micro Insurance Innovation facility
PROTECTING THE WORKING POOR

International Labour Office
Geneva

WEATHER INDEX-BASED INSURANCE IN A CASH CROP REGULATED SECTOR: EX ANTE EVALUATION FOR COTTON PRODUCERS IN CAMEROON

Antoine Leblois
Philippe Quirion
Benjamin Sultan

RESEARCH
PAPER No.21

AUGUST 2012

WEATHER INDEX-BASED INSURANCE IN A CASH CROP REGULATED SECTOR: EX ANTE EVALUATION FOR COTTON PRODUCERS IN CAMEROON

ANTOINE LEBLOIS[1], PHILIPPE QUIRION[2] AND BENJAMIN SULTAN[3]

ABSTRACT

In the Sudano-sahelian region, which includes Northern Cameroon, the inter-annual variability of the rainy season is high and irrigation is scarce. As a consequence, bad rainy seasons have a massive impact on crop yield and regularly entail food crises. Traditional insurances based on crop damage assessment are not available because of asymmetric information and high transaction costs compared to the value of production. Moreover the important spatial variability of the weather creates a room for pooling the impact of bad weather using index-based insurance products. We assess the risk mitigation capacity of weather index-based insurance for cotton growers. We compare the capacity of various weather indices coming from different sources (daily rainfall, temperatures and satellite imagery) to increase the expected utility of a representative risk-averse farmer.

We first find that weather index-based insurance is associated with huge basis risk, no matter what the index or the expected utility function is chosen, and thus has limited potential for income smoothing (in accordance with previous results in Niger: Leblois et al., 2011). We show that using observed cotton sowing dates significantly increases the performance of indices based on daily rainfall data. We give a tractable definition of basis risk and use it to show that calibrating parameters in sub-regions allows to reduce dramatically basis risk and to avoid non negligible balancing out between distinct geographical zones, even within a relatively bounded area. For instance the use of remote sensing indicators, that have the strong advantage of being cheap, easy to use and available freely, only improve the performance of insurance when calibrated to the appropriate spatail level. This leads to think that weather index-based insurance are worth only if calibrated on an area subject to a homogeneous climate, but potentially distinct weather during the same cropping season. In our case, the size of the area corresponds to about one decimal degree. We finally provide raw evidence showing that idiosyncratic (intra-village) yield and price shocks are also quite significant, comparing the amplitude of income variations due to those shocks relatively to weather shocks and conclude that they should be considered with greater attention. Those results have to be seen under the light of the recent findings showing very low take-up rates of weather index insurances when actually offered to farmers.

1. INTRODUCTION

Cotton sectors in Francophone Western and Central Africa are characterized by their input distribution scheme. National cotton companies, often follow the 'fili`ere' model inheritated from the colonial era (Delpeuch and Leblois, 2012). They act as a monopsonic buyer, providing inputs on credit (with no other collateral than the cotton future harvest) at the sowing and during the growing season. They also supply extension services (mostly infrastructure and agronomical research).

Cotton sales and production were boosted by the devaluation (1994) in the whole CFA zone, the sector strenght has been however challenged since the beginning of the century. Profits in cotton growing activities are quite limited given the need for costly inputs use and thus highly depend on input and cotton prices. Inputs whose production is energy intensive, are bought at a price under constant upward pressure since the year 2000. On the other hand cotton prices are linked to euro/dollar exchange rate that dramatically increased since 2002.

The sector also suffers from several geographic and climatic challenges: isolation of the North of the country, decline in soil fertility due to increasing land pressure. Moreover cotton is rain fed in almost all sub Saharan African (SSA) producing countries, and largely depends on rainfall availability. The impact of a potential modification of rainfall distribution during the season or the reduction of its length has been found as of particular importance and could even be higher under global warming (cf. section 2.3).

Cotton is the major cash crop of Cameroon and represents the major income source (monetary income in particular) for growers of the northern provinces (Nord and Extrˆeme Nord, Folefack et al., 2011). It is grown by smallholders (320 000 for 203 000 ha in 2006 and 210 000 for 138 000 ha in 2007 according to Mbetid-Bessane et al., 2009 and Kaminsky et al., 2011) with about .6 hectares dedicated to cotton production on average in the whole area (Gergerly, 2009).

1 CIRED (Centre International de Recherche sur l'Environnement et le Developpement), leblois@centre-cired.fr
2 CIRED, LMD (Laboratoire de M´et´eorologie Dynamique)
3 LOCEAN (Laboratoire d'Oc´eanographie et du Climat Lxperimentation et Approches Num´eriques).

The very low surface grown with cotton per farmer added to the very low sparing capacity makes the sector particularly depending on exogenous shocks such as rainfall. When growers are not able to reimburse their input credit at the harvest[4], they are not allowed to take a credit next year. Falling into a situation of unpaid debt thus is very painful for those cotton growers, especially when little livestock is owned by the family (Folefack et al., 2011).

Traditional agricultural insurance, based on damage assessment cannot efficiently shelter farmers because they suffer from an information asymmetry between the farmer and the insurer, especially moral hazard, and from the cost of damage assessment. An emerging alternative is insurance based on a weather index, which is used as a proxy for crop yield (Berg et al., 2009). In such a scheme, the farmer, in a given geographic area, pays an insurance premium every year, and receives an indemnity if the weather index of this area falls below a determined level (the strike). Weather index-based insurance (WII) does not suffer from the two shortcomings mentioned above: the weather index provides an objective, and relatively inexpensive, proxy of crop damages. However, its weakness is the basis risk, i.e., the imperfect correlation between the weather index and the yields of farmers contracting the insurance. The basis risk can be considered as the sum of three 1 The standing crop is used as the only collateral and credit reimbursement is deducted from growers' revenue when the national company buys the cotton, cf. section 2.2 for further descriptions. risks: first, the risk resulting from the index not being a perfect predictor of yield in general (the model basis risk). Second, the spatial basis risk: the index may not capture the weather effectively experienced by the farmer; all the more that the farmer is far from the weather station(s) that provide data on which index is calculated. Third, the heterogenities among farmers, for instance due to their practices or soil conditions are often found quite high in developing countries. This last idiosyncratic shocks are often considered to be more easy to overcome at the village level, by private tranfers through social networks. This paper therefore aims at calibrating WII contracts in order to shelter cotton growers against drought risk (either defined on the basis of rainfall, air temperature or satellite imagery). Insurance indemnities are triggered by low values of the index supposed to explain yield variation. It allows to pool risk across time and space in order to limit the impact of meteorological (and only meteorological) shock on producers income.

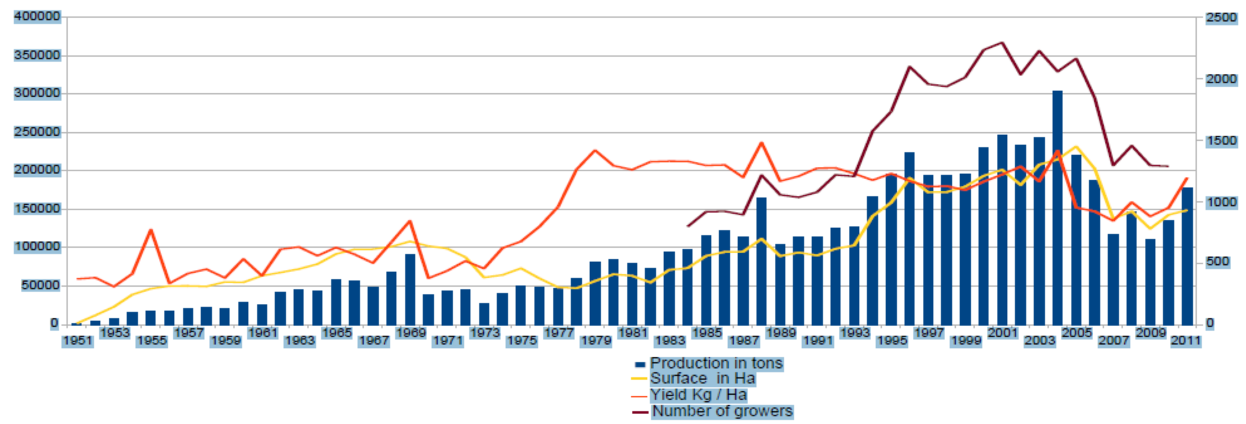
The first section describes the cotton sector in Northern Cameroon, the data and underlying agrometeorological methods. The second section is dedicated to the hypothesis: the insurance design and the calibration of the model. The last section displays the reduction of the risk premium using different indices among different zoning, discussing the optimal insurance sheme for pooling income shocks.

2. CONTEXT, AREA AND DATA

2.1 NATIONAL FIGURES

Cameroon national cotton company (Sodecoton) suffered from a decreasing trend in yields since the end of the 80's (Fig. 1). Such feature, at least a rupture from the increase in African cotton yield between the 60's and the 80's, can be observed in most of major African producing countries (Vitale et al., 2011).

Figure 1: Evolution of Cameroon seed cotton yield, production, surface and number of growers.



4 The standing crop is used as the only collateral and credit reimbursement is deducted from growers'
revenue when the national company buys the cotton, cf. section 2.2 for further descriptions.

It could be due to fertility loss and/or soil erosion. It is indeed accompanied with an increase of surface grown with cotton, such development of the cotton sector area often pointed out as a source of long run reduction in yield levels. The decreasing trend could be linked to market entry by new less experienced farmers, using less fertile land, encouraged by the availability of quality fertilizer on credit, as pointed out by Delpeuch and Leblois (2012). Stabilized buying price and the distribution of inputs on credit (for cotton but also more recently for cereals) at favorable prices and are indeed strong incentives for growing cotton.

The more recent decrease in production level (cf. Fig. 1) has mostly been explained by two major issues, from which almost every cotton producing country in West and Central Africa suffers from: institutional issues, such as side-selling and credit default, linked to country specific sector management[5] as well as by high fertilizer prices (Cr´etenet, 2010). The recent decrease in production however seem to be mostly explained by the decrease in the number of growers.

2.2 STUDY AREA AND DATA

We dispose of yield and gross margin per hectare time series and at the sector level from 1977 to 2010, provided by the Sodecoton. Gross margin is the profit after input reimbursement, excluding labor. We matched this data to a unique meteorological (daily rainfall and temperatures: minimal, maximal and average) data from different sources[6], with at least one rainfall station per sector (Fig. 2). The cotton administration counts 9 regions divided in 38 administrative sectors (cf. Fig. 3), themselves divided in about 250 subsectors (Sadou et al., 2007). Sectors agronomical data are matched to rainfall data using the nearest station that is at an average of 10km and a maximum of 20km. Sectors location are the average GPS coordinates of every Sodecoton's producers group (PG) within the sector, it represents about 900 squared kilometres on average.

