Climate change and technical efficiency of farms in Cameroon

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Summary

The objective of this paper is to analyze the impact of climate change on the technical efficiency of farms in the Adamawa, North, West and South regions of Cameroon. The empirical analysis was done in two stages. The first stage involved estimating the efficiency scores of a sample of 793 farms located in the above regions, using the DEA method. The second stage used a Tobit-type model to determine the influence of climate variables on the efficiency scores obtained. The results show that the technical efficiency of farms is relatively low in these regions. On the other hand, disruptions in the start dates of the rainy seasons and the increase in the average temperature during the rainy season have a negative and significant impact on the technical efficiency of farms. In addition, adaptation of the agricultural calendar, adoption of improved irrigation techniques and intensive use of fertilizers can mitigate the effect of climate shocks on technical efficiency.

Keywords: Climate change;technical efficiency; farms; DEA; Tobit, Cameroon

Introduction

Agriculture is one of the important pillars of the economy in Sub-Saharan Africa in general and in Cameroon in particular. Its weight in the economy is estimated at an average of 20% of GDP and employs more than 60% of the working population and nearly 90% of rural households (MINEPAT, 2016). Crops are diversified and include, among others: (i) cash crops, including coffee grown mainly in the West and North regions, cocoa grown mostly in the Centre, South, and South West regions, oil palm found in the Littoral and South regions, rubber trees for which a private company (HEVECAM) holds a monopoly in the South region, dessert bananas produced in the Littoral region, cotton and wheat grown in the North and Far North regions, and (ii) food crops including corn, peanuts, tubers, fruits and vegetables grown in almost all regions of the country. Millet, sorghum and onions are produced mainly in the Far North regions.

Cash crops are exported to industrialized countries, particularly the Netherlands (44.74%), France (11.15%), Belgium (3.56%), the United States (2.71%) and Spain (2.49%) (UNCTAD, 2021). The agricultural goods exported are generally produced by small family farms. The production of some (coffee, cocoa and cotton) is managed by parastatals or by mixed economy companies (bananas, rubber and oil palm).

Food crop yields as defined by some authors (Atkinson and Cornewell, 1994, Amara and Romain, 2000) are not only low in Cameroon, but have a downward trend (MINADER, 2020). Indeed, agricultural efficiency, which we equate with agricultural technical efficiency, expresses the ability or capacity of an enterprise to obtain the maximum possible output from a given level of productive resources or by using the minimum possible quantities of inputs (Atkinson and Cornewell, 1994, Amara and Romain, 2000). The purpose of productive efficiency is to judge the capacity of a production system to produce 'at best' through the use of all the means of production (capital, land and labour) (Coelli et al., 1998). Therefore, if we take as an example the production per hectare of some food crops, we can see that this quantity has evolved over time according to Table 1 below:

Table 1: Yields per hectare of some food crops (in tons)

Year	Pineapple	Bananas	Cassava	Yam
2011	35.12	16.49	13.93	11.53
2019	26.22	15.55	13.54	7.21

Source : MINADER (2020)

Table 1 shows that all of the food crops mentioned above experienced a decline in yield per hectare between 2011 and 2019. For example, the output per hectare of pineapple dropped from 35.12 tons in 2011 to 26.22 tons in 2019, while that of yam witnessed a dropped from 11.53 to 7.21 tons over the same period. Several factors are generally cited to justify these low yields, including: rural exodus, low public investment, marketing difficulties, outdated or inappropriate technologies and climatic, ecological and social factors (Dontsi, 1994; Nankap et Dontsi, 2022; Molua and Lambi, 2007).

Climatic factors are a major concern in Sub-Saharan Africa not only because of the specificity of agriculture, which is primarily rain fed farming, but also due to the phenomenon of climate change. Climate change refers to a statistically significant variation in the mean state of the climate or its persistent variability over long periods of time (usually decades or more). This is a phenomenon experienced in Cameroon. Indeed, we are witnessing a decrease in rainfall of -2.2% per decade between 1960 and 2015, an increase in average annual temperature of +0.7°C between 1960 and 2007, an irregularity of rainfall in the rainy season that intensifies and increases the occurrence of extreme weather situations such as flooding, drought, bush fires and heat waves with very significant consequences on the production capacity of farms (Amougou et al., 2015).

