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Wealth, institutions and adoption of climate change strategies: empirical evidence from the Cotton basin of Bam in Burkina Faso.

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Abstract*:* The aim of this article is to analyze the effects of wealth and institutional factors on decision making of Bam cotton producers regarding the adoption of climate change strategies. To achieve this aim, the methodology used was the Multiple Correspondence Analysis (MCA) approach and a probit model. The data used came from a comprehensive survey of 371 Bam cotton producers. The study analyses three climate change strategies: stony cord, half-moon and "*zai technique*". The study found a non-linear effect of institutional factors on the adoption behavior of Bam cotton producers. On the other hand, the wealth index did not have a significant positive effect on adoption. The low level of adoption could be explained by poor institutional quality particularly that of customary law, traditional law and land law.

Keywords: Index, Institutions, Adaptation, Climate Change

JEL Classification: D02 - P46 - N57.

Richesses, institutions et adoption des stratégies face au changement climatique : évidence empirique dans le Bassin cotonnier du Bam au Burkina Faso.

Résumé : *L'objectif de cet article est d'analyser les effets de la richesse et des facteurs institutionnels sur les décisions d'adoption des stratégies face au changement climatique au sein des producteurs du coton du Bam. Pour y parvenir, la méthodologie d'approche d'Analyse en Correspondance Multiple (ACM) et un modèle probit ont été utilisés. Les données utilisées proviennent d'une enquête exhaustive auprès des 371 producteurs de coton du Bam. L'étude analyse trois stratégies d'adaptation face au changement climatique : la technique Zai, les cordons pierreux et les demi-lunes. L'étude est parvenue à un effet non linéaire du facteur institutionnel sur le comportement d'adoption des producteurs de coton du Bam. Par contre, l'indice de richesse s'est révélé n'avoir pas un effet significativement positif sur l'adoption. La faiblesse du niveau d'adoption s'expliquerait par une mauvaise qualité institutionnelle notamment celle du droit coutumier, du droit traditionnel et du droit foncier.*

Mots-clés : *Indice, Institutions, Adaptation, Changement Climatique*

Codes JEL : *D02 - P46 - N57.*

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1. Introduction

Bam is starting to be among the localities of Burkina Faso which are experiencing a rainfall crisis characterized by persistent deficits. However, since the last decade, precipitation is increasing in this area. This slight recovery was not enough to induce a change of status of semi-arid province. In fact, the 2017/2018 crop year was marked by water stress and long periods of drought, leading to a cereal deficit for about 18 provinces in Burkina Faso. Taking into account that precipitation required for cotton must be in [500 mm; 1200 mm] and distributed between different phases of cotton development (Freeland et al., 2010), we can note, in the province of Bam, that water stress, especially its severity and duration, can negatively affect the development of cotton and justifies the adoption of climate change strategies. Several complementary strategies are used to protect against climate change effects: stony cords, half-moon and "zaï" technologies.

Zaï technology is an ancient peasant technique perfected by various actors with the peasants. They are seed holes about 30 to 40 cm in diameters and 10 to 15 cm deep. The distance between the holes is 70 to 80 cm, which gives about 10,000 holes per ha (Ouiminga, 2018).

To build **half-moon** into a field, these steps must been done : (i) find flow direction of water when it rains, (ii) draw a four-meter line and create a curved line connecting the two ends of the line. The curved side must be downhill from the straight side, (iii) dig 15 to 30 cm deep in the soil inside the half moon, (iv) pile the soil on the edge of the arc to a height of 5 to 10 cm for extra support, put rocks on the curved edge, (v) put a pile of organic manure inside the half moon, (vi) mix the manure into the soil, (vii) plant seeds in the half-moon after it rains. This technology uses organic fertilizers from livestock.

The construction of **stony cord** is a semi-permeable structure consisting of two to three levels/rows of stones arranged in a contour (Lompo and Ouedraogo, 2006). This technique slows down run-off so that it infiltrates more quickly. According to Ouiminga (2018), soil restoration is ensured by stony and Zai, and thus, investments in natural resource management can be said to induce profitability, improve biodiversity and contributed to improve people's standard of living.

During the period 1967-1986, because of favorable climatic conditions of the time, Bam area and its surroundings remained the most important basin of cotton in Burkina Faso. Since 1987, this area seems to have lost this status. The development organization has initiated adaptation actions in the area for producers. However, to our knowledge, no study has identified the real determinants of adaptation in the areas. Therefore, the aim of this article is to fill this research gap through examining this problem in Bam. Water stress in Bam province, especially its severity and duration, has negatively affected the development of cotton. Loka and Oosterhuis (2012) show that the breeding season is very sensitive to extreme drought because water stress leads to significant crop losses compared to other periods. As a result, the challenge of the cotton sector remains double for government and producers. Faced with such a situation, producers, first actors concerned, deriving substantial monetary income should not remain indifferent.

Barry (2016) notes that the improved varieties of climate change strategies introduced by the Institute for the Environment and Agricultural Research (IEAR) only experienced very low adoption rates of 8.07%. Considering Barry (2016)'analysis based on economic factors, Agossou and al. (2012)'analysis based on the social, cultural and institutional factors, and finally analysis based on a combination of factors in two groups, our study want to build synthetic indices as proxies for measuring economic or institutional variables.