Figure 2: Meteorological (large circles) and rainfall stations (small circles) network of the region and centres (dots: average of PG's locations) of sectors. Sources: Sodecoton, IRD and GHCN (NOAA).

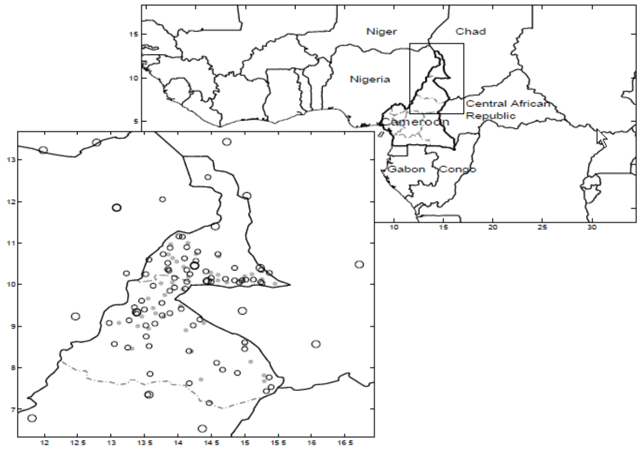
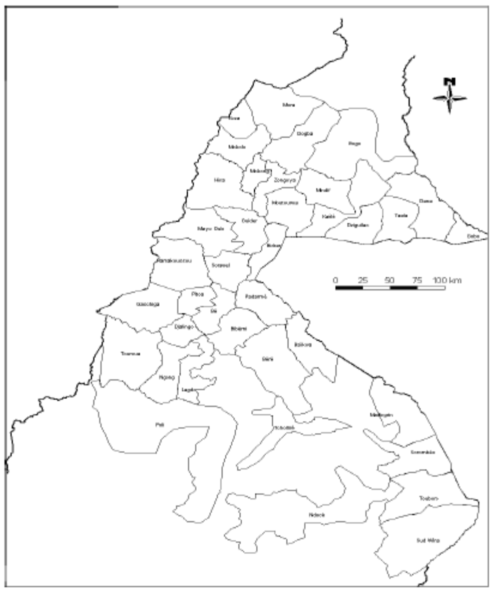


Figure 3: Sodecoton's administrative zoning: the sectors level. Source: Sodecoton



5 Including side-selling in borderland areas to countries where price are higher, Nigeria in the case of Cameroon, or where the cotton sector has been liberalized which permit to avoid input credit reimbursement, cf. Aurojo-Bonjean et al. (2003).A major part a the input credit is indeed reimbursed after harvest when the national cotton society buys seed-cotton to producers. According to Kaminsky et al. (2011) the buying prices in Nigeria could have reached three times as much as the Cameroonian price in recent years. Smuggling, that particularly occurs in the North-West of the cotton zone, creates a potential loss of about 16% of the national production for the authors. However, side-selling always existed in Cameroon, when looking at annual (for instance in 1989) Sodecoton's briefs reporting heavy leaks of cotton going to Nigeria. Credit default in Cameroon did not exceed 5% untill 2005, but reached 10% after 2006.

6 Institut de la Recherche pour le Developpement (IRD) and Sodecoton's rain gauges high density network.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Annual cumulative rainfall (mm)	949.533	227.269	412	1790	849
Growing season cumulative rainfall (mm)	816.028	195.748	339	1538	849
Yield	1150.216	318.006	352	2352	849
Cotton margin* (CFA francs per Ha)	114846.708	50065.931	-7400	294900	849

* Profit after inputs (excluding labor costs) reimbursement.

We interpolated, for each sector, temperature data from ten IRD and Global Historical Climatology Network[7] (GHCN) synoptic meteorological stations of the region (including six in Cameroon and four in Chad and Nigeria). We used a simple Inverse Distance Weighting[8] interpolation technique, each station being weighted by the inverse of its squared distance to the sector considered applying a reduction proportional to 6.5 celsius degree (C) per 1000 meters altitude. The average annual cumulative rainfall over the whole producing zone is about 950 millimetres (mm) as showed in Table 1, hiding regional heterogeneity we explore in the next section.

We finally used the Normalized Difference Vegetation Index (NDVI)[9]), available for a 25 year period spanning from 1981 to 2006. This vegetation index is a relative measure of the spectral difference between visible (red) and near-infrared regions and is thus directly related to green plants photosynthesis. It has a high attrition rate before 1991 (about one third of the data), but very limited between 1991 and 2010.

2.3 INPUT CREDIT SCHEME

The cotton society, Sodecoton (Soci´et´e de Developpement du Coton du Cameroun) and its Malian, Senegalese and Chadian counterparts, are still public monopsonies (Delpeuch and Leblois, forthcoming). Those parastatals are thus the only agent in each country to buy cotton from producers at pan-seasonally and -territorially fixed price. The specificity of those institutional setting is also characterized by the input provision at the 'fili`ere' level. Costly inputs (but also agricultural extension services, infrastructures...) are indeed provided on credit by the national companies at the sowing, ensuring a minimum quality level and their availability in spite a great cash constraint that characterize the lean season in those remote areas.

In that purpose collective guarantee circles (CGC, named Groupe d'Initiative Commune in French: GIC's) were set up to control the risk of bad management in large groups. Each grower put up bond for the group, hence creating a new associative layer within the village (Enam et al., 2011). However, in spite of a self-selection process to form those groups, the mechanism suffers from local elite pressure and influence from traditional power structures, as described in Kaminsky et al. (2011). GIC's exist since 1992, the 2010 reform of the producers' organization however led to a pool of villages producers' groups (PG's) at the zone level (2000), union of GIC's at the sector level (48) and a federation of unions at the region level (9). We study an insurance mechanism at the sector level (due to data availability constraint, see section below), which thus naturally lead the unions of the producers' organization to be the insured entity. The is about 2000 active PG's in 2011, which represent an average of about 50 PG's per sector.

Moreover, the producers' organization already has recently played part of a risk pooling role (or more precisely income smoothing) when reallocating the annual surplus of good years into a compensation found for bad years. Before that the surplus was simply distributed as a premium to producers for the next growing season (Gergely, 2009). Besides, the the producers' organisation also urge the villages to stock cereals in order to increase consumption smoothing and to lower the risk of decapitalization in case of a negative income shock (Kaminsky et al., 2011).

3. AGROMETEOROLOGY OF COTTON IN CAMEROON AND METHODS

3.1 WEATHER, CLIMATE CHANGE AND COTTON GROWING IN CAMEROON

The critical role of meteorological factors in cotton growing in Western Africa has been widely documented. Blanc et al. (2008) for instance pointed out the impact of the distribution and schedule of precipitation during the cotton growing season on long run yield plot observations in Mali. Length of the rainy season, and by extension late onset or premature end of the rainy season, is also seen as a key element determining cotton yields in most of the recent studies on this region of the world. The onset and duration of the rainy season was recently found to be the major

7 National Oceanic and Atmospheric Administration (NOAA): http://www7.ncdc.noaa.gov

8 IDW method (Shephard 1968), with a power parameter of two.

9 The NOAA remote sensing data (GIMMS-AVRHH: available online at http://www.glcf.umd.edu/data/gimms), Pinzon et al. (2005).

drivers of year-to-year and spatial variability of yields in the Cameroonian cotton zone (Sultan et al., 2010). The impact of change in precipitations is thus supposed to be driven by the increase in extreme events (droughts and floods), the lenght of the rainy season and the onset predictability (ICAC, 2007).

The prevision of an increase in temperature level and the variability of precipitations during the coming century is quite reliable in spite of a lack of consensus about the evolution of the level of precipitations in Western Africa (IPCC, 2007). Although, the recent evolution differs along the Guinean coast were an increase of the precipitation has been observed, probably accompanied with a greening phenomenon also taking place in the soudanian zone, in contrast to the evolution of the sahelian zone characterized by the severe droughts of the 70's and the 80's and a very shy reversal from the end of the 90's (IPCC: AR4, 2007).

According to the literature, the main (and most robust) estimated impact of climate change on cotton production goes through the channel of an increasing temperature. ICAC (2007) draw attention on the fact that an increase of the temperature can either increase of reduce cotton yields, although in West Africa it will probably reduce the yield potential, especially given that arid areas are very vulnerable to climate change. A temperature increase can either increase or reduce yield, depending on the capacity to sow earlier, which will probably not be the case in the region of the study. However it also depend on the cultivar, the region and the fibres characteristics. Luo (2011) reports that instantaneous air temperature above 32oC reduces cotton pollen viability, and temperature above 29oC reduces pollen tube elongation.

3.2 GROWING SEASON DEFINITION AND CUTTING-IN GROWING PHASES

We define and only consider significant daily rainfall, that will not be entirely evaporated, as superior to .85 mm following the meteorological analysis of Odekunle (2004). We first considered the cumulative rainfall (CR) over the whole rain season. We then consider a refinement of each of those simple indices by bounding daily rainfall at 30 mm, corresponding to water that is not used by the crop due to excessive runoff (Baron et al., 2005). However result on risk pooling capacity of both indices tend to show that such considerations are not critical for cotton.

We will thus mainly study the length of the growing season (GS), cumulative (significant) rainfall (CR) on the whole growing season and by growing phases. We then also compare the pooling capacity of bi-monthy satellite imagery (above-mentionned NDVI) during the growing season (beginning of April to the end of October). There is 2 major ways of using NDVI that are already a sum of hourly or daily data: one can alternatively consider the maximum value of the sum of the periodical observation of the indicator for a given period (say the GS). Turvey (2011) considers that the maximum represents the best vegetal cover attained and will proxy yields and Meroni and Brown (2012) proxied biomass production by computing an integral of remote sensing indicators (in their case: FAPAR) during the growing period.

