conditions in this region are usually more favourable, but it was weakened by the cotton crisis of the 2000s. As for remittances, their impact is positive, though it needs to be qualified: they enable households to solve temporary food security situations, but they have no effect on structural food security issues.

Keywords: Food security, Rainfall variability, Partial proportional odds model, Remittances, Mali.

JEL Classification : C35, F24, Q18, Q54

1 Introduction

Climate variability is perceived as one of the main threats on agricultural production and food security in sub-Saharan countries, especially in those characterized by a Sahelian climate, in which cereal and rain-fed agriculture predominate. Regional rainfall is there distinguished by high intra-annual and inter-annual variability which results in alternating droughts and floods (Lobell et al., 2008). Mali is among the countries which are the most exposed to climate variability, and since the 2000s it has experienced chronic food insecurity situations, which spread from the northern Sahelian area to the Sudanian climate area further south. According to Ba et al. (2011), the vulnerability of rural households in southern Mali is the result of a combination of factors linked to the alternance of good and bad harvests, to the demographic pressure and to the evolution of crop- and livestock-farming systems. Bruijn et al. (2005) stress the role of the cotton crisis of the 2000s in worsening the food situation of rural households and in increasing their vulnerability to rainfall variability.

In order to insure themselves against climate risks, these households rely on traditional insurance mechanisms, but also on remittances (Harrower and Hoddinott, 2005).[1] Remittances are essential to the households' ability to face various types of risks (Yang and Choi, 2007). Previous studies have shown the strong potential of remittances for reducing poverty through their positive effect on income and consumption (Adams and Page, 2005). However, little attention has been paid to the effects of these transfers on food security to this day. Thus, political endeavours to use their potential for increasing the food security of rural households have been few and far between (Maphosa, 2007).

It is nevertheless accepted that remittances can influence the households' consumption and nutrition in several ways. They can have a direct positive impact on the households' income and thus on their food security as well as on the variety and quality of the food eaten. By contributing directly to the income of households, remittances allow for better economic access to food and to health services. Households can thus face shocks, and in particular sudden increase in food prices (Gupta et al., 2009). According to Nyikahadzoi et al. (2013), remittances limit the probability for Mozambican senior-headed households to experience food insecurity while public transfers have no significant effect. According to Babatunde and Martinetti (2011), households benefiting from remittances in Kwara State (Nigeria) have better food access. The authors

[1] Traditional insurance mechanisms include the diversification of the agricultural income through crop diversification and / or through non-agricultural activities.

stress the fact that a major part of the remittances is used to smooth consumption and to buy necessity goods; they thus only impact the food quantity, not its quality.

This paper follows up on previous work analyzing the impact of remittances on the adaptive capacity of households, but differs from it in two important aspects. First, we try to assess the direct impact of rainfall variability on the food insecurity risk of Malian households while taking into account how remittances influence their ability to absorb these negative shocks. Second, we study the impact of remittances on the ability of households to guarantee their food security by reinforcing their productive capacity. To this end, we distinguish between households experiencing "structural" and "chronic" food insecurity, using a threshold based on the quantity of agricultural equipment owned (Chiwaula, Witt and Waibel, 2011).

Our sample relies on the CSFVA-Mali household survey (*Comprehensive Food Security and Vulnerability Analysis*) which was conducted throughout Mali in December 2005 by the WFP,[2] in association with CFS[3] and UNICEF.[4] The advantage of the CFSVA survey is that it gives a national picture of the food security of rural households in a "normal year". This survey constitutes significant progress since the food situation in Mali had until then only been studied locally, and in the northern part of the country in particular. [5]

We use a *partial proportional odds logistic model* (Peterson and Harell, 1990) to estimate the impact on food security of rainfall fluctuations and of the households' various adaptive strategies. The key advantage of this model is that it estimates the impact of control variables on the probability to switch from one food category to the other, while allowing for the impact of control variables to vary with the different categories. We consider that the assets of a given household define its potential to guarantee and maintain a minimal food access level despite the negative impact of rainfall fluctuation and irregularity. More precisely, the household survey allows us to identify several thresholds representing the households' vulnerability to rainfall fluctuations, notably by taking into account their adaptive potential and in particular the impact of remittances.

[2] World Food Program
[3] Committee on World Food Security
[4] United Nations Children's Fund
[5] A first CFSVA survey was conducted in 2002 but it was limited to the areas located above the 14th parallel, deemed as the most vulnerable. WFP and EWS (Early Warning System) then realized a quick survey in October 2004, assessing the impact of an invasion of locusts on the food security of households in the Northern parts of Mali of the 14th parallel and affected by the invasion. Finally, a household food security survey funded by ECHO was conducted in June 2005 by WFP and EWS in the three northern regions of the country.

The paper is organized as follows. In section 2, we present the method used to assess the food security level of Malian households, as well as the results. In section 3, we introduce the methodological framework as well as the economic outlook used to assess the main factors of vulnerability and adaptation to food insecurity. Our different results are displayed in section 4, with an emphasis on the role of remittances. Section 5 concludes.

2 Household Food Security in Mali

2.1. Scope of the study

The data we use to estimate the food security level of Malian rural households are taken from the CFSVA survey (2005). This survey relies on the answers given by 2074 rural households spread over 209 villages situated within seven agro-climatic zones, which are defined by WFP and FEWS-NET Mali (see figure A.1 attached). This zoning system gives a representative sample on the national scale. It enables us to work around the biases linked to the regional heterogeneity in standards and manners of living by identifying homogeneous zones which are rather defined by their agro-climatic characteristics.

Our study is focused on the Sahelian and Sudanian agro-climatic zones. The specific climates found in the desert and in the Niger delta were deemed to be beyond the scope of this study. This is best justified on the one hand by the importance of nomadism in the desert zones situated at the northernmost limit of Mali, and on the other hand by the hydrographic specificities of the floodplains: these stretch over more than 350km between the 17th and 13th parallel north and between the 2°30 and 6°30 meridians west, and human organization in this area relies willingly on climate hazards.

Our sample is made up of 1158 rural households, 626 of which are in the Sahelian zone (northern and southern Sahel), and the other 532 in the Sudanian zone (northern and southern Sudan). The Sahelian zone includes all the localities surveyed in the agro-pastoral and dry agriculture zones situated between isohyets 200 and 750 mm. From north to south, the whole zone stretches from Timbuktu to Ségou and also includes the northern part of the Kayes region as well as the Mopti region. The Sahelo-Sudanian climate includes the localities set between isohyets 750 and 1200 mm, which according to Rodier’s classification (1964) corresponds to the Sudanian climate, the “pure tropical” or the “transitory tropical”. This climate zone is characterized by more abundant rainfall. It stretches over the northern Sudanian zone, where millet and sorghum are the main food cultures and cotton the main commercial one, and the southern Sudanian zone, where maize, cotton, fruit and tubers are the main cultivated foods.

