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SOCIOECONOMIC EFFECT OF ADOPTING CLIMATE-RESILIENT RICE VARIETIES ON THE WELL-BEING OF FARMERS IN THE GAO REGION

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ABSTRACT

Rice is considered a strategic product in Mali because of its importance for food security but also for the country's economic development given its preponderant place in production, agricultural employment and income generation for farmers. Rice is the most widely grown and consumed cereal in the Gao region. It is practiced by the majority of farmers in a traditional way (in free submersion, flood recession rice cultivation and pond cultivation) and modern in hydro-agricultural development (controlled submersion and total water control). Despite the enormous potential for planting, rice production is declining year after year in the Gao region. The objective of this study is to understand the mechanisms of the adoption of high-performance and climate-resilient varieties and to analyze the determinants of variety adoption at the family farm level. This study was conducted in the Gao region among 253 farmers with a margin of error of 6%. The methodology used integrated qualitative and quantitative research approaches. Data were collected individually and in focus groups by way of interview, using pre-established semi-structured questionnaires and interview guides. Data were collected from rice farmers and technical services. Several approaches were combined to conduct this study. The Tobit simple, Logit, and Probit models were used for adoption and analysis of determinants of variety adoption. The study found that the adoption of short-cycle varieties is the most prevalent resilient practice among producers, at 47%. This practice is more used in controlled submersion. It is followed by the use of local varieties by 30% of producers. However, improved varieties are only adopted by 7% of growers, suggesting that they are not widely accepted. Area and subsidy are the main determinants of the adoption of resilient rice varieties with a portability of less than 1% (P≤0.002).

These results can serve as a compass for the promotion of adaptation strategies in the context of climate change in the Gao region.

Keywords: Effects of adoption, resilient varieties, determinants of adoption, Gao.

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1. INTRODUCTION

In Mali, the country's economy is closely linked to the agricultural sector, which is dependent on the climate. Mali's climate is characterized by a significant rainfall deficit, a harsh nature and a fragile natural environment at risk. Rainfall is characterized by strong interannual and spatio-temporal irregularities. This has a direct impact on yields and agro-pastoral production. Climatic hazards affecting the stability of agro-pastoral production and export earnings are weakening the country's economy. However, it is clear that in recent years, the cereal production record has been less and less rosy (World Bank, 2022).

Rice ranks 2nd in percentage of production with 28.6% behind maize which accounts for 41.1% of Malian cereal production.

The country has significant rice-growing potential, with areas deemed suitable for irrigated rice cultivation. These areas are estimated at nearly 2,200,000 ha, of which only 20% is developed (DNA, 2019). Rice productivity remains well below its potential: a few high-performance rice farmers obtain yields of 9 to 10 tons/ha under total control, while the national average for this production system is 5.9 tons/ha. In rainfed rice farming, some producers obtain yields of 6.1 tons/ha while the national average is only 1.9 tons/ha (DNA 2022).

Rice is the most widely grown and consumed cereal in the Gao region. It is practiced by the majority of farmers in a traditional way (in free submersion, flood recession rice cultivation and pond cultivation) and modern in hydro-agricultural development (controlled submersion and total water control). The Gao region has enormous potential in terms of cultivable land. However, it is difficult to find precise figures on the exact amount of fertile land not being farmed specifically for the region. Due to the cyclical droughts of the last ten years in the region, the only possibility of cultivation without large investments is river cultivation.

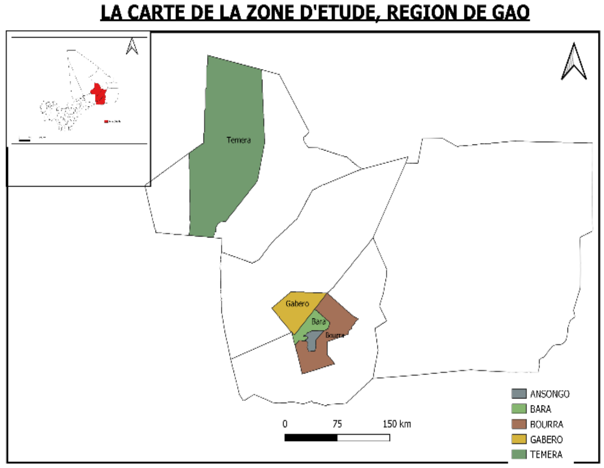
Despite the enormous potential for planting, rice production is declining year after year in the Gao region. It is facing several problems that hinder the development of the rice sector. Climate change, poor soil, lack of technology and insufficient managed land are the factors contributing to the abundance of agriculture.

