Analysis of Technical Efficiency and Determinants of Cereal Production on Family Farms in the Dogon plateau in Mali.

ABSTRACT :

The area of the Dogon plateau located in central-eastern Mali is an arid agricultural region with difficult morpho-pedological and climatic conditions where peasant populations derive their income and especially their food from agriculture. The objective of this study was to determine the level of technical efficiency of family farms in this area and subsequently to identify the factors explaining their inefficiency. Data were collected from a sample of 400 farms through a quantitative survey. The stochastic frontier production method was used to determine their efficiency scores. Truncated regression was used to identify farm inefficiencies.

The results of the study show that in the Dogon Plateau area family farms have an average efficiency score of 72.75%, which means an overall loss of 27.25% of production factors. The maximum efficiency score is 92.60% against a minimum of 0.21%. In addition, it appears that less than 20% of farms in the area have a below-average technical efficiency score.

The analysis of the determinants of the technical inefficiency of farms shows that the association of agriculture with livestock, the possession of agricultural land with a land title and the cultivation of onion/shallot positively and significantly influence the level of technical efficiency of family farms in the Dogon Plateau area. Contrary to our expectations, the decrease in cultivated areas due to the residual insecurity of our study area has no significant effect on the technical efficiency of the farms.

Keywords: family farm, technical efficiency, stochastic production frontier, Dogon Plateau, cereal production.

The type of article: Original research Article

1. INTRODUCTION

Like several African countries, agriculture holds a predominant place in economic activity and the fight against food insecurity in Mali, it is dominated by family-type farms that occupy the largest proportion of the country's agricultural land. This type of farm, of modest size, is marked by great diversity, according to agroecological and socio-economic conditions.

Specifically, in the Dogon plateau area (an arid agricultural region with difficult morpho-pedological and climatic conditions), most peasants derive their income and especially their food from agriculture. Despite the hostile physical features (cliffs and rocky outcrops), they have developed, over the centuries, an agricultural system based on rainfed cereal farming, off-season market gardening, and livestock. Farmers mainly grow millet, sorghum, funio, some groundnuts, and cowpeas. Cultivation techniques are essentially manual: the use of animal traction is generally reserved for the transport of manure, crops, and people.

Yields from rainfed agriculture remain very low in the area, especially for millet (staple cereal); in 2020, they varied from 0.6 to 1.19 t/ha on average according to figures from the Regional Directorate of Agriculture (DRA) of the Mopti region. This high variability is explained, among other things, by the irregularity of rainfall, the fragility of the land, which is a major obstacle to the mechanization of agriculture, the rare and timid contribution of chemical fertilizers, and the weak support of technical structures of supervision.

The various agricultural policies that have succeeded over time have failed to ensure a good level of cereal yield in the Dogon Plateau area compared to other localities in the country. Low yields, coupled with sometimes high production costs (especially those of mechanization, purchase of inputs, and especially permanent and casual labor), generate insufficient added value. As a result, cereal production (millet, sorghum, and funio) in the Dogon plateau, estimated at 439,831 tones during the 2019-2020 agricultural season according to the DRA of Mopti, is far from covering the food needs of its population.

Produce more to feed a growing population despite the threat posed by climate change, but also Produce *better* while conserving natural resources. These are the challenges posed by Malian agriculture to ensure food security in the coming decades. To meet this challenge, improving agricultural performance, in terms of technical efficiency, has therefore become an absolute obligation for farmers, as well as for decision-makers, to guarantee sustainable food security at the national level and particularly for households in the Dogon Plateau area.

Increasing the technical efficiency of family farms significantly increases productivity and national cereal production, but also remains an effective means of combating food insecurity while strengthening people's livelihoods and contributing to the improvement of the local economy.

The analysis of the efficiency of farms is essential to understand their functioning, the means of production available to them, the socio-economic conditions in which they work, their different production objectives, and the resulting consequences on the diversity of agricultural production systems practiced. In addition, it makes it possible to highlight the different types of farms involved in the agricultural development of a given locality.