2.2 Construction of the food security index

International organizations give several definitions of food security.[6] The World Bank (1986) defines food security as « access by all people at all times to enough food for an active, healthy life". In 2002, the FAO broadens this definition: food security thus exists "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." According to the definition given by the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), food insecurity occurs when people can no longer meet their needs with their own production and/or annual income, leading them to use their savings, to sometimes sell their means of production, or even to rely on solidarity. Thus, food insecurity corresponds to all the situations in which individuals experience or risk experiencing hunger (Nakelse and Ouedraogo, 2011). It includes four aspects: food availability, production stability, optimal biological use of food and its geographical accessibility.[7]

The variables used to build a composite food security index should thus represent, on the one hand, the households' ability to acquire a sufficient food quantity through their economic accesses (e.g. exchange, production and transfer capacity), and on the other hand, the more or less optimal use of dietary diversity by decomposing the consumption frequency of different foods (Maxwell et al., 2008).

The variables we use to assess the households' food security level are displayed in table 1. First, we take into account the dietary diversity through the consumption frequency of the main foods. According to Smith and Subandoro (2012) and Hoddinott and Yohannes (2002), dietary diversity is a good index of the households' food security because it represents both the quantities eaten and the nutritional qualities of the various food types. This index thus represents a real improvement on the vulnerability and poverty indices which are only based on consumption and income. Indeed, a rise in consumption expenditures and/or in the quantities consumed might hide a degraded nutritional situation when the food prices rise.

We then take into account economic access to food, captured by the share of food within total expenditures, the constitution of cereal stocks per capita, and the amount of culture set aside for in-home consumption (Maxwell et al., 2008). These variables enable us to take into account the households' capacity to maintain their consumption levels during a food crisis. A variable

[6] According to Owens and Hoddinott (1999), almost 200 definitions and 450 indicators can be identified.
[7] This last dimension of food security is excluded from our analysis due to a lack of sufficient data.

representing food consumption resulting from expenditures made within the seven days preceding the survey is added as a control variable. Finally, the number of TLUs (Tropical Livestock Units) is also included as a variable explaining food security. Indeed, livestock possession conditions the ability to sell it (decapitalization) so as to create the financial cash flow needed to buy cereals and thus to meet food needs.

The composite index is estimated through two Factor Analyses (FA). A first FA is done on the first variable group, which represents the quality and diversity of the food eaten. A second FA allows for the synthesis of the information given by the second variable group, which shows the households' economic access to food. For each FA, we keep the factor explaining the main part of the total variance and we compute the factor scores.[8]

These scores are then assigned to each household in order to give a synthetic view of their food security level. Once the scores of dietary diversity and of economic access to food are assigned to the households, the said households are divided into three homogeneous food security categories, using a clustering method based on the k-median algorithm (Bradley et al., 1997). This algorithm is an iterative process which allows for the identification of *k* categories (or clusters) which group individuals bearing similar characteristics. First, the scores which were computed and assigned to the households are associated to the group with the nearest cluster center. Then, each group is updated with the geometric median of its assigned scores.[9] These stages are then iterated until the scores assigned to the different food security categories stop changing.

Table 1: Food consumption and food accessibility variables

Economic access to food	*Dietary diversity*
1 - Food expenditure as a share of total expenditure.	1 - Frequency of cereal consumption
2 – Tropical Livestock Unit (TLU) owned by households	2 - Frequency of tubers consumption
3 – Cereal stocks per capita during the survey (kg).	3 - Frequency of cowpea consumption
4 – On-farm consumption (kg).	4 - Frequency of dried fish consumption
5 - Household consumption expenditure (during the last 7 days before the survey).	5 - Frequency of milk / eggs consumption
	6 - Frequency of fruits / vegetables consumption
	7 - Frequency of sugar and oils consumption

[8] The method of Anderson and Rubin (1956) is used to calculate the factor scores that are not correlated with other factors.
[9] Preference was given to the k-median method rather than the standard k-means clustering method since it is more robust to outliers.

2.3. Food security categories

The results of each FA are presented with no rotation of the factor matrix, and with a *Varimax* rotation (table 2 and 3). *Varimax* rotation allows for simplified interpretation by maximizing the number of independent variables which are correlated to a factor. However, only the factors of the FA with no rotation of the factor matrix are used in the computation of the factor scores because of their higher explanatory power. We first verify the internal consistency of the FAs using Cronbach's alpha. Since the statistics of Cronbach are higher than 0.60, the internal consistency of each FA may be deemed "acceptable". We also use Bartlett's test of sphericity, which gives the statistical probability for the correlation between variables to be non-null. This test is significant at the 1% threshold for each FA, which shows that the matrixes of the food security and of the food accessibility variables are factorizable.

The FA results dealing with the households' food consumption are copied in table 2. They show that the first factor explains 34% of the total variance of the food consumption, while the next factor only explains 16% of it. The first factor mainly points to the consumption of rice or bread which are pricier, but also preferred by young urban populations (Reardon, 1993).[10] Besides, high correlation with foods such as sugar, oil, fish (fresh or dried), and meat, suggests that the first factor mainly concerns the consumption of richer households, which is the most diversified. On the contrary, the second factor indicates less diversified consumption, made up mainly of the basic cereals of rural areas, such as millet and sorghum.

These cereals are essential to the food security of all West African countries, especially in areas where income is low and climate conditions difficult. They thus remain the chief source of energy, proteins, vitamins and mineral salts for the poorest rural populations. The two factors resulting from the FA and concerning the economic accessibility of food suggest different means of access: in-home consumption and the constitution of security stocks on the one hand, access to local markets on the other (table 3). The first factor explains a large share of the total variance of the economic accessibility of food (59%). This factor represents households which access food through stock constitution and own production. The second factor explains 38% of the total variance of the economic accessibility of food, and proves to be highly correlated to food expenditures. It thus represents the households which are the most exposed to food crises when the price of foodstuffs rises.

[10] The relatively low price of imported rice has led to a rise in demand while local rice prices remain high. This cereal remains, like bread, a luxury product which is rarely consumed in rural areas.

Table 2: Results of the Factor Analysis on food consumption.

	No rotation		*Varimax rotation*
	Factor 1	Factor 2	Factor 1
Corn	0.09	0.55	-0.12
Rice	0.61	-0.43	0.76
Mil	-0.18	0.41	-0.08
Tubers	0.23	0.12	0.02
Bread	0.54	0.23	0.14
Dried fish	0.15	0.13	-0.09
Fresh fish	0.50	-0.43	0.80
Large ruminant	0.42	0.09	0.13
Small ruminant	0.37	-0.02	0.09
Eggs	0.18	-0.06	0.09
Cowpea	0.21	0.23	-0.01
Vegetables	0.24	0.28	-0.01
Oils	0.59	0.12	0.24
Sugar	0.45	0.00	0.18
Fruits	0.29	0.12	0.07
Fonio	0.09	0.48	0.02
Semolina	0.13	-0.21	0.11
Sorghum	0.02	0.50	0.03
Milk	0.53	-0.11	0.26
Eigenvalues	2.44	1.25	1.49
Explained variance	34%	16%	17%
Cronbach's α	0.73		0.63

Note: Only the factors with eigenvalues greater than 1 are shown according to the Kaiser rule.