Faced with this situation of poverty and climate change, it is necessary to provide answers to this evil in Gaoise agriculture. Hence the idea for this study.

2. MATERIALS AND METHODS

a) Choice of study sites:

LA CARTE DE LA ZONE D'ETUDE, REGION DE GAO



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The Gao Region was chosen because of the place that rice cultivation occupies in the working life of the population. It is the most widely grown and consumed cereal in the region. It is practiced by the majority of farmers in a traditional way (in free submersion, flood recession rice cultivation and pond cultivation) and modern in hydro-agricultural development (controlled submersion and total water control). Of the 110,000 hectares in potential, only 30% is developed. It is one of the regions most impacted by climate change. The Gao region is less rainy and has a Sahelian-type climate. The Niger River is crossed from end to end by the Niger River, hence the importance of surface water, the quality of which depends on annual floods. The region also has large ponds, including those of Tessit, Amalawlaw, Indélimane, Tintichiori in the circle of Ansongo; Samit in N'Tillit, Zankabilo in Gabéro in the Gao circle.

b) Secondary data collection

Figure 1: Map of the study

Secondary data were collected to better supervise the field phase. Secondary data collection consisted of the use of books, study reports, scientific articles, government publications, and official statistics. During this period, discussions with resource persons (Director of Agriculture of Gao, the presidents of the Chamber of Agriculture of Gao and the coordinator of the regional AOPP of Gao) were initiated to better understand the problem. At the end of these exchanges, the major production areas of the Gao region were identified according to the typologies of production system. This information has made it possible to develop a field questionnaire that is better adopted by the region to make a choice of sampling.

c) Sampling

The sample size is defined according to the financial means of the study. It was calculated by the following formula:

$n = (1.96)^2 \text{ x } N / [(1.96)^2 + I2 \text{ x } (N-1)]$

n: the sample size

N: Population size

I: Margin of error (or confidence interval)

The methodology used integrated qualitative and quantitative research approaches. The formal surveys were carried out through individual interviews based on a semi-structured questionnaire administered to rice farmers. The choice of the sample took place in two stages: the first stage consisted of choosing the collection communes. The choice of communes was made on the basis of productivity, the areas sown, the number of farmers, the production systems practiced in the commune and on the basis of the security context. Thus, the communes of Ansongo, Bourra, Bara, Gabero and Temera were chosen. The second step was to choose the operators in the municipalities mentioned above. Rice farmers were identified through the sampling method known as systematic random sampling. Thus, a sample of 253 farmers out of 170,000 farmers (parent population) was selected for our study with a margin of error of 6%.

The sampling took into account women, men, young and old for a good representativeness.

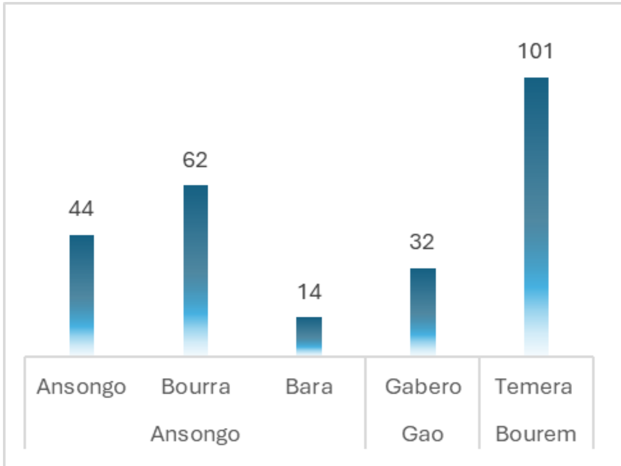

Figure 2: Sample distribution

d) Primary Data Collection

- **Collection in the field:**

Data were collected individually and in focus groups by way of interviews from October 2022 to March 2023, using pre-established semi-structured questionnaires and interview guides. Data were collected from rice farmers and technical services (DRA-GAO, IER and the Bourem and Ansongo agriculture sectors). The respondent's informed consent is sought before the interview begins.