The objective of this paper is to determine the level of technical efficiency of family farms and subsequently to identify the factors explaining the inefficiency of farms in the Dogon Plateau area. The assumptions underlying this research are as follows:

- ✓ the majority of family farms in the Dogon Plateau area is technically inefficient;
- ✓ the factors of inefficiency of family farms in the Dogon Plateau area are technical, organizational, institutional, and economic.

The interest of this study is that it complements the economic literature relating to the estimation of the levels of technical efficiency of family farms but also to the identification of the factors explaining their inefficiency. In addition, the study will make policy recommendations to increase the level of technical efficiency of farms. In addition to the introduction and conclusion, this paper is divided into two sections: the first presents the materials and methods of analysis and the second presents the results and discussions. Finally, it leads to the formulation of recommendations.

2. MATERIALS AND METHODS

2.1. Sampling and data collection

The sample is calculated with the following formula:

$$n = \frac{\mu_\alpha^2 * P(1-P) * N}{\mu_\alpha^2 * P(1-P) + (N-1) * y^2}$$

With:

- **n**: sample ;

- **N**: the size of the estimated target population (number of farms[1]);
- **P**: expected proportion of a population response or actual proportion; by default, it is set at 50%. It is recommended to apply this value by default when, for example, one wishes to maximize the sample size to improve the accuracy of the indicators a posteriori;
- **μ_α**: sampling confidence interval, the chosen level is 95% (in this case, $\mu_\alpha = 1.96$);
- **y**: margin of sampling error, set at 5%.

The application of this formula, considering the above parameters, leads to a minimum size of 380 family farms, distributed among the administrative districts constituting our study area. The number of villages sampled is 38, based on a minimum of 10 farms to be surveyed per village. Two additional villages were surveyed to address cases of non-response or collection error; This will bring the total number of villages to 40, for a total sample of 400 farms.

The physical access to our study area is extremely difficult, as well as the constant volatility of the security situation in the area in recent years have led us to adopt a two-stage sampling methodology. The first step is the identification of study sites or villages by a municipality that are representative of the livelihood area and production systems of the target crops in our study area. This choice was made in a reasoned manner based on research findings but considering the importance of cereal production (millet and sorghum) in the village, and the accessibility of the village (in connection with insecurity) at the time of the implementation of the survey. In the second stage, there was a random choice on the observation unit, which is the family farm in the selected villages. To this end, an exhaustive enumeration of the farms in each village was drawn up by the surveyors, with the help of the village chiefs or certain resource persons of these localities. In each village 10 farms were surveyed with equal probability from the list drawn up following the enumeration.

2.2. Empirical methods for analyzing efficiency and rationale for choosing the stochastic frontier method.

To establish a production frontier and estimate technical efficiency, two main approaches are retained by the economic literature and are the most widely used: one parametric, econometric approach known as *stochastic frontiers (SFA),* and the other nonparametric, an approach based on mathematical programming and known as *data envelopment analysis (DEA).*

[1] The number of family farms in our study area is estimated at 37267 farms, according to information collected from the Regional Directorate of Agriculture of Mopti in January 2022.

The stochastic production frontier (SFA) is a method for estimating a parametric production frontier and a technical efficiency score specific to each farm. It decomposes the error of the function studied into two independent elements: first, an asymmetric component reflecting the degree of inefficiency of production units concerning the border. Then a symmetric component allows purely random variations, reflecting measurement errors, poor model specification (variations related to variables not considered in the model), and uncontrollable factors implying that the farm has no decision-making power to improve its efficiency [1]. *These factors cannot be negligible, especially in agriculture, which is always affected by recurrent climatic hazards and repetitive natural disasters impacting the productivity of farms.* The integration of this term gives the stochastic nature to this type of efficiency frontier. This breakdown of the error term will therefore lead to a more accurate measurement of technical efficiency.

The DEA method calculates the technical efficiency scores of individual farms from an efficiency frontier. Farms located on the border are considered technically efficient with a score of 1 (100%) and those located below the border are inefficient with a score below 1 [2]. These inefficient farms, therefore, have room to improve their performance [3]. They will be able to refer to technically efficient farms to apply their best practices [4]. According to Gunther and Chauveau (2002), quoted by Ben Nasr et al., "*this approach is particularly suitable for measuring the efficiency of firms combining several inputs to produce several outputs"* [5].