Table 3: Results of the Factor Analysis on economic access to food

	No rotation		*Varimax Rotation*	
	Factor 1	Factor 2	Factor 1	Factor 2
Cereal stocks	0.73	0.48	0.94	-0.06
On-farm consumption	0.77	-0.56	0.95	-0.10
Tropical Livestock Unit (TLU)	0.24	0.13	0.25	-0.06
Food expenditure / total expenditure.	-0.66	0.65	-0.05	0.93
Consumption expenditure (Last 7 days)	-0.37	0.04	-0.24	0.27
Eigenvalues	2.26	1.49	1.90	1.84
Explained variance	59%	38%	49%	47%
Cronbach's α	0.70		0.61	

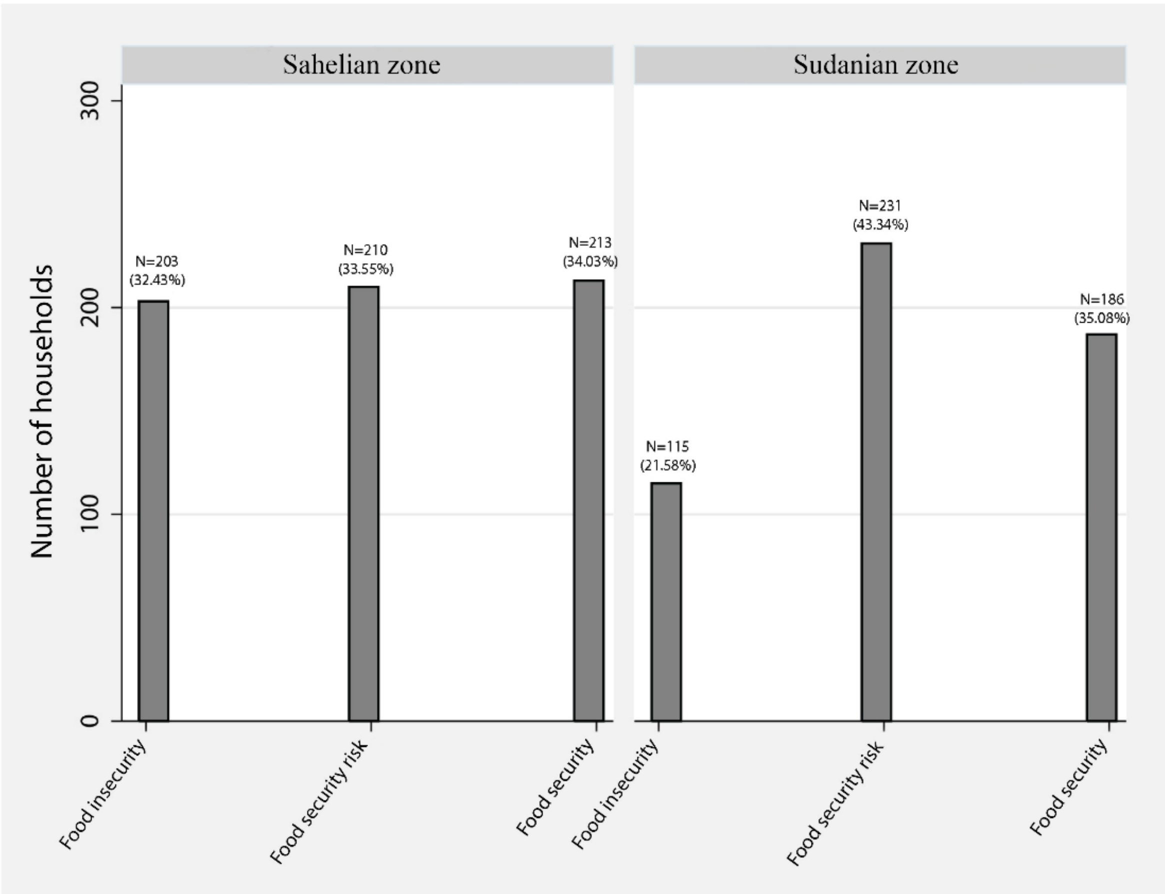
Note: Only the factors with eigenvalues greater than 1 are shown according to the Kaiser rule.

The results of k-median clustering allow for the creation of three household categories based on their economic access to food and on their food consumption (figure 1). The first group is made up of food-insecure households which are characterized by low dietary diversity and low economic access to food. They amount to 27.46% of the households surveyed within the Sahelian or Sudanian climate zones. However, the climate-based analysis shows that a higher share of the households suffers from food insecurity in the Sahelian area (32.43%) than in the Sudanian one (21.58%).

The second category is made up of at-risk households: they show dietary diversity but low economic accessibility to food. They amount to 38.08% of the households surveyed. These households are deemed to be at risk because they show a low score of economic accessibility to food. This suggests that in-home consumption, the use of food stocks, or the consumption of self-production only represent a small share of the capacity of these households to guarantee food security in the face of an insufficient food offer or of a steep rise in prices. This second category is highly represented in the Sudanian zone (43.34% of households against 33.55% in the Sahelian one).

Finally, food-secure households are characterized by a good level of economic accessibility to food and a diversified diet. They represent 34.03% of the households in the Sahelian zone and 35.08% of those in the Sudanian one.

Figure 1: Food insecurity profile in Mali, 2005.



These results evidence the food pressure affecting the two climate areas of Mali. Around 65% of the rural households thus either experience or risk experiencing food insecurity.

3. Food security determinants in Mali

We now want to analyze the determinants of the various food security levels of Malian rural households in the Sahelian and Sudanian climate zones. We focus on the impact of remittances and of rainfall variability on the probability for households to switch from one food category to another.

3.1 Methodology

We use a *partial proportional odds* model, as described by Peterson and Harell (1990). Unlike the standard ordered model, the *partial proportional odds* model allows for the estimated coefficients of the model to vary between the three food security categories previously identified and denoted Y_i (where $i = 1{,}2{,}3$). This operation is made possible by the introduction of an additional parameter γ measuring the deviation of coefficients between the three categories.