The main data collected will be data on the socio-economic characteristics of farms (size or population, economic activities, education, producer organizations, etc.), data on the effects of the adoption of climate-resilient varieties on farm well-being, and data on the determinants of the adoption of climate-resilient varieties.

e) Data analysis

The data collected was analyzed and processed through SPSS, Stata and Excel software. The choice of SPSS, STATA, and Excel for data analysis depends on several factors, including the specific needs of the analysis, the user's skills, and the features offered by each software.

f) Theoretical framework

Several adaptation strategies are being developed in different forms and scales of implementation to deal with climate change in both urban and rural areas (De Munck, 2013). Some strategies are developed by producers and others by scientific research. The rice farmer has a multitude of adaptation strategies from which he chooses according to his capacity (human and financial capital, arable land; etc.) and the agro-ecological zone to which he belongs.

For the assessment of the effects of the adoption of climate-resilient varieties on farm well-being, the simple Tobit model is used to account for the intensity of adoption, which has led to a model where the explained variable is quantitative but limited. In this sense, we must model the probability that the dependent variable belongs to the interval for which it would be observable.

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The Logit model will be adequate for the analysis of the observed probabilities (0,1) where the information on the latent variable will only be observed.

The Probit model is similar to the Logit model in that it will allow the use of both quantitative and qualitative variables. Both of these models will be used to estimate the likelihood that a producer will adopt a given technology. The Logit and Probit models will therefore all be dichotomous models for qualitative data, in which the explained variable can only take two modalities (dichotomous variable). It is generally a question of explaining the occurrence or non-occurrence of an event, or a choice.

The binary (0, 1) that is usually used for the dichotomous models, Probit and Logit, will allow us to define the probability of occurrence of the event as the expectation of the variable Y which is established as follows:

$E[Y_i]=Pr(Y_i=1) \times 1+Pr(Y_i=0) \times 0=Pr(Y_i=1)$.

And then make an analysis of the use of the income from rice farming.
The model of analysis on the adoption of agricultural innovations, which states that adoption remains an individual decision (Rogers, 2003) and is usually based on the economic principle of rationality of neoclassical theory (Varian, 2006), will be used. Thus, the producer adopts a new technology if and only if it allows him to maximize his utility. The producer will adopt a practice, regeneration, if the expected utility, represented by, would be greater than that which he would obtain if he had not adopted it, represented by either. However, the benefit that the producer will obtain from adopting either of the practices would not be observable. However, it will depend on the socio-economic and demographic characteristics of the producer and its institutional environment.
The analytical approaches most often used in decision studies on the choice of innovations to estimate will be the Probit and the Logit.

Table 1: Explanatory variables used in the production function according to the logit model

Variables	Description of the variables	Expected effects
Sex	Producer's gender (1=Male; 0=Female)	+/-
Cultivation practice	Good cultural practice (1 = yes; 0= no)	+/-
Surface	Average area under cultivation in ha	+/-
Improved variety	Use of improved varieties (1 = yes; 0= no)	+/-
Type d'irrigation 1	Use of controlled submersion (1 = yes; 0= no)	+/-
Agricultural credit	Access to agricultural credit (1 = yes; 0 = no)	+/-
Type d'irrigation 2	Use of organic manure (1 = yes; 0= no)	+/-
Organization Membership	Belong to an organization (1 = yes; 0= no)	+/-
Water fee	Pay water fees (1 = yes; 0= no)	+/-
Level of education	Use of fungicide on crops (1 = yes; 0 = no)	+/-
Technical and financial factors	Collaboration with TFPs (1 = yes; 0= no)	+/-

Number of years of experience	Production experience (1 = yes; 0 = no)	+/-
Age of producers	Age range of the producer (1 = yes; 0= no)	+/-
Subsidy	Fertilizer subsidy (1 = yes; 0 = no)	+/-

+: positive expected effect; - Negative expected effect

3. RESULTS OBTAINED

Socio-economic characteristics:

The general characteristics of the producers surveyed are presented in Table 2. The majority of producers are married men (88%). The analysis of variance showed a highly significant difference according to the belonging of the plots by sex. The level of education of the producers surveyed is relatively low. Fifty percent of the producers attended Koranic school. The analysis of variance showed a highly significant difference between producers according to the study areas.