The main difference between these two approaches analyzed lies in the assumptions concerning, on the one hand, the consideration of random factors and, on the other hand, the functional or non-functional specification of the production frontier. Each of these methods is therefore based on a different conception of the construction of this effective border. Because of the above, the (SFA) approach will be adopted in this study. The choice of this method is explained, on the one hand, by considering random factors beyond the control of farms (global warming, poor distribution of rainfall over time and space, etc.) that affect their product performance and on the other hand, considering an analysis framework with a mono-output production process (the total quantity of cereal produced by the farm). In addition, this method of analysis will consider the considerable measurement errors usually contained in data collected at the farm level.

2.2.1. Specification of stochastic frontier production model

To estimate the technical inefficiency of family farms in the Dogon Plateau area, we opted for the parametric approach of stochastic frontier production, because it differentiates between inefficiency related to producers and that due to random effects not controllable by producers. This provides a more accurate measure of technical efficiency.

The structural form of the stochastic production frontier is represented by the following form [6]:

$$\boldsymbol{Y_i = f(X_i;\ \beta)\exp(v_i - u_i)} \qquad (1)$$

With i = 1, 2, ..., n;

- Yi denotes the production of each holding in the sample (i = 1, 2, ..., n);
- f(Xi;β) represents a production function of a form chosen a priori (translog, or Cobb-Douglas) whose β parameters are unknown;
- Xi is a vector of inputs (1×k) used by the farm;
- vi is a random error term that captures stochastic effects that are not under the control of the operator. They are assumed to be independent and identically distributed with a normal distribution of zero mean and unknown variance N ($0;\ \sigma_v^2$);
- UI represents the random variable, positive or zero, reflecting the technical inefficiency, in terms of production of i. This term represents the effects of technical inefficiency. They are independent and distributed according to a normal distribution truncated to zero with mean *μi* and variance σu² (N ()).$u_i;\ \sigma_u^2$

If we consider an output Y (total cereal production) produced using four separate inputs (cultivated area X1, number of permanent assets X2, quantity of organic fertilizer X3, quantity of mineral fertilizer X4, and quantity of external labor X5); the technical efficiency level (TE) of operation i is determined by the following formula, [7]:

$$\boldsymbol{TE_i = \frac{y_i\, réalisé}{y_i\, max} = \frac{f(xi;\beta)\exp(v_i - u_i)}{f(xi;\beta)\exp(v_i)} = \exp(-u_i)} \qquad (2)$$

The stochastic frontier model given by equations 1 and 2 is therefore used to estimate the technical efficiency.

The average level of technical efficiency varies not only with the estimation method but also with the functional form used. In the case of modeling with a parametric approach (SFA), it is necessary to specify beforehand the most suitable functional form that reflects the production technology as closely as possible. There are two main categories of functional estimation models:

- The *Translog* *function* is flexible and allows easier estimation of production technology and technical efficiency levels. It imposes fewer constraints on the production structure, the levels of elasticities of substitutions, and returns to scale while allowing econometric analysis.

  In addition, it makes it possible to consider the interactive effects between the factors of production; It has several properties including continuity, homogeneity, linearity, and concavity. It is also based on an economic model, which makes it possible to introduce all the theoretical properties required by the production technology. However, it should be noted that from a Translog function, the estimated coefficients are not directly interpretable (as in the case of the Cobb-Douglas function). The elasticities of the factors of production under consideration should be calculated.

  The translog production function looks like this [7]:

$$lnY_i = \beta_0 + \sum_{j=1}^{n} \beta_j \, ln \, X_{ij} + \frac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{ij} \, ln \, X_{ij} + (v_i - u_i) \qquad (4)$$

- *the* *Cobb-Douglas* function which is a special form of the Translog production function where the coefficients of the squared terms and interaction of the input variables of the Translog function are assumed to be zero. Despite its restrictive properties, the coefficients of the Cobb-Douglas production function directly represent the effect of a change in the number of inputs on output and are easy to interpret and estimate as the Translog frontier [8]. The Cobb-Douglas production function is as follows:

$$lnY_i = \beta_0 + \sum_{j=1}^{n} \beta_j \, ln \, X_{ij} + (v_i - u_i) \qquad (3)$$

  - LN: log-neperian,
  - Yi: the total harvested production (kg) of holding i,
  - Xij: the amount of input j used by holding i,
  - *(β0, βj, βij)*: the unknown parameters,
  - n: number of factors of production,
  - $vi - u_i$: represents the compound error term.

