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Feasibility Study: Which micro-insurance mechanisms are most beneficial to cotton growers in Mali?

This article presents a feasibility study of a micro-insurance product targeted to cotton producers in Mali. Based on an empirical analysis of data on yields, rainfall and satellite images, we show that an index based on average yields is the most appropriate insurance product for cotton producers facing a climatic shock.

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I. Introduction

Given the vulnerability of cotton growers to weather risks, the importance of the cotton sector in the Malian economy, and the significant poverty of Malian cotton growers, PlaNet Guarantee[1] decided to examine the possibility of introducing index insurance in Mali. By limiting the exposure of producers to risk, the insurance contract aims to reduce poverty resulting from poor harvests and stimulate investment. Thanks to funding from the ILO[2] Micro-insurance Innovation Facility, PlaNet Guarantee coordinated a group of experts who conducted a feasibility study between January and September 2009. The present paper summarizes work by Michael Carter and Catherine Guirkinger with help from Ombeline De Bock, Rachid Laajaj and Andres Moya. They considered two types of indices: a weather index and an index based on average yields[3], the so-called Area Yield Based Insurance (ARBY). The construction of the rainfall-based weather index is based on a technical analysis carried by Sandro Calmanti[4].

The issue of protecting farmers against risks is particularly relevant in developing countries where economic activity relies heavily on the farming sector. In Mali, almost 70% of the population relies on agricultural sources of income. Farmers face many risks and have difficulty protecting themselves. A poor harvest often has negative long-term impacts on poor households. When facing a reduction in income, these households are often forced to either sell their assets in order to maintain a minimum consumption level, or to reduce their consumption level (such as school expenditure) in order to keep their assets. This may adversely affect human capital accumulation and therefore future income. Repeated exposure to negative shocks can thus lead to the vicious cycle of a poverty trap (Morduch, 1995; Dercon, 2002). Maintenance of assets and income in poor crop years is made more difficult because most cotton growers in Mali take loans in order to cover production costs. In fact, farmers have to generate enough cash to pay back their loans as soon as possible and if unable to do so may find themselves obligated to sell their productive assets, such as traction animals. Farmers' exposure to risk can also discourage investment in highly profitable but risky activities and thus deprive households of an enrichment opportunity[5].

[1] PlaNet Guarantee is the unit of the PlaNet Finance Group dedicated to the promotion and development of microinsurance. Its objective is to enable the populations, which usually do not have access to traditional insurance systems, and which do not benefit from social protection mechanisms, to protect themselves against different risks (health, natural disasters, etc.).
[2] International Labour Organisation
[3] Carter M. *et. al.* (2009) "Technical analysis for a district-level area-based yield index insurance contract for Mali cotton producers" summarizes the technical analysis.
[4] Calmanti (2009), working paper for Planet Guarantee.
[5] In fact, there is a trade-off in agriculture between yields and risk. A farmer who invests in cutting edge technologies is exposed to higher losses in the case of a negative shock.

In this context, having access to insurance might dramatically improve farmers' welfare by helping in poor harvest seasons and by stimulating investment in highly profitable but risky activities. This knowledge has led to growing interest in micro-insurance programs that are targeted to the special needs of poor populations who are not served by conventional markets, and to the institutional and natural environment of developing countries. An example of such programs is agricultural insurance based on an index[6]. The index insures against the occurrence of an easily identified event that correlates to an expected decrease in the revenue of the farmers in the area. A possible event is lack of rainfall. If rainfall falls below a predetermined threshold, the insured farmers are compensated proportional to the difference between the observed rainfall and the threshold. The fundamental difference with classic insurance lies in the nature of the event that triggers the payment of compensation; it is not a damage suffered by the insured, but rather an event that indicates a probable damage. As we will show later, this considerably simplifies the management of the insurance product. A disadvantage is that the index may not perfectly reflect the shocks experienced by individuals.

Indices are increasingly being used for new agricultural insurance. The most direct index is a measure of the average yield of a specific region. If the average yield is lower than a predetermined threshold based on historical data, the insured are compensated. The advantage of such an index is that it is more correlated with individual yields than for example a weather index. A major drawback is that efficient indices require reliable and quick compensation which may prove difficult when measuring average yields. It may be more efficient to measure rainfall or even the quality of vegetative cover thanks to satellite imagery, which explains the predominance of these types of indices.

In the following discussion, we present two possible insurance indices targeting Malian cotton producers: a weather index and an average yield index. This article is structured as follows: we first introduce the concept of micro insurance and the notion of an index. Chapter 2 presents the characteristics of cotton production in Mali and defines the study region. Chapters 3 and 4 study the weather index and the average yield index respectively. The last chapter compares the two indices and we conclude by choosing the index most appropriate to the study region. By the end of the analysis, we suggest the implementation of a small-scale index insurance contract based on an average yield, which is accessible to cotton growers and which covers agricultural production in the study region.

[6] There are ongoing experiments on various crops in Mexico (Skees et al. 2001) and in India (Kalavakonda et Mahul, 2005; Veeramani et al., 2005; Zant, 2007), on copper in Thailand (Gilbert et al. 2001), on coffee in Kenya, Ethiopia, Uganda, Tanzania and Zimbabwe (Gilbert et al. 2002), on crops in Morocco (Skees et al. 2001), on cocoa in Ghana (Sarris, 2002) and on corn in Malawi (Hess et Syroka, 2005).

II. Micro-Insurance

Low-income countries are particularly vulnerable to weather hazards since an important part of their economy relies on agriculture[7]. A natural disaster that damages the harvest and destroys the production infrastructure can have negative long term consequences for economic growth (Carter *et al.*, 2007). In addition, the risk premium, which includes the cost of mitigating the current shock and the potentially high cost of protecting against future shocks, is particularly harmful for poor farming households located in rural areas. The vulnerability of low-income countries is magnified by the lack of infrastructure, the weaknesses of legal systems and less developed communication systems.

Agricultural risks have a significant impact on poor populations' growth and welfare. A natural question to ask is why insurance markets have not developed in order to absorb those risks? This fundamental question was the subject of much debate (Pauly, 1974; Shavell, 1979; Arnott and Stiglitz, 1991). It is useful to review two key points to address this question: the presence of asymmetric information in the insurance market and particularly high transaction costs in rural areas of developing countries.

First, let us review how the provision of an insurance contract can suffer from asymmetric information issues between the insurance company and the insured agent (Skees et al, 2008). The insurer does not know the agent's characteristics and can only partially control his behavior. Therefore, two types of risks are likely. First, the insurer does not have reliable data on individual yields; he cannot distinguish between "good" and "bad" customers (those who engage in riskier activities) so, he applies the same premium to all potential customers. This premium is higher than it would be if only good customers were included. It is even possible that buying the insurance is not profitable for these customers, which is the classic adverse selection problem: good customers leave and only the less careful ones accept the insurance contract. In other words, "an ill-informed person offers a contract that pushes away the customers that she would like to attract" (Cayatte, 2009, p207). Additionally, the farmer who buys the insurance is likely to be less careful, by not applying the necessary pesticide or providing less effort than if he were not insured, thereby increasing the probability of loss. This change in the farmer's behavior is called "moral

[7] According to the World Resource Institute (2007), agricultural production accounts on average for 23% of GDP in low income countries.

hazard". This risk can also occur ex post, after the adverse shock. In fact, the farmer has an incentive to exaggerate his loss when he reports it to the insurance company so he receives more compensation. Crucially, the insurance company cannot verify if the farmer lied. This is the reason individual insurance is essentially nonexistent in agriculture. Note that information problems are more pronounced in developing countries for several reasons such as the weakness of institutions, the absence of court-ordered appraisals capable of resolving litigious cases, the absence of a data center with information on the creditworthiness of potential customers, and the lack of accounting systems that allow insurance companies to monitor farmers' revenue.

The second possible answer to why insurance markets have not developed deals with the relatively high transaction costs compared to the amount insured. These costs tend to be high in developing countries. First, fixed costs are key since if the amount insured is small, high fixed costs reduce profitability for the insurance company. In addition, it is more difficult and more expensive to verify reported damages in rural areas because of poor infrastructure and large distances between clients.

In this context of incomplete insurance markets, the goal of micro-insurance is to offer products tailored to the needs of households excluded from the conventional insurance market. The premise is to share risk. The word "insurance" implies regular premium payments with indemnity payouts following negative shocks; the word "micro" refers to a decentralized program, based at the community level and covering small amounts of money. In order to tailor insurance to this specific group of customers, some innovative products have been introduced, including index insurance.

There are different types of indices. The most intuitive ones are those directly based on average yields data. In addition, many specific indices have been constructed to cope with natural hazards. The most common indices are constructed from weather indicators in a given region, such as an index based on precipitation, temperature variation, wind speed, seismic activity using the Richter scale, or the vegetative cover.

Index insurance, compared with conventional insurance contracts, is advantageous because it is not based upon the occurrence of a specific event for the insured or on an assessment of direct damages. Rather, it is based on direct payment for losses resulting from variation in the chosen index. Thus, indemnity payments depend on the level of the index; as soon as the predetermined threshold is reached, the payment is made to farmers who had purchased the insurance.