Table 2: Socio-economic characteristics

Characteristics	Ansongo		Bourem		Gao		Site Ensemble		Value	Ddl	Asymptotic meaning
	N	(%)	N	(%)	N	(%)	N	(%)			
Sexes											
Man	97	81	94	93	31	97	222	88	10,476a	2	,005***
Wife	23	19	7	7	1	3	31	12			
Ethnicities											
Fulani	-	-	-	-	20	63	20	8			
Sonrhai	120	100	75	74	12	38	207	82	194,642a	6	,000***
Tamasheq	-	-	26	26	-	-	26	10			
Level of education											
Functional literacy	1	1	-	-	2	6	3	1			
None	-	-	83	82	20	63	103	41	173,470a	8	,000***
Koranic school	104	87	15	15	7	22	126	50			
Primary	10	8	2	2	1	3	13	5			
Secondary	5	4	1	1	2	6	8	3			
Marital Status											
Bachelor	-	-	1	1	-	-	1	,4	1,511a	2	,470
Married	120	100	100	99	32	100	252	99,6			

* significant at 10%; ** significant at 5%; significant at 1%

Experience in agriculture

The average number of years of experience in agriculture is 22 years in Bourem, a value significantly higher than that of Ansongo, which is 17 years old, and Gao at 19 years old.
Overall, we can conclude that the farmers in the study area have considerable experience in agricultural practice.

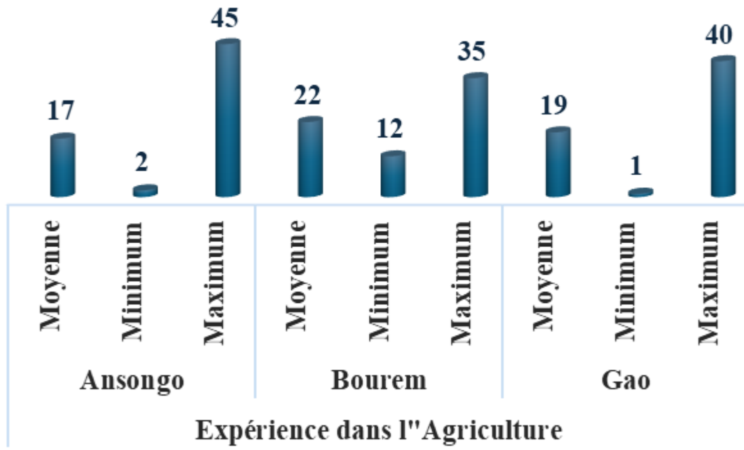

Figure 3: *Agricultural Experience*

Indicators of the profitability of the production of the Ghogown variety

The average yield is 1345 kg/ha for local varieties against 1100 kg/ha for Ghogown. The analysis of variance showed a significant difference of 5% for yields. The average unit selling price is 354 CFA francs/kg for local varieties against 500 CFA francs for Ghogown. The average variable and fixed costs are respectively 133,401 CFA francs and 145,715 CFA francs for local varieties against 87,500 CFA francs and 251,250 CFA francs for Ghogown. As for the analysis of variance, it shows a highly significant difference at the 1% threshold for price and fixed and variable costs.