As **economic factors**, Barry (2016) used the number of cattle owned by the producer, while Ouedraogo et al. (2010) used the level of producer equipment, the practice of breeding, and the area owned by the producer. Mounirou (2015) used access to credit and agricultural supply in terms of areas of different agricultural species.

There are many proxy variables used in the literature as **institutional factors**. Ouedraogo et al. (2010) use separately the variables "tenure status" and "traditional religion". Mounirou (2015) uses the variable «producer cultural method» that takes 1 if traditional method and 2 or 3 if modern methods. Barry (2016) uses the variable "belonging to a peasant organization".

Finally, the authors as Adger et al. (2009), Agossou et al. (2012) and Vincent (2007) combine the variables already mentioned without attempting to consider the creation of synthetic indices both for the measurement of wealth and institutions. Agossou et al., (2012) note that the adoption of new cultures as a strategy depends on the capital assets of the producer and the institutional environment in which he finds himself.

To summary, the economic literature is abundant in terms of the use of proxy variables, such as level of wealth and quality of institutions, especially in adoption studies. However, the weak development of synthetic indices in this area is likely to limit our understanding of the phenomenon.

According to Vincent (2007), in the absence of established data based on a holistic approach to reliably determine the levels of adaptability of the different populations of the world, it is natural that the discussions on the determination of adaptability have been built on the basis of finding a rapprochement between country comparisons related to vulnerability and those related to wealth as measured by Gross Domestic Product (GDP) *per capita*. Alongside this thesis, we note the emergence of a second thesis that minimizes the role of economic and technological capabilities in adaptation. Economic and technological capabilities are only part of the solutions and the limitations related to adaptation and can sometimes be very marginal factors, according to Adger et al. (2009).

However, Magnan (2009) recognizes that the overwhelming majority of writers point out that adaptive capacity depends on social, political, economic, cultural, institutional and environmental factors. Vincent (2007) indicates that at the country level, adaptive capacity does not only depend on the availability of a financial resource but also crucially on the degree of institutional capacity for the efficient allocation of resources in the areas and groups of people who are more vulnerable.

At the household level, whether or not a person can adapt to climate change depends on factors, such as their basic knowledge, which can enable them to anticipate change and

identify new livelihood opportunities (Vincent, 2007). The basic knowledge of the household certainly comes from traditional customs and institutional rules that are very informal. Smit and Wandel (2006) indicate that adaptive capacity is context-specific and varies from country to country, from community to community, between social groups and individuals, and over time. Despite these contributions, which take into account the various factors in the explanation of adaptation, Magnan (2009) notes that questions remain, however, including questions concerning the characteristic of the nature of adaptive capacity. The author indicates that there are still few works that seek to go further in exploring the mechanisms that explain why, for example, socio-cultural or institutional attributes act in one direction or the other on adaptive capacity.

The debate on adaptation to climate change is at the center of a controversy. The contributions mentioned above remain theoretical and much more country-oriented. It is then necessary that empirical investigations take into account the specificities of the localities and thus give important knowledge to the decision makers for the implementation of policies adapted to the localities. The construction and use of a synthetic economic and social index and an institutional index could improve our understanding of the level of adoption of semi-arid cotton producers. For this, some authors prefer the Main Component Approach (Rutstein and Johnson (2004), Filmer and Pritchett (2001), Cezar (2012) and Anago et al. (2015), Zayati and Gaaliche (2013)). Other authors use Multiple Component Analysis (Vyas and Kumaranayake (2006)).

The article is organized into five other sections. Section 2 questions the existing literature to justify the importance of the investigation. Section 3 discusses the data sources and gives a presentation of the study area. The fourth section presents the results, while the fifth section is devoted to discussions and policy implications.

2. Literature Review

2.1 Theoretical Review

The theoretical model is based on Davis' theory of technology acceptance (Davis, 1989) and Hayami and Ruttam's theory of induced innovation (1985) and institutional incentives. However, the emphasis is on risk as an essential element in the producers' decisions for several reasons: the risk generally mentioned in this type of literature remains linked to the risk of results from implementation. In the agricultural sector and especially in a situation in which producers do not have the status of a landowner, another significant risk appears: **expropriation risk** on the land that has used adaptation strategies.

Risk has long been considered the main factor that reduces the rate of adoption of a new technology (Rosenberg 1976; Lindner 1987). In this study, technologies that we taking to account are stony cords, half-moon and “zaï” technologies. Investments in natural resource management have important impacts and therefore contribute to increasing productivity and agricultural production (Ouiminga, 2018). For this study, stony cords, half-moon and zaï applied reduce the negative effect of climate change on the crops. The concept of risk mentioned by Rosenberg (1976) and Lindner (1987) is related to the results from the implementation of the new technology. However, risk of expropriation

of the land of non-landowners that have applied stony cords, half-moon and "zaï" technologies is no neglected. This second risk, seemingly ignored in the economic literature, can be mitigated by the establishment of good institutions. The establishment of insurance companies in the agricultural field may help to reduce the first risk, but they have no effect on the second type of risk, the risk of expropriation.

Marra et al. (2003), in the context of risk, proposes to distinguish different elements in the decision-making process, such as the learning and perception of producers of the distribution of present and future probabilities of expected profits and losses of the technology, the covariance of profits between the old and the new technology and the return on investment time of the technology. However, it can be noted that these elements relate to the first risk, i.e., the risk of results from using the new strategy.