The likelihood ratio test will allow us to select the most appropriate functional form for our analysis model.

2.2.2. Estimating and interpreting model parameters

Production frontier parameters with technical inefficiency effects can be estimated simultaneously by the maximum likelihood method. The results of these estimates are used to obtain the variances of the errors:

$$\boldsymbol{\sigma^2} = \boldsymbol{\sigma_u^2} + \boldsymbol{\sigma_v^2} \quad (5) \text{ and } \quad \boldsymbol{\gamma} = \frac{\boldsymbol{\sigma_u^2}}{\boldsymbol{\sigma_u^2} + \boldsymbol{\sigma_v^2}} \quad (6)$$

The parameters σ2 and γ describe the contribution of technical efficiency to production. σ^2 is defined as the sum of the variance of the inefficiency term and that of the random term and γ as the share of the inefficiency term in the total variance [9]. These parameters (*γ, σ^2, β_0 ... βk*) are to be estimated by the Maximum likelihood method at the model level.

This method, therefore, amounts to maximizing the logarithm of the likelihood function concerning unknown parameters. It makes it possible to estimate the frontier and to separate the error components reflecting technical inefficiency from the purely random components. The variance parameters explain the variations concerning the stochastic production frontier:

- When *γ = 0, deviations from the frontier are entirely due to noise and error terms* vi *(i.e., a zero* value of *γ* represents the absence of stochastic technical inefficiency). The ordinary least squares (OLS) method is applicable in this case.
- If *γ* = 1 then in this case the deviations from the frontier are entirely due to the occurrence of inefficiency *ui*.
- The closer the value *of γ* is to 1, the smaller the difference between the results of a stochastic estimate and those of a deterministic estimate.

2.2.3. Testing the model and parameters

Before estimation, a hypothesis test will be carried out to see if the chosen model is appropriate and also to know the relevance of the analysis. The three hypotheses to be tested are the discrimination between the translog and Cobb-Douglas models, the absence of technical inefficiency in the model, and the non-stochastic nature of the errors. These tests are carried out by making the following assumptions, respectively:

- **H1** : = 0, the stochastic function is of the Cobb-Douglas type.β_{ij}
- **H2** : $\gamma = \sigma_1 = \cdots = \sigma_n = 0$, the model has no inefficiency effects.

- **H3** : = 0, technical inefficiency effects are not stochastic.γ

2.2.4. Technical Inefficiency Model Specification

The realization of the stochastic production frontier allows us on the one hand to determine the technical efficiency scores of family farms and on the other hand to study the factors that characterize their inefficiencies. In agriculture, the technical inefficiency of a production unit can be explained by certain factors such as the size of the holding, the age and education of the head of the holding, etc., rather than by the irrationality of the producers.

The literature review indicates two methods for estimating the technical inefficiency model.

The first method is to estimate two equations simultaneously, one representing the frontier and the other representing the relationship between inefficiency and explanatory factors [6]. The idea is to distinguish, in the usual specification of the stochastic frontier of production, the inputs noted Xi (area, labor, etc.), from the factors that explain the inefficiency noted Zi (age of the farmer, access to agricultural credit, supervision, etc.). In general, these factors are assumed to be under the control of the entrepreneur during the production process.