Several authors have attempted to analyze the technical efficiency of farms (Jouve, 1992; Helfand and Levine, 2004; Ekou, 2006; Thiam et al., 2001; Binam et al., 2004; Coelli and Fleming, 2004; Bagamba et al., 2007; Battesse and Coelli 1995; Coelli and Fleming, 2004; Bifarin et al., 2010; Abatania et al., 2012). Most of these works have not, to our knowledge, integrated climate change, those that have done so have not taken into account elements such as the length of the rainy season and the start date of the rains, which can constitute two important parameters in the economic behavior of the farmer. In addition, the non-linearity that is increasingly pronounced in the economic literature dealing with the relationship between climate change and agricultural production points to the need to take into account the farmer's adaptation strategies.

The objective of this paper is to analyze the impact of climate change on the technical efficiency of farms in Cameroon. This objective leads to the following research question: "***What is the impact of climate change on the technical efficiency of farms in Cameroon***?

The rest of the article is organized as follows: the first section provides a critical review of existing work in order to make our modest contribution (1). This contribution will be useful in defining the methodology adopted, which will be the subject of the second section (2). The third section will be devoted to the interpretation and discussion of the results (3). Finally, policy recommendations will allow us to conclude the analyses.

1. Literature review

Many authors have analyzed farm efficiency in developing countries or regions by considering different factors in their studies (Thiam et al., 2001). Given the large number of publications in the field, we will only mention the most recent ones that have small farms as their field of investigation and those that include climatic factors as determinants of technical efficiency (Table 2 in the Appendix). Table 2 illustrates that the most important factor of farm efficiency in Sub-Saharan Africa is climate. Thus, Mulwa and Kabubo-Mariara (2017) apply a stochastic translog monotonic frontier (SFA) and find a low efficiency score (63%), explained by decreasing rainfall and increasing temperatures, among others. These results are obtained by Vigh et al (2018), Singh et al (2019), Abdelradi and Yassin (2020) in different settings and for the distinct products.

In a wider scope, Ogundari and Onyeaghala (2021) analyze the effect of climate change on total factor productivity (TFP) growth in African agriculture and test whether TFP levels in agriculture are converging in the region. Their study uses cross-country balanced panel data covering 35 countries from 1981 to 2010 and relies on a technological catch-up model based on Ricardian analysis. Country-level historical precipitation and temperature are climate factors included in the model. Empirical results indicate that African agricultural TFP levels are converging over time, though the rate of convergence appears to be relatively slow in the region. They also find that rainfall significantly increases agricultural TFP growth while temperature does not.

From observations, the majority of studies linking climate change and technical efficiency have not taken into consideration certain climatic factors such as the length of the rainy season and the start date of the rainy season, which could disrupt the economic perspectives of farmers and, as a result, negatively influence technical efficiency, particularly in a context marked by the preponderance of rain fed agriculture. Indeed, the life of family farms, most of which are poor, is punctuated by the agricultural production cycle, which generally depends on the start of the rainy season. This date marks the beginning of the agricultural season, with the preparation of plots (clearing, weeding and ridge formation) and sowing activities. Farmers make their anticipations based on traditional knowledge of the onset of rains in the different agro-ecological zones of Cameroon. As this period approaches, some farmers recover their savings collected from ‘njanguis’ or microfinance institutions for the purchase of agricultural inputs, while others build up a stock of inputs by drawing on their agricultural reserves. They mobilize family labour or use either neighbours for mutual aid or agricultural workers who are hired.

However, with climate change, two cases can be distinguished that deviate from the norms: where the rains start before the expected period and where they start after the expected period. When the rains start before the expected period, producers are forced to quickly mobilize resources to purchase agricultural inputs and proceed with plot preparation and sowing. However, small farm with little or no possibility of borrowing money to undertake these activities will be delayed, which is detrimental to the proper development of the plant and therefore to agricultural production.