The modelling of ordinal variable Y_i depends on the class to which the continuous hidden variable Y_i^* belongs. Latent variable Y_i^* represents any socioeconomic quantity which might influence the switching from one food security category to the next. Parameters $\alpha_0, \dots, \alpha_3$ represent the thresholds within the distribution of Y_i^* where $-\infty < Y_i^* < \infty$, $\alpha_0 = -\infty$ and $\alpha_3 = \infty$:

$$Y_i = \begin{cases} Y_1 \text{ if } \alpha_0 \leq Y_i^* < \alpha_1 \\ Y_2 \text{ if } \alpha_1 \leq Y_i^* < \alpha_2 \\ Y_3 \text{ if } \alpha_2 \leq Y_i^* < \alpha_3 \end{cases} \quad (1)$$

Where Y_1 is the category of food-insecure households, i.e. households which have low access to food and low dietary diversity Y_2 is the category of households at risk, i.e. households which have low access to food despite a diversified diet. Finally, Y_3 includes food-secure households, i.e. households with high access to food and dietary diversity scores. Variable Y_i^* is defined thus:

$$Y_i^* = x_i'\beta + \epsilon_i \quad (2)$$

Where x_i' is the $p \times 1$ vector of the p explanatory variables and β is the $p \times 1$ vector of the regression coefficients assigned to the p variables within x_i'. In the *partial proportional odds* model proposed by Peterson and Harrell (1990), cumulative probabilities are defined thus:

$$\Pr\ (Y_i \geq j|x') = \lambda(-\alpha_j - x_i'\beta - \tau_i'\gamma_{j)} \quad (3)$$

i.e.

$$\Pr\ (Y_i \geq j|x') = \frac{1}{1+\exp(-\alpha_j - x_i'\beta - \tau_i'\gamma_{j})} \quad (4)$$

Where $j = 1, 2, 3$; τ_i' is a $q \times 1$ vector (with $q \leq p$) including the values of the i observations of some of the p explanatory variables for which the parallel lines assumption is relaxed. γ_j is a $q \times 1$ vector of the regression coeffcients assigned to the q variables in τ_i', so that $\tau_i'\gamma_j$ is an increment associated only with the j^{th} logit. If $j = 0$ for all j, then this model is equivalent to the odds proportional model. If these variables do not meet the parallel lines assumption, γ_j is then non-null, the elements of γ_j being denoted γ_{jl} where $l = 1, \ldots, q$.

Once these conditions are set, a simultaneous null hypothesis test of the parallel regressions is calculated to check whether the final model meets the parallel lines assumption. The log-likelihood of the model is defined by:

$$L(\beta, \alpha, y, x', \tau', \gamma) = \sum_{i=1}^{n} \sum_{j=1}^{3} Y_i^{(j)} \ln \Pr\ (Y_i = j|\ x_i') \quad (5)$$

We verify the functional form of the model using a goodness-of-fit test and we conclude that the model is well specified; we then use the Belsley, Kuh and Welsch test (1980), which indicates the absence of colinearity or quasi-colinearity between the variables of the model.[11]

3.2 Description of the explanatory variables

The explanatory variables of the food security level (table 4) include variables related to the shocks impacting the households, to their adaptive capacity as well as to the productive and non-productive assets they own. Variables measuring the households' exposition to shocks take into account the diversity of potential shocks and stem from various sources. Thus, a first data series taken from the CFSVA – Mali survey (2005) accounts for the biophysical and socioeconomic shocks reported by households during the year preceding the survey.[12] The value of the shock variable is set to 1 if a shock is reported by the head household and to 0 otherwise. We also use data from the Climate Prediction Center (CPC) to take into account shocks linked to rainfall variability.[13] We compute two rainfall variability indices using monthly total rainfalls, which are available from 15 weather stations between 1982 and 2011. The first index measures

[11] Test results are available upon request.

[12] Biophysical shocks include floods, droughts, locust plagues, silting and extreme temperatures. Socioeconomic shocks include, in turn, higher consumer prices and lower output prices.

[13] NOAA NCEP CPC EVE (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/ .EVE/outline.html).

inter-annual rainfall variability (I_{inter}). It results from the index defined by Nicholson et al. (1989) and it is computed for each year between 2002 and 2005. [14] The centered reduced index is written:

$$I_{inter} = \sum_{i=2002}^{2005} \left(\left(\frac{X_i - \bar{X}}{\sigma} \right) - \bar{X}_n \right) / \sigma_n \quad (6)$$

X_i is the rainfall height of year i in *mm*, $\bar{X}$ is the yearly rainfall average (in *mm*) between 2002 and 2005, σ is the standard deviation of rainfall height between 2002 and 2005, $\bar{X}_n$ and σ_n are the average and standard deviation of the rainfall historical mean, respectively.[15] The second index, I_{intra}, measures intra-annual variability and is based on the rainfall seasonality index proposed by Walsh and Lawler (1981). This index uses the difference between the monthly rainfall quantities and a reference situation (I_i) in which rainfall are spread evenly throughout the year: $I_i = \frac{1}{X_i} \sum_{k=1}^{12} \left| X_k - \frac{X_i}{12} \right|$ where X_k is the rainfall height in *mm* for each month *k*. The intra-annual variability index is written:

$$I_{intra} = \sum_{i=2002}^{2005} \frac{I_i - \bar{I}}{\sigma} \quad (7)$$

Where $\bar{I}$ is the average of seasonality indices between 2002 and 2005. Rainfall data is assigned to the surveyed households according to which weather station is the nearest to their village. The matching is done using the great circle method, which uses the geographical coordinates (longitude and latitude) of the villages and weather stations (see figure A.1 in appendix).

Among the different variables susceptible to account for shock adaptation possibilities, we keep variables pointing to monetary factors such as the total income from remittances, sales of productive assets and livestock and the total number of available credit sources. Productivity is explained by the number of land under cultivation and total amount of agricultural and non-agricultural equipment.[16] Human capital related factors are also measured by several variables: the age of the head of household, the migration rate, the households' dependency ratio, and the

[14] The calculation of a rainfall variability index between 2002 and 2005 is justified by the need to consider lagged effects of rainfall shocks. This lagged impact of two to three years is based on the results of the empirical literature (Mohapatra et al., 2012; Couharde and Generoso, forthcoming).
[15] The annual precipitation normal was calculated between 1985 and 2009.
[16] Income from remittances (in FCFA) are in log. Agricultural equipment includes the number of plows, carts, tractors and oxen. Non-agricultural assets include, beds, radios, televisions, habitat quality (quality of materials) as well as possession of a motorcycle and a bike. The total number of livestock (measured in TLU) owned by households and the amount of on-farm consumption (in kg) are not included among the explanatory variables because they are included in the calculation of the food insecurity index.

presence of a household member with a chronic condition.[17] The last two variables help monitoring the exposition of households to food insecurity through idiosyncratic shocks. The migration rate is included as an independent variable in order to monitor the impact of short distance migration on food security."

Table 4: Description of the explanatory variables of food security

Variables	*Description*
Age	Age of household head.
Dependency ratio	Members whose age is > 65 and < 15 years on total household size.
Migration rate	Number of members in migration divided by the total size.
Chronic illness	1 in case of chronic illness and 0 otherwise
Education	1 if the household head is literate and 0 otherwise.
Remittances	Log of the income from remittances (in FCFA)
Cultures	Number of crops harvested by the household.
Credit sources	1 if the household has credit sources and 0 otherwise.
Sales	1 when households sell assets / livestock and 0 otherwise.
Agr. Equipt	Total number of agricultural equipment owned.
Non agr. Equipt	Total non-farm equipment owned (durable goods).
Iinter	Indicator of inter-annual variability in precipitation.
Iintra	Indicator of intra-annual rainfall variability.
Shocks	1 = Biophysical; 2 = Economical; 3 = Biophys. and economic; 0 = No shock

4 Results

4.1. Food security determinants

We display in table 5 the results obtained applying the *partial proportional odds* logit model to each of the climate zones. The analysis of the estimated coefficients shows that the effects which the shocks and the households' adaptive strategies have on food security are indeed different in the two climate regions.