Let us examine the case of a rainfall index. The insurance contract specifies several thresholds or trigger points that correspond to losses in agricultural production. The thresholds are determined according to the agro-ecologic characteristics of the region. If rainfall is below the threshold, the insurance pays a predetermined indemnity for all insured, regardless of whether they suffered losses directly from lack of rain. Thus, it is possible that some are compensated even if they did not incur losses. Note that indemnity increases as the index value falls farther below the average index value. Typically, for each millimeter below the agreed threshold, the insurance pays an indemnity based on the average loss incurred by farmers due to the lack of rain. In order to serve as the basis for insurance contracts, these indices should be highly correlated with farmer losses (Skees e*t al.*, 1999). On the other hand, if rainfall levels do not drop below the threshold, no one receives indemnity payments even if some farmers suffer catastrophic yields from non-rainfull reasons such as locust plagues or crop diseases that prevent them from harvesting a full crop. This difference between individual risk and risks covered by the insurance company through indemnity payments is basis risk.

Basis risk occurs when the compensation that the farmer receives does not exactly match the loss that he incurred. There are three reasons behind this phenomenon. (Goodwin and Mahul, 2004; Barnett *et al.*, 2006). First, the index variables are the same for all farmers in the community and thus they do not cover idiosyncratic risks specific to each farmer[8]. The second reason is that the index is not exhaustive and is rarely capable of reflecting all issues faced by farmers in the community (for instance, a rainfall index cannot account for fluctuations in the market price in a given region). The final reason relates to the payment schedule since the delay does not allow farmers to cope with fluctuations in their income. In order to minimize basis risk, it is important to ensure a high correlation between the index and the losses suffered (Molini et al., 2007).

With an area based yield index, the correlation between individual yield and the index is higher than with that of a weather index. If for instance the farmer is dealing with a locust infestation, it is taken into account since it reduces the yield of all the farmers. Although the correlation is high, there still remain uncovered risks that affect farmers individually. In other words, basis risk persists.

[8] Idiosyncratic risks are better managed by traditional insurance mechanisms.

Index insurance has many advantages. It significantly reduces the problem of asymmetric information. The risk of moral hazard is also lowered since the effort level of the farmer has no influence on the occurrence of the shock. In fact, payments are not based on actual losses, but on the index level. Therefore, farmers have the incentive to reduce risky behavior in order to minimize their losses (Corbett, 2005). As for the issue of adverse selection, it is no longer present since the premium does not depend on the specific occurrence of the shock. Among the various types of indices, the average yield index has the significant advantage of taking into account all sources of variation in the yield that trigger indemnity payments to farmers, irrespective of the cause. However, it is often more expensive and more difficult to implement.

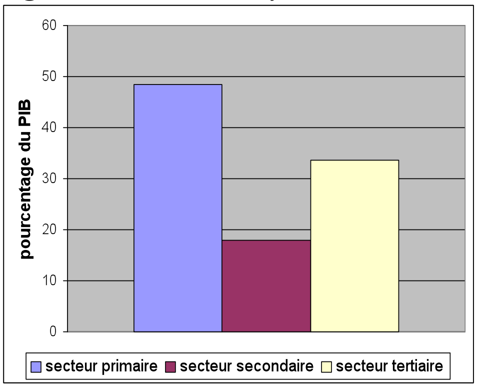
III. Cotton production in Mali

Mali Statistics

Mali is a landlocked country in western Africa with an area of more than 1,240,000 km² and a population in excess of 13 million. It is among the least developed countries in the world according to both GDP and the human development index (it holds the ranking of 168 out of 177 countries). Currently, 59% of the Malian population is below the poverty line.

Agriculture and animal breeding are the main income sources of the country. The primary sector has an average growth rate of 47% of the Malian GDP in 2007, as is shown in Figure 3.1. More than 70% of the population works in the agricultural sector, which in 2007 was 48.4% of the GDP. Cotton plays a major role in the Malian economy as it represents the main source of foreign currency to the country. The revenue from cotton exports represents more than 10% of the country's budget income. Cotton is mainly produced by small family farms and represents farmers' main source of cash income, other crops are mainly used for subsistence (Commission de l'UEMOA, Comité de convergence et BCEAO, April 2007).

Figure 3.1: GDP by sector in Mali



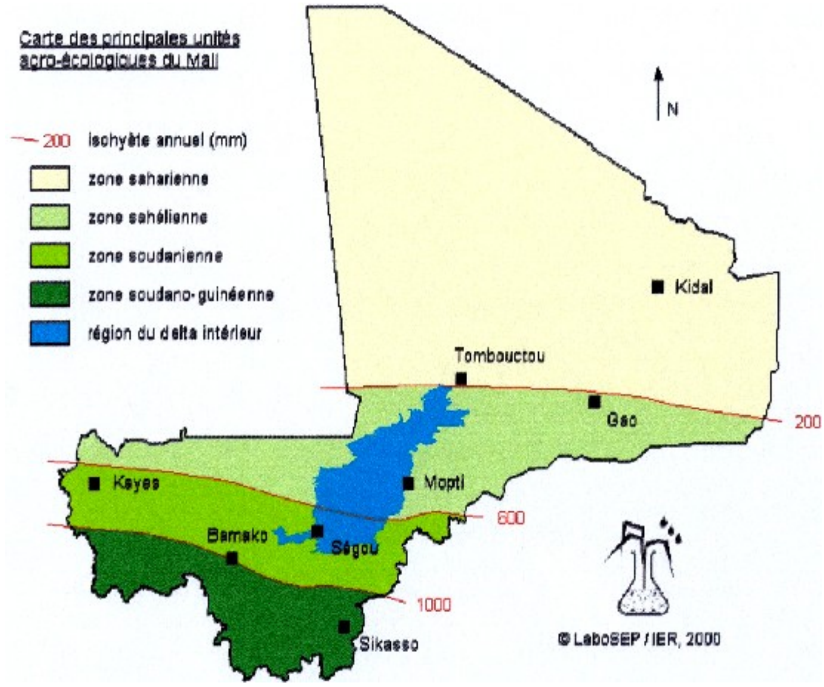
Source: Rapport SOS Faim, 2007

Cotton cultivation is one of the driving forces of the rural development process. Investments in cotton transportation infrastructure have facilitated access to remote areas. Income resulting from the introduction of cotton cultivation has led to improvements in living conditions, with better access to capital and consumption goods, as well as to the creation of health and literacy centers (Bonnassieux, 2005).

Mali is a landlocked country and has a long dry season (8 to 9 months) and a short rainy season. It also has diverse climate regions with irregular rainfall ranging from 200 mm in the north to up to 1200 in the south, as shown in Figure 3.2.

Figure 3.2: Climate zones of Mali

There are four climatic zones from the North to the South: the North belongs to the sub-Saharan zone, the inner delta of Niger is in the semi arid Sahelian area where there is a transition between the desert and the savanna; the South is endowed with a Sudanese climate. Finally, the extreme South belongs to the Sudan Guinean sector.



Cotton requires a long growing season, with large amounts of sun and water during the growth period and dry weather during the harvest. In southern Mali there is an area of 96,000 km² (7.7% of the total area of the country), which has these characteristics, a part of which is the Sikasso area that we will study in detail.

Brief history and perspective

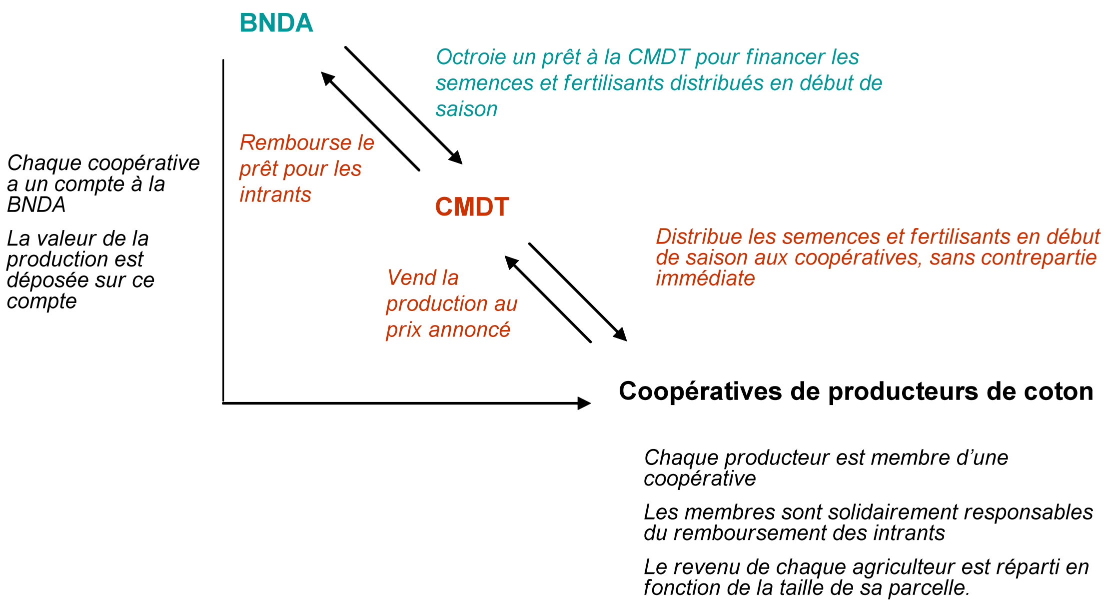
Following the creation of the Malian cotton company, la Compagnie Malienne de Développement du Textile (CMDT) in 1974, cotton production has dramatically increased. The CMDT organizes the production and marketing of cotton within a strongly integrated sector.