In order to consider only the rainfall used by the crop it is usefull to know when the growing cycle begins (typically the sowing or emergence date). We used the informations about sowing date reported by the Sodecoton in their reports: the share of the acreage sowed with cotton at each of every 10 days between the 20 of may untill the end July. We defined the beginning of the season (the emergeance) as the date for which half the cotton area is already sown (has already emerged).
Since this information was not available for the whole sample, we also simulated a sowing date following a criterium of the onset of the rainfall season defined by Sivakumar (1988). It is based on the timing and of first rainfall's daily occurence and validated by Sultan et al. (2010) on the same data. will test whether observing the date of the growing cycle, could be useful to weather insurance by using both the raw and approximated date of sowing and emergeance. Simulated sowing date seem to perform well in the case of millet in Niger as shown by Leblois et al. (2011).

We compare two growth phase schedules: the observed one is referred to as obs and the one simulated; it is referred to as sim in the paper. The onset of the simulated growing season is triggered by a rainfall zone specific threshold in cumulation of significant rainfall (between 40 and 50 mm during 5 days), the offset is the last observed significant rainfall.

Finally we try to distinguish different growing phases of the cotton crop, indices based on that growing phases schedules will be referred as sim gdd. It allows to determine a specific trigger for indemnifications in each growing phase. We do that by defining emergence, which occurs when reaching an accumulation of 15 mm of rain and 35 growing degree days (GDD)[10] after the sowing date. We then set the length of each of the 5 growing phases following emergence only according to the accumulation of GDD, as defined by the M´emento

10 Calculated upon a base temperature of 13 C.

de l'agronome (2002), Cr´etenet et al. (2006) and Freeland et al. (2006). The end of each growing phases are triggered by the following thresholds of degree days accumulation after emergence: first square (400), first flower (850), first open boll (1350) and harvest (1600). The first phase begins with emergence and ends with the first square, the second ends with the first flower. The first and second phases are the vegetative phases, the third phase is the flowering phase (reproductive phase), the fourth is the opening of the bolls, the fifth is the maturation phase that ends with harvest.

There is however a different seasonal schedule following the use of heterogeneous cultivars across time and space[11] that are adapted to the specificity of the climate, with much shorter growing cycle in the drier areas. We thus took into account the evolution of different cultivars used through time in order to compute simulated dates of harvest and critical growing phases using Dessauw and Hau (2002) and Levrat (2010). More precisely, the beginning and end of each phase have been constraint in order to fit each cultivar's growing cycle (Table 10 in the Annex review the critical growing phases for each cultivar).

The total need are 1600 GDD, corresponding to about an average of 120 days in the considered producing zone, the length of the cropping season thus seem to be a limiting factor, especially in the upper zones (Table 2) given that an average of 150 needed for regular cotton cultivars, Cr´etenet et al. (2006).

3.3 DEFINITION OF AGRO-ECOLOGICAL AND RAINFALL ZONES

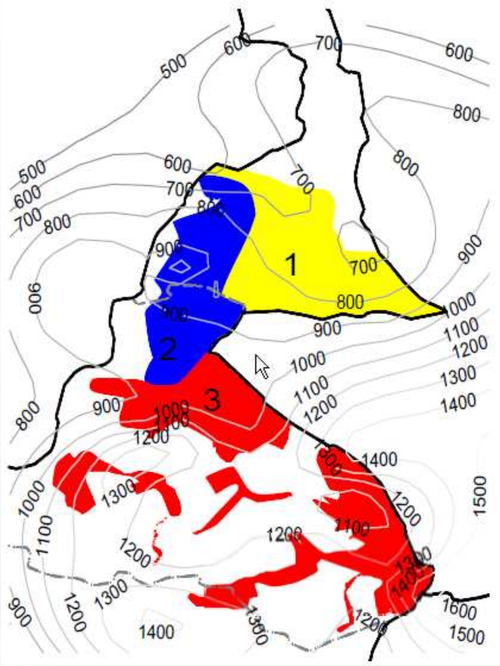
De Bock et al., 2010 justify the use of different zones across the Malian cotton sector in order to insure yields. Pooling yields across heterogeneous sectors in terms of average yields indeed leads to a subsidization of sectors characterized by low yields. Moreover, considering different areas associated with heterogeneous climate would also lead to subsidize drier areas in the context of an drought index-based insurance framework.

11 For instance, recently, the IRMA D 742 and BLT-PF cultivars were replaced in 2007 by the L 484 cultivar in the Extreme North and IRMA A 1239 by the L 457 in 2008 in the North province. See the Annexe: Figure 7 for the spatial distribution of cultivars and Table 10 for the description of all cultivars and schedules.

Table 2: Agro-ecological areas summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
North-East					
Yield	959.459	243.07	352	2241	302
Annual cumulative rainfall (mm)	803.37	158.587	412	1244	302
$Length_{sim}$	102.278	15.065	56	123	302
CR_{sim}	717.61	151.848	355.9	1128.8	302
$Length_{sim\ gdd}$	117.01	8.663	100	135	302
$CR_{sim\ gdd}$	659.908	144.493	319	1044.1	302
$SumNDVI$	5222.26	479.148	3914.5	6546.17	248
$Length_{obs}$	111.185	13.158	84	141	146
CR_{obs}	612.321	128.466	299	973	146
North-West					
Yield	1225.828	290.505	594	1981	299
Annual cumulative rainfall (mm)	946.338	164.52	540	1575	299
$Length_{sim}$	109.151	12.491	73	123	299
CR_{sim}	817.08	158.386	340	1247	299
$Length_{sim\ gdd}$	118.351	6.726	100	133	299
$CR_{sim\ gdd}$	733.089	148.195	267	1087	299
$SumNDVI$	6226.557	842.911	4311.75	8489.08	237
$Length_{obs}$	118.773	15.276	80	173	172
CR_{obs}	716.437	165.82	279	1114	172
South					
Yield	1291.348	319.317	593	2352	248
Annual cumulative rainfall (mm)	1131.375	233.86	541	1790	248
$Length_{sim}$	114.016	9.798	72	123	248
CR_{sim}	959.296	208.322	340	1538	248
$Length_{sim\ gdd}$	118.274	8.619	110	155	248
$CR_{sim\ gdd}$	846.451	194.217	267	1419	248
$SumNDVI$	8267.915	1568.815	5953.41	12817.25	190
$Length_{obs}$	128.27	13.235	96	161	148
CR_{obs}	915.504	222.21	319	1439	148

Figure 4: Agro-ecological areas (North West: 1, North East: 2 and South: 3) and isohyets



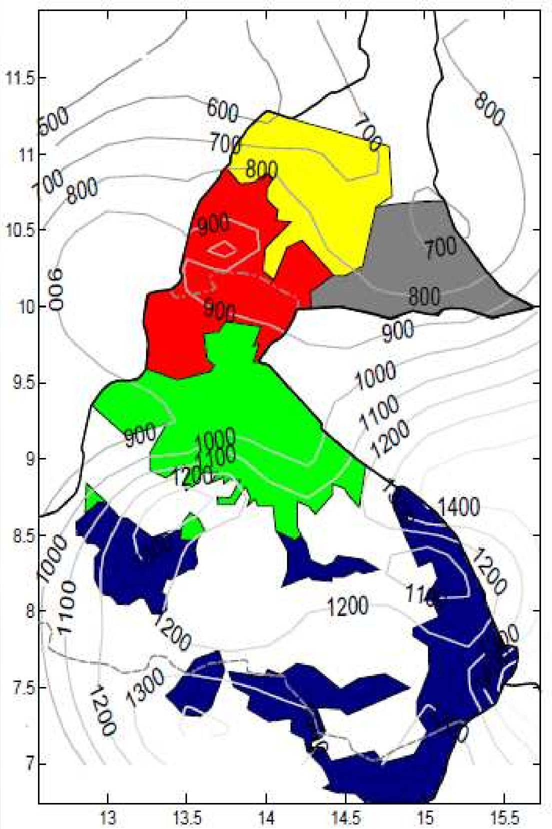
Average annual cumulative rainfall varies between 600 and 1200 mm in the cotton producing area characterized by a sudano-sahelian climate: sudanian in the Southern part and sudano- sahelian in the Northern part. We grouped 7 agro-ecological zones in three distinct groups in order to get a significant sample of matched yield and meteorological data in each of them. The initial agro-ecological zoning borrowed from Adoum Yaouba (2009) also matches and socio-economic indicators used by Kenga et al. (2003). It is used together with agro-climatic ones in order to characterize farming systems of the region. The first is the North East, mostly situated above the 800 mm isohyet (meaning it benefit from less than 800 mm of rainfall per year, Fig. 4), is characterized by the dryness of the rainy season. The second regroup the centre of the cotton producing zone and the North West, more rainy than the North East, due to topographical reasons (the presence of the Mandara mounts); the third is the Southern part of the zone that is more humid, i.e. benefiting from about 1000 mm per year or more (Table 2).

We finally defined 5 zones only following rainfall levels of each sector (referred as rainfall zones below), classing them by average annual cumulative rainfall on the whole period and grouping them in order to get a significant sample. The zoning is displayed in Figure 5 and the descriptive statistics per zones in Table 3.

Table 3: Rainfall zoning summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
North					
Yield	985.385	244.393	352	1746	149
Annual cumulative rainfall (mm)	785.39	147.413	412	1174.2	149
$Length_{sim}$	101.98	16.495	56	123	149
CR_{sim}	699.21	139.369	355.9	1128.8	149
$Length_{sim\ gdd}$	114.342	9.259	100	135	149
$CR_{sim\ gdd}$	642.438	132.051	319	1044.1	149
$SumNDVI$	5050.988	617.441	3914.5	8653.110	121
$Length_{obs}$	113.065	13.239	84	140	77
CR_{obs}	626.765	115.761	388	1030	77
North West					
Yield	943.494	238.774	513	2241	141
Annual cumulative rainfall (mm)	821.930	162.83	464	1244	141
$Length_{sim}$	102.787	13.634	68	123	141
CR_{sim}	735.977	156.458	366.7	1128.8	141
$Length_{sim\ gdd}$	119.66	7.4	100	132	141
$CR_{sim\ gdd}$	676.779	150.347	333.9	1044.1	141
$SumNDVI$	5439.067	454.6	4424.14	6546.17	116
$Length_{obs}$	109.985	12.679	86	141	65
CR_{obs}	627.6	149.684	299	955	65
North East					
Yield	1279.068	298.864	725	2352	207
Annual cumulative rainfall (mm)	965.877	185.685	541	1575	207
$Length_{sim}$	111.647	11.239	76	123	207
CR_{sim}	815.518	175.658	340	1247	207
$Length_{sim\ gdd}$	115.411	4.943	110	128	207
$CR_{sim\ gdd}$	726.430	165.325	267	1098.7	207
$SumNDVI$	6772.352	591.613	5629.56	8489.08	165
$Length_{obs}$	123.016	15.478	86	173	127
CR_{obs}	730.310	195.576	279	1211	127
Center					
Yield	1262.766	337.617	557.38	2189	197
Annual cumulative rainfall (mm)	1151.99	238.341	505.8	1790	197
$Length_{sim}$	113.025	11.029	71	123	197
CR_{sim}	983.404	208.171	422.7	1538	197
$Length_{sim\ gdd}$	119.949	9.026	112	155	197
$CR_{sim\ gdd}$	871.451	190.605	384.3	1419	197
$SumNDVI$	8323.054	1935.995	4765.33	12817.25	154
CR_{obs}	968.405	214.428	319	1439	100
$Length_{obs}$	129.28	14.035	92	157	100
South					
Yield	1181.59	279.553	594	1981	155
Annual cumulative rainfall (mm)	944.257	164.959	540	1575	155
$Length_{sim}$	107.968	12.654	73	123	155
CR_{sim}	828.598	151.168	420.2	1221	155
$Length_{sim\ gdd}$	120.174	7.279	100	132	155
$CR_{sim\ gdd}$	743.288	139.236	364.3	1087	155
$SumNDVI$	5885.955	664.364	4311.75	7587.360	119
$Length_{obs}$	115.876	13.523	80	143	97
CR_{obs}	734.71	152.561	318	1100.5	97