As regards the impact of shocks, inter-annual and intra-annual rainfall variability has negative consequences on food security in the Sudanian region. Indeed, the estimated coefficients, which are negative for each index, show that a rise in rainfall variability is linked to an increase in the likelihood of being in a lower food security category. The estimated coefficients are −1.523 and −2.618 respectively and they are both significant at the 1% threshold. Computing the marginal

[17] The dependency ratio is calculated as the share of the inactive population in the household divided by the total size of the household. The inactive population consists of all members of a household aged under 15 and over 65.

effects confirmed the high exposition of households in this region to annual and seasonal rainfall variability.[18] Thus, the marginal effect of a rise in inter-annual rainfall variability is an increase of the probability to switch to a food insecurity situation by 20.7%, and to a risk situation by 11.5%. The marginal effect of a rise in intra-annual rainfall variability is bigger: the probability to become food-insecure or at risk increase by 39.2% and 17.4% respectively. Results of the estimate for the Sahelian zone show that only the coefficient assigned to inter-annual variability (−2.032) is significantly non-null at the 1% threshold. The marginal effect of the inter-annual variability rainfall index displays a 38.5% rise of the probability for food-secure households to become food insecure, and proves to be non-significant for the at risk household category.

Biophysical shocks have a significant negative effect on the food security levels only for the Sahelian zone, while the food security of households within the Sudanian region seems to be rather affected by external shocks of economic origin.

Regarding the households' adaptive strategies against shocks, results show that access to credit has a positive impact on the probability to switch to a higher food security category, with a coefficient estimated as 0.757 in Sahelian regions, and as 0.496 for Sudanian regions (significant at the 1% threshold). Ownership of agricultural and non-agricultural equipment also has positive effect in both regions. On the contrary; sales of equipment and of livestock has a significant effect on the probability of being food-secure only in the Sudanian zone, with a 0.466 coefficient which is significant at the 5% threshold. Migration also has different effects in the two regions. While the migration rate increases the probability of being food-secure in the Sahelian zone, it proves to be non-significant in the Sudanian one. In this latter region, the positive effect of migration on food security is shown by the remittances with a 0.508 coefficient, significant at the 1% threshold.

Overall, Malian rural households situated within the Sudanian zone are characterized by a food security level which is highly sensitive to rainfall variability. However, remittances limit the probability for these households to become food-insecure.

[18] We compute the Average Marginal Effect, i.e., for each observation of the explanatory variables. This methodology is more relevant than the marginal effects at the mean when dichotomous regressors are included in the model (Bartus, 2005). Results are shown in table A.1 in appendix.

Table 5: Results of the partial proportional odds model

	Sahelian zone		Sudanian zone	
Estimation of the $\boldsymbol{\beta}$ parameters				
Human capital				
Age	-0.004	(0.006)	-0.005	(0.006)
Education	1.012*	(0.538)	1.495**	(0.665)
Dependancy rate	0.848**	(0.412)	-0.904	(0.644)
Chronic illness	0.261	(0.182)	-0.678***	(0.182)
Migration rate	1.295**	(0.641)	-0.126	(0.831)
Assets / adaptation capacity				
Remittances	0.050	(0.143)	0.508***	(0.131)
Cultures	-0.067	(0.043)	0.045	(0.049)
Credit sources	0.757***	(0.188)	0.496***	(0.184)
Sales	0.079	(0.198)	0.466**	(0.196)
Agr. Equipment	0.540***	(0.093)	0.409***	(0.099)
Non agr. equipment	0.274***	(0.073)	0.277***	(0.068)
Rainfall variability				
I_{inter}	-2.032***	(0.569)	-1.523***	(0.702)
I_{intra}	-0.313	(0.331)	-2.618***	(0.698)
External shocks (déclarés)				
Biophysical	-0.912***	(0.226)	-0.105	(0.230)
Economic	-0.005	(0.306)	-0.648**	(0.258)
Economic and biophysical	-0.152	(0.185)	0.065	(0.292)
Estimation of the $\boldsymbol{\gamma}$ parameters				
I_{inter}			-0.561**	(0.280)
Education	-1.591***	(0.617)	-1.920***	(0.729)
Equipements non agricoles	0.154**	(0.072)		
Estimation of the $\boldsymbol{\beta}^*$ parameters				
I_{inter}			-0.348	(0.238)
Education	0.576	(0.423)	0.414	(0.415)
Non agr. equipment	0.428***	(0.073)		
Test statistics				
N	616		532	
χ^2	226.53		123.63	
$prob > \chi^2$	0.000		0.000	
Pseudo R^2 (Cox and Snell)	0.261		0.293	

*Note: When γ is significantly different from zero, the effect of the estimated coefficients is different between categories. A new coefficient β^* is calculated to measure the chances of passing from the category "food risk" to the category "Food Security". β^* is calculated as the sum between the corresponding β's and γ's. Standard deviations are in parentheses. *** p<0,01, ** p<0,05, * p<0,01.*

4.2. Remittances and food security

To further specify the positive effect of remittances on food security in the Sudanian zone, we compute predicted probabilities which were estimated using the values of the rainfall variability indices (figure 2).