BOX 3.1: An integrated cotton industry

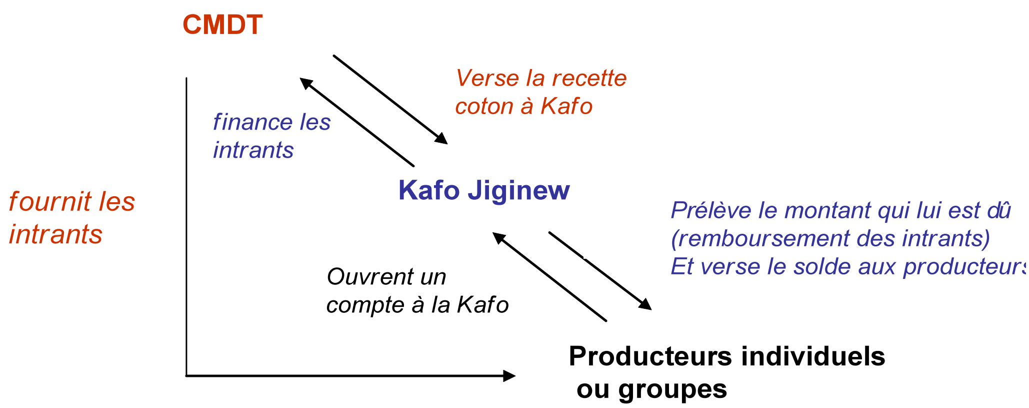
The production of cotton in Mali has two characteristics: First, the vertical integration of the industry, and secondly the existence of a guaranteed minimum price for producers that varies according to the season.

The Compagnie Malienne de Développement du Textile (CMDT) plays a key role in the organization of the industry. It guarantees the collection, marketing and shelling of cottonseeds. In addition, it guarantees the exports of cotton fibers and their sales to the textile industry. As a monopoly on the purchase and marketing of Malian cotton, it sets the producer price for farmers at the beginning of the season and guarantees the purchase of the total crop.

To date the CMDT deals directly with cotton producer cooperatives. Therefore, every farmer must be affiliated with a cooperative in order to optimize financing for the season. The National Agricultural Development Bank (BNDA) is the main financier of the sector by covering more than 90% of the funding of inputs in the cotton growing region. At the beginning of the season, the CMDT provides the different cooperatives with seed and fertilizers. Once the crop is harvested, the value of the total product is deposited in the cooperative account in the BNDA. After subtracting the fertilizers and seed costs, the cooperative members are paid according to the area of their plot and the prices announced by the CMDT at the beginning of the season. Note that the members of the CMDT are jointly responsible for the repayment of the inputs.



The Kafo Jiginew mutual company covers the financing of inputs for the remaining 10% of the area allocated to cotton. The loan finances the purchase of cotton inputs for the individual farmers; it is a loan in kind guaranteed by the cotton receipts of the borrowers. The Kafo Jiginew, meaning Attics Union in the local dialect, is the largest network of popular saving and credit banks in Mali. The villages covered by these banks represent 194,890 cotton farms with 223,500 members. Besides the input credit[2], Kafo offers a large range of products including the season's loan[1], the equipment loan[3], mainly used for the purchase of bulls, or the storage of grain[4]. In contrast to the CMDT, every farmer has an individual account with Kafo, even though the organization is used as a cooperative for the distribution of inputs. Although Kafo accepts both individual farmers and groups as customers, repayment is not subject to joint guarantee therefore it is more sensitive to the success of the harvest.



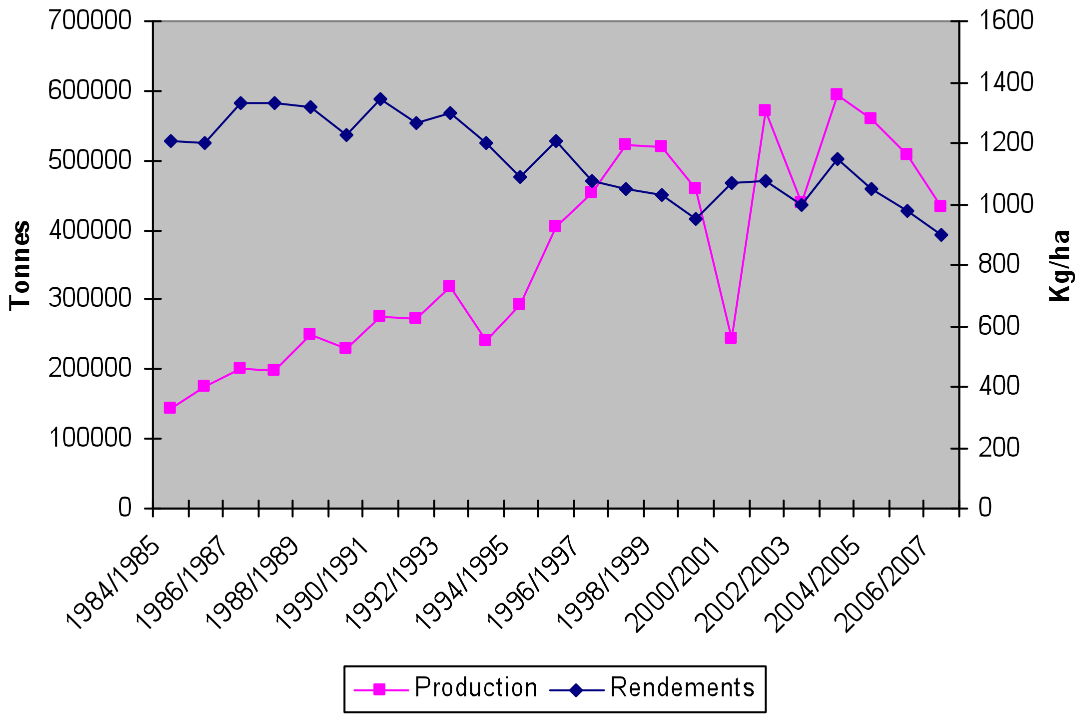
1. term : from 7 to 12 months, 24% annual declining rate
2. term: approximately 9 months, 10% annual nominal rate
3. term : from 12 to 36 months, 18% annual declining rate
4. term : from 6 to 12 months, 10% annual rate

Figure 3.2 below illustrates the evolution of cotton production and yields in Mali since the middle of the 1980s. The national production increased from 144,000 tons to 518,000 tons by the end of the 1990s. This period constitutes the golden age for cotton in Mali and the spectacular increase in the production is primarily due to the devaluation of the CFA franc in 1994. The graph also shows a significant decline in production during the harvest period of 2000/2001, which is due to a farmers' strike following the announcement by the CMDT of a lower than usual price. The CMDT was faced with a severe financial crisis, caused by the decline in the price of cotton on the world market. Farmers disagreed with CMDT management practices and specifically with the lack of transparency when sharing value added (Delarue *et al.*, 2009 ; Hugon, 2005). These issues led many growers not to grow cotton during the 2000/2001 harvest.

Production reached its historical peak in 2003/2004 with more than 593,000 tons produced. During that period, the sector was made of more than three million Malians and 160,000 farms. Since 2005 the area devoted to cotton has been sharply decreasing mainly because of a decline in nominal prices, which we will discuss later.

Figure 3.2: History of Cotton Production and Yields in Mali

Figure 3.2: Evolution de la production et des rendements du coton au Mali



The history of cotton yields does not follow the same trend. Since the early stages of CMDT, the increased use of inputs and equipment, more mechanization, improved literacy and professional training, and the integrated organization of the sector contributed significantly to increased yields until the middle of the 1990's.

During the latter half of the 1990s, despite the increase in the area devoted to cotton, the average yield per hectare decreased in Mali. Cotton yields are very sensitive to rainfall and therefore can vary up to 25%. Cotton typically requires 500mm of water per year, uniformly distributed from the germination to the forming of the cotton bud. However if rainfall is scarce or irregular, the proportion of flowers that will develop into buds can fall from 1 in 3 to only 1 in 10. If there is excess rainfall the roots lack air and the plant will not show any visible sign of abnormality, whereas during a drought, the plant is unable to absorb the nutrients necessary for its development. Furthermore, a study by USAID (2009) notes that expected yields have decreased since many farmers do not follow recommended cultivation practices.

The cotton sector is very sensitive to the price on the world market, which is volatile. World cotton prices had been very low until 2003, a favorable year to cotton growers, but then prices fell. In 2005, the system of CMDT setting the producer price was modified by linking the domestic price to the international market so as to reduce deficits for CMDT caused by difference in guaranteed prices and the world price. This liberalization of prices had an immediate adverse impact as the price dropped from 210 FCFA/kg in 2004/2005 to 160 FCFA/kg in 2005/2006 (Delarue et al, 2009).

Since 2007, world prices have been rising but Mali has not increased the price paid to national producers due to the previous financial problems of the CMDT as well as increasing input costs. This development is worrying and according to Hugon (2005), the price paid to the farmers (set at the level of 200 FCFA per kg in 2008) might not cover production costs (fertilizers, pesticides, seasonal labor, machinery, potential rental of bulls).