Table 1: the indicators of production profitability of the Ghogown variety compared to local varieties

Type of varieties	Local	Ghogown	Together	t	ddl	Sig. (bilateral)
Yield (Kg/ha)	1 345	1 100	1 342	4,128	3,340	0,021**
Unit Price (CFA francs/kg)	354	500	356	-31,705	307,000	0,000***
Gross product (CFA francs/ha)	473 984	550 000	474 952	-2,574	3,353	0,073*
Charges variables (F CFA/ha)	133 401	87 500	132 816	4,832	9,058	0,001***
Marge brute (F CFA/ha)	340 583	462 500	342 136	-3,932	3,598	0,021**
Charges fixes (F CFA/ha)	145 715	251 250	147 059	-20,094	307,000	0,000***
Net marge (F CFA/ha	218 265	282 500	219 083	-2,117	3,356	0,115
Labour Productivity (CFA francs/hjr)	65 527	55 728	65 401	1,145	5,517	0,299
Gross operating income (CFA francs/ha)	218 265	282 500	219 083	-2,117	3,356	0,115

Revenu net d'exploitation (F CFA/ha)	194 868	211 250	195 077	-,554	3,266	0,615
Break-even point in value (CFA francs/ha)	183 690	299 573	185 166	-13,874	14,086	0,000***
Margin of safety (CFA francs/ha)	290 294	250 427	289 786	1,188	3,392	0,311

[*] significant at 10%; [**] significant at 5%; significant at 1%

Evaluation of the effect of adopting the Ghogown variety

The technical evaluation of the marginal effect on yields showed a mean difference of 244.81 kg/ha for yield. The analysis of variance showed that there is no significant difference in the technical efficiency of the yield of the two types of varieties. On the other hand, there is a highly significant difference at the 1% threshold according to the technical efficiency of the price, variant and fixed costs with average differences of respectively -146 FCFA/kg, 46027 FCFA/ha and -105609 FCFA/ha according to the technical evaluation of the marginal effect for the two types of varieties.

Table 4: Effect of Ghogown Adoption on Rice Farmers

Parameters	Average difference	Bias	Standard error	Sig. (bilate)	Effet marginal
Yield (Kg/ha)	244,81	,0623	51,2621	0,1179	206,793
Unit Price (CFA francs/kg)	-146,02	,0491	4,5349	0,0010***	18,097
Gross product (CFA francs/ha)	-76412,34	55,8117	25734,2627	0,1179	103732,191
Charges variables (F CFA/ha)	46027,84	301,8937	8983,8980	0,0010***	34572,154
Marge brute (F CFA/ha)	-122440,18	-246,0821	27304,5722	0,0899*	105803,632
Charges fixes (F CFA/ha)	-105609,43	-16,7971	5229,0948	0,0010***	20976,321
Net marge (F CFA/ha	-64773,69	-233,3488	26437,8081	0,1179	104632,120
Labour Productivity (CFA francs/hjr)	9798,91	-295,8241	7665,8247	0,3047	29759,376
Gross operating income (CFA francs/ha)	-64773,69	-233,3488	26437,8081	0,1179	104632,120
Revenu net d'exploitation (F CFA/ha)	-16830,75	-229,2849	26156,9131	0,5734	104350,453
Break-even point in value (CFA francs/ha)	-115933,08	91,2832	7653,4974	0,0010***	29477,963
Margin of safety (CFA	39520,75	-35,4716	28459,1591		113218,358

francs/ha)	0,2328

* significant at 10%; ** significant at 5%; significant at 1%

Determinants of Variety Adoption at the Farm Level

Table 51 presents the determinants of the adoption of resilient varieties in production systems. It appears that acreage and subsidy are the main determinants of the adoption of resilient rice varieties with a portability of less than 1% (P≤0.002). The marginal effect induced by the parameters (area and subsidy) is 4.068 and 15.098 respectively.

Gender is a determinant of the adoption of resilient rice varieties with a portability of less than 5% (P≤0.048). The marginal effect induced by this parameter is 136132 with a correlation coefficient of -0.142588.

Age of producers, level of education, agricultural credit and type of irrigation are determinants of the adoption of resilient varieties in production systems with a portability of less than 5%.