The stochastic frontier is written in this case:

$$Y_i = f(x_i, \beta)e^{vi-ui} \quad (7)$$

With ui > 0 is an asymmetric random variable verifying:

$$U_i = Z_i\delta + \omega_i \quad (8)$$

In this type of modeling, the problem of specification bias arises, which affects both the coefficients and the coefficients of the frontier when important variables affecting farm inefficiency are omitted. While inputs and outputs are generally available to estimate production boundaries, the variables explaining efficiency are not necessarily available (age of equipment, working conditions, etc.). In most cases, only a limited number of variables explaining inefficiency are introduced. In this case, the one-step method cannot be recommended.$\delta\beta$

The second method commonly used to explain inefficiencies in frontier models is to proceed in two stages. In general, this assumes that the variables explaining inefficiency are those that the operator does not control in the production process. We first estimate the inefficiencies (from a parametric frontier), then, in a second step, we regress the efficiency scores on the Zi variables .

The stochastic production frontier defined in the first step makes it possible to isolate the factors likely to influence technical inefficiency, which is represented by the error term *Ui.* In the second step, this error term will be the explanatory variable of the following model:

$$U_i = \delta_0 + \sum_{k=1}^{n} \delta_k Z_{ki} + \varepsilon_i \qquad (9)$$

- Zki: represent the socio-demographic, economic and institutional variables that explain the technical inefficiency of the operation i;
- δk: is a vector of unknown parameters that will have to be estimated;
- ε : is the error term that follows a truncated normal distribution defined by .

$$\varepsilon_i \leq -Z_i\delta$$

Regression, performed in the second step, is approached using either the ordinary least squares method or a dichotomous model (Tobit, Probit) to account for the truncated character (between 0 and 1) of the variable efficiency score [10].

This two-step procedure therefore assumes that the variables explaining inefficiency are those that the operator does not control in the production process. It has the advantage that in case of specification error in the second step, the bias affects only the estimated coefficients of the determinants and not the coefficients of the frontier [11]. In addition, it avoids the bias included in the first step, according to which the level of efficiency is independent of these variables while in the second step they are considered dependent.

In order to analyze the technical efficiency of family farms, this study adopts the two-step procedure, and the truncated regression model (variant of the Tobit model) is applied in the second step. The Tobit model refers to models with a finite dependent variable for which the dependent variable is continuous but observable only over a specific interval.

3. RESULTS AND DISCUSSIONS

3.1. Testing Model Hypotheses

As a prelude to the use of stochastic method (SFA) for the estimation of the production frontier, it is necessary to verify the assumptions about the model specification. For this, we used the likelihood ratio (LR) test. The first test is to examine the best fit specification between the Translog functional form and the Cobb Douglas functional form while the second test checks for inefficiencies in our sample.

The value of the likelihood function obtained after estimating the Cobb Douglas function and that obtained after estimating the translog function provides the statistic λ (the likelihood ratio), which is equal to -0.45 with a Prob > chi2 = 1.0000. Thus, at only 1%, the functional form Cobb-Douglas is adequate for this study and can be estimated by the maximum likelihood method.

Moreover, the null hypothesis that there is no inefficiency is also rejected at the 1% threshold with a statistic LR = - 45,457.

Thus, the production function can be represented by the translog functional form and there is a technical inefficiency that can be explained by various variables. This allows us to make econometric estimates of this function, first presenting the technical efficiency scores and highlighting the variables determining the inefficiency of family farms in the Dogon Plateau area.

Table 1 : Hypothesis test results

Assumptions	Statistics LR test	Significance	Decisions
Hypothesis 1: The stochastic function is of the Cobb-Douglas type. **H0** : = 0,β_{ij}	-0,45	Prob > chi2 = 1.0000	No release of H0
Hypothesis 2: The model does not have inefficiency effects. **H0** : $\gamma = \sigma_1 = \cdots = \sigma_n = 0$,.	-45,457	Prob < = z = 0.000	Release of H0

Source: Author's construction, July 2022.

3.2. Estimating the stochastic production frontier

The analysis of Table 2 first tells us that the estimated model is globally significant because the value of the crack probability is equal to 0.000 and the test statistic is 912, corresponding to a law of chi2 with 5 degrees of freedom.

The values of Sigma_u and Sigma_v representing the variance of the inefficiency term and the random term respectively are also significant at the 1% level. The share of the inefficiency term in the total variance designated by Gamma (γ) has a value of 0.9. It is significant at the 1% threshold and ranges from 0 to 1, indicating the stochastic nature of the production frontier. This result allows us to reject the null hypothesis that technical inefficiency effects are not stochastic.