In fact, while one approach focuses on the decision to invest in an uncertain environment, another explores the relationship between the risk posed by technology and the attitude of producers towards it (Mounirou, 2015). The analysis of the change in the production system according to the degree of risk aversion shows that for the small farmers, the structural and functional constraints delimit more the field of the possibilities than their behavior *vis-à-vis* the risk (Alary, 2005).

The absence of structural and functional constraints within the landowning producers is established by the fact that they have, on the one hand, land reserves and, on the other hand, their landowner status entitles them to land rights. Kebede (1992) shows that a non-agricultural source of income can reduce risk-taking. Bam cotton producers with landowner status may have non-farm income through renting or selling uncultivated farmland. Thus, their risk taking through the adoption of new strategies can be reduced. However, relativizing studies by Kebede (1992), the results of Mounirou (2015) indicate that pluriactive individuals have a greater tendency to adopt new technologies particularly because this status often facilitates access to more financial resources and information. The results of Kebede (1992) and Mounirou (2015) argue that the constraint of wealth remains important in the adaptation behavior of producers. However, their analyses do not take into account the risk of expropriation suffered by non-landowning producers. Shapiro et al. (1992) conclude that adopters may behave more securely than non-adopters. Nevertheless, their result remains valid for the first type of risk but could be questionable when the second type of risk is taken into account. For this reason, we think that non-adopters may behave more securely than adopters in some of the producers' situations. In conclusion, we deplore the lack of effort to develop and use synthetic indices of wealth and quality of institutions.

2.2 Methodological review

Composite or synthetic indices in several domains were constructed using the *Principal Component Analysis* (PCA) approach (Rutstein and Johnson (2004), Filmer and Pritchett (2001)). The advantage of such an approach as pointed out by Cezar (2012) and Anago and Houngbemé (2015) is that it allows the use of an index sensitive to the level of development of the studied phenomenon. In our case, the index must be sensitive to the adoption behavior of the producer. Using this procedure, Cazer (2012) proposed a new financial systems development index that is relevant and sensitive to financial

development. Zayati and Gaaliche (2013), in the context of building an aggregate governance indicator, used the PCA. They build an improved version of the World Bank (WB) governance indicator by proceeding an arithmetic mean between the WB governance indicator and the governance indicators proposed by Freedom House[1]. A few years later, with the aim of constructing a synthetic indicator of inclusive growth, Anago and Houngbemé (2015) also used the principal component approach to determine the weights of the variables in the synthetic indicator of inclusive growth. However, for variables with discrete and limited modalities as in case, it is possible to consider different weights for each modality of the variable in the synthetic variable that would be constructed. The principal component analysis is limited in the case in which one exclusively has discrete variables in a limited number of modalities. By attributing the same weight to a variable, such an approach does not make it possible to take into account the specificity of the different modalities of the variable. However, a Multiple Correspondence Analysis (MCA) solves this problem. Moreover, Vyas and Kumaranayake (2006) have already pointed out the limitations of using principal component analysis for essentially discrete variables and have thus suggested the use of MCA.

2.3 Methodological choices

2.3.1 Survey methodology and selection bias problem resolution

Compared with areas recognized as cotton producing areas in Bam, a few producers cultivate cotton. For this situation, survey takes into account all cotton producers in the area. All cotton producers in this area are members of Group of Cotton Producers (GCP). This group works closely with the cotton company, Faso Cotton. The names of GPC and list of members in this GCP are got from Faso Cotton. This company buys all cotton produced in the area (*monopsony*). The survey methodological approach avoids the problems of selection bias.

2.3.2 Methodology for building the wealth index

The wealth index constructed is based on the multiple correspondence analysis approach. Vyas and Kumaranayake (2006) used this approach as part of constructing a well-being index. As noted above, this approach is relevant when the terms of the variables are discrete and finite. The variables used in building the wealth index are summarized in Table 1. The choice of these variables is based on the existing literature and particularly on the contributions of Vyas and Kumaranayake (2006). These variables can be grouped into six lots, and each lot provides a specific value in the wealth of the producer. The international applied economics literature is full of studies of adoption which make it clear that household and farm characteristics, their connection with input and output markets, and their reliance on and access to credit and information are all potentially important in the adoption decision and the extent of adaptation. In this line, lot 1, lot 3 and lot 6 take into account the household characteristics. Also, lot 2 and lot 5 take into account the farm characteristics. In this table, the column “weighting coefficient” gives the weight of each category of the variable according to the MCA.

[1] Freedom House is an institution building a dataset about governance.

Table n° 1: Weights, Groups and natures of the variables used in the construction of the wealth index