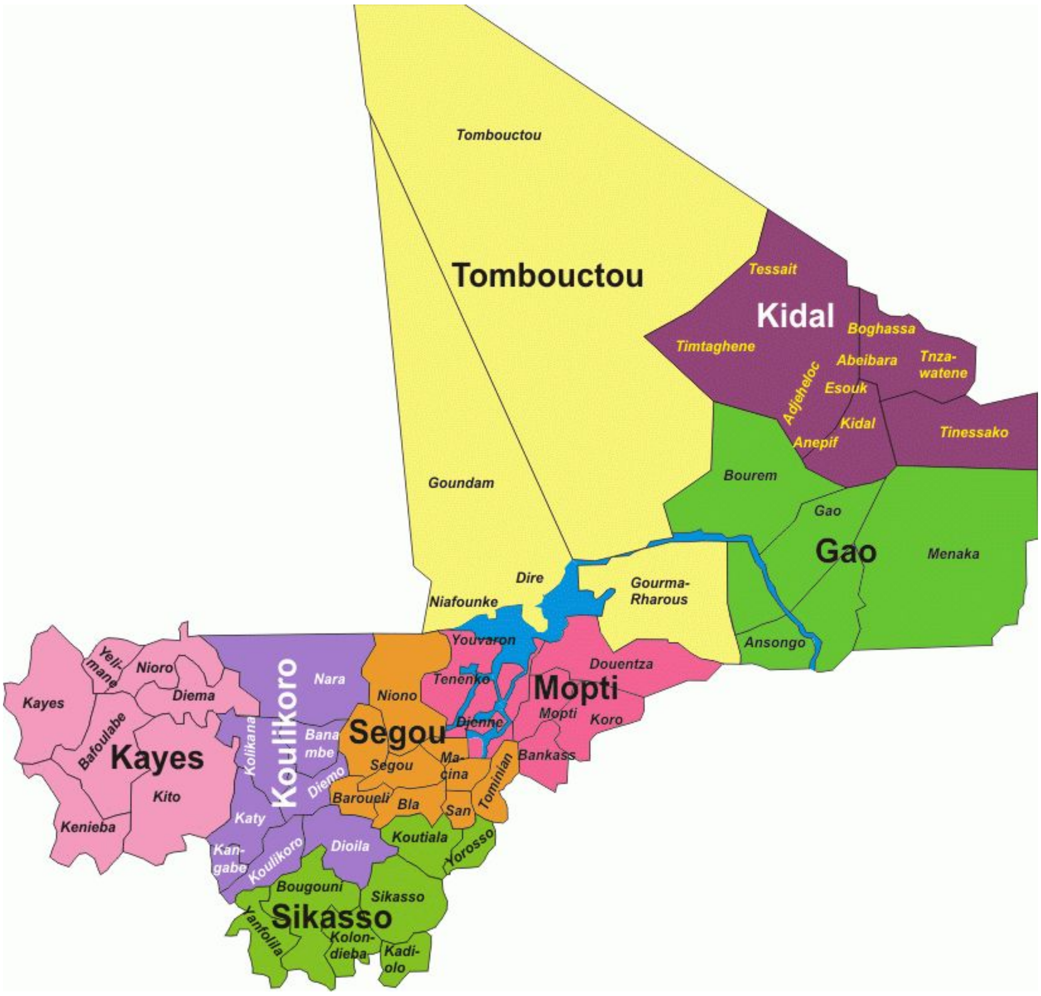
In this context of uncertainty, the cotton sector in Mali is facing many challenges. The reforms which started at the beginning of 2000 and the subsequent liberalization were designed to lead to the creation of 4 subsidiaries that share the management of the Malian cotton sector. This reorganization aims at reestablishing the competitiveness of the Malian economy. After many years of negotiations, an agreement protocol in relation to the social plan of 2010 of the CMDT was signed by the board of the directors and the unions on January 7th [2010].

Methodology of the feasibility study

The feasibility study targets an area in Sikasso, a region in southeastern Mali, which includes the districts of Koutiala, Fana, Bougouni and Kita. It is worth mentioning the political and administrative division of Mali in order to better understand the level of disaggregation of the study. The country is divided into three administrative units: 8 areas represent the most aggregated level. These areas are divided into circles, which are in turn divided into urban districts, as it is shown in Figure 3.4 below.[9] The urban districts are intermediate administrative entities (the average cotton production is equivalent to 15,000 ha per district) which cover different townships, each comprised of several villages.

[9] CMDT focuses on agricultural production areas of particular villages.

Figure 3.4: ***Political map of Mali***



The data for the feasibility study was collected during a weeklong expedition to Mali at the end of March. The first step was to interview cotton producers about the demand level, their needs, and the yield and size of the area under cultivation. Besides this individual information, several institutions (Minister of the agriculture, CMDT) provided us with average yield data. The mission also collected locally available climate data, augmented by data obtained from the national meteorological authority, with the assistance of a climatologist. The second step was to contact local microfinance institutions operating in the agricultural sector (BNDA, Kafo Jiginew, CVECA Kita). The final step was to organize focus group discussions aimed at understanding the creation of the proposed insurance product, as seen by the potential beneficiaries.

Risks to which the farmers are exposed

Cotton growing exposes farmers to numerous risks, which could adversely affect a household's income and thus its standard of living. First, an unpredictable climate is a key source of uncertainty since cotton production is rain fed. In fact, the cotton plant itself has very sensitive water requirements during each stage of life, from sprouting to blooming.

As part of the survey coordinated by PlaNet Guarantee in Mali in March 2009, farmers reported situations they perceived as being the most detrimental to their wellbeing. Rain delay or variability was a particular concern. In Mali, cotton is sown at the beginning of the winter with the arrival of the big rains. The commonly acknowledged signal to begin sowing is when rainfall reaches at least 20mm. If this trigger occurs too early or too late in the season it causes lower yields. In order to avoid such losses, the CMDT generally recommends sowing between May 25th and July 20th. A shorter rainy season prevents the plant from reaching complete maturation, causing damage to the harvest while if the rainy season is interrupted by a long dry period (more than 10 consecutive days), the plant can be seriously damaged. Finally, excess rain can also be devastating, reducing the quality of the fiber or simply reducing the effectiveness of pesticides. Climate risks are expected to become more pronounced because of climate change, which may destabilize future agricultural activities.

Another major issue for farmers is soil fertility (and conservation) since it influences the productivity of the harvest. However high prices of manure and other fertilizers reduce farmers' access. Also, when farmers obtain fertilizers, they allocate some of them to food production (maize, millet, and sorghum).

Crucially, harvest quality depends on the origin of the seeds. Seeds are supplied by the CMDT at the beginning of the season, and hence quality is out of farmers' control. Change in the seed variety requires adapting agricultural practices by farmers. Other issues farmers mentioned were deterioration of the irrigation infrastructure, lack of production equipment, and strong land and animal pressure.

In addition to these physical factors, farmers mentioned delays in payments by the CMDT. This is particularly a problem if farmers have to make investments for the new season before they receive their income from the previous season. Delayed payments may force farmers to sell the inputs of the current season in order to obtain cash, which decreases their chances of good yield in the next season.

We also have to take into account events specific to each farmer for a complete risk assessment. A broken leg, unanticipated schooling expenses, the death of a family member… these are all events that threaten the fragile economic balance of the household.

The CMDT is also exposed to market risk since it fixes the purchase price at the beginning of the season and the price depends upon world developments. Mali is thus sensitive to foreign shocks from the moment the price is fixed to the final transaction with farmers. It is important to note that input prices have continued to rise in recent years[10], while the price paid to farmers has remained low, which worries them.

Since farmers repeatedly mentioned climate factors as a source of potential risk, the feasibility study created a weather index as the base for the insurance product. Using available data, Michael Carter's[11] team investigated the expected effects of an index based on the average yields and detailed two alternative weather indices.

[10] However, since the purchase price is set at the beginning of the period, the change in input prices does not represent a risk, strictly speaking.

[11] Based on data collected by the expedition to Mali, Carter, Laajaj and Moya (2009) wrote a technical report on which this section is based.

IV. The Area-Based Yield Index

Concept

An index insurance contract based on average yields depends directly on the aggregated return of a given geographical zone and is composed of a deductible and a premium.

The principle is simple: based on time series data of historical cotton yields, the insurer defines a **critical threshold** for the zone to be insured, y_{sc}. When the average yield $\bar{y}$ is less than y_{sc}, then subscribers receive a payout[12] proportional to the difference between the average yield of the cotton in the region and the critical threshold. This amount I_{it} for farmer *i* during harvest *t*, is thus defined in the following way (Carter *et al.* 2007):

$$I_{it} = \max\left(y_{sc} - \bar{y}, 0\right)$$

There is a systematic statistical relationship between the output per person y_i and the average of this one for all the farmers in the area $\bar{y}$ (Miranda, 1991):

$$y_i = \mu_i^y + \beta_i^y\left(\bar{y} - \mu^y\right) + \varepsilon_i^y$$

For a given harvest, the farmer's yield is thus a function of his/her expected or average yield μ_i^y, the difference between the average yield realized in the given season and the average expected yield in the region μ^y, as well as an individual error term ε_i^y, which represents idiosyncratic shocks. The coefficient β_i^y characterizes the relationship between the individual farmer's output and the average yield of the region. This relationship determines the utility that the farmer derives from the insurance. The closer the coefficient β_i^y is to one, the more beneficial the insurance is since the farmer's output will more closely mirror changes in yield. In order to understand this, suppose that the coefficient is equal to one. Then change in the yield of a given farmer is equal to the change in the average yield of the region. Imagine one year the cotton harvest is particularly good and is 250 kg higher than the average year. Then the farmer's harvest will also be 250 kg higher than his own average yield. On the other hand, if the coefficient is zero, the insurance looses its value since the farmer's yield is not correlated with the average yield of the region. In other words, as the

[12] Note that the payout is defined in kg of cotton per hectare.

correlation approaches zero basis risk increases, and index insurance does not reduce fluctuations in farmer's revenue.