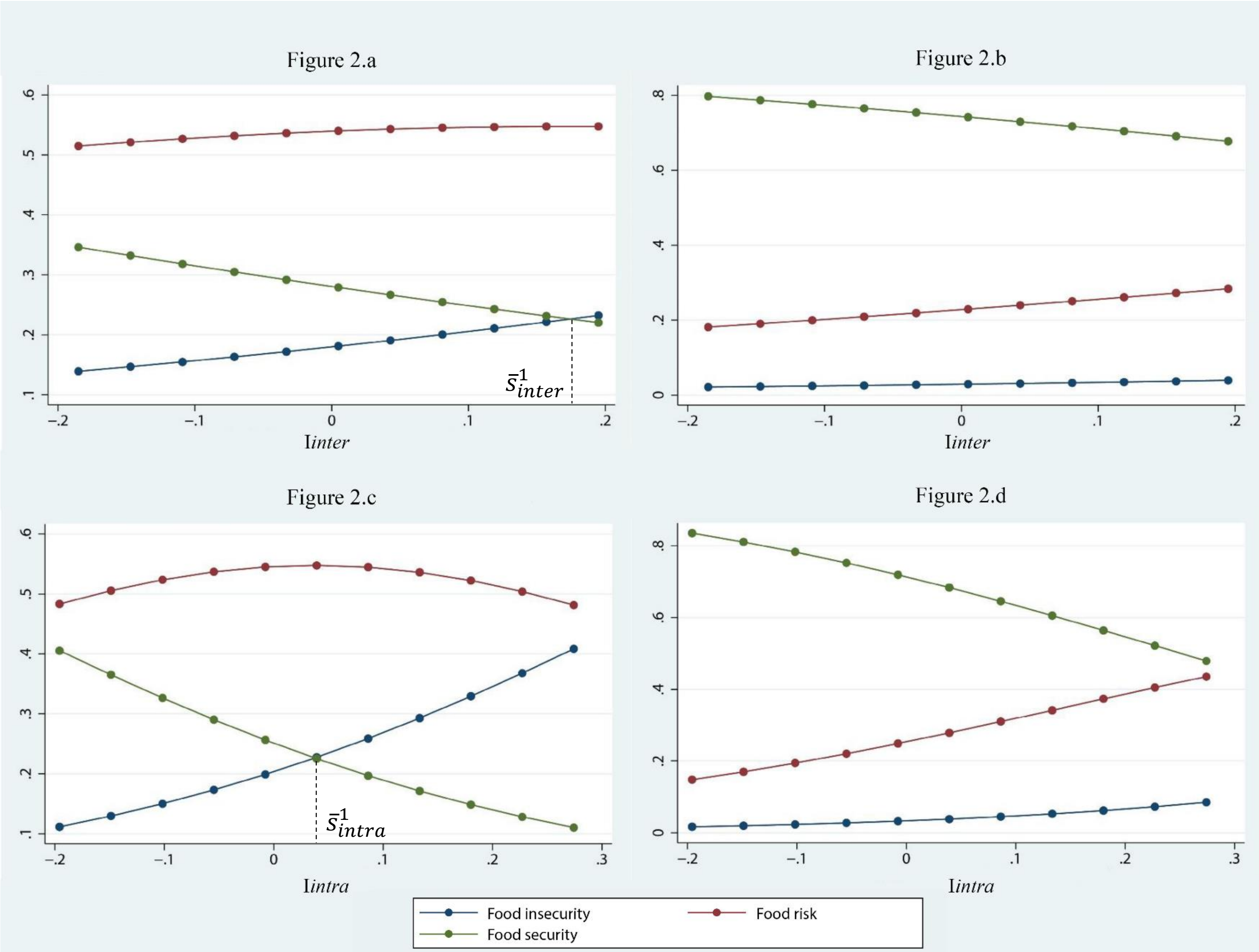
Figure 2a and 2b show how the likelihood of being in a specific food security categories varies according to the values of the inter-annual rainfall variability index, when the value of remittances is set to zero (figure 2a) and when it is maximal (figure 2b). When the value of remittances is set to zero, the probability of belonging to the food-insecure category rises progressively and meets the probability of being food-secure for $\bar{s}_{inter}^{1} = 1.8$. This is the inter-annual rainfall variability threshold, from which the probability of becoming food-insecure exceeds that of being food-secure when all variables expect remittances are set to average values. When remittances are set to their maximum value (figure 2b), the probability for households to be food-secure increases. The probability of belonging to the “food insecurity” category decreases and its probability range comes close to zero, so much so that no threshold appears.

Figures 2c and 2d represent the same probability trends, but according to the values of the intra-annual rainfall variability index. The results show that remittances also reduce the negative effect of intra-annual rainfall variability on food security. Indeed, in the absence of remittances, the propensity score of belonging to the food-insecure household category increases along the inter-annual variability index (figure 2c). The probability of belonging to the food-secure category follows an opposite and quasi-symetrical trend, leading the two propensity scores to meet for $\bar{s}_{intra}^{1} = 0.03$. When the value of the remittances variable is set to its maximum (figure 2d), the probability of belonging to the food-secure household category increases. This probability decreases as the intra-annual rainfall variability index increases, thereby emphasizing the likelihood of becoming at risk, although no critical threshold appears.

Overall, our results demonstrate the importance of remittances for the food security of rural households in the Sudanian region of Mali. Thus, beyond their effect in smoothing consumption in the advent of negative income shocks (Gubert, 2002), remittances also constitute an efficient way of maintaining some level of food security in an environment characterized by high rainfall instability.

However, the food security of households does not only depend on their ability to maintain a minimal consumption level; it is also explained by their ability to accumulate productive assets. To specify the determinants of food security, it is thus necessary to question the various effects which remittances may have on the ability of households to produce themselves instead of using this external source of income to satisfy their food needs.

Figure 2: Predicted probabilities based upon the precipitation variability index (Sudanian zone).



4.3. Remittances and « structural » food security

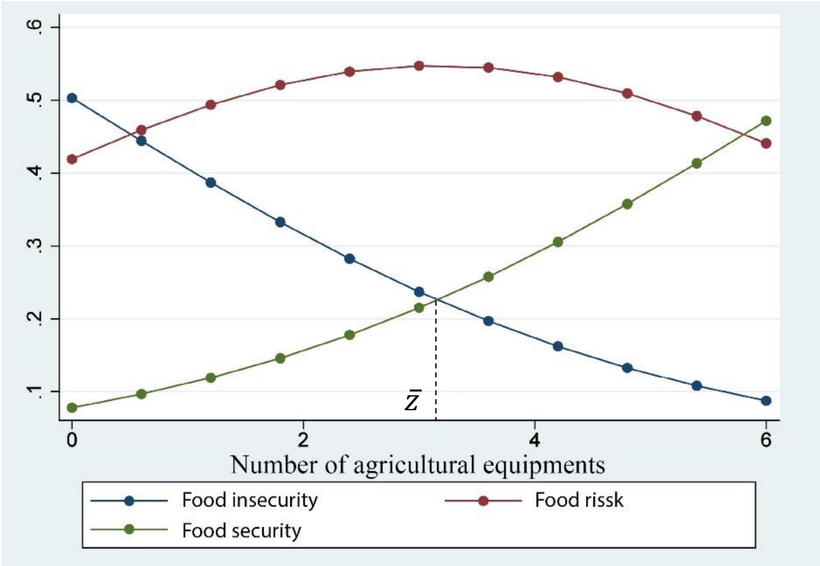
Several studies have shown that the structural characteristics of small production units do not enable coping with low productivity in land exploited to its limits, in particular in the former cotton basin (Koutiala) and in the lakeside area (Delarue et al., 2009; Harrower and Hoddinott, 2005). Extensive farming as well as the diversification of income sources (agricultural and non-agricultural) represent the main adaptive strategies of producers, when the reinforcement of productive capacities is of central importance for food security in a context of high dependence on rainfall fluctuations (Nikiéma, 1999).

To analyze the impact on remittances on the productive capacities of rural households in the Sahelo-Sudanian zone of Mali, we first estimate a level of agricultural assets at which households are food-secure. Figure 3 represents the propensity scores of the *partial proportional odds* model according to the quantity of agricultural equipment owned by households, every other variable being set to their average level. The propensity score of the food-insecure household category meets that of the food-secure category at a threshold of three agricultural equipment items owned. At this critical threshold ($\bar{z}$ = 3), a household doesn't have enough production capacity to ensure its own food security.