Figure 5: Zoning based on meteorological (annual cumulative rainfall) classification (different areas are called North: 1, North West: 2, North East: 3, Centre: 4 and South: 5) and isohyets (in mm on the 1970-2010 period). Source: author calculations.



The three defined agro-ecological and rainfall zones have significantly (student, probability of error lower than 1%) different average yield and cumulative rainfall. As mentionned in the section 2.3, yield seem very sensitive to the sowing date. The two northern rainfall zones are sowed (and emerge) 10 to 15 days later; such feature could explain part of the discrepancies among yields, in spite of the development of adapted cultivars for each zone by the agronomic research services. There is still a huge difference between observed and simulated cropping cycles that could be partly explained by measure approximation of 10 days in the observed sowing date. Due to administrative delays or other issues in the delivering of seeds or inputs and because cotton growing cycle begins quite late when compared to other crops, the sowing date is not simply triggered by the installation of the rainy season and finally not acutely simulated when only taking rainfall into account.

Finally there is still structural differences between average yield in different sectors within an agro-ecological zone. However, in our case, optimizing insurance in each of the agro-ecological zones lead to largely better pooling for each of them, but standardizing[12] indices by sector did not improved significantly the results.

4. WEATHER INDEX-BASED INSURANCE

4.1 INDEMNITY SCHEDULE

In this section we simulate the impact of an insurance based on weather indices used to pool yield risk across sectors. The indemnity is a step-wise linear function of the index with 3 parameters: the strike (S), i.e. the threshold triggering indemnity; the maximum indemnity (M) and λ, the slope-related parameter. When λ equals one, the indemnity is either M (when the index falls below the strike level) or 0. The strike represents the level at which the meteorological factor becomes limiting. We thus have the following indemnification function depending on x, the meteorological index realisation:

$$I(S, M, \lambda, x) = \begin{cases} M, & \text{if } x \leq \lambda.S \\ \frac{S-x}{S\times(1-\lambda)}, & \text{if } \lambda.S < x < S \\ 0, & \text{if } x \geq S \end{cases} \quad (1)$$

It is a standard contract scheme of the WII literature. The insurer reimburse the difference between the usual income level and the estimated loss in yield, yield being proxied by the meteorological index realization.

4.2. INSURANCE POLICY OPTIMIZATION

We use different objective function and show that our results are robust to such choice. We consider the three following objective function, respectively the Semi Standard Deviation (SSD, equation 2), a constant relative risk aversion (CRRA) utility function (equation 2) and finally a negative exponential, i.e. constant absolute risk aversion (CARA) utility function (equation 4). They are the following:

$$U_{ssd}(\tilde{y}) = E(\tilde{y}) - \phi \times \sum_{i=1}^{N} \Big(\max\left(E(y) - y_i, 0\right) \Big), \quad \tilde{y} = \{y_1, ..., y_N\} \quad (2)$$

$$U_{crra}(\tilde{y}) = \frac{(y_i + W_i)^{(1-\rho)}}{(1-\rho)}, \qquad \tilde{y} = \{y_1, ..., y_N\} \quad (3)$$

12 Considering the ratio of the deviation of each observartion to the sector average yield on its standard deviation.

$$U_{cara}(\tilde{y}) = 1 - \exp\left(-\psi \times (y_i + W_i)\right),$$
$$\tilde{y} = \{y_1, \ldots, y_N\} \quad (4)$$

$\tilde{y}$ is the vector of cotton margin within the period and among the sectors considered, N the number of observations, and Wi other farm and non-farm income. ϕ , ρ and ψ are respectively the risk aversion parameter in each objective function.

We maximised the expected utility of these three utility functions and computed the risk premium, i.e. the second term of the first objective function and the expected income minus its certainty equivalent in the two latter, for each of them. The first function is simply capturing the income 'downside' variability (i.e. variations are considered only when yield is inferior to the average yield considered to be particularly harmful). The second term represents the average downside loss, loss being defined as yield inferior to average of yield distribution among the calibration sample (whole sample, AEZ or rainfall zone). It represents about 1/3 of average yield with very little change when considering different samples.

The second and third objective functions are quite standard in the economic literature; we added an initial income level, following Gray et al. (2004). Given that we use the aversion to wealth (and not transitory income) in both case we assume that $\psi = \rho$ /W, according to Lien and Hardaker (2001).

$$Y_i = Y - P(S^*, M^*, \lambda^*, x) + I(S^*, M^*, \lambda^*, x) \quad (5)$$

The loading factor is defined as a percentage of total indemnifications on the whole period (fixed at 10% of total indemnification), plus a transaction cost (C) for each indemnification, fixed exogenously to one percent of the average yield.

$$P = 1/10 \times \sum_{i=1}^{N} I_i(S^*, M^*, \lambda^*, x) + C \times \sum_{i=1}^{N} F_i, \text{ with } F_i = \begin{cases} 1 \text{ if } I_i > 0 \\ 0 \text{ if } I_i = 0 \end{cases} \quad (6)$$

We finally optimize the three insurance parameters in order to maximise utility and look at the reduction in the risk premium depending on the index and the calibration sample. The strike is bounded by a maximum indemnification rate of 20% and the maximum indemnification to the first quartile of the cotton margin distribution (100000 CFA francs for an average of 120000 CFA francs). Those levels are however very rarely attained due to the presence of basis risk.

4.3. MODEL CALIBRATION

4.3.1. INITIAL WEALTH

We use three surveys ran by Sodecoton in order to follow and evaluate growers' agronomical practices. They respectively cover the 2003-2004, 2006-2007 and 2009-2010 growing seasons. We also use recall data for the 2007 and 2008 growing season from the last survey. Each survey is independant and growers were not followed from one year to another by surveyors. The localizations of surveyed clusters (as displays in Fig. 13) are distributed accross the whole zone.

We computed the share of cotton-related income in on-farm income for 5 growing seasons. Cotton is valorized at the average annual buying price of the Sodecoton and the production of major crops (cotton, traditional and elaborated cultivars of sorghos, groundnut, maize, cowpea) at their annual sector level price observed at the end of the lean season period, corresponding to April of the next year. The lower level of observation (especially for recall data) is explained by the year by year crop rotation that make farmers with low surface grow cotton only one year each two years. We can however not exclude that recall is not perfect and that some missing data remains.

Table 4: On-farm and cotton income of cotton producers during the 2003-2010 period (in thousands of CFA francs)

Variable	Mean	Std. Dev.	Min.	Max.	N
2003					
Coton income	247.560	265.141	0	1750.655	1565
Non-cotton related farm income	271.446	377.684	0	8985	1540
On-farm income	499.513	468.344	0	3775	1565
Cotton share of income (%)	46.5	21.6	0	100	1562
Farming capital**	390.242	555.091	0	8977.5	1557
Wealth***	661.286	759.130	0	11212.5	1533
2006					
Coton income	207.187	282.108	0	3140.006	950
Non-cotton related farm income	265.760	531.126	0	14660.5	943
On-farm income	472.104	670.122	4.000	14660.5	943
Cotton share of income (%)	38.3	20.5	0	100	943
2008*					
Coton income	164.013	279.322	0	2574.600	1457
Non-cotton related farm income	108.225	204.997	0	2537.5	1457
Cotton share of income (%)	57	30.3	0	100	939
On-farm income	272.238	432.927	0	4050.643	1457
Wealth***	354.544	449.860	0	5102.275	1457
2009*					
On-farm income	570.947	796.680	0	9520.681	1457
Coton income	184.158	278.633	0	1895.712	1457
Non-cotton related farm income	386.790	608.222	0	8190.625	1457
Cotton share of income (%)	35.1	23.9	0	100	1111
Wealth***	633.109	723.508	0	8415.625	1457
2010					
Coton income	126.179	143.842	0	1423.485	1457
Non-cotton related farm income	529.978	727.286	0	9000	1457
On-farm income	656.157	741.454	0	9236.930	1457
Cotton share of income (%)	24.9	25	0	100	1449
Farming capital**	246.319	376.338	0	4545	1457
Wealth***	776.297	815.430	0	9242.5	1457

Source: Sodecoton's surveys and author's calculations.
* Recall data from the 2010 survey.
** Mainly including agricultural material and livestocks.
*** Composed of farming capital and non cotton-related farm income.

As showed in Table 4 the share of cotton in on-farm income of cotton growers is .4 if we take the average of those 4 annual surveys. We thus fixed average on-farm income as the double of average cotton income of our sample. We also tested on-farm income increasing in function of cotton income[13] but it did not modify the results.

4.3.1. RISK AVERSION

We used a field work (Nov. and Dec. 2011) to calibrate the risk aversion parameter of the CRRA function. We assumed the CRRA preferences in that section because it is standard in such field work, but, as said previously, the two other paramters can be inferred from the level of the calibrated relative risk aversion.

13 For three major reasons it can be assumed that cotton yields and other incomes (mainly other crops yields) are being correlated. First, even if each crop has its own specific growing period, a good year for cotton in terms of rainfall is probably also a good rainy season for other crops growing during the rainy season. Second, a household that have a lot of farming capital is probably able to get better yields in average for all crops. Third, cotton being the main channel to get quality fertilizers, the higher is the cotton related input credit, the higher the collateral.