It also emerges from the analysis that at the 1% threshold the coefficients of the variables number of permanent assets, cultivated area and quantity of organic fertilizer are significant while the amount of mineral fertilizer is significant at the 10% threshold. The significant coefficients thus obtained stipulate that in the Dogon Plateau area, if the quantities of factors (permanent asset, area, organic fertilizer, and mineral fertilizer) are increased by 1%, cereal production will increase by 0.09%, 0.84%, 0.02% and 0.01% respectively.

With a coefficient of 0.84, the area variable has a higher contribution to the increase in cereal production of farms in our study area. This result is all the truer since the main challenge faced by these farmers is the availability of arable land. Moreover, the amount of external labor is not significantly correlated with our dependent variable.

Table 2: Family farms production frontier of the Dogon plateau area

Variable	**Parameters**	**Coefficients**	**Standard deviation**
Constant	β_0	6,151212***	0,04563
Ln_Number of permanent assets	β_1	0,098437**	0,03956
Ln_Quantity of External Labor	β_2	0,012998	0,02056
Ln_cultivated area	β_3	0,849398***	0,03501
Ln_Quantity of organic fertilizer	β_4	0,021532**	0,00678
Ln_Quantity of mineral fertilizer	β_5	0,013798*	0,00825
sigma_u	σ_u	0,404451***	0,03218
sigma_v	σ_v	0,255631***	0,01884
Sigma-Square	σ^2	1,582166***	0,04373
Gamma	γ	0,999716***	-
Log-likelihood		-237,8371***	

** P < 0,05, ** P < 0,01 and *** P < 0,001.*

Source: Author's construction, July 2022.

On average, the technical efficiency score of family farms in the Dogon Plateau area is 72.75% with a minimum of 0.21% and a maximum of 92.60% which shows a very large disparity between farms.

Table 3 : Descriptive statistics of technical efficiency scores

Variable	**Obs**	**Average**	**Standard deviation**	**Min**	**Max**
Efficiency	400	0,7275111	0,1541832	0,0020569	0,9259663

Source: Author's construction, July 2022.

Table 4 shows that most of the farms have a technical efficiency score of between 60 and 80%. The farms closest to the production frontier (score ≥ 80%) represent 39.25% of our sample while 18% of the farms have an efficiency score below 60%.

Table 4 : Distribution of technical efficiency scores

Efficiency score	Actual	Percentage
< 20%	5	1,25
[20-40%[	6	1,50
[40-60%[	61	15,25
[60-80%[	171	42,75
[80-100%]	157	39,25
Total	400	100

Source: Author's construction, July 2022.

The analysis in Table 4 shows that the average cereal production of farms increases as one approaches the production frontier. By focusing on the upper and lower bounds of the efficiency scores, we can see on the one hand, that on an average area of 2.29 hectares, the most efficient farms achieve an average production of 1 304.18 kg of cereals (millet, sorghum and funio), or an average of 569.5 kg/ha. This average production is achieved with 4.17 workers, 82.33 man-days of external labor, 1.6 tons of organic fertilizers and about 200 kg of mineral fertilizer. On the other hand, the least efficient farms cultivate on average 0.5 hectares for an average production of 50 kg, which is well below the national average. The latter use a little more than 2 bags of mineral fertilizer (urea and NPK) but do not use organic fertilizer; They also use 41 man-days of external labor in addition to the 3.8 permanent assets of the farm.

In general, it should be noted that the agricultural season was considered bad in this area mainly because of the poor distribution of rainfall over time and space. And this variable is an unobserved feature of our stochastic production frontier model, meaning that its effect is included in the random error term *(vi)* that captures stochastic effects that are not under the control of the operator.

Table 5 : Averages of production frontier variables based on efficiency scores.