Thus, the first step of the analysis is to estimate the coefficient β_i^y. This estimation determines the proportion of basis risk present in the product. A small coefficient β_i^y implies lower participation of farmers in the insurance program. In order to construct the insurance contract, the analysis is performed in three steps. Carter et al. first estimate the yields distribution in the study region. They then determine the critical threshold y_{sc} below which payments will be made, and third they determine the premium. As a final step, a feasibility study simulates the payment frequency and the value of the indemnity paid (in kg per ha), so as to evaluate the benefits that cotton growers receive from the contract.

Data

Defining the geographic region of the study is crucial in order to establish an index based on average yields. The smaller the region, the better able the product is to meet the needs of farmers. In order to estimate the coefficient β_i^y two types of data are required: historical data on average yields of the study region and data on individual farmer yields.

The analysis is based on data provided by the CMDT. This data show changes in the annual average yield of cotton over the six last harvests (from 2002/2003 to 2007/2008). The data encompass thirty-two districts located in six circles of the Sikasso region. The second type of data, required for the measure of basis risk, is also provided by the CMDT and pertains to 165 households living in 13 different villages. This data covers three harvest seasons (2000/2001 to 2002/2003), and are the most disaggregated level for the analysis.

Calculation of basis risk

Household level data allows for the assessment of benefits of the insurance contract for every farmer of the study area, and for the estimation of the amount of risk covered by the average yield index. The higher the correlation between farmer output and the average yield index, the more likely it is that the insurance meets the needs of cotton growers, which will increase the probability of a successful index project.

Therefore it is crucial to calculate the basis risk. In this sample, basis risk is 30%, a reasonable proportion. It means that the constructed index is **able to explain 70% of the average annual variation of the yields for each village.**

Contract elaboration

Step 1: Estimating the distribution of yields in the study region

Among the 32 selected districts, the long run yields vary strongly. Carter *et al.* have identified three existing categories in the sample. This categorization enables the insurer to offer targeted insurance contracts, based upon the average per hectare production level in the district. The disadvantage of not doing this, which would be to offer a unique insurance contract, is to be more attractive to farmers belonging to low yield districts, and more likely to surpass the critical threshold. Here is a description of three districts:

District	Kg of cotton/hectare	Yield Category
Bougouni	1054 kg/ha	High yields
Yanfolila	970 kg/ha	Medium yields
Bla	812 kg/ha	Low yields

There are notable differences between the districts and more information would need to be collected in order to understand the causes behind the different yields. However Carter et al. point out that it is not necessary to know the precise causes in order to be able to adopt the insurance based on the average yields; it is in fact enough to know their distribution.

A Weibull density function was used to estimate the distribution, which is a commonly used function for the representation of yields data. A key advantage of this distribution is its high degree of flexibility; it can represent at least an infinite number of probability distributions, and has the characteristic of eliminating negative values.

The Weibull density function is the probability $f(y)$ of obtaining yield y at the end of the harvest as follow:

$$f(y) = ab^{-a} y^{a-1} e^{-(y/b)^a}$$

where a and b are the Weibull parameters. The determination of these parameters allows the determination of the yields distribution of a given district. The parameter a (shape factor) is without dimension and determines the shape of the frequency distribution. The parameter b (scale factor) determines the height (and thus the density) of the distribution, since a change in this parameter is equivalent to a change in the x-axis.

Given the differences in long-term average yields, the authors chose to estimate these parameters by district. This is likely to induce a loss of statistical significance because of the small number of observations.

$$a_d = a_0 + a_1 \overline{y}_d$$

$$b_d = b_0 + b_1 \overline{y}_d$$

Step 2: Determining the threshold level y_{sc}

The determination of the critical level is crucial. On the one hand, if it is too high, the cost of the premium might discourage the farmers from purchasing the product. On the other hand, if it is too low, the frequency of indemnity payments is very low. This is problematic since timing of indemnity payments are important for building farmers' trust in new types of insurance products.

In fact, if we determine a **unique critical threshold of 80%,** it means indemnity payments to farmers occur only when the average yield of the district is lower than 80% of the historical yield. This corresponds to a financial intervention on the part of the insurer only 15% of the time, which is approximately every 7 or 8 years.

It is thus important to design a contract that incorporates two levels of critical thresholds so as to better meet the needs of the farmers. The first level is relatively high and results in partial compensation. When the relatively low second level is reached, full compensation is paid to the farmers as agreed.

The compensation level I_{idt} is therefore:

$$I_{idt} = \max\left(y_{2sc} - \overline{y_{dt}}, \frac{1}{2}(y_{1sc} - \overline{y_{dt}}, 0 \right)$$

where y_{1sc} the first critical level, equal to **90%** of the average yield of the district, and

y_{2sc} the second critical level, equal to **80%** of the average yield of the district.

The double critical level leads to higher frequency of compensation: 29% of the time, the equivalent of once every four years. This increases the attractiveness of the insurance contract to farmers.

Step 3: Setting up the insurance premium

Generally, the insurance premium paid by the insured is composed of different parts. In addition to the basic premium, the amount of the expected average disaster that the insured will face, a risk factor and an administrative cost are all included in the insurance price. We will only compute the pure premium in this study in order to estimate the cost of the contract. However, we should keep in mind that the actual insurance premium paid by the customers will be slightly higher. Formally, the per hectare pure premium p_{id} is equal to the expected loss:

$$p_{id} = \int_0^\infty I_{idt}(y_d) f(y_d) dy$$

If we compare contract A, endowed with a unique threshold of 80%, with contract B, offering a double threshold, we expect that the premium price is higher in contract B. In fact, the indemnity payments in contract B are higher. The calculated estimates confirm this hypothesis: while premium required by contract A is less than 2% (or equivalently 14 kg/ha in low yield districts, 17 in districts with a medium yield, and 19 in high yield districts), the premium required by contract B is about 2.4% of the long run average yield (or respectively 18, 22.5 and 25 kg/ha according to yield category) .

The three graphs below illustrate the determinants of the two types of contracts for the three categories of district. First, the estimated density function (Weibull distribution) is represented in these graphs. It is centered on the average yields for the category in hand (for example, 812 kg/ha for the district of Bla). The yield density is represented in the right y-axis. Second, we observe the triggering threshold of compensation payments for every type of contract. If we consider the example of Bla, we realize that starting from the far right of the x-axis the double threshold payment is triggered earlier, as soon as the yield reaches 90% (equivalent to 731 kg/ha). Payments of the first single threshold contract begin only when the average cotton production falls below 650 kg/ha. Since between 731 kg/ha and 650 kg/ha the two contracts compensate farmers at different levels (contract B is only to a level of 50%), the slope of the line representing contract B is flatter.