A survey was implemented in 6 sodecoton groups of producers in 6 different locations, each in one region, out of the nine administrative regions of the Sodecoton, two in each agro-ecological areas (the localization of those six villages are displayed in Figure 14 in the annex), were about 15 cotton growers where randomly selected[14] to answer a survey (concerning socio-economic considerations, yields, technical agronomic practices and meteorological apreciations such as the sowing date choice and criteria). Those producers were asked to come back at the end of the survey and lottery games were played. We use a typical Holt and Laurry (2002) lottery, appart from the fact that we do not ask for a switching point but ask a choice between two lotteries (one risky and one safe) for a given probability of the bad outcome. It thus allows the respondant to show inconsistent choices, ensuring that they understood the framework.

At each step (5 lottery choices displayed in Table 5) the farmers have to choose between a risky (I) and a safer (II) situation, both consituted of two options represented by schematic representation of relalistic cotton production in good and bad years that were randomly drawed by one voluntary lottery player or childrens of the village. For each lottery, the options are associated with different average gains, probabilities were represented by a bucket and ten balls (red for a bad harvest and black for a good harvest). The gains represent the yield (in kg) for 1/4 of an hectare, the unit used by all farmers and Sodecoton for input credit and plot management such as informal wages etc.

The games were played and actual gains (between 500 and 1500 CFA francs, representing about one day of legal minimum wage) were offered at the end. We began with the lotteries in which the safer option was more interesting. Each lottery was then increasing the relative interest of the risky option. We thus can compute the risk aversion level (ρ) using to the switching point (or the absence of switching point) from the safe to the risky option, assuming CRRA preferences. They are displayed in Table 5, BB goes for black balls and RB for red balls.

We dropped inconsistent choices representing 20% of the sample (16 individuals on 80). We choose the average of each interval extremities as an approximation for ρ , as it is done in the underlying literature.

Table 5: Lotteries options

	I		II			
Number of BB (prob. of a good outcome)	RB	BB	RB	BB	Difference of expected gain	ρ of agents switching from I to II
No risky option chosen						$\succ$ 1.7681
5/10	50	350	150	250	0	]1.1643,1.7681]
6/10	50	350	150	250	20	]0.7236,1.1643]
7/10	50	350	150	250	40	]0.3512,0.7236]
8/10	50	350	150	250	60	]0,0.3512]
9/10	50	350	150	250	80	≤ 0

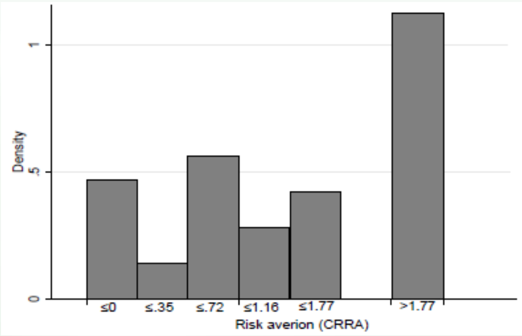
14 Randomly taken out of an exhaustive list of cotton growers detained by the Sodecoton operator in each village in order to manage input distribution each year. Those groups of producers are very homogeneous in terms of size because they are formed by the Sodecoton in order to meet management requirement and divide into 2 groups when there is too numerous producers in one single group.

5. RESULTS: REDUCTION OF RISK PREMIUM

5.1. RISK AVERSION

We display the distribution of risk aversion parameters found according to the previous methods in Figure 6.

Figure 6: Distribution of risk aversion parameter density under CRRA utility function



We thus conclude that the relative risk aversion parameter goes from 0 to more than 2, half of the sample having a risk aversion superior to 1.5. We will thus test a range of values between 1 (the median value) and 3 for the CRRA. The parameters of the SSD and the CARA[15] objective function are set in accordance, considering the observed distribution of cotton profit: we considered a set of parameter Φ = [.5, 1, 1.5].

5.2. WHOLE COTTON AREA

There is not much theoretical work on the defition of basis risk in the context of index insurance calibration since Miranda (1991). The coefficient of correlation is the only (but very imperfect) measure used as for evaluating basis risk since that time. We propose a tractable definition of it, based on the computation of a perfect index that is the observation of the actual cotton gross margin at the same level for which meteorological or remote sensing indices are available. We express the outcome of insurance based on different indices by reporting the reduction of the risk premium (in CFA francs) to the reduction of the risk premium that would happen if the index was perfect (i.e. an areayield insurance at the sector level, without any transaction cost nor moral hasard issues). The certain equivalent is the average utility of all situations (years - sectors), i.e. the expected utility to whiwh we apply the inverse of the utility function (in CFA francs). The risk premium is the difference between the average income and the certain equivalent income. The reduction in risk premium as compared to the one of the perfect index is very similar to the certain equivalent income (CEI) rapported to (in percentage of) the perfect index CEI. This perfect index is the cotton gross margin observation at the sector level itself, on which we simulated the same (as defined in section 3.2) insurance contract. It is thus equivalent to compare our WII to an area-yield insurances (moral hasard and costs free), assuming no income variations within a sector. It allows to compare basis risk in different samples and with regard to distinct objective functions. We will study such comparison in a broader scope and on the same data in a companion paper, comparing different source of risks and considering intra-sector income variations.

We thus propose to compare the basis risk of an index as the fraction of the reduction of risk premium it allows when compared to the best index, i.e. the observed income at the level considered. As a comparison, the optimal (area-yield) insurance is reducing the risk premium of about 20% of the average profit (between 10% and 20% depending on the objective function).

Table 6: Share of the maximum risk premium reduction among different indices and samples (1991-2004).

	SSD			CRRA			CARA			
	$\phi=1$	$\phi=2$	$\phi=3$	$\rho=1$	$\rho=2$	$\rho=3$	$\psi=1/W$	$\psi=2/W$	$\psi=3/W$	N
Annual cumulative rainfall (CR)	7.15%	7.15%	8.47%	.00%	.00%	.00%	.00%	.00%	.00%	479
CR_{sim}	1.16%	5.44%	5.44%	.00%	.72%	.66%	.83%	.66%	.47%	479
$CR_{sim\ gdd}$	2.09%	5.85%	5.85%	.00%	1.17%	1.24%	1.39%	1.03%	.71%	479
Sum NDVI	12.64%	13.34%	13.34%	.00%	.00%	.00%	.00%	.00%	.00%	479
$Length_{sim}$	13.18%	13.18%	13.18%	.00%	.00%	.00%	.00%	.00%	.00%	479
$Length_{obs}$	28.79%	31.19%	31.75%	.00%	12.14%	15.85%	17.14%	20.03%	19.92%	247
CR_{obs}	18.70%	21.31%	21.31%	.00%	1.45%	1.38%	1.53%	5.02%	5.27%	247
Sowing date$_{obs}$	33.93%	33.93%	33.93%	.00%	20.89%	21.20%	22.94%	22.85%	22.39%	247
% of area where cotton emerged at June the 30	22.20%	22.20%	22.20%	13.67%	23.80%	23.74%	24.29%	26.29%	28.74%	252
Max. temp. in March	20.13%	20.13%	20.13%	.00%	2.07%	3.45%	3.93%	3.41%	5.11%	479

15 Cf. section 3.2.

We only show the results for the period 1991-2004 in Table 6, excluding panel data before 1991 that are strongly unbalanced and after the year 2005 characterized by a collapse of the Cameroonian cotton sector[16]. We displayed the result of the contract simulated with using different indices, indices in bold (sowing dates and temperatures) letters are contract that insure against high values of the index. Only the best performing indices are showed due to space issues and regarding the large number of indices tested for each sample.

The first results yield by optimizing insurance parameters for the whole cotton zone is the high basis risk level (always inferior to one fourth of the maximum reduction of the risk premium). Risk premium reduction allowed by the WII is even zero (for two objective function on the 3 considered) when considering simple indices (such as annual cumulative rainfall or simulated length of the growing season). Insuring against a late sowing is very effective to reduce basis risk, but simulating that date does not help. Among the different dates for which information is available (cf. section 2.4) the observed area sown with cotton at the end of June also comes across when looking at their relative performance at reducing the risk premium. Using the actual sowing date in an insurance contract is usually difficult because it cannot be observed costlessly by the insurer. However, in the case of cotton in francophone West Africa, cotton production mainly relies on interlinking input-credit schemes taking place before sowing and obliging the cotton company to follow production in each production groups[17]. Under those circumstances observing sowing date or even make the growers to declare it would not be so costly for the cotton buyer.

5.3. SPECIFIC AEZ AND RAINFALL ZONES

Looking at optimizations among different AEZ and RZ the picture seem quite different. First, it appears that the previous calibration exercice lead to significant balancing out: the driest part (northern part) of the cotton zone being subsidized at the cost of the southern part. This feature can even be observed when calibrating insurance parameters on AEZ cutting: there seem to be a subsidization of the driest part of AEZ 1 (defined as rainfall zone 1). Calibrating insurance paramters among homogeneous rainfall zone indeed shows that the second rainfall zone do not benefit of insurance based on wuch index. Because calibrating insurance on a sector specific index never gave a better performance, we conclude that the rainfall zone (corresponding to about one decimal degree, i.e. 10 thousands squared kilometers in that location of the globe) is the optimal level for calibrating a WII for cotton growers in northern Cameroon.

Second, some indices seem to fit much better some agro-ecological or rainfall zones: The share of the acreage dedicated cotton that has been sowed at the end of June is showing very low basis risk (less than 30% of the risk premium reduction) in the Northern part of the zone (Table 8). NDVI reduces basis risk as compared to cumulative rainfall over a simulated growing season (or the annual cumulative rainfall) for the two driest AEZ but seem to show significant basis risk in two to three rainfall zone (Table 7) out of five depending on the objective function (Table 8). I shows once more that balancing out between sectors could be seen as a false sign of performance if not enough attention is drawn to such issues.

Third, using temperature indices seem worth it for the most humid part of the cotton zone (2 most humid optimal zones). The average temperature in March shows suprisingly high performance for predicting bad yield in the southern part of the zone (Table 7 and 8). Such relation could probably be used as a yield prediction by the cotton company as a tool for better management of input distribution accross sectors or for improving risk coping during the crop season.