Using this threshold and the nutritional situation of households, we then distinguish three household categories. The first category includes households who experience structural food insecurity. These households are not only food-insecure, but they also own a small number of agricultural equipment pieces (z_h) which is strictly inferior to the critical threshold ($z_h < \bar{z}$), and which tends to keep them durably in a food insecurity situation. The second category includes households who experience transitory food insecurity. These are households who are food-insecure but who own a number of agricultural equipment items equal to or higher than the critical value $\bar{z}$. Finally, the third category includes households experiencing structural food security. These households are food secure and their productive capacity is sufficient to maintain durable food security.

We estimate a multinomial logit model to analyze the determinants of structural food security. The dependent variable of the model can take three discrete values *m*, indicating the situation of a household based on the number of agricultural equipment items owned and on their nutritional situation, i.e. whether it experiences structural food insecurity, chronic food insecurity, or structural food security. The computation of the marginal effects shows that the probability for households to be below the critical threshold $\bar{z}$, as measured by the amount of agricultural equipment, is sensitive to rainfall fluctuations and to socioeconomic shocks.

Figure 3: Predicted probabilities based upon the number of agricultural equipment (Sudanian zone).



The marginal effect of an increase in the inter-annual rainfall variability index leads to a decrease of the probability of experiencing structural food security by 51.6%, and to an increase of switching to a structural food insecurity situation by 33.3%. Intra-annual rainfall variability has an important effect on the probability of switching between categories. The marginal effect of an increase of the index leads to a 64.2% decrease of the probability of experiencing structural food security, and to an increase of the probability of switching to transitory food insecurity (+36.1%), or to structural food insecurity (+28.8%). As for socioeconomic shocks, they lead to a 14.8% increase of the probability for households to experience structural food insecurity, and they have no impact whatsoever on the probability of switching over to the transitory food insecurity category.

Regarding the adaptive strategies deployed by households against shocks, our results show that access to credit is the only variable having a positive effect on both the accumulation of agricultural equipment and on food security. Computing the marginal effect indeed shows that an increase in access to credit leads to a 13% rise of the probability for households to experience structural food security, and to a 13.4% decrease of the probability for households to experience structural food insecurity.

As for remittances, they have no effect on structural food insecurity and thus on the accumulation of agricultural equipment. Indeed, their increase only implies a change in the probability for households to experience transitory food insecurity and structural food security. The computation of the marginal effects shows that a one-unit rise of the remittances value leads to an 11.4% increase in the likelihood of switching to structural food security, and to an 11.7% decrease in that of switching to transitory food insecurity.

Thus, remittances do have a positive impact on the food security of households situated in the Sudanian zone of Mali. However, this effect occurs because remittances allow for the buying of food, not because they lead to an accumulation in productive capital. In the end, remittances seem to constitute a viable adaptive strategy deployed by households to cope against shocks, and especially the rainfall shocks which these households face. Unlike access to credit however, they do not allow households to get out of a structural food insecurity situation.

Table 6: Results of the multinomial logit model, the marginal effects (Sudanian zone)

	Structural Food Insecurity		Transitory Food Insecurity		Structural Food Security	
Age	-0.006***	(0.001)	0.003**	(0.001)	0.002*	(0.001)
Education	0.039	(0.086)	-0.038	(0.092)	-0.001	(0.079)
Dependency ratio	0.117	(0.148)	-0.360**	(0.162)	0.243	(0.165)
Chronic illness	0.003	(0.044)	-0.050	(0.048)	0.047	(0.044)
Migration rate	-0.001	(0.200)	0.130	(0.213)	-0.129	(0.203)
Remittances	0.003	(0.036)	-0.117***	(0.044)	0.114***	(0.032)
Cultures	-0.020*	(0.012)	-0.002	(0.012)	0.023**	(0.011)
Credit sources	-0.134***	(0.046)	0.004	(0.048)	0.130***	(0.042)
Sales	-0.114**	(0.055)	-0.040	(0.069)	0.154**	(0.074)
I_{inter}	0.333**	(0.152)	0.183	(0.182)	-0.516***	(0.139)
I_{intra}	0.288**	(0.146)	0.361**	(0.167)	-0.642***	(0.167)
Biophysical	0.089*	(0.049)	-0.068	(0.059)	-0.021	(0.053)
Economic	0.148**	(0.065)	0.004	(0.067)	-0.152***	(0.053)
Bio and économic	0.128**	(0.057)	-0.044	(0.076)	-0.084	(0.074)
Test statistics						
N (by group)	159		208		165	
N			532			
χ^2			124.4			
$prob > \chi^2$			0.000			
Pseudo R^2 [a]			0.1720			

Note: The null hypothesis of independence of classes (IIA) is respected according to the Hausman tests and Hsiao (1985). [a] *Pseudo R2 is McFadden. Standard deviations are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

5. Conclusion

In this paper, we have analyzed the main determinants of household food security using the CFSVA survey conducted in Mali in 2005. Using this survey shows, first, that food situation is tense in the whole country, with as much as 65% of rural households experiencing food insecurity. This food pressure is as much observed in the Sahelian zone of the country, characterized by 150 to 750 *mm* annual isohyets, as in the more humid southern zone, which is also more favorable to agriculture with 750 to 1200 *mm* annual rainfall.

The results obtained using a *partial proportional odds* logit model show that the food security of Malian rural households is sensitive to rainfall fluctuations. In particular, results for the Sudanian zone show high exposition of local households to inter-annual and intra-annual rainfall variability. These findings demonstrate the weakening of this zone which, though favorable to agriculture, relies upon a "cotton system" undergoing a crisis since the 2000s.

In this context, we show that the diversification of income sources, through the reception of remittances, constitutes one of the main ways of coping with the negative impact of climate hazards on the food security level of rural households situated in this region. However, breaking down food security into a structural component linked to the accumulation of agricultural assets and a transitory one linked to food consumption, we show that remittances only have a positive impact on the transitory component. Thus, remittances seem only susceptible of smoothing food consumption in the advent of a transitory income shock. They do not have any impact on the capacity of the less resilient households to get out of a structural food insecurity situation, the degree of resilience being here measured by the ownership of a minimal stock of agricultural assets.

Although, to this day, the CFSVA – Mali survey (2005) is the most exhaustive and representative survey of food security on a national scale, the absence of repeated survey data is limiting. Without such data, our study makes strong assumptions about the inter-temporal variation of household consumption profiles, and only gives a static picture of food security in Mali. The availability of such data and their use within the framework of panel data econometrics should allow for more specific analysis of the dynamics of food security in Mali. It could thus lead to more precise recommendations for political action against food insecurity.