Figure 3

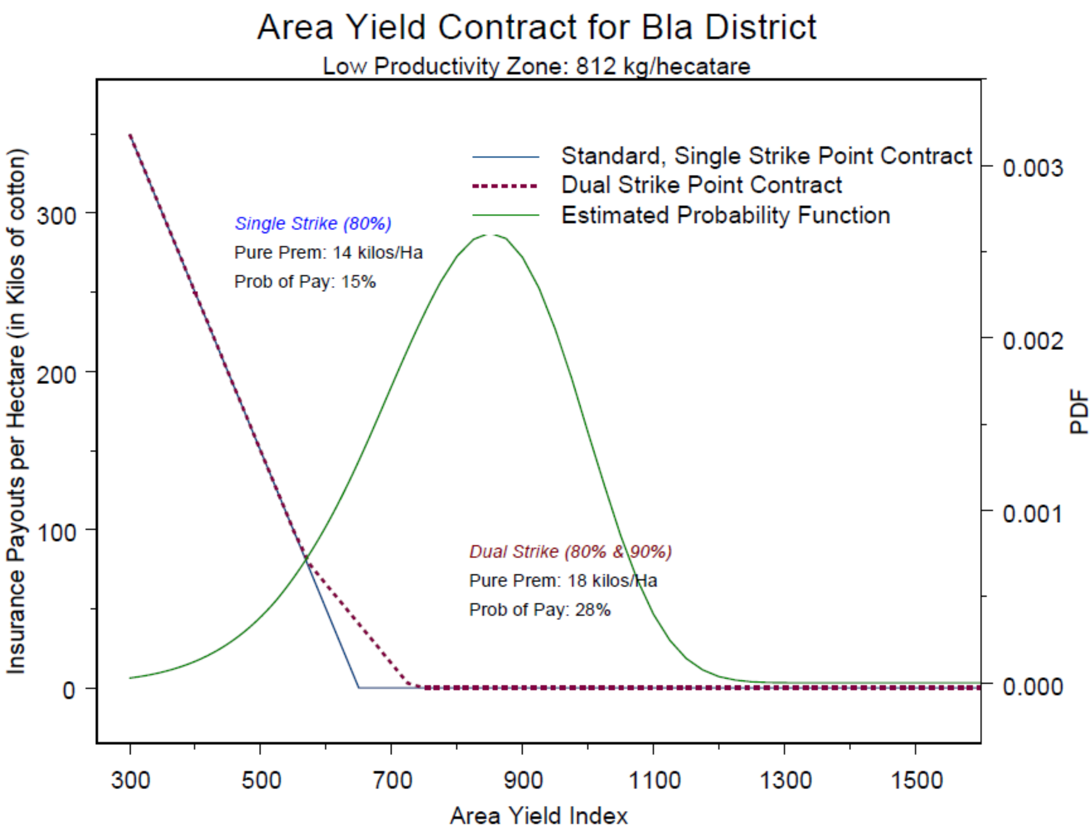


Figure 4

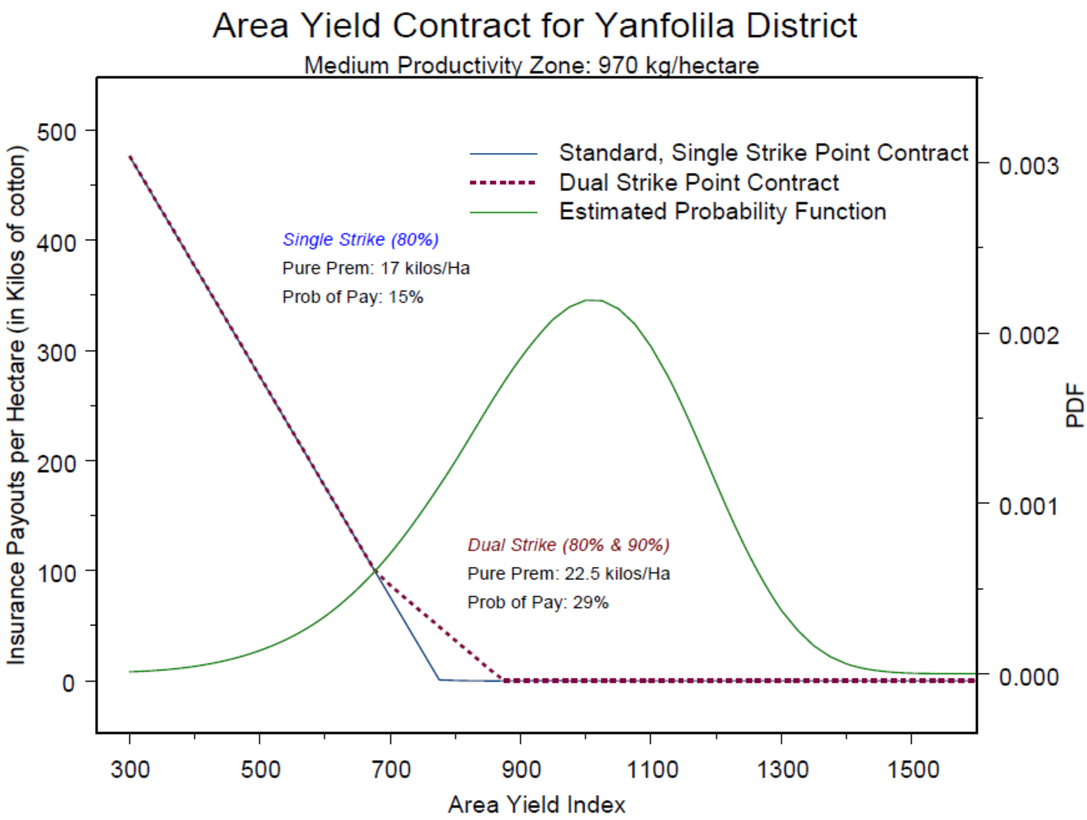
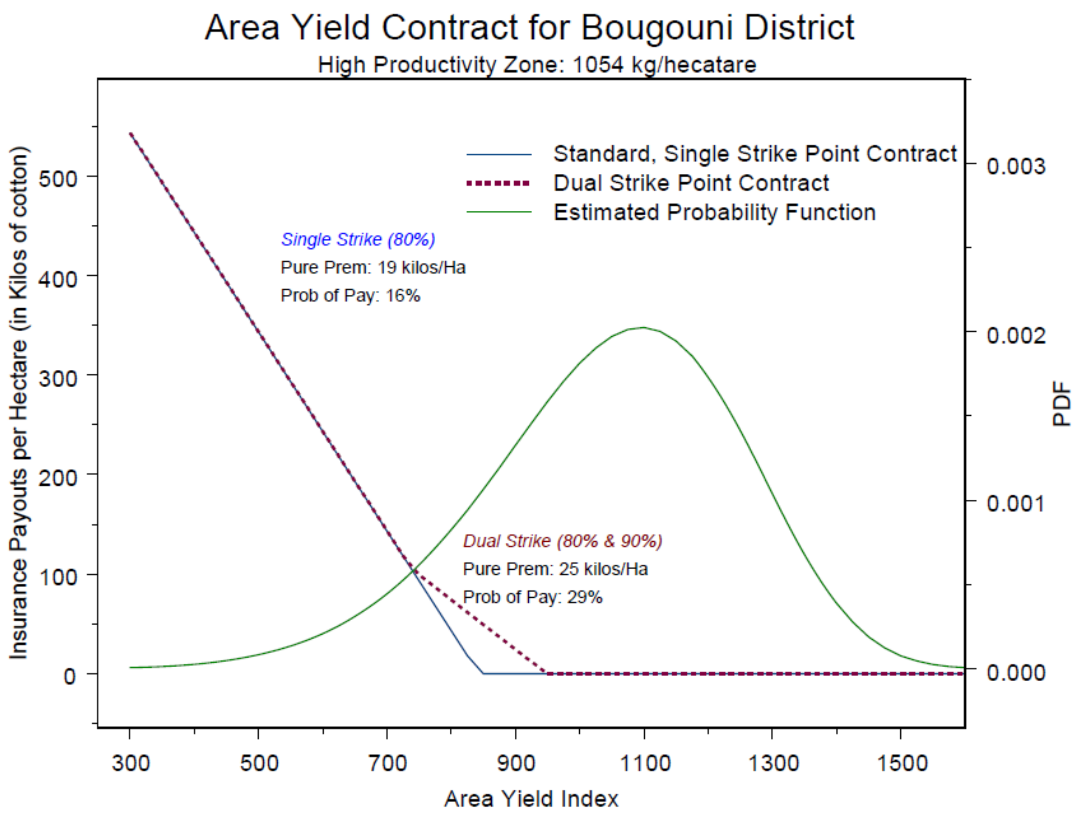


Figure 5



Step 4: Implementing the contract

Discussion with the reinsurer[13] Swiss Re strongly influenced the design of the contract. As a precursor to financial involvement, the reinsurer required that the portfolio reached a minimum size and targeting farmers individually may not have resulted in sufficient subscriptions for reinsurer involvement. Therefore, we devised an alternative solution, which reduced uncertainty in the number of contracts. Instead of insuring farmers directly, we insured the cotton portfolio of the micro-finance organization that grants loans to the local cotton farmers. However, a key aspect of involving the NGO is to ensure that farmers are supported when adverse events occur. To ensure this happens, we introduced a provision that requires the local microfinance institution to transfer the compensation it receives during poor harvest years to farmers by reducing their debt. Since cotton farmers borrow money in order to finance their crops, the distribution method does not exclude any farmer.

Providing farmers with protection through the microfinance institution in order to receive reinsurance backing may also contribute to the success of the project. A significant limitation of micro-insurance is its high transaction costs and a possible reason why only a few private options are currently in the market. On the one hand, the administration of many small contracts is expensive and the distribution of the compensation is complex when the number of contracts is high. But since microfinance institutions already have systems in place for working with many farmers, directly insuring the institution is a potential solution since it brings into play an already established yet untapped agent.

Another potential advantage of this method of implementation compared to individual insurance products may be its impact on the financial market. In fact, the insurance is likely to stimulate the supply of agricultural loans by protecting the micro-insurance institution against widespread default from a poor harvest in the region.

[13] Harini Kannan and Roman Hohl were speakers.

V. The weather index

Concept

The other type of index that we analyze is a weather index. The idea is to define a threshold with respect to a climatic indicator such as rainfall. As in the case of average yield index, the benefit of the insurance depends on the correlation between the chosen index and a farmer's yield. However, for a given geographic area, the correlation is inevitably smaller in the case of the weather index since the weather index uses the climatic indicator to predict the average yield for the area at hand. Thus, this is a source of basis risk for the farmer. In fact, the coverage does not account for individual yield shocks that are not reflected in the average yield, and it does not cover average yield shocks that are not correlated to the weather index (for example, locust infestation). Therefore, a weaker correlation between the weather index and the individual yield implies higher basis risk for the farmer.