We finally can say that cutting simulated growing season into different phases did not seem to improve insurance outcome. The relatively low performance of the indices based on simulated growing period, depending on the area, largely limit the scope of this last result.

---

16 We were particularly testing if a potential spurious correlation between the collapse of the cotton sector after 2004 and a increasing of the average temperatures could explain the good performance of temperature indices. It prooved that such cautious measure was justified since all high gains computed for temperature indices-based insurance on the whole period disapeared when only considering the period excluding the cotton sector collapse.
17 As mentionned by De Bock et al., 2010, cotton parastatals (i.e. Mali in their case and Cameroon in ours) already gather information about production, yield, input use and costs and the sowing date (corresponding to seed and input distribution) in each region. It is thus at no cost that it would be available to the production management departement at the Sodecoton, however making it transparent and distorsion free could introduce some costs.

Table 7: Share of the maximum risk premium reduction among different indices and samples (1991-2004) among different agro-ecological zones (AEZ).

	SSD			CRRA			CARA			
	$\phi=1$	$\phi=2$	$\phi=3$	$\rho=1$	$\rho=2$	$\rho=3$	$\psi=1/W$	$\psi=2/W$	$\psi=3/W$	**N**
Calibrated on the first AEZ sample (AEZ=1, North)										
CR_{sim}	5.75%	5.68%	5.68%	.00%	1.48%	1.43%	.00%	1.59%	1.56%	174
$CR_{sim\ gdd}$	7.59%	9.92%	9.92%	.00%	1.48%	2.09%	.00%	1.59%	2.40%	174
CR_{obs}	23.70%	23.37%	23.37%	.00%	2.11%	2.12%	.00%	2.37%	2.39%	86
$Sum\ NDVI$	6.22%	6.14%	6.14%	.00%	4.97%	4.88%	.00%	5.16%	5.11%	174
$CR\ Phase3_{sim\ gdd}$	17.33%	17.09%	17.09%	.00%	6.10%	5.48%	.00%	6.15%	5.01%	174
$CR\ Phase4_{sim\ gdd}$	17.33%	21.29%	21.42%	.00%	5.63%	5.44%	.00%	5.78%	5.63%	174
$CR\ Phase5_{sim\ gdd}$	30.93%	30.50%	30.50%	.00%	4.52%	4.34%	.00%	4.74%	4.61%	174
$Length_{sim}$	.00%	.00%	3.20%	.00%	.00%	.00%	.00%	.00%	.00%	174
$Length_{obs}$	21.18%	20.89%	20.89%	.00%	12.77%	20.81%	.00%	13.67%	22.48%	86
% of area where cotton emerged at June the 30	50.31%	49.61%	49.61%	32.67%	39.88%	42.17%	34.26%	40.63%	42.76%	87
Sowing date$_{obs}$	4.55%	4.48%	4.48%	.00%	2.04%	2.07%	.00%	2.49%	2.45%	86
Calibrated on the second AEZ sample (AEZ=2, Center)										
$CR_{sim\ gdd}$	2.70%	2.70%	2.70%	.00%	.00%	.00%	.00%	.00%	.00%	173
CR_{obs}	11.62%	11.62%	11.62%	.00%	5.85%	6.18%	.00%	6.57%	6.73%	90
$Sum\ NDVI$	24.84%	24.84%	24.84%	.00%	3.68%	10.63%	.00%	4.20%	10.41%	173
$CR\ Phase5_{sim\ gdd}$	28.12%	28.86%	28.86%	.00%	11.09%	15.64%	.00%	17.85%	17.21%	173
$CR\ Phase4_{sim\ gdd}$	19.09%	19.09%	19.09%	.00%	11.09%	15.64%	.00%	17.85%	17.21%	173
$Length_{obs}$	13.92%	13.92%	13.92%	.00%	5.85%	6.17%	.00%	6.57%	6.73%	90
Max. temp. in March	29.29%	29.29%	29.29%	6.95%	4.88%	4.78%	7.09%	4.91%	4.72%	173
Mean temp. in July	9.37%	9.43%	9.48%	6.94%	4.87%	4.77%	7.10%	4.92%	4.73%	173
% of area where cotton emerged at June the 30	18.99%	18.99%	18.99%	21.25%	14.89%	15.28%	21.88%	15.09%	15.22%	94
Calibrated on the third AEZ sample (AEZ=3, South)										
CR_{obs}	9.26%	9.26%	9.26%	.00%	.00%	.00%	.00%	.00%	1.53%	71
$Length_{sim}$	.00%	3.49%	3.49%	.00%	.00%	.00%	.00%	.00%	.00%	132
$Length_{sim\ gdd}$	5.51%	5.51%	5.51%	2.18%	2.01%	1.82%	2.43%	2.27%	2.11%	132
$Length_{obs}$	9.53%	11.42%	11.42%	.00%	.00%	2.15%	.00%	.00%	2.52%	71
Max. temp. in March	18.10%	18.10%	18.10%	.00%	.00%	8.07%	.00%	.00%	.00%	132

Table 8: Share of the maximum risk premium reduction among different indices and samples (1991-2004) among different rainfall zones.

	SSD			CRRA			CARA			
	$\phi=1$	$\phi=2$	$\phi=3$	$\rho=1$	$\rho=2$	$\rho=3$	$\psi=1/W$	$\psi=2/W$	$\psi=3/W$	N
Calibrated on the first rainfall zone sample										
CR_{sim}	40.59%	40.59%	40.59%	.00%	5.94%	6.62%	.00%	5.89%	6.78%	84
$CR_{sim\ gdd}$	42.42%	42.42%	42.42%	.00%	9.81%	10.61%	.00%	9.65%	11.26%	84
CR_{obs}	59.59%	59.59%	59.59%	.00%	.00%	6.60%	.00%	.00%	4.79%	41
$Sum\ NDVI$	27.50%	27.50%	27.50%	.00%	.00%	.00%	.00%	.00%	.00%	84
$CR\ Phase2_{sim\ gdd}$	23.79%	24.06%	24.06%	.00%	.00%	1.46%	.00%	.00%	1.67%	84
$CR\ Phase3_{sim\ gdd}$	44.34%	44.34%	44.34%	.00%	.00%	10.60%	.00%	.00%	9.94%	84
$CR\ Phase5_{sim\ gdd}$	45.12%	45.47%	46.60%	11.44%	18.60%	17.27%	13.95%	18.53%	17.94%	84
$Length_{sim}$	11.07%	11.79%	11.79%	.00%	.00%	.00%	.00%	.00%	.00%	84
$Length_{obs}$	78.03%	80.98%	80.98%	.00%	18.85%	18.39%	.00%	19.29%	20.60%	41
% of area where cotton emerged at June the 30	97.42%	97.42%	97.42%	.00%	70.36%	72.13%	.00%	67.39%	70.83%	41
Calibrated on the second rainfall zone sample										
$Sum\ NDVI$	9.80%	9.80%	9.80%	.00%	.00%	.00%	.00%	.00%	.00%	80
$CR\ Phase3_{sim\ gdd}$	32.89%	32.89%	32.89%	.00%	5.58%	5.22%	4.64%	4.64%	5.41%	80
$CR\ Phase4_{sim\ gdd}$	32.89%	32.89%	32.89%	.00%	5.36%	5.13%	5.71%	5.71%	5.46%	80
$CR\ Phase5_{sim\ gdd}$	40.04%	40.23%	40.23%	.00%	17.73%	16.87%	18.80%	18.80%	17.58%	80
% of area where cotton emerged at June the 30	58.45%	58.45%	58.45%	98.41%	48.38%	47.07%	51.10%	51.10%	48.52%	42
Max. temp. in March	51.58%	52.57%	52.57%	.00%	18.35%	17.76%	19.14%	19.14%	18.50%	80
Mean temp. in July	11.00%	11.94%	11.94%	.00%	9.37%	8.97%	9.71%	9.71%	9.18%	80
Calibrated on the third rainfall zone sample										
$CR\ Phase2_{sim\ gdd}$	13.02%	13.61%	13.61%	.00%	2.65%	2.46%	.00%	2.82%	2.69%	125
$CR\ Phase3_{sim\ gdd}$	3.67%	9.44%	9.44%	.00%	2.65%	2.45%	.00%	2.82%	2.68%	125
$CR\ Phase4_{sim\ gdd}$	13.65%	13.65%	13.65%	.00%	2.65%	2.45%	.00%	2.83%	2.68%	125
Calibrated on the fourth rainfall zone sample										
$CR\ Phase4_{sim\ gdd}$	18.52%	14.20%	14.20%	.00%	9.45%	8.34%	.00%	10.54%	9.85%	105
$CR\ Phase5_{sim\ gdd}$	23.18%	27.25%	27.25%	.00%	9.45%	8.34%	.00%	10.54%	9.85%	105
CR_{obs}	28.18%	30.81%	30.81%	.00%	23.36%	24.44%	.00%	27.07%	26.53%	47
% of area where cotton emerged at June the 30	39.72%	39.72%	41.46%	7.70%	19.88%	26.36%	8.73%	22.67%	28.83%	51
Sowing $\mathbf{date}_{obs}$	35.97%	37.59%	37.59%	17.84%	17.80%	24.59%	19.74%	27.07%	27.01%	47
Emergence $\mathbf{date}_{obs}$	34.41%	34.41%	34.41%	.00%	23.08%	23.86%	.00%	26.40%	26.03%	47
$Length_{sim}$	7.25%	7.25%	7.25%	.00%	1.50%	1.33%	.00%	1.77%	1.58%	105
$Length_{obs}$	43.20%	43.20%	43.20%	10.19%	18.50%	24.26%	11.21%	26.49%	26.63%	47
Max. temp. in March	23.73%	23.73%	23.73%	.00%	.00%	11.59%	.00%	.00%	10.82%	105
Mean temp. in July	37.14%	37.14%	37.14%	.00%	14.36%	16.48%	.00%	12.29%	14.19%	105
Calibrated on the fifth rainfall zone sample										
CR_{sim}	13.20%	13.20%	13.57%	.00%	5.72%	5.71%	.00%	6.30%	6.18%	85
$CR_{sim\ gdd}$	18.44%	19.01%	19.01%	.00%	6.56%	6.27%	.00%	6.82%	6.52%	85
CR_{obs}	22.01%	22.01%	22.01%	8.16%	6.21%	5.92%	8.44%	6.34%	6.02%	49
$Sum\ NDVI$	42.49%	42.49%	42.49%	.00%	22.40%	24.29%	.00%	21.28%	22.75%	85
% of area where cotton emerged at June the 30	43.99%	43.99%	43.99%	46.30%	31.66%	31.79%	46.37%	31.69%	31.40%	49
$CR\ Phase3_{sim\ gdd}$	13.63%	13.63%	32.12%	15.24%	7.24%	6.60%	15.40%	8.93%	7.73%	85
$CR\ Phase4_{sim\ gdd}$	30.05%	30.06%	30.07%	11.87%	8.46%	8.11%	12.00%	8.60%	8.15%	85
Max. temp. in March	45.97%	45.97%	45.97%	18.14%	14.36%	15.60%	17.90%	14.39%	15.69%	85
Mean temp. in July	26.56%	26.56%	26.56%	18.16%	14.69%	14.27%	17.90%	14.70%	14.10%	85