Efficiency score	Total cereal production (Kg)	Number of permanent assets	Quantity of external labor (M/D)	Area under cultivation (Ha)	Amount of organic fertilizer (Kg)	Quantity of mineral fertilizer (Kg)
< 20%	50	3,80	41	0,50	-	110
[20-40%[	320	4,33	12	1,93	1 500	70
[40-60%[	612,95	4,54	35,40	2,51	1 537,66	145,35
[60-80%[	721,91	3,64	32,18	2,14	1 048,06	164,02
[80-100%]	1 304,18	4,17	82,33	2,29	1 621,85	199,12

Source: Author's construction, July 2022.

3.3. Determinant of the technical inefficiency of family farms

The analysis of the determinants of the technical inefficiency of farms in the Dogon plateau zone from the truncated regression model tells us that at the 1% threshold the "*Agriculture and livestock*" modality of the *variable "Type of farm"* has a negative and significant effect on the technical inefficiency of family farms (coef. = -0.0418889***; P>z=0.014); the same applies to the modality "*Purchase with the land title*" of the variable *"Mode of land acquisition"* (coef. = -0.5019141***; P>z=0.009) and the variable *"onion/shallot culture"* (coef. = -0.0545811***; P>z= 0.001). In other words, these variables act negatively on the technical inefficiency of family farms and thus contribute to the increase in cereal production.

Indeed, in the Dogon Plateau area, farms that combine agriculture and livestock are much more efficient than those that practice agriculture alone, insofar as the possession of livestock provides them with organic manure to fertilize their plots but also constitutes a source of income allowing them to use external agricultural labor or to buy mineral fertilizer.

Farms with agricultural land with title to land show a higher level of efficiency than those with land on loan or customary allocation. It should be noted that in the Dogon Plateau area, the operators able to obtain land titles are generally wealthy and have incomes well above average. They therefore have easy access to factors of production such as inputs and labor; They also have access to equipment and new production technologies such as improved seeds. In addition, the land titles they have allowed them to obtain agricultural credit and make sustainable investments in this land. These results corroborate those of [5], which measured in 2016, the technical efficiency of 47 irrigated farms belonging to the perimeter of Sidi Ali ben Salem in Kairouan, Tunisia, using a Cobb-Douglas stochastic frontier production function. The way in which land is held is one of the reasons given by the authors to explain the levels of technical inefficiency. A study carried out in the Office du Niger area in

Mali also revealed that the rental of land (mode of access) is a determining factor and has a positive impact on the technical efficiency of rice farmers [12].

As for the cultivation of onions/shallots, it is not surprising that it has a negative impact on farm inefficiency as it is one of the main activities and sources of income for households in the Dogon Plateau area. This activity, which occupies all strata of the population during the off-market gardening season, provides sufficient income to meet not only the food and non-food needs of households but also to buy the necessary inputs (seeds, mineral fertilizers, and phytosanitary products) for cereal production.

Contrary to our initial expectations, the literacy of the head of household and his age do not have a significant effect on the technical inefficiency of farms. In the same vein, [13] also found that age does not have a significant effect on crincrin production in Benin's Mono Valley. On the other hand, these results are contrary to those of several authors. Through the method of stochastic production frontiers,[14] have found that age improves the technical and economic efficiency of maize farmers in the Kanem oases of Chad. In Côte d'Ivoire, [15] also concludes that educated farmers have the opportunity to learn about the prices of agricultural inputs, which increases their bargaining power with traders and therefore acquire these inputs at a lower cost; Therefore, this plays in favor of reducing the producer's level of inefficiency. In 2018, [1] also found that the level of education has a positive and significant impact on the level of technical efficiency of olive farms in the Chbika region of Tunisia.

The analysis of our results indicates that the access of the farm to agricultural credits and its supervision by the technical services also have no significant effect on its inefficiency. These results are the opposite of those obtained by [15], which analyzed the technical efficiency of women food crop farmers in Côte d'Ivoire; It shows that access to extension and credit has a positive effect on improving the technical efficiency of these farms. In addition, [14] who applied the stochastic production frontier method on a representative sample of 135 farmers who are members of the Network of Pineapple Producers of Benin and concluded that the most efficient producers are among the producers who respect the recommended technical route. The extension of technical information on agricultural production and compliance with the technical route have a positive influence on the technical efficiency of producers. Using the stochastic production frontier method on panel data, [16] found that the presence of agricultural support staff is a determinant of technical efficiency in rice production in Cambodia.