Similarly, when the start date of the rainy season is delayed, farmers must mobilize additional labour and sufficient financial and material resources. Sowing must be repeated two or three times (because of false starts) in order to obtain a level of yield close to that obtained when the rains start at the expected time. The costs increase even when mutual aid is called upon, as the mobilized workers must be fed and the farmer must make himself available to help others in turn. However, the poverty level of the farmer does not allow him to do this.
With regard to the length of the rainy season, it can have several effects on the agricultural technical efficiency. During production, short growing seasons and changes in rainfall patterns lead to shortening of crop maturation time, increased water stress and consequently disturbances on flowering and seed set (Banda, 2014). The extension of the rainy season, on the other hand, leads to soil degradation, increased early rotting of certain products such as fruits and vegetables, and crop drowning. Pockets of dryness in the rainy season lead to the decline of a certain number of products, such as groundnuts and corn.
Thus, we will attempt to include the onset dates of the rainy season as well as the length of the rainy season into the empirical analysis in order to judge their impact on agricultural technical efficiency. It will also examine the effectiveness of coping strategies used by the sampled farmers.

1. Methodology and data

1.1. Methodology

The Data Envelopment Analysis (DEA) approach is used to assess the technical efficiency of farms in this study. It is known as the CCR model (Farrell, 1957). It creates a piecewise linear frontier from the observed data and therefore makes no assumptions about the functional form or distribution of the error terms. Hence, it calculates the technical efficiency scores of individual farms from an efficiency frontier. Farms located on the frontier are considered technically efficient with a score of 1 (100%) and those located below the frontier are inefficient with a score below 1 (Heidari et al., 2011).
The DEA model chosen in this study focuses on inputs because farmers have more control over inputs than output (Coelli et al., 1998). Furthermore, this type of model offers greater flexibility since it does not require any a priori assumptions about the functional relationship of inputs and outputs. Initially proposed by Charnes et al. (1978), it is constructed as follows:

Maximize $$TE_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (1)$$

Under constraints $$\frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1 \qquad j = 1, \dots, n \quad (2)$$

$$u_r, v_i > 0 \qquad \forall\, r = 1, \dots, s;\ i = 1, \dots, m$$

Where:

- y_{rk} represents the quantity of output r produced by the farm k using m inputs to produce s outputs;

- x_{ik} is the quantity of the input i consumed by the farm k ; u_r is the weight of the output r ;

- v_i refers to the weight of the input i ;

- n is the number of farms to be evaluated;

- s and m represent respectively the number of outputs and inputs.

The inputs are: crop area; labour; amount spent on seeds; amount spent on pesticides; the amount spent on fertilizers; and amount spent on other production-related expenses. The output is captured through the farm's production and the turnover generated. The choice of these variables is justified, as noted by Binam et al. (2004) by the fact that they are generally used to estimate agricultural production frontiers in developing countries.
The Tobit model is then used to evaluate the impact of climate variables on the technical efficiency of farms. It is given by the following equation:

$$TE_i = \beta_0 + \beta_1 PSP_i + \beta_2 TSP_i + \beta_3 LSP_i + \beta_4 DSP_i + \beta_5 Sex_i + \beta_6 Age_i + \beta_7 Educ_i + \beta_8 Exp\_expl_i + \beta_9 OP_i + \beta_{10} ST_i + \beta_{11} Adapt_i + \beta_{12} Créd\_agri_i + \beta_{13} Rev\_non\_agri_i + \beta_{14} Sup\_expl_i + \varepsilon_i \quad (3)$$

Where:

- TE are the technical efficiency scores (between 0 and 1) obtained by the AED;

- PSP is a discrete variable representing precipitation;

- TSP are the average temperatures of the rainy season;

- LSP is the length of the rainy season;

- DDP is the start date of the rains;

- Sex is the gender of the head of the farm;

- Age represents the age of the farmer;

- Exp_expl captures the experience of the farmer;

- OP captures the farmer's membership in a peasant organization;

- ST is the degree to which the farmer is informed about good agricultural practices;

- $Educ$ represents the level of education of the farmer;

- $Adapt$ is a variable that informs whether the farmer uses a climate change adaptation technique or not;

- $Cr\acute{e}d$ informs on whether or not the farmer has access to credit;

- Rev_non_agri indicates whether or not the operator has a source of income other than farming;

- Sup_expl is the exploited area;

- ε is the error term.