Group of variables and contribution to wealth	Nature of the variables	Comment	Coefficient of weighting obtained by the MCA
Lot 1: Work factor stock according to qualification: a household with a large stock of skilled labor is potentially richer than a household with a large stock of unskilled labor	Number of adults with a primary level education	Low skilled work stock.	We have 0.007, 0.006, 0.004, 0.007, 0.008, 0.006, 0.003, 0.005, 0.006, 0.003, and 0.004 for variable values from 0 to 11, respectively.
	Number of adults with a secondary level education	Relatively qualified work stock.	We have 0.005, 0.006, 0.005, 0.011, 0.004, and 0.005 for values from 0 to 4, respectively.
	Number of adults with university level education	Stock of skilled work.	We have respectively 0,000, 0.007, 0.017, and 0.004 for 0, 1, 2, and 4, respectively.
	Number of adults at the illiterate level	Low skilled work stock	We have 0.001, 0.009, 0.008, 0.028, and 0.004 for 0, 1, 2, 3, and 4, respectively.
Lot 2: Stock accumulation of capital and public investment in social infrastructure:	Material of residential walls	Indicates the value of the household's GFCF (investment)	We have 0.007 and 0,000 for 1 and 2, respectively.
	House roof material		We have 0.010, 0.010, 0.005, and 0.029 for 1, 2, 3, and 4, respectively.
	Water source	The living environ-ment of the household	We have 0.001, 0.016, 0.016, and 0.006 for 1, 3, 5, and 6, respectively.
Lot 3: Household assets:	Attic Enclosure; Radio; Motorbike; Draft beef; Donkey; Motorcycle traction; Home Telephone; Solar energy; Bike, etc.	Each good is a variable. Possession of these goods is synonymous with having wealth.	We have (0.006, 0.000 for 0, 1, respectively, with regard to the Attic); (0.020, 0.003 for 0, 1, respectively, for Enclosure); (0.045, 0.008 for 0, 1, respectively, for Radio); (0.015, 0.001 for 0, 1, respectively, with regard to the Telephone); (0.031, 0.008 for 0, 1, respectively, with regard to the Motorcycle); (0.009, 0.044 for 0, 1, respectively, for Solar); (0.009, 0,000 for 0, 1, respectively, with regard to the Bike); (0.018, 0.002 for 0,1, respectively, with respect to the Donkey); (0.21, 0.009 for 0, 1, respectively, for Beef); (0.018,

			0.000 for 0, 1, respectively, with regard to Motorcycle traction); (0.012, 0.001 for r 0, 1, respectively, with regard to Toilet)
Lot 4: Experience capital in cotton production	Number of years in cotton production	The number of years can be an important element in the acquisition of means of production	Values range from 0.001 to 0.015. There are approximately 40 values that have been calculated.
Lot 5: Venture capital	Loss of crop insurance	The existence of loss of crop insurance can be seen as capital used to finance the risk.	We have weights of 0.001 and 0.026 for 0 and 1, respectively.
Lot 6: Financial capital	Bank account	Measures access to the financial system	We have weights of 0.001 and 0.023 for 0 and 1, respectively.
	Credit and bank loan	Measures access to credit for activity	We have weights of 0.001 and 0.0233 for 0 and 1, respectively.

Source: Author

The wealth index is used in our statistical and econometric analyses. It has the advantage of federating several variables, each bringing a specific aspect in terms of wealth.

2.3.3 Methodology for building the specific institutional index

The construction of the Institutional Measurement Index was also considered using Multiple Correspondence Analysis. In an article on the development of a new financial development index, Cezar (2012) used a similar approach, to determine the weights of variables in the new index. The use of several wealth proxy variables in isolation also does not allow us to know precisely the effect of the level of richness in adoption or to identify the existence of the nonlinear and complex effects of this variable.

Institutional variables, such as traditional religion and land ownership status, if dichotomized lead to a loss of information especially when the possible modalities could exceed three or even four. The purpose of this article is therefore to propose an alternative method that avoids over-simplifications. Both institutional variables would intrinsically influence the adoption behavior of cotton producers. The institutional index that we want to build must be specific to agriculture area. The so-built global institutional index cannot explain the adoption of climate change strategies. Our specific institutional index built using the propriety and the religion variables, has a higher explanatory power than global institutional index. Indeed, in terms of informal constraints, North (1990) notes, among other things, customs and traditions—justifying here the introduction of the traditional religion variable in the construction of the institutional index—such as codes of behaviour, e.g., the code of behaviour in the Muslim religion and the code of behaviour in the Christian religion, etc.

Finally, formal constraints include laws and property rights. Our land tenure variable plays this role fully. In some developing countries, the public authority does not question traditional land tenure; on the contrary, he respects it for welfare and social cohesion. In our study, this variable has three categories, namely, the landowner, the tenant and the user at no cost. Our land tenure variable takes into account the definition of institution

proposed by Voigt (2013). For him, institutions (rules) refer to prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships. Prescriptions refer to which actions (or states of the world) are required, prohibited, or permitted. Rules are the result of implicit or explicit efforts by a set of individuals to achieve order and predictability within defined situations. The synthetic combination proposed in this investigation has institutional foundations. It is proposed by Voigt (2013). Codes of behavior, whether they reflect Muslim or Christian or Traditional religions, can defeat the incentives to adopt climate change strategies (stony cords, half-moon and zai) if and only if they do not guarantee confidence in the climate change investment. Any expense in term of stony cords, half-moon and Zaï is an investment for the producer. Similarly, the "land tenure" variable used in this analysis, with the exception of the landowner category, and the other two modalities do not guarantee in principle the confidence in investment. The variables selected are therefore listed in Table 2.

Table 2: Variables used in our study regarding the rule proposed by Voigt

Rule	Variable used in our study
1. Convention	Variable « Religion »
2. Ethical rules	Variable « Ethics »
3. Custom	Not applicable for that study
4. Formal private rules	Not applicable for that study
5. State laws	Variable « Land tenure »

Source: Author

A toll-free user can and should expect the landowner to withdraw the land for free. If the latter had made investments in adapting to climate change (expenses in term of stony cords, Zai and half-moon), there may be no compensation linked to its investments even in a situation of withdrawal. Moreover, the risk of being dispossessed of land offered for free becomes very large in this situation. In addition, the producer in the annual rental of land situation must expect non-renewal of the contract by the landowner. From what precedes, our intuition is that this variable should have a negative effect on the adoption of the strategies by the Bam cotton producers.