If the basis risk is higher in the case of the weather index, why would one consider it? On one hand, the data required is easier to collect and to measure (since the data are objective indicators such as rainfall). Also data precision is higher since it targets a smaller geographic area (the resolution of satellite images is particularly high and allows a level of detail of areas of 8km²).

Among the available climatic indices, we compare two. The first is constructed using only measures of daily rainfall. The second is built from satellite images that contain both rainfall measures and the composition of plant cover.

A. Rainfall index

The expedition to Mali enabled us to more precisely identify risks related to variable rainfall. Based on the different risks mentioned by the farmers, Calmanti has created the five following indicators.

- **Start of the rainy season**: the first day of the year in the first week when cumulative rainfall is more than 20mm
- **Cumulative rainfall during the germination phase**: the first four weeks of the rainy season.

- **Period of severe dryness**: more than 10 consecutive days with less than 5mm of rainfall per day
- **Dry period**: cumulative rainfall from the beginning of September to the end of November
- **Annual rainfalls**

Thus, the plan is to compare the available data on average yields to these five climatic indicators in order to correlate poor harvests, those with an average yield less than the critical threshold, with specific weather shocks. In other words, the goal is to determine the combination of these indicators that most accurately reflects the situation in southern Mali. Nevertheless, the analysis by Calmanti has revealed that only a significant decrease in annual rainfall is likely to be linked to the decrease in cotton yields. This connection is shown to be strong in the Koutiala district, for which longer historical data is available.

Data

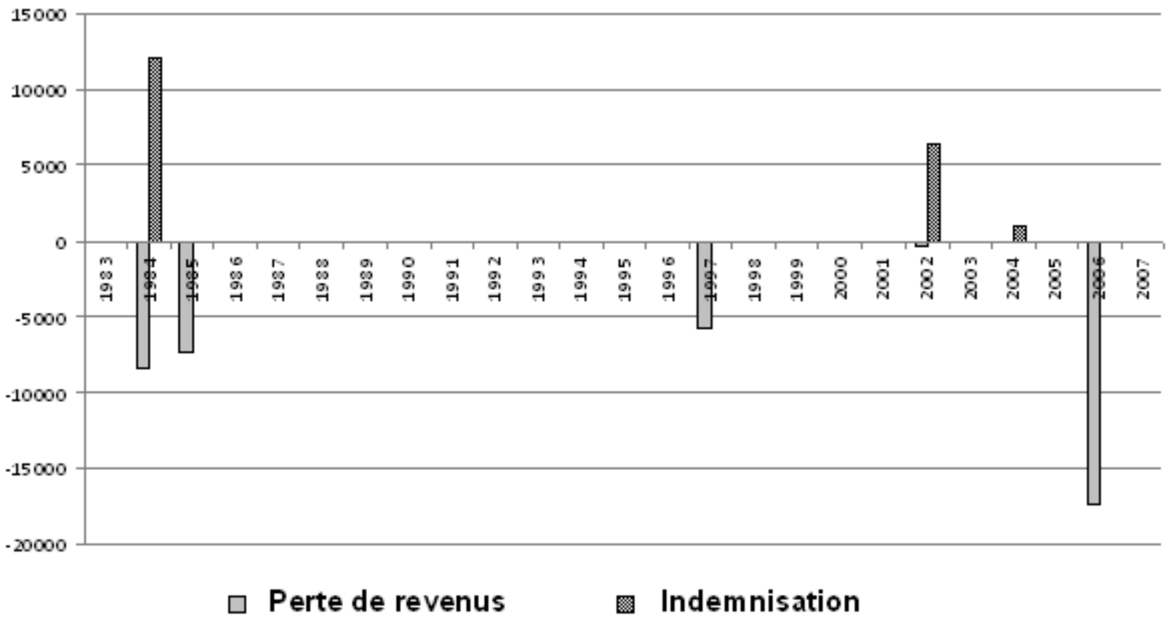
Although Mali has many weather stations, only a small number are still operational and have continuous historical data. Consequently, the relevant data necessary for a complete analysis is insufficient. In fact, most of the data is collected at the regional level. However, the comparison with the average yield requires two more levels of detail: the district level. Therefore, the evaluation of the weather risk is limited to the districts of Koutiala, Sikasso and Bougouni, since for these data is available of both average yields and annual rainfall. However, the sample was further restricted since only the Koutiala district showed the required correlation between historical average yields data and rainfall data.

It is worth noting that the data collected are historical and therefore allows for the construction of a time series long enough to distinguish between potential trends.

Simulation

Consider a prototype contract aimed at insuring all possible cases where the yield falls below the threshold of 90% of the long run average yield. In order to simplify the index, we only consider annual rainfall and choose a critical precipitation threshold equal to 700mm.

Based on these criteria, graph 4.1 presents the years for which there would be insurance, and specifies the amount of compensation (assuming that the farmers receive 100 CFA for every mm of rainfall below 700). The lack of concurrence shows that based on these criteria the insurance does not account for the losses of the cotton growers during the poor harvest.



In fact, the variation attributable to basis risk is extremely high, at greater than 80%. This implies that in the Koutiala district, less than 20% of the variation in the yields is explained by the rainfall vagaries. This high basis risk precludes the possibility of using the rainfall index as a risk management tool.

B. Satellite-based index

Concept

The premise behind this index is the same, only the construction of the index changes. This index is based on satellite images. These data evaluate the rainfall and determine the composition of the vegetative cover. The latter provides an indication of the strength and density of vegetation. Thus, the idea is to compare the current state of the vegetation with those of prior periods (whether on a monthly, a daily or other basis).

Once the relationship between the cotton yield and the satellite index is established, we determine a response function of the cotton yield (the parameters of the function may vary depending upon the geographic area).

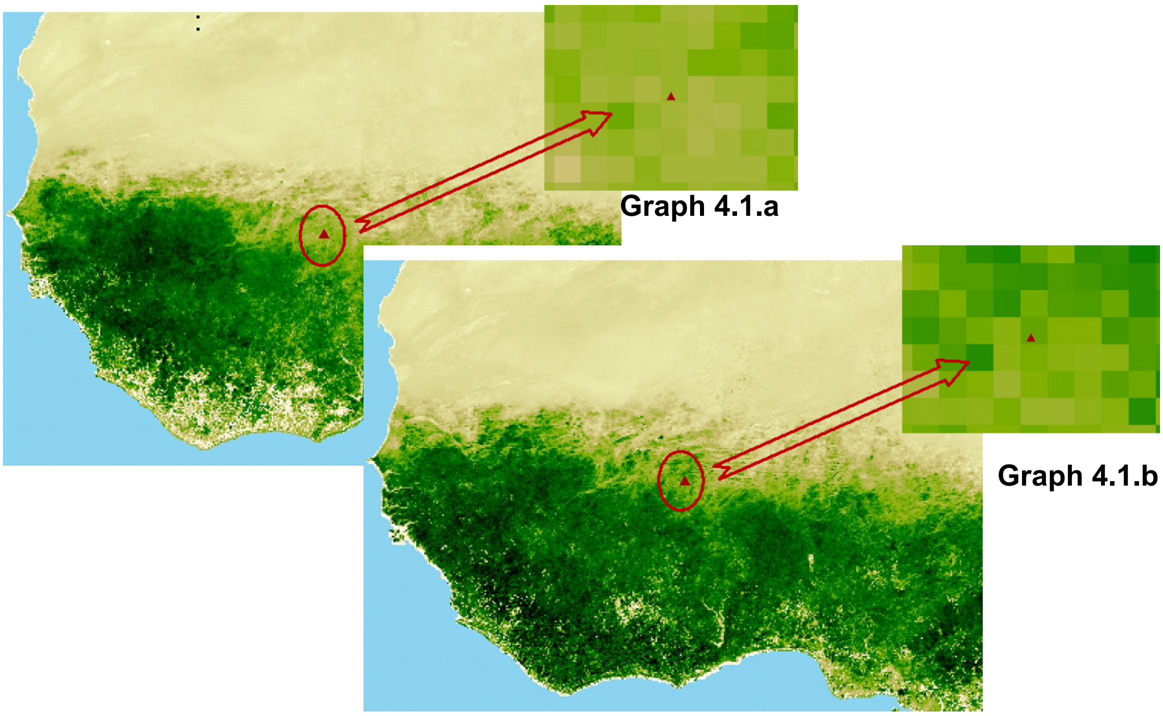
The satellite-based index contains more information, and has a high level of accuracy by dividing the region in squares of 8 km per side. The disadvantage of this index is that only the variations directly caused by changes in vegetative cover or in the rainfall level can be assessed and therefore insured.

Data

Unlike the two previous indices, data are easily accessible. In fact, multiple years of satellite images are free on the Internet without spatial constraints.

Below is an example of the usefulness of the vegetation index

:



Graph 4.1.a

Graph 4.1.b

Comparing the two graphs shows that the second is “greener”, meaning that the vegetation is denser. This matches reality, since the harvest corresponds to the second square that shows yields.

Results

The construction of a weather index based on satellite imagery has an explanatory power clearly higher than the explanatory power of an index based only on the rainfall. Basis risk for this index is now only 36%. This improvement is mainly due to the quality of the data collected.

However, satellite images only display a small difference between villages in the same district. Therefore, the advantage of the precision is counterbalanced by the increased complexity of the satellite index. Consequently we prefer the simpler index, based on average yields.