1.2. Data

➢ Data source

The data used in the empirical analysis come from several sources and are all secondary data. The climatic data, namely rainfall amounts during the rainy season, rainy season temperatures, rainy season lengths, and rainy season onset dates, were obtained from the databases of several national and international organizations. These include the Department of National Meteorology (DNM), the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) and the National Oceanic and Atmospheric Administration (NOAA). These data cover the period from 1950 to 2020. They have been aggregated at the regional level. However, only data corresponding to the period representing the cropping season of each region were used in order to avoid possible biases in the results.

The data for the other variables are taken from the survey conducted by ONACC (2020) in the Adamawa, North, West and South regions, hence the choice of our field of study. It should also be mentioned that these regions are the only ones that have climate profiles developed by ONACC. They are also distributed in three of the five agro-ecological zones of the country. The ONACC survey was carried out randomly in the two major councils of each Department. After cleaning the survey forms, the sample comprised 793 family farms distributed as follows: 238 farmers in the Adamawa (Mbere Division), 233 in the North (Benue Division), 154 in the West (Noun Division) and 168 in the South (Dja and Lobo, and Villa Divisions). The selected Divisions are home to the major production basins of the targeted crops (groundnuts, corn and cassava for the Adamawa region; millet/sorghum, groundnuts and corn for the North region; corn, beans and tomatoes for the West region; and corn, cassava and cocoyams for the South region). These crops play an important role in the diet of local populations and in the trade of agricultural products.

➢ Measurement of variables

The variables of the efficiency score model are evaluated as follows: the area of production is expressed in hectares; labour is the number of people working on the farm per day; expenditures for the purchasing of seeds, plant protection products, fertilizers and other production-related expenses are expressed in thousands of CFA francs; the volume of production is evaluated in tons per hectare; and sales are measured in thousands of CFA francs. Table 3 below provides descriptive statistics for these variables.

Table 3: Descriptive statistics of inputs and outputs

	Variable	Observations	Average	Standard deviation	Minimum	Maximum
Inputs	Production area	793	2.77	2.18	1.2	14
	Labour force	793	4.74	2.15	1	16
	Spending on seeds	793	66353.98	154081.40	0	2352000
	Expenditure on plant protection products	793	49226.68	85638.92	0	720000
	Spending on fertilizers	793	54777.24	125354.30	0	1500000
	Other expenses	793	8511.24	23793.33	0	200000
Outputs	Production	793	5.83	7.07	0.01	62
	Sales	793	698774.40	1238358.00	0.05	1,00E+07

Data source : ONACC survey (2020)

For the Tobit model, the variables are measured as follows:

- TE are obtained by the DEA and are between 0 and 1;

- PSP is measured through the average rainfall accumulation of the rainy season (in mm);

- TSP is measured in degrees Celsius;

- LSP is the number of days between the start and the end of the rains;

- DDP is evaluated through the day of the year (from January 1st) when a successive number of_at least six days of rainfall is recorded, with a cumulative rainfall of more than 20mm on the first three days;

- Sex takes the value "1" if the farmer is male and "0" otherwise;

- Age takes the value "1" if the farmer is more than 30 years old and "0" otherwise;

- Exp_expl takes the value "1" if the farmer belongs to a farmer organization and "0" otherwise;

- ST takes the value "1" if the farmer receives technical support or information on good agricultural practices and "0" if not;

- $Educ$ takes the value "1" if the farmer has a primary education level, "2" for secondary, "3" for higher and "0" otherwise;

- $Adapt$ takes the value "1" if the farmer uses a climate change adaptation technique and "0" otherwise;
- $Créd$ takes the value "1" if the farmer has access to credit and "0" otherwise;
- Rev_non_agri takes the value "1" if the farmer has a source of income other than agriculture and "0" otherwise;
- Sup_expl is measured in hectares.

2. Results and discussions

2.1. Analysis of the technical efficiency of farms

Table 4 below shows the distribution of the number of farms and the summary statistics for the technical efficiency scores.