Additionally, since institutions have a primary role, such a situation could lead the wealth indicator to have a significantly negative effect on the likelihood of producers adopting adaptation strategies. This can be explained by the fact that although some adaptation strategies require significant financial resources and may lead to improved welfare for the producers who use it, those with the means to adopt it could behave similar to those who do not have the means to adopt it if they are not sure that the investments they will make on the land would be on land that would remain their property.

The institutional index resulting from this multiple correspondence analysis is used in the statistical and econometric analysis of producers' adaptation behaviors face to climate change. It has the advantage of federating several variables, each one contributing some aspect in terms of institutional quality.

Table n ° 3: Nature of the variables used in the construction of the specific institutional index

Variables used in the constructio n of the institutional -oriented index	Modalities	Comment	Coefficient of weighting obtained by the MCA
Religion	Traditional	Traditional religion has an unfavorable view of the protection of the environment and natural resources. Thus, by offering fields to users free of charge, woody resources are exploited by landowners. Likewise, the user without charge is obliged to give up the land when the time comes. This user in the no cost situation reduces the probability of investing in climate change adaptation.	The weight obtained by the MCA is 0.259
	Muslim	In the Muslim religion, there are lessons promoting the protection of natural resources and the forest. It can act in favor of the environment. Projects of Muslim associations in this area can be a factor stimulating good behavior, i.e., the protection of natural resources and therefore the forest.	The weight obtained by the MCA is 0.074
	Christian	In the Christian religion, there are teachings on the environment and the forest. Existing Christian associations can transmit knowledge that is able to change the behavior of producers. Some Christian associations encourage producers to adopt behaviors that reconcile man with his environment.	The weight obtained by the MCA is 0.167
Land status	Landowner	The landowner has no risk by investing in his field. However, landowners are generally few. In a village, the land may belong to a limited group of families. Thus, in a locality where landowners are numerous as in our case, the proportion of those who will adopt adaptation strategies will be high.	The weight obtained by the MCA is 0.015
	Land tenant	These are people who usually come from other places. To produce, the dominant strategy they use is renting land from landowners. In such a situation, rental expenses are already an investment. Any strategy that will enable the reduction of the risk incurred will be implemented. Therefore, they will be predisposed to adopting coping strategies.	The weight obtained by the MCA is 0.233
	Free user	Village households, which are not landowners, are generally free users. In the event of a conflict with the landowner, the landowner may by jealousy withdraw the land that was granted free of charge. Hence, there is an investment risk for this category of producer. As a result, they will tend to not adopt climate change strategies.	The weight obtained by the MCA is 0.25
Expected sign of the institutional index on the probability of adoption	By the ACM method	The producers obey the codes of behavior existing in the religion they practice. It is expected to have an overall negative effect for our case; the overall effect is the sum of two null effects and a negative effect. Similarly, the current land tenure situation is expected to have a negative effect. Hence, the expected NEGATIVE overall effect.	

Source: Author

2.3.4 Model and Econometric Issues

The adoption of climate change adaptation strategies by the producer is motivated by a goal of maximizing profit. The producer will adopt a new strategy only when it gives him a profit greater than that derived from the use of the old strategy. However, some technologies that can be used for several years (stony cord, half moon, "*zaï* technic", etc.), but their payback period can extend 3 years to 5 years. Therefore, the inter-temporal profit maximization objective is to determine the factor influencing the choice of the producer. As a result, uncertainty is taken into account in the analysis and institutional factors could therefore be decisive in the behavior of the producer, thus justifying the need to take institutional factors into account in the analysis.

The purpose of adoption is to avoid water stress that reduces cotton yields and thus increases the poverty of producers Freeland et al. (2010). Adoption is the result of economic, social and institutional factors. A model that integrates all these factors is likely to allow us to understand the behaviour of producers face to climate change. It is recognized that some technologies can be used without climate change to increase yields. But in climate change context, it's more for curbing the adverse effects of climate change that remains the main reason for adopting.

Three models have been used frequently to analyse the phenomena of the adoption of new strategies. These are models with linear probability, namely, the *logit* model, the *probit* model and the *tobit* model (Jacquot 2000, Barry 2016). However, models of the multinomial type are noted increasingly more in the literature. The first two models have similar characteristics according to Amemiya (1981): the only difference being in the laws of probabilities (the normal law for the probit model and the logistic law for the logit model). The coefficients of the probit model and the logit model are bound by the constant 1.55.

The use of the tobit model requires information about the adoption of a technology, and several studies provide information on the level of the use of the technology (Barry, 2016). Issoufou et al. (2017) referred to the logit model in determining adaptation factors. As our analysis did not have data on the level of use of the technology, we opted for the probit model. Indeed, the objective of our study is to assess the behaviour of cotton producers face to available adaptation strategies.

As previously stated, the theoretical model is based on Davis's theories of technology acceptance (1989), induced innovation (Hayami and Ruttam, 1985), and institutional incentives. To analyze the determinants of adoption, we use an econometric model. Formally, adoption is modeled as follows:

$$Adoption\ of\ climate\ change\ adaptation\ strategies: \quad A_i = \begin{cases} 1\ si\ A_i^* > 0 \\ 0\ si\ A_i^* \leq 0 \end{cases} \quad A_i^* = X_i\beta + \varepsilon_i \quad ,$$

where ε_i is the error term of zero mean and unit variance : $E(\varepsilon_i / X_i) = 0$, and A^* represents the latent variable of the adoption of the climate change adaptation strategy.