6. AREA-YIELD AND PRICE INSURANCE VS. WII

Let suppose that the potential yield $(\bar{y})$ is depending on the meteorological index following a function ϕ :

$$\bar{Y} = \phi(I) \quad (7)$$

The individual yield is compose of an idiosyncratic exogeneous shock (ϵ_i) and an individual part (u_i):

$$y_{it} = \bar{Y} + \epsilon_{it} + u_i \quad (8)$$

The individual cotton profit of year t depend on the price P_t:

$$\Pi_{it} = (\phi(I) + \epsilon_{it} + u_i) \times P_t \quad (9)$$

The individual farm income of year *t* depend on the non-cotton income (W_0):

$$R_{it} = W_0 + \Pi_{it} \quad (10)$$

Under such hypothesis, the deviation of yield from the potential yield is only a small part of the overall variation in income. Basis risk is a combination of price, idiosyncratic exogeneous shock (such as weather spatial variations that are not captured by the index) and heterogeneity over the population of a sector (individual potential, efforts...). We will then look at two other source of risk that are the idiosyncratic and price risks and on which farmers get no hold on.

6.1. SPECIFIC AEZ AND RAINFALL ZONES

Using the data on plot level yield (2003 - 2006 - 2008 - 2009 - 2010), we can assess the distribution of yield within a sector (standardized by sector). We tried different probability laws to fit the observed density distribution of sector-specific yields. The obsereved distribution showed in the Figures 9 and 10 is the distribution of the plot level yields observed in different sectors during the above-mentionned Sodecoton surveys. We first tried to fit a gaussian and a lognormal distributions (Figure 7) on that distribution following Claasen and Just (2011) and a Weibull distribution (Figure 8) following Debock et al. (2010).

When fitting a Weibull distribution and simulating the same insurance contract, we found that the risk premium reduction gained thanks to insurance supply decrease drastically when considering the CRRA and CARA utility fonction.

Figure 7: Observed and fitted (normal and lognormal) distribution of sector-specific yields.

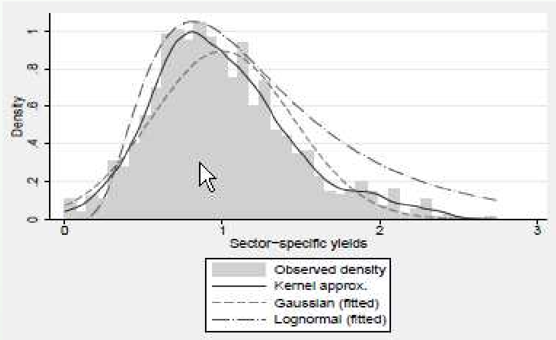


Figure 8: Observed and fitted (weibull) distribution of sector-specific yields.

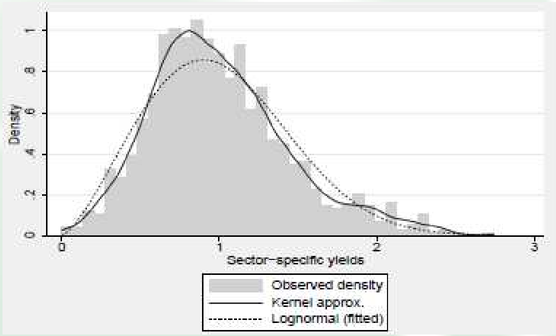
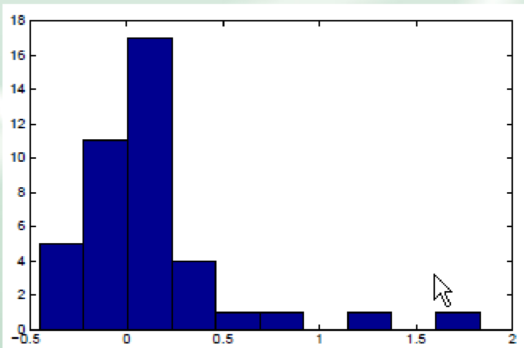


Figure 9: Distribution of intra-seasonal price variations.



6.2. PRICE INSURANCE

Our argument is the following: as Sodecoton announces harvest price at sowing, the firm completely insures farmers against international intra-seasonal price variations. Furthermore, looking at the variation in percent of sectoral yields and intra-annual international cotton price variations, it seems that both factors influencing cotton growers income are very similar in terms of risk level.

We computed the relative variation between the average price during a 4 months period before sowing and compared it to the 4 month period after harvest, Figure 11 plots the distribution of intra-seasonal price variations during the 1970-2010 period. The role of price in the risk taking place during the growing cycle is not negligible. It represents a large part of the sector-specific margin[18] variations (Figure 12) that is composed of the combination of price and yield risk (the latter is displayed in Fig. 13).

We can indeed see in Figure 10 that sector-specific yield variations or sector specific cotton profit (margin after input cost deduction distribution, displayed in Figure 12 in the annex) during the 1977-2010 period, are of the same order than intra-annual price variations (Figure 13 in the annex). It underlines the specificity of cash crop regarding index-based insurance with respect to this price risk that should be considered which great attention.

Figure 10: Distribution of variations of sector-specific margin after input cost reimbursement.

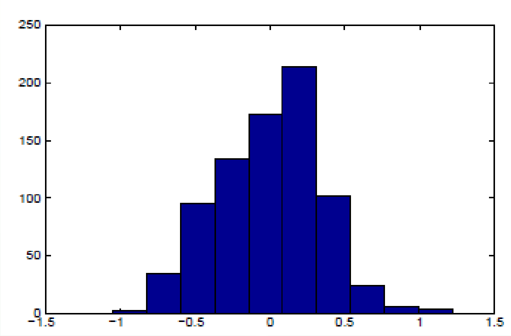
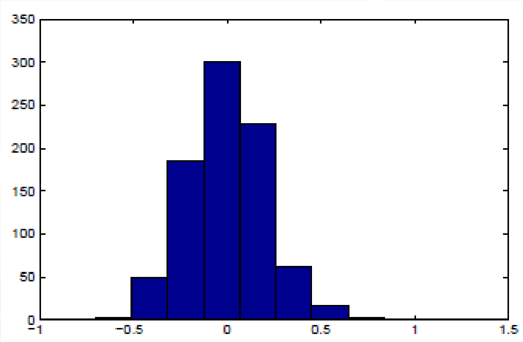


Figure 11: Distribution of sector-specific yield variations.



18 Yields and margin were normalized with respect to their sectoral average level over the 33 years period.

7. CONCLUSION

The first conclusion we can draw from such results is that one should be extremely precautionous when designing and testing ex ante insurance contracts, since the results is very depending on the sample choice and (as pointed by Lebois et al., 2011).

In the context of a heterogeneous climate, weather indices are not able to pool risk across the whole cotton zone. The north situated in the sudano-sahelian zone is subject to significant lack of rainfall but the center and southern part of the cotton growing zone are (more humid) savanna's and cotton growing seem to be more suffering from the heat. It is important for two main reasons, first it underlines the need for a precise calibration fitting local climate characteristics even for a unique crop and in a relatively bounded area. Second, it shows that different calibration leads to a geographical redistribution, taxing the most humid zones and subsidizing the driest ones within a calibration area and sectors benefiting from such insurance shemes thus largely depends on this cutting out of different zones for paramters calibration. According to our data, the optimal zoning is the rainfall zone were reduction of the risk premium was higher. It suggests that calibrating an index-based insurance contracts requires to consider an area that is subject to a homogeneous climate. Such homogeneous area corresponds in our case to about 10 thousand of squared kilometers, about 1 decimal degree in that part of the globe.

The remote sensing index we considered (NDVI) seem to reduce basis risk for only 1 to 3 out of 5 optimal zones, depending on the objective function. This is however very interesting when looking at the cost efficiency of such insurances, because this index is totally free and times series are now almost 30 years old (which is a requirement for insurers and reinsurer, Leblois and Quirion, 2012). The use of an observed sowing date seem very critical for computing indices on the actual crop growth period. It reduces significantly basis risk and thus allows a much better pooling of situations of low cotton income. In the light of the very low observed take-up rates found when index based insurance where offered to farmers (Cole et al., 2012), we can argue that calibrating a contract that will be worth implementing is not trivial and seem to need precise agrometeorological data with a significant density of observations (depending on the spatial and interannual variability of the climate), at least for the Sudano-sahelian zone.

We finally argue that the variability of prices should be considered with careful attention in the case of a cash crop as well as idiosyncratic shocks, both having a large impact on individual level year to year and spatial variability of cotton yields and income.

REFERENCES

Araujo-Bonjean, C., J.-L. Combes, and P. Plane (2003): "Preserving vertical Co-ordination in the West African Cotton Sector," Discussion paper, CERDI.

Baron, C., B. Sultan, B. Maud, B. Sarr, S. Traore, T. Lebel, S. Janicot, and M. Dingkuhn (2005): "From GCM grid cell to agricultural plot: scale issues affecting modelling of climate impact," Phil. Trans. R. Soc., 360, 2095–2108.

Berg, A., P. Quirion, and B. Sultan (2009): "Can weather index drought insurance benefit to Least Developed Countries' farmers? A case study on Burkina Faso," Weather, Climate and Society, 1, 7184.

Blanc, E., P. Quirion, and E. Strobl (2008): "The climatic determinants of cotton yields: Evidence from a plot in West Africa," Agricultural and Forest Meteorology, 148(6-7), 1093 – 1100. Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo, and P. Yanda (2007): "Africa: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)," Climate Change 2007, p. 433467, In: Parry et al. (2007).

CIRAD-GRET (2002): M´emento de l'agronome. Minist`ere des affaires ´etrang`eres.