Table 4: Distribution of farms by technical efficiency scores

Technical efficiency scores	Global	Adamawa	North	West	South
[0 ; 0.2[	84	38	32	8	6
[0.2 ; 0.4[	372	121	123	60	68
[0.4 ; 0.6[	125	15	34	32	44
[0.6 ; 0.8[	65	15	23	15	12
[0.8 ; 1[	50	18	8	10	14
[1 ; 1.2[	97	31	13	29	24
Total	793	238	233	154	168
Average	0.46	0.43	0.40	0.51	0.46
Standard deviation	0.28	0.30	0.23	0.29	0.27
Min	0.15	0.15	0.15	0.17	0.15
Max	1	1	1	1	1

Data source: ONACC survey (2020)

Table 4 above reveals that the average level of total technical efficiency obtained for the 793 farms in the sample is 0.46 or 46% with a standard deviation of 0.28. In other words, with the same level of input used, these farms could improve the volume of their outputs by 54% averagely. This result indicates a relatively low average level of technical efficiency on the farms in the sample.

In addition, there is a very wide gap between the farms that determine the frontier and the others. In this respect, the minimum efficiency level in the sample is 0.15, while the maximum efficiency level (1) is only reached by 97 farms out of the 793 in the sample, i.e. less than 13% of the sample. The least technically efficient farm could increase its output by 85% while maintaining the same level of inputs.

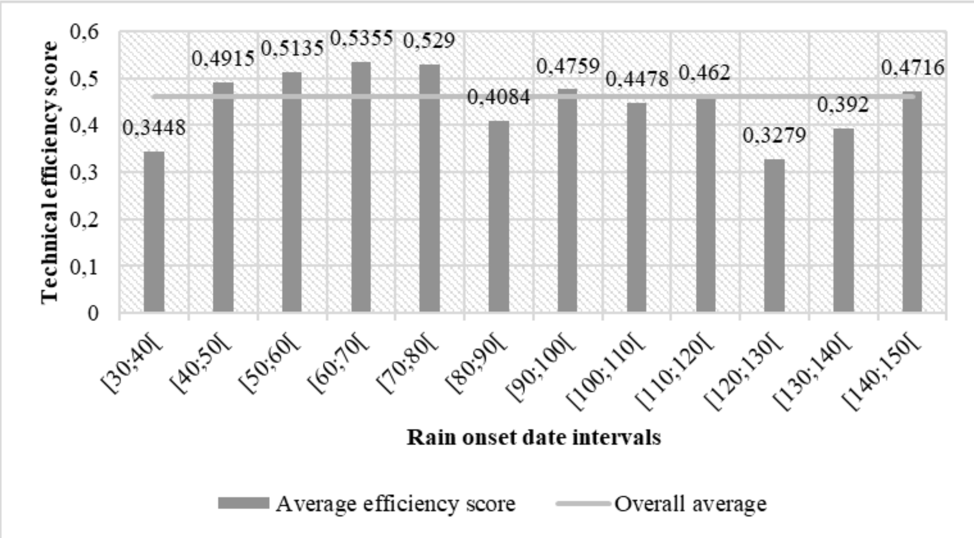
Finally, farms in the North region are less efficient compared to those in the other three regions. The West region has the highest average level of technical efficiency (0.51). The average efficiency scores are 0.43, 0.40 and 0.46 in the Adamawa, North and South regions respectively.

2.2. Analysis of the impact of climate factors on technical efficiency

2.2.1. Descriptive analyses

The correlation matrix (Appendix 1) indicates a negative and significant correlation at the 1% threshold between technical efficiency scores and the dates of the beginning of the rainy season (-0.15). This result is also confirmed by Graph 1 below:

Graph 1: Dates of rainfall onset and technical efficiency

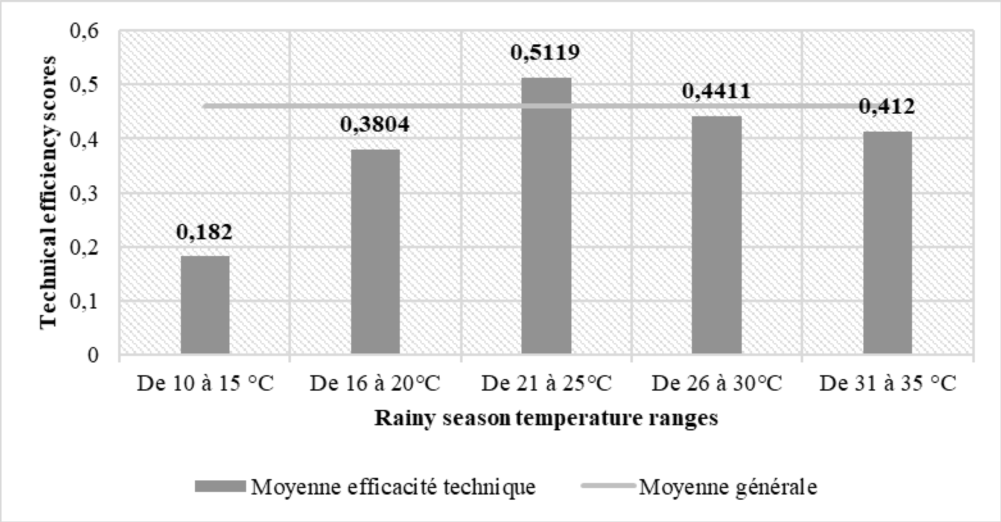


Data source: ONACC (2020)

Graph 1 above shows that farmers are on average more efficient when the rains begin in the first half of March, between the 60th and 70th days from January 1st. This is justified by the predominance in our study of regions whose rains begin most of the time in March (Centre, West, Adamawa). In addition, when the rains begin too early or late, the efficiency of the farms is less important on average than that of the farms experienced the beginning of the rains between the third dekad of February and the second dekad of March.

The correlation matrix also indicates a negative and significant correlation between temperatures during the rainy season and technical efficiency scores (-0.13). Low temperatures (between 10 and 20° Celsius) penalize technical efficiency, as do high temperatures above 30° Celsius, as illustrated in Graph 2 below:

Graph 2: Rainy season temperatures and technical efficiency



Data source: ONACC survey (2020)

Graph 2 shows that the optimum temperatures are around 20 and 30°Celsius, since it is at this range that we find the most efficient operations on average. The amount of rainfall is positively and significantly correlated with technical efficiency. This is not the case for the length of the rainy season, whose correlation, although positive, is not significant.
These results are complemented by those of the econometric analysis which are relatively more robust.

2.2.2. Econometric results

The results of the Tobit model estimation are presented in Table 5 below:

Table 5 : Tobit estimation results

Explanatory variables		Coefficient	Standard deviation	Z-Stat	P-value
Climatic variables	Rainy season precipitation	0.077	0.131	0.588	0.458
	Rainy season temperature	-0.090	0.035	-2.507	0.012
	Length of rainy season	0.036	0.062	0.595	0.551
	Beginning of the rainy season	-0.033	0.010	3.300	0.002
Adaptation to climate change	Adaptation of the agricultural calendar	Reference			
	Irrigation	-0.027	0.015	-1.854	0.047
	Intensive use of fertilizers	-0.052	0.021	-2.476	0.002
Socio-economic characteristics	Age (Under 45 years old)	-0.007	0.002	2.753	0.003
	Operator experience	0.096	0.011	8.515	0.000
	Surface area operated	0.036	0.006	6.003	0.000
	Farmers' organization (Yes)	0.064	0.024	2.607	0.009
	Sex (male)	-0.071	0.024	-2.866	0.004
	Technical support (Yes)	0.084	0.024	3.440	0.000
	No level	Reference			
	Primary level	0.027	0.026	1.024	0.168

	Secondary level	0.009	0.031	0.297	0.765
	Upper level	0.044	0.094	0.468	0.896
	Off-Farm Income (Yes)	-0.090	0.025	-3.630	0.000
Constant		0.676	0.065	10.291	0.000
General characteristics of the model					
Number of observations					793
Log likelihood					-415.475
LR Chi 2 (17)					178.51
P-value Chi2					0.000
Pseudo R^2					0.378
/sigma		21612.23	985.796		

Table 5 above shows that climatic disturbances (temperature, rainfall) have a negative and significant impact on the technical efficiency of the farms in our sample.Other things being equal, an increase of one degree Celsius decreases efficiency by an average of 0.09 or 9%. Similarly, a one-day delay in the onset of rains reduces technical efficiency by 3.3%. As for the amount of rainfall and the length of the rainy season, their positive impact on technical efficiency was not significant.

Farms that use climate change adaptation strategies are technically more efficient than those that do not. Indeed, the three adaptation strategies encountered during this survey, namely adjusting the agricultural calendar, intensive use of fertilizers and the use of