In this respect, A^* represents the expected net gain for the producer in adopting adaptation strategies to climate change, particularly in precipitation. Nevertheless, the choices are only $A_i = 1$ if the producer adopts; otherwise, $A_i = 0$. Some techniques may even be adopted without climate change to maximize yields. But, the survey specifically asked producers to indicate the strategies that they use face to climate change.

X_i represents the explanatory variables, the wealth index and the quality index of institutions that were described in the methodology part, and the other explanatory variables, namely, the age of the producer, the existence of the alert system, and early agricultural technical advice.

The dependent variable, which is the adoption variable, is also presented. Consider the case where the producer adopts ($A_i = 1$). The probability p is therefore given by $P(A_i = 1)$, which means that $P(A_i^* > 0) = P(X_i\beta + \varepsilon_i > 0)$. We thus have $P(X_i\beta > -\varepsilon_i) = F(X_i\beta)$ with F the distribution function of the normal distribution. The functional specification of the normal law is given by $P(A_i^*) = F(X_i\beta) = \int_{-\infty}^{X_i\beta} \frac{e^{-t^2/2}}{\sqrt{2\pi}} dt$. The formal model to be estimated is therefore given by $P(X_i\beta > -\varepsilon_i) = \int_{-\infty}^{X_i\beta} \frac{e^{-t^2/2}}{\sqrt{2\pi}} dt$.

3. Study area and Data

Bam is in the North Central region of Burkina Faso (BF). Adaptation strategies, such as "*Zaï technique"*, have long been practiced in these localities before being introduced later in other provinces of BF. The study area is covered by Faso Cotton, one of the three cotton companies in BF. The cotton producers, if they want to sell their production, are obliged to be members of a Cotton Producers Group. With the assistance of the technical agents of Faso Cotton, the *Pathways to Resilience in Semi-Arid Economies* (PRISE) team has got the exhaustive list of Cotton Producer Groups (CPG) in the province. The producer can use or not, the advices of the technical agents of Faso Cotton. Bam is bounded by the provinces of *Lorum* and *Soum in the north*, by the province of *Sanematenga* in the east on the south by the *Passore* and by the province of *Yatenga* in the west.

The data come from a comprehensive survey of cotton producers in Bam province as part of the PRISE (Pathways to Resilience in Semi-arid Economies) project. Table 4 shows the definition of the variables in the model.

Table n° 4 : Dictionary of Variables

Variable	Definition	Expected sign
Adoption	Adoption of adaptation strategy to rainfall change (equals 1 if the producer adopts stony cord, half-moon and "*zaï* technique" and 0 otherwise)	(Dependent variable)
Age	Age of head of household measured in years	+
Technical advice	Agricultural Technical Advice in Agriculture (equals 1 if the producer received advice and 0 otherwise)	+
Alert system	Existence of an early warning system to climate change (equals 1 if early warning system exists and 0 otherwise)	+
Wealth index	Composite variable (constructed on the basis of the MCA, using the variables described in the methodological approach).	+
Institutional index	Composite variable (constructed on the basis of the MCA, using the variables described in the methodological approach).	+

Source: Author

4. Results

4.1 Statistical results

In this section, the link between the wealth index and adoption, the dominant role of the institutional index in adoption and the question of religion's neutrality in adoption are examined.

Table 5: Chi-square test between adaptation variable and wealth level, religion and land status

Name of Variable	Empirical value of the Chi-square	Degree of liberty	Theoretical value of the chi-square at 5%
Wealth level in term of quintile	4.643	3	7.82
religion	26.28	2	5.99
Land status	3.293	2	5.99

Source: author, using PRISE survey 2017

The Chi-square (χ^2) test between adaptation variable and level of wealth shows that the empirical value of Chi-square (4.643) is less than the theoretical one at 5%. (7.82). The Likelihood statistic is 4.735. The adaptation variable and the level of Wealth are independent. All so, land status and adaptation variable are independent. But, religion and adaption variable are dependent at 5%. In our case, the proportion of landowners is 91.64% compared to 8.09% for free users and 0.27% for tenants (see table annex 1 and table annex 2). The proportion of adoption of strategies should be at least 91.64%. In the data, this rate is 53%. This could be explained by the fact that the landowners, having at

their disposal undeveloped land, will prefer to clear new fields as the areas on which they exploit deteriorate. Some areas are retroceded to populations with the status of free operator. The latter fearing that the landowner will return a few years to claim this land will not begin to develop adaptation strategies that are often expensive and not very profitable immediately. It is highly likely that producers in rental situations and those with free user status will not invest in a situation in which institutional quality remains poor.

In our case, if the proportion of these two types of producers increases, we will also see an increase in the proportion of individuals in the sample who are at high risk of being losers by adopting coping strategies, hence, the decline in the probability of adoption. If the proportion of landowners increases, we will expect a decline in the proportion of producers who do not run a risk of investment. However, the availability of land in reserve will mean that these categories of producers will not invest in the implementation of adaptation strategies. They will clear new fields, while abandoning old farms to non-landowners.