Our results also indicate that the tillage method practiced by farms has no significant effect on their technical efficiency. This observation is explained by the fact that despite the technological progress made in this field, more than 3/4 of the farms (77%) of our study area practically manual ploughing and 16% practice harness ploughing (plough and oxen) which does not improve their productive capacities. It should also be noted that the morpho-pedological conditions of the Dogon Plateau area do not favor the use of modern equipment such as motorized ploughs and tractors to plough their plots to improve their technical efficiency.

Despite the volatile security context of our study area, we find that the decrease in cultivated areas for security reasons does not have a significant effect on the level of efficiency of farms. This is mainly because we did not include in our sample farms in the areas most affected by this insecurity.

Table 6 : Results of the estimation of the technical inefficiency model

Variables	Parameter	Coefficient	Standard deviation
Constant	δ_0	0,7822998***	0,033802
Age of the manager	δ_1	-0,000322	0,0005754
Literacy of the EAF Chief	δ_2	-0,0168937	0,0158577
Practice *Agriculture and Livestock*	δ_3	-0,0418889**	0,0171101
Decrease Area for insecurity	δ_4	-0,0153706	0,0223398
EAF Technical Coaching	δ_5	0,0356501	0,0248565
Access to agricultural credit	δ_6	0,0580131	0,0390618
Land acquisition process	δ_7		
Customary attribution		-0,0011649	0,0207946
Ready		-0,0131655	0,0479531
Purchase with land title		-0,5019141**	0,1911522
Method of ploughing	δ_8		
Coupled		0,017266	0,0215374
Motorized		0,0877527	0,1074209
Manual and Harness		0,0379534	0,034974
Manual and Motorized		0,0311571	0,1510927
Onion/shallot culture	δ_9	-0,0545811**	0,0164055
/sigma		0.1492195***	0,0052812

** P < 0,05, ** P < 0,01 et *** P < 0,001.*

Source: Author's construction, July 2022.

4. CONCLUSION AND RECOMMENDATIONS

We retain at the end of our study that in the Dogon plateau area family farms are characterized by technical inefficiency with an average efficiency score of 72.75%, which means an overall loss of 27.25% of production factors. The most efficient farm has an efficiency score of 92.60% while the least efficient has a score of 0.21%. All other things being equal, the latter could clearly improve their cereal production with the same amounts of inputs that they currently use.

The analysis of the determinants of the technical inefficiency of agricultural holdings shows that the association of agriculture with livestock, the possession of agricultural land with a land title and the cultivation of onion/shallot positively and significantly influence the level of technical efficiency of family farms in the Dogon Plateau area. However, the literacy of the head of household and his age, the access of the farm to agricultural credits and supervision by the technical services and the method of ploughing practiced do not have a significant effect on the level of technical efficiency of the holdings. Similarly, contrary to our expectations, the decrease in cultivated areas due to the residual insecurity of our study area has no significant effect on the technical efficiency of farms.

In view of these results, it is essential to formulate policy recommendations for decision-makers and all actors working to improve the performance of family farms in general and particularly those of the Dogon plateau and this from a perspective of sustainable food security. These are essentially:

- improve farmers' access to arid agricultural land through the creation of an agricultural village in the Office du Niger area (fertile and irrigable land) for the benefit of the populations of the Dogon plateau area;
- Securing farmland owned by farmers through their registrations allows farmers to obtain legal documents that can serve as collateral for obtaining agricultural credit or making sustainable investments on their plots;
- improve producers' access to agricultural inputs in sufficient quantities, including mineral fertilizers, through price subsidies;
- further promote onion/shallot cultivation through technical training and the establishment of a financing mechanism for this activity, which provides farms with considerable income to partially finance cereal production activities, including the purchase of fertilizers and the payment of external labor;

- strengthen the technical supervision system for farms through the development of a training action plan on production techniques and good agricultural practices;
- Establish local and formal mechanisms for access to agricultural credit through the creation of village savings and credit associations, the creation of input banks (with a mechanism of repayment in kind).

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