Table 5: Determinants of the adoption of resilient rice varieties in production systems

Impact parameter	Coefficient	Standard error	With	P>|z|	Effet marginal (dy/dx)
Sex	- 0,142588	0,173168	- 1,8800	0,048**	136132
Cultivation practice	0,000420	0,006816	0,0600	0,951	1,017807
Surface	0,581442	0,258517	2,2500	0,002***	4,068191
Improved variety	0,193426	0,109191	1,7700	0,076*	1,012653
Type d'irrigation	0,265873	0,106878	2,4900	0,013**	1,112717
Agricultural credit	0,206931	0,107351	1,9300	0,054**	0,9658787
Organization Membership	0,248106	0,282927	0,8800	0,381	1,221805
Water fee	0,164289	0,101751	1,6100	0,101	4,498815
Level of education	0,284524	0,119602	2,3800	0,017**	4,250207
Technical and financial factors	- 0,161320	0,117685	- 1,3700	0,17	17,75064
Number of years of experience	0,028211	0,134333	0,2100	0,084*	90,51535
Age of producers	0,248260	0,112492	2,2100	0,027**	1,466976
Subsidy	6,746685	0,271333	24,8600	0,000***	15,09787

* significant at 10%; ** significant at 5%; significant at 1%

4. DISCUSSIONS

The average number of years of experience in agriculture is 22 years in Bourem, a value significantly higher than that of Ansongo, which is 17 years old, and Gao at 19 years old.

The most widespread rice production system is free-submerged rice farming. It was adopted by a significant majority, i.e. 74% of rice farmers. The controlled submersion rice cultivation system is used by 25%. It should be noted that the total water control rice cultivation system is the least common, used by only 1% of producers. This system is more commonly used in OPVs. This is also confirmed by the annual report of the DRA of GAO, where 16,490 Ha cultivated, free submersion occupies 12,200Ha in 2023. This distribution of production system choices reflects the preferences and agricultural practices of producers.

Adoption of short-cycle varieties is the most prevalent resilient practice among growers, at 47%. This practice is more used in controlled submersion. It is followed by the use of local varieties by 30% of producers. However, improved varieties are only adopted by 7% of producers, suggesting that they are not widely accepted. Producers are less likely to opt for the improved variety due to a lack of infrastructure to control the rise of the river's water. Due to the delays in the rains, the agricultural calendars are shifted and after sowing, the flow of the river becomes important and floods the fields, only local varieties resist these phenomena which are more frequent in the Gao region. This result confirms the finding made by RABEARINTSOA (2017) in Madagascar, the use of climate-resilient varieties and the reduction of non-climatic disturbances of water resources are the main practices in the region.

The more climate-resilient cultivation practice and the availability of water are the main reasons for the choice of the production system with 19% of citations. The more climate-resilient cultivation practice and access to water are the reasons for the choice of 33% of producers for free submersion against 1% for controlled submersion. Less expensive cultivation practices and the availability of more adopted varieties are the reasons for the choice of 31% of producers for free submersion against 1% for controlled submersion.

It appears that acreage and subsidy are the main determinants of the adoption of resilient rice varieties with a portability of less than 1% ($P \leq 0.002$). Similarly, (Ndèye et al. 2018) had concluded that the total available area is decisive in exposure to varieties with a significance threshold of 1% in Senegal.

Gender is a determinant of the adoption of resilient rice varieties with a portability of less than 5% ($P \leq 0.048$). The age of producers, the level of education, agricultural credit and the type of irrigation are determinants of the adoption of resilient varieties in production systems with a portability of less than 5%.

5. CONCLUSION

Rice is considered a strategic product in Mali because of its importance for food security but also for the country's economic development given its preponderant place in production, agricultural employment and income generation for farmers.

Adoption of short-cycle varieties is the most prevalent resilient practice among growers, at 47%. This practice is more used in controlled submersion. It is followed by the use of local varieties by 30% of producers. However, improved varieties are only adopted by 7% of producers, suggesting that they are not widely accepted. Producers are less likely to opt for the improved variety due to a lack of infrastructure to control the rising water in the river

It appears that acreage and subsidy are the main determinants of the adoption of resilient rice varieties with a portability of less than 1% ($P \leq 0.002$)

Gender is a determinant of the adoption of resilient rice varieties with a portability of less than 5% ($P \leq 0.048$). The age of producers, the level of education, agricultural credit and the type of irrigation are determinants of the adoption of resilient varieties in production systems with a portability of less than 5%.

These results can serve as a compass for the promotion of adaptation strategies in the context of climate change in the Gao region.

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