Table n ° 6 : Role of the wealth variable in adoption

Level of wealth	Lander owner (% adopted)	Free users (% adopted)	Tenant (% adopted)	Sample (% adopted)
Quintile 1	65	86	-	66.67
Quintile 2	77	55	100	75.24
Quintile 3	61	100	-	63.41
Quintile 4	64	56	-	62.89
Total	**67.35**	**65.38**	**100**	**67.39**

Source: Author, using PRISE survey 2017

The distribution of landowners by wealth index shows that more than 25.90% of landowners are in the last quintile and that 49.12% are in the penultimate and the last quintile. Only 23.5% of producers are in the first quintile, reflecting a low level of poverty within their group. It is therefore not a wealth problem that hinders the adoption of strategies by producers with landowner status. Rather, it is the availability of undeveloped land and their higher yields compared to the benefits of the adoption option that justify the choice not to invest in adoption within these categories of producers. This result casts a new light on the subject of adoption, particularly in the agricultural sector.

4.2 Institutional and economic determinants of the cotton producers' adoption of climate change

The Model 1: $P(X_i\beta > -\varepsilon_i) = P\big(\alpha_0 + \alpha_1 Wealth\ index_i + \alpha_2 Age\ of\ the\ producer_i + \alpha_3 Early\ warning\ system_i + \alpha_4 Institutional\ Index_i + \alpha_5 (Institutional\ Index)^2{}_i + \alpha_6 Technical\ Advice_i > -\varepsilon_i\big) = \int_{-\infty}^{X_i\beta} \frac{e^{-t^2/2}}{\sqrt{2\pi}} dt$

Since institutional index is between 0 and 1, the square of this index is less than the index. Therefore, in addition to the estimate presented of Model 1, we re-estimate the model 2 by introducing a variable (1 + institutional index) and (1+ institutional index)^2 to assert the robustness of the results in the nonlinear effect. All discussions use the result

of the estimation of model 1. We have presented the estimation of model 2 to assert the robustness of the results in the nonlinear effect of institutional index.

The model 2: $P(X_i\beta > -\varepsilon_i) = P(\alpha_0 + \alpha_1 Wealth\ index_i + \alpha_2 Age\ of\ the\ producer_i + \alpha_3 Early\ warning\ system_i + \alpha_4(1 + Institutional\ Index_i) + \alpha_5(1 + Institutional\ Index)^2{}_i + \alpha_6 Technical\ Advice_i > -\varepsilon_i) = \int_{-\infty}^{X_i\beta} \frac{e^{-t^2/2}}{\sqrt{2\pi}} dt.$

Table n °7 Results of the estimation of the probit model

Probit Variable dependence: Adoption of strategies in the face of precipitation change (1, the producer adopts; 0, the producer does not adopt)				
Variables	Model 1		Model 2	
	Marginal effects	P(Z)	Marginal effects	P(Z)
Wealth index	-0.6106	0.480	-0.6106	0.481
Age of the producer	0.0025*	0.060	0.0025*	0.060
Technical advice	-0.0084***	0.001	-0.0084**	0.001
Early warning system	-0.0017**	0.031	-0.0017**	0.031
Institutional Index	-3.990***	0.001		
(Institutional Index)^2	7.7201***	0.002		
(1+Institutional Index)			-19.431***	0.002
(1+Institutional Index)^2			.7201***	0.002
Observation P = 0.53				Pseudo R^2 = 0.0974
Prediction P = 0.55	Pseudo R^2 =0.0024	P>chi2 =0	Prediction P = 0.53	LR chi2 = 49.97
N observation 371	LR= -231.45	chi2=49.97	Observation P=0.55	P>chi2 = 0

Source: Author, using PRISE survey 2017. Note: * p<0.1; ** p<0.05 et ***p<0.01

The Model 2 confirms the non-linear effect of the institutional index: the model is well specified, and the overall significance of the parameters is satisfactory when one looks at the P > chi2 = 0. The Log Likelihood statistic of -231.45 is significant at the 1% level. The percentage of those who adopt adaptation strategies to climate change (precipitation) in the data is 53%. This proportion is not far from the value predicted by the model, which is 55%. The estimated coefficients lead to the following analyses and interpretations.

4.2.1 Socioeconomic factors and discussion

Social and technical variables. The coefficients of the social and technical variables were all significant at the threshold of at least 10%.

The ***age*** of the cotton producer positively affects the probability that the producer will adopt climate change adaptation strategies. Thus, at the 10% threshold, the fact that the producer is older increases producer adaptation of the climate change strategies. Older people with accumulated experience and knowledge are supportive of resilient behaviors. This result is similar to that found by Barry (2016) in south-central region in Burkina Faso about the adoption of improved varieties of maize and to that found in

Benin as part of the study on perception and the adoption of agricultural innovations in the cotton basin of Banikoara by Mounirou (2015). It should nevertheless be noted that for this author, age is significant only when we include the variable "age squared", as this makes the effect of this variable non-linear. However, our results improve results found among farmers in Burkina Faso by Ouedraogo et al. (2010). These authors came to the conclusion that age does not have a significant effect in the adoption of new varieties and Soil and Water Conservation (SWC) approach.