VI. Conclusion

We have examined two insurance options based on different types of indices. We have first considered the direct measurement of historical average yields. Then we considered weather indices by exploring first a precipitation index and then looking at a satellite based index.

The results of this study were dependent upon the availability of data (32 districts in the region of Sikasso), which limits the explanatory power of the indices. However, based on the data collected, we advocate the creation of an index based on the average yield, with a double critical threshold in the contract. The latter aims to decrease premium costs while increasing the frequency of payouts by the insurance company.

The index based on the average yield is in fact preferred to the two alternative indices because it explains 70% of the annual yield variation of every village whereas the best alternative index, the one based on satellite images, explains only 64% of the variability. The explanatory power of the average yield index is greatest because it directly accounts for variation in yield when determining indemnity payments instead of modeling yields based on climatic indicators.

The availability of an insurance product based on the average yield of the district of Koutiala is a useful risk management tool for households producing cotton. The use of an index eliminates the problem of asymmetric information between the insurer and the insured. Crucially, insurance against income shocks allow households to smooth their consumption and better manage the selling of assets. Thus, we hope that with insurance, a farmer avoids selling a productive asset important to his future activity, such as a bull, as a coping response to an unexpected natural disaster. The availability of index insurance is thus expected to reduce the likelihood of a rural household falling into a poverty trap.

During the pilot phase of the project, it is important to clearly identify potential distribution channels for the insurance product. Sales and distribution can be through producer cooperatives and the BNDA, or sales can be expanded to include individual contracts with the support of local microfinance institutions. It is also important to develop a communication strategy that relays the benefits of the product in order to inform and educate local farmers. Finally, the payment method of the premium should be determined, and may for example be included in the input loan typically taken by a farmer at the beginning of the season.

The current situation of the cotton sector in Mali involves issues and challenges that need to be addressed carefully. First, we should take into account the changes in frequency and magnitude of climatic variability due to global warming, and adjust insurance products accordingly. Secondly, the potentially negative trend in cotton yields observed in recent years is worrying. This phenomenon is likely to affect the payment probabilities of the insurance contracts, so it is therefore important to investigate its origin. Finally, the cotton sector as a whole will soon face a significant change due to the upcoming privatization of the CMDT. Hence, it will be interesting to follow developments and monitor how farmers adjust to these changes.

Bibliography

ARNOTT, R., STIGLITZ, J., (1991), "Moral Hazard and Nonmarket Institutions: Dysfunctional Crowding Out or Peer Review?" The American Economic Review, Vol. 81, No. 1, pp. 179-190

BARNETT B.J., BARRETT, C.B. et SKEES, J.R. (2006), "Poverty traps and index-based transfer products". Mimeo.

BONNASSIEUX A. (2005), « Filière coton, émergence des organisations de producteurs et transformations territoriales au Mali et au Burkina Faso », Cahiers d'Outre-mer, p. 421-434

CALMANTI (2009), working paper for Planet Guarantee

CARTER M.R. et C.B. BARETT (2006), "The Economics of Poverty Traps and Persistent Poverty: An Asset Based Approach." Journal of Development Studies, Vol. 42, pp. 178–199.

CARTER, M.R., GALARZA, F. et S. BOUCHER (2007), "Underwriting Area-based Yield Insurance to Crowd-in Credit Supply and Demand", *Savings and Development*, University of Wisconsin,
Madison. (http://www.aae.wisc.edu/carter/Papers/CarGalBouRevision.pdf).

CARTER M., GUIRKINGER C., LAAJAJ R. et MOYA A. (2009), « Technical analysis for a district-level area-based yield index insurance contract for Mali cotton producers ».

CAYATTE J-L. (2009), "Microéconomie de l'incertitude", Bruxelles : de boeck, 2ème édition, 254 pages

Commission de l'UEMOA, Comité de convergence et BCEAO, (2007), http://africonseil.ifrance.com/malieco.htm

CORBETT, J.D. (2005) "Making Climate-related insurance work in Africa: targeting and monitoring micro-insurance programmes"

DELARUE J., MESPLE-SOMPS S., NAUDET J.D., ROBILLIARD A.S. (2009), « Le paradoxe de Sikasso : coton et pauvreté au Mali », DIAL, Septembre 2009.

DERCON, S., (2002), "Income Risk, Coping Strategies, and Safety Research Observer, Vol.17, pp.141–166.

GILBERT C., J. CONNOR, P. JUMPASUT, H. SMIT, J. YARON and W. ZANT (2001) "Assessing the feasibility of transmission of risk management instruments to natural rubber smallholders in Thailand". International Task Force on Commodity Price Risk Management.

GILBERT, C.L. et ZANT, W. (2002), "Coffee price risk in east Africa: The feasibility of intermediating price risk management to coffee farmers and coffee co-operatives in Ethiopia, Kenya, Uganda, Tanzania and Zimbabwe". Common Fund for Commodities.

GOODWIN, B. K. et MAHUL, O. (2004), "Risk modelling concepts relating to the design and rating of agricultural insurance contracts". World Bank Policy Research Working Paper 3392.

GORSE, F., (2008), « Institutions de microfinance au Mali, Evaluation rétrospective », Rapport de l'AFD, série Evaluation et capitalisation, No 14
http://www.lamicrofinance.org/files/23893_file_evaluationmali.pdf

HESS, U. et SYROKA, J. (2005), "Weather-based insurance in Southern Africa: the Malawi case study". World Bank Agricultural and Rural Development Discussion Paper 13.

HUGON, P. (2005), "Les réformes de la filière coton au Mali et les négociations internationales." Afrique contemporaine, N° 216

KALAVAKONDA V. et MAHUL, O. (2005), "Crop insurance in Karnataka". World Bank Policy Research Working Paper 3654.

LINNEROOTH-BAYER, J., MECHLER R. et PFLUG G. (2005), "Refocusing Disaster Aid. "*Science* Vol. 309, pp. 1044–1046.

MECHLER R., LINNEROOTH-BAYER, J. and PEPPIAT, D. (2006), "Microinsurance for Natural Disaster Risks in Developing countries: Benefits, limitations and viability". ProVention Consortium.

MIRANDA M. (1991), "Area Crop Yield Insurance Reconsidered", *American Journal of Agricultural Economics*, Vol. 83, No. 3, pp. 650-665.

MOLINI, V., KEYZER, M., van den BOOM, B. et ZANT, W. (2007), "Creating safety nets through semi-parametric index-based insurance*:* A simulation for Northern Ghana." European Association of Agricultural Economists, 101 Seminaire, Juillet 5-6, 2007, Berlin Allemagne

MORDUCH, J. (1995), "Income Smoothing and Consumption Smoothing", *Journal of Economic Perspectives*, Vol. 9(3), pp.103-114.

MORDUCH, J (2004), "Micro-insurance ; The next revolution ?" In Bannerjee, A. et al, What have we learned about Poverty? Oxford: OUP.

Pauly, M., (1974), "Overinsurance and Public Provision of Insurance: The Roles of Moral Hazard and Adverse Selection", Quarterly Journal of Economics, No 88, pp. 44-54.

SARRIS A. (2002), "The demand for commodity insurance by developing country agricultural producers: theory and an application to cocoa in Ghana" World Bank Policy Research Working Paper 2887.

SHAVELL, S., (1979), "On Moral Hazard and Insurance", Quarterly Journal of Economics, pp. 41-562.

SKEES, J. R., BARNETT, B. J. et MURPHY A. (2008), "Creating insurance markets for natural disaster risk in lower income countries: the potential role for securitization", *Agricultural Finance Review*, Vol. 68, pp.151-167.

SKEES J. R., HARTELL J., MURPHY A. (2007), "Using Index-based Risk Transfer Products to Facilitate Micro Lending in Peru and Vietnam." *American Journal of Agricultural Economics* Vol. 89, pp.1255–1261.

SKEES J.R, GOBER,S., VARANGIS, P., LESTER R. et KALAVAKONDA, V. (2001), "Developing rainfall-based index insurance in Morocco". World Bank Policy Research Working Paper 2577.

SKEES J.R., HAZELL P. et MIRANDA M. (1999), "New approaches to Crop Yield insurance in developing countries." EPTD Discussion Paper No. 55

VEERAMANI V.N., MAYNARD, L.J. et SKEES, J.R. (2005), “Assessment of the risk management potential of a rainfall based insurance index and rainfall options in Andhra Pradesh, India.” *Indian Journal of Economics & Business* 4, Vol 1, pp. 195-208.

WORLD RESOURCE INSTITUTE (2007), Earthtrends: The Environmental Information Portal. Searchable Database; Research Topic: Economics, Business, and the Environment, GDP: Percent GDP from Agriculture, Washington, DC
http://earthtrends.wri.org/searchable_db/index.php?theme=5

ZANT W. (2007). “Is index insurance useful for cash crop growers? Simulating production and price index insurance for Indian smallholder pepper growers”. Mimeo.

ZOOM MICROFINANCE, No. 23 (Oct 2007), « Les crédits d’équipement de Kafo Jiginew (Mali) : investir au sein des exploitations familiales » Publié par *SOS Faim*
http://www.sosfaim.be/pdf/fr/zoom/23_credits_equipement_kafojiginew_exploitations_familiales.pdf