Claassen, R., and R. E. Just (2011): "Heterogeneity and Distributional Form of Farm-Level Yields," American Journal of Agricultural Economics, 93(1), 144-160.

Cole, S., X. Gin, J. Tobacman, P. Topalova, R. Townsend, and J. Vickrey (2012): "Barriers to Household Management: Evidence from India," Discussion Paper 09-116, Harvard Business School.

Cr´etenet, M. (2010): "Questions de recherche `a r´esoudre pour une relance durable des productions en zone cotonni`ere," in S´eminaire G´eocoton; Relance durable des produc-tions en zone cotonni`ere : outils et strat´egies.

Cr´etenet, M., and D. Dessauw (2006): "Production de coton-graine de qualit´e, guide technique No.1," Discussion paper, CIRAD.

De Bock, O., M. Carter, C. Guirkinger, and R. Laajaj (2010): "´Etude de faisabilit ´e: Quels m´ecanismes de micro-assurance privil´egier pour les producteurs de coton au Mali ?," Discussion paper, Centre de Recherche en Economie du D´eveloppement, FUNDP - D´epartement de sciences ´economiques.

Delpeuch, C., and A. Leblois (2012): "Sub-Saharan African cotton policies in retrospect," Discussion paper, CIRED.

Dessauw, D., and B. Hau (2008): "Cotton breeding in French-speaking Africa: Milestones and prospectss," in Invited paper for the Plant Breeding and Genetics research topic.

Enam, J., D. Folefack, C. Kouebou, and M. Fok (2009): "Tottering associative process in Cameroon: Collateral damage of the cotton policy adjustment," Life sciences international journal, pp. 112–122, Cotton Conference on "Rationales and Evolution of Cotton Policies", 2008-05-13/2008-05-17.

Folefack, D. P., J. Kaminski, and J. Enam (2011): "Note sur le contexte historique et gestion de la fili`ere cotonni`ere au Cameroun," WP.

Freeland, J. T. B., B. Pettigrew, P. Thaxton, and G. L. Andrews (2006): "Chapter 13A in guide to agricultural meteorological practices," in Agrometeorology and cotton production.

GAMP (2010): "Guide to Agricultural Meteorological Practices," Discussion paper, World Meteorological Organization, Commission for Agricultural Meteorology report No.134.

Gergely, N. (2009): "The cotton sector of Cameroon," World Bank, Africa Region Working Paper No.126.

Gray, A. W., M. D. Boehlje, B. A. Gloy, and S. P. Slinsky (2004): "How U.S. Farm Programs and Crop Revenue Insurance Affect Returns to Farm Land," Applied Economic Perspectives and Policy, 26(2), 238-253.

Holt, C. A., and S. K. Laury (2002): "Risk Aversion and Incentive Effects," American Economic Review, 92, 1644–1655.

IPCC (2007): "Climate Change: Impacts, Adaptation and Vulnerability," Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), p. 581615.

Kaminski, J., J. Enam, and D. P. Folefack (2011): "H´et´erog´en´eit´e de la performance contractuelle dans une fili`ere int´egre : cas de la fili`ere cotonni`ere camerounaise," WP.

Kenga, R., M. M'Biandoun, A. Njoya, M. Harvard, and E. Vall (2002): "Analysis of constraints to agricultural production in the Sudano-Sahelian zone of Cameroon using a diagnostic survey," in Savanes africaines: des espaces en mutation, des acteurs face `a de nouveaux d´efis.

Leblois, A., and P. Quirion (forthcoming): "Agricultural Insurances Based on Meteorological Indices: Realizations, Methods and Research Challenges," Meteorological Applications.

Leblois, A., P. Quirion, A. Alhassane, and S. Traor´e (2011): "Weather index drought insurance: an ex ante evaluation for millet growers in Niger," Discussion paper, CIRED.

Levrat, R. (2010): Culture commerciale et developpement rural l'exemple du coton au Nord-Cameroun depuis 1950. L'Harmattan.

Lien, G., and J. Hardaker (2001): "Whole-farm planning under uncertainty: impacts of subsidy scheme and utility function on portfolio choice in Norwegian agriculture," European Review of Agricultural Economics, 28(1), 17–36.

Luo, Q. (2011): "Temperature thresholds and crop production: a review," Climatic Change, 109, 583-598, 10.1007/s10584-011-0028-6.

Mbetid-Bessane, E., M. Harvard, K. Djondang, D. Kadekoy-Tigague, D.-P. Folefack, D. Reoungal, and J. Wey (2009): "Adaptation des exploitations agricoles familiales en `a la crise cotonni`ere en Afrique centrale," in Savanes africaines en d´eveloppement: innover pour durer.

McLaurin, M. K., and C. G. Turvey (2011): "Applicability of the Normalized Difference Vegetation Index in Index-Based Crop Insurance Design," SSRN eLibrary.

Meroni, M., and M. Brown (2012): "Remote sensing for vegetation monitroing: potential applications for index insurance," Ispra. JRC, ftp://mars.jrc.ec.europa.eu/indexinsurance-meeting/presentations/7 meroni brown.pdf.

Miranda, M. J. (1991): "Area-Yield Crop Insurance Reconsidered," American Journal of Agricultural Economics, 73, 233-242.

Odekunle, T. O. (2004): "Rainfall and the length of the growing season in Nigeria," International Journal of Climatology, 24(4), 467–479, 10.1007/s00704-005-0166-8.

Pinzon, J., M. Brown, and C. Tucker (2005): Satellite time series correction of orbital drift artifacts using empirical mode decomposition.

Sadou, F., A. Abdoulaye, B. Oumarou, M. Theze, and Y. Oumarou (2007): "Demarche de diffusion des SCV dans la zone cotonni`ere du Nord Cameroun: dispositifs, atouts, limites," in S´eminaire r´egional sur l'agro´ecologie et les techniques innovantes dans les syst`emes de production cotonniers.

Shepard, D. (1968): "A two-dimensional interpolation function for irregularly-spaced data," in Proceedings of the 1968 23rd ACM national conference, ACM '68, pp. 517–524, New York, NY, USA. ACM.

Sivakumar, M. V. K. (1988): "Predicting rainy season potential from the onset of rains in Southern Sahelian and Sudanian climatic zones of West Africa," Agricultural and Forest Meteorology, 42(4), 295 – 305.

Sultan, B., M. Bella-Medjo, A. Berg, P. Quirion, and S. Janicot (2010): "Multi-scales and multi-sites analyses of the role of rainfall in cotton yields in West Africa," International Journal of Climatology, 30, 58–71.

Vitale, J. D., H. Djourra, and A. Sidib (2009): "Estimating the supply response of cotton and cereal crops in smallholder production systems: recent evidence from Mali," Agricultural Economics, 40(5), 519–533.

Yaouba, A. (2009): "Pr´esentation du contexte agro-´ecologique et socio-´economique de la zone cotonni`ere du Cameroun," Discussion paper, Sodecoton.

ANNEX

Figure 12: Spatial repartition of cultivars in 2010, dots are representing producers groups bying seeds, IRMA 1239 in black, IRMA A 1239 in green, IRMA BLT-PF in yellow and IRMA D742 in cyan.

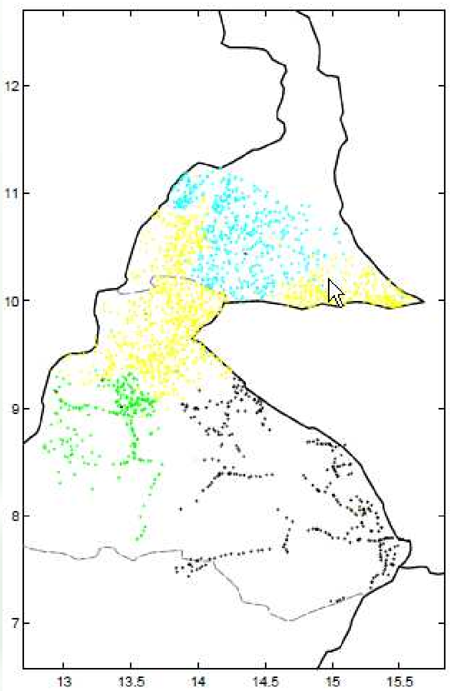


Table 9: Cotton cultivars average spatial and temporal allocation

Cultivars *(by province)*	1^{st} flower date (Days after emergence)	1^{st} boll date (Days after emergence)	Period of use
Allen commun	61	114	untill 1976
444-2			untill 1976
Allen 333	59	111	1959-197?
BJA 592	61	114	1965-197?
Nord			
IRCO 5028	61	111	untill 1987
IRMA 1243	53	102	1987 - 1998
IRMA 1239	52	101	2000-2007
IRMA A 1239	52	101	2000-2007
L 457	52	104	2008-onwards
Extrême-Nord			
IRMA L 142-9	59	109	until 1984
IRMA 96+97	55	115	1985 - 1991
IRMA BLT	51	99	1999-2002
IRMA BLT-PF	56	116	2000 - 2006
IRMA D 742	51	95	2003-2006
IRMA L 484	51	105	2007 - onwards

Sources: Dessauw (2008) and Levrat (2010).

Figure 13: Sodecoton's surveys localization: light gray dots for 2003, dark gray circles for 2006 and black circles for 2010.

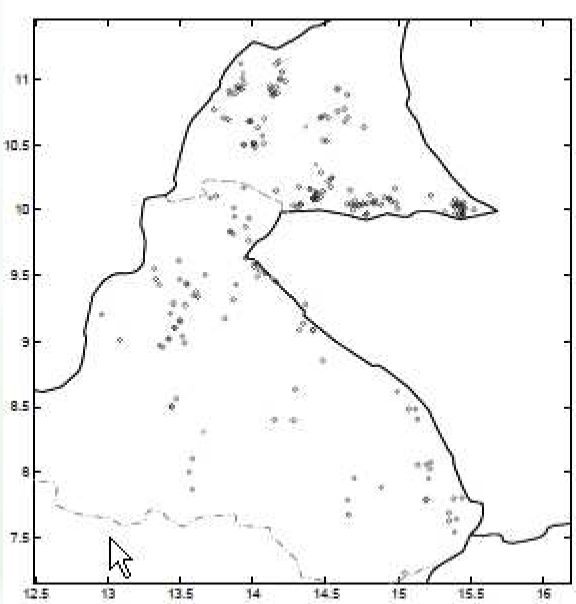


Figure 14: Villages in which lotteries were implemented.