The producer, having received ***technical advice***, tends to have a lower probability of adoption than one who did not receive this service. At the 1% level, the results indicate that the producer who benefited from this service has less probability to adopt climate change strategies compared to the probability of adoption of those who did not receive it. To the best of our knowledge, most of the advice given by agents is more related to the use of inputs, including chemical fertilizers and pesticides, harvesting and cotton conservation. This technological knowledge package may not have changed to include modules on climate change. This situation can explain the negative effect of the technical advice to adopt climate change strategies. Ouedraogo et al. (2010) have found partially the same result. They have indicated that management affects positively new varieties adoption and negatively the use of Soil and Water Conservation (SWC) and organic manure. The management also impacts negatively the date of sowing. This result may seem paradoxical in view of the insignificant effect of the wealth index in our data. The wealth of the producer has no influence on the adoption. Therefore, the poverty is not the reason for the low rate of adoption of strategies face to climate change.

Producers who have benefited from an ***early warning service*** also tend to have a lower probability of adopting strategies face to climate change. When the technical services predict a bad rainfall year, the producer integrates this information in to their adoption decision-making. Information indicating poor rainfall leads the producer to also anticipate a poor result in cotton production. He decides not to produce cotton.

4.2.2 Irrelevance of wealth variable in adoption and discussion

Wealth variable effect. The coefficient of the economic variable, namely, wealth index built, was found to have no significant positive impact in explaining the adoption. The average costs of adoption strategies are between 80 dollars and 100 dollars for relatively smaller areas, according to interviews during the survey. It is therefore reasonable to think that the producer can mobilize this amount to adopt these strategies especially if the expected return is sufficient to cover expenses. Some areas are offered to producers with the status of free operator. The latter fearing that the landowner will return a few years to claim this land will not begin to develop adaptation strategies that are often expensive and not very profitable immediately. This justifies why despite an increase of wealth level, the probability of adoption is significantly zero. It is highly likely that producers in rental situations and those with free user status will not invest in a situation in which the quality of institutions remains bad. Our result supports the result found by Mounirou (2015). The author has indicated that the level of equipment and the practice of breeding, both proxies for measuring the level of wealth, are not relevant in the explanation of the adoption in the cotton basin of Banikoara. To ensure that the variable has no nonlinear effect, the (wealth index) squared variable was introduced into our model. Both proved to have no

significant impact on adoption. Our result completes those existing in the literature by examining nonlinear effect using a synthetic variable of wealth measurement.

4.2.3 Primary role of the institutional index in adoption in Bam and discussion

The institutional index has a negative effect on the adoption of climate change strategies in Bam cotton producers. For the low value of institutional index, the effect on adoption of climate change strategies by bam cotton producers is negative and significant at 1%. But, considering the sign of $(\text{institutional index})^2$, we can say that the high value of institutional index has positive and significant effect on adoption of climate change strategies. Finally, the opposite sign of coefficients of the institutional index and $(\text{institutional index})^2$ shows that institutional index has a non-linear effect on adoption. Indeed, the modelling used in the literature did not allow to examine the complex and often non-linear relationships of institutional variables.

Our modelling approach has taken into account these complex and non-linear relationships. At the end of this investigation, we can mention the primacy of institutions in adopting adaptation strategies among cotton producers in Bam. The institutional index built as part of this investigation is related, on the one hand, to the agricultural sector in which the cotton sector is located and, on the other hand, to the study environment. For this reason, variables, such as land tenure, which are still linked to traditional land tenure and religion codifying the behaviour of economic agents in a number of areas, are likely to summarize the institutional quality in this area.

This index will be sensitive to investment risk in the agricultural sector, especially in terms of the acquisition of new technologies (in this case, it is the investment in adaptation strategy). When we have a situation with a weak level of the institutional index, increasing institutional quality is not enough to allow the beneficiary categories of institutional improvement to adopt even more climate change strategies. In a second step, when this value reaches the incentive threshold level of the beneficiary groups, a further increase of the institutional index will lead to an increase in the probability of producers adopting the strategies. The poor quality of institutions, having a negative effect on the adoption of climate change strategies, means that cotton producers who have a level of wealth to adopt strategies are not incentivized. In the presence of poor quality institutions, an increase in the wealth level of the producer has no significant positive effect on the adoption of climate change strategies. The lesson learned from this result is that institutions remain paramount in promoting climate change adaptation strategies in rural Burkina Faso.

5. Conclusion

At the end of this research, it is clear that institutions have an important role in the adaptation of stony cords, Zai and half-moon. The rural land law can negatively have an impact on the choices and the level of adaptation of cotton producers. The cotton producers 'fields are comparable to agricultural companies. The climate change risk and the risk of appropriation must be analyzed by the producers before taking a decision about investment and production. This research indicates that it is highly likely that producers in rental situations and those with free user status will not invest in a situation

in which the quality of institutions remains bad. Government must work to improve the quality of institutions especially those impacting directly the rural area.

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Annexes

Table annex 1: Dominant status of Christians in the sample and the role of religion in adoption

Religion	Percentage distribution of respondents	Percentage of producers who adopted
Traditional	19.49	68.85
Muslim	34.50	70.37
Christian	46.01	65.28
Total	100	100

Source: Author, using PRISE survey 2017

Table annex 2: Distribution by land status and by type of religion of respondents who adopted and predominant status of landowners in the sample

	Percentage by land status and by type of religion of respondents who adopted				Percentage in the sample by status	Percentage having adopted by status
	Traditional	Muslim	Christian	Total		
Landlords	95.24	94.76	91.50	93.40	91.64	67.35
Tenants	2.38	0.00	0.00	0.47	8.09	66.67
Free users	2.38	5,26	8.50	6.13	0.27	100
Total	100	100	100	100	100	67.39

Source: Author, using PRISE survey 2017