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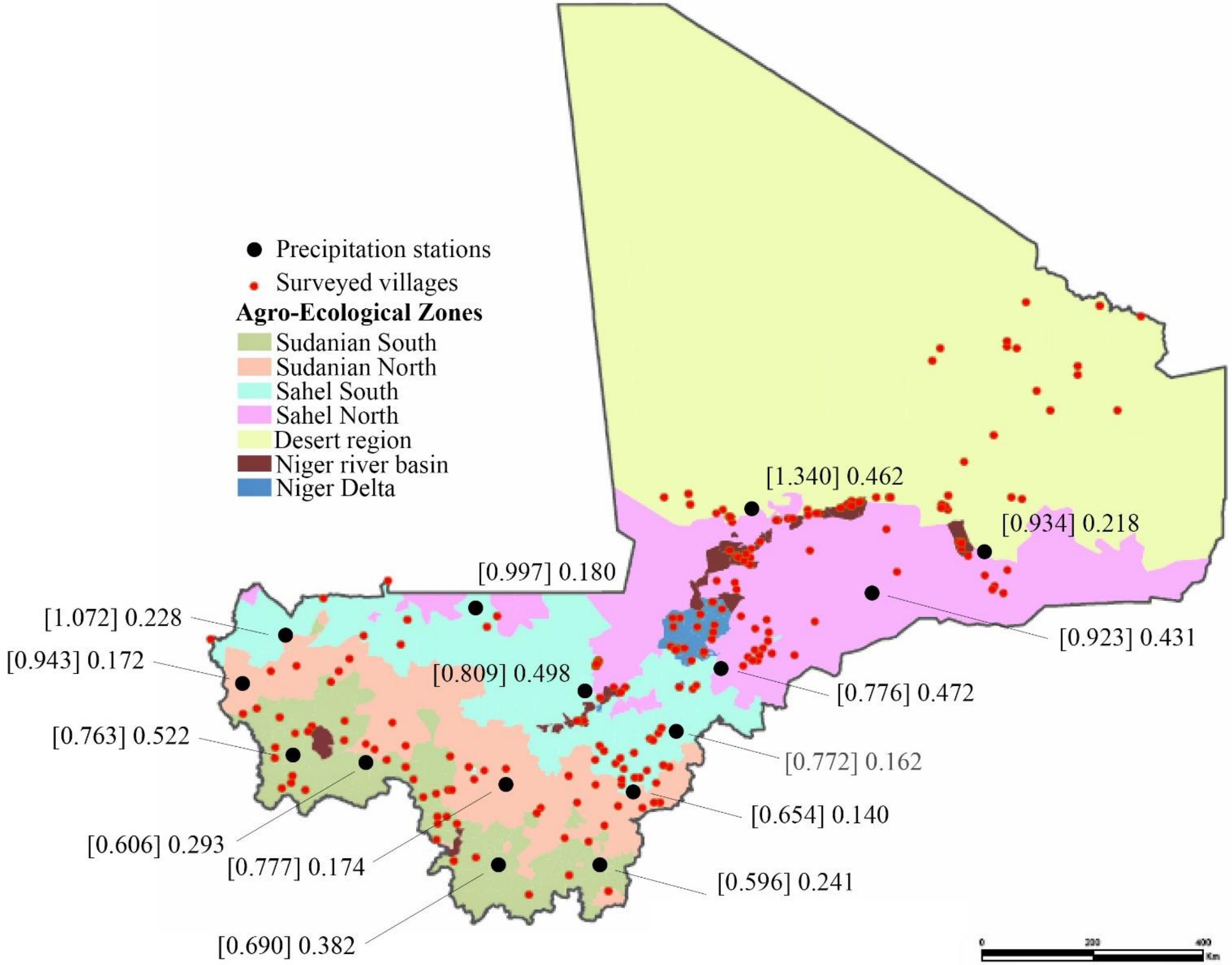
Appendix

Figure A.1: Location of the rainfall stations and surveyed villages (CFSVA-Mali, 2005)



Note: Values of the intra-annual variability rainfall index is reported in brackets.

Table A.1: Average Marginal Effects

	Sahelian zone			Sudanian zone		
	Food Insecurity	Food sec. Risk	Food Security	Food Insecurity	Food sec. Risk	Food Security
Age	0.000	0.000	-0.000	-0.000	-0.000	0.001
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Education	-0.151**	0.249***	-0.098	-0.138***	0.191***	-0.053
	(0.058)	(0.076)	(0.062)	(0.035)	(0.078)	(0.073)
Dependency ratio	-0.180	-0.005	0.185	-0.129	-0.064	0.193
	(0.111)	(0.015)	(0.114)	(0.090)	(0.047)	(0.135)
Chronic illness	-0.050	-0.003	0.054	-0.006	-0.003	0.009
	(0.033)	(0.005)	(0.037)	(0.025)	(0.012)	(0.038)
Migration rate	-0.245**	-0.007	0.252**	0.018	0.008	-0.027
	(0.122)	(0.021)	(0.125)	(0.119)	(0.059)	(0.178)
Remittances	-0.009	-0.000	0.009	-0.069***	-0.038***	0.107***
	(0.027)	(0.001)	(0.028)	(0.018)	(0.012)	(0.027)
Cultures	0.019**	0.000	-0.020**	-0.006	-0.003	0.009
	(0.008)	(0.001)	(0.008)	(0.006)	(0.003)	(0.010)
Credit sources	-0.143***	-0.004	0.147***	-0.074**	-0.028**	0.099***
	(0.035)	(0.011)	(0.036)	(0.028)	(0.011)	(0.037)
Agr. Equipt	-0.102***	-0.003	0.105***	-0.052***	-0.029***	0.082***
	(0.018)	(0.008)	(0.018)	(0.015)	(0.010)	(0.023)
Non agr. Equipt	-0.052***	-0.031**	0.083***	-0.036***	-0.020***	0.056***
	(0.013)	(0.013)	(0.014)	(0.009)	(0.006)	(0.014)
Sales	0.002	0.000	-0.002	-0.059**	-0.045	0.105**
	(0.040)	(0.000)	(0.041)	(0.024)	(0.033)	(0.052)
Iinter	0.385***	0.011	-0.397***	0.207**	0.115**	-0.323**
	(0.125)	(0.033)	(0.132)	(0.095)	(0.053)	(0.149)
Iintra	-0.059	-0.001	0.061	0.392***	0.174***	-0.567***
	(0.063)	(0.005)	(0.064)	(0.099)	(0.079)	(0.150)
Biophysical	0.281***	0.012	-0.294***	0.015	0.007	-0.022
	(0.043)	(0.021)	(0.045)	(0.033)	(0.014)	(0.048)
Economic	0.001	0.000	-0.001	0.103**	0.024**	-0.128***
	(0.058)	(0.001)	(0.059)	(0.045)	(0.010)	(0.046)
Bio and eco	0.029	-0.000	-0.028	-0.009	-0.004	0.014
	(0.063)	(0.005)	(0.059)	(0.040)	(0.023)	(0.063)

*Note: Standard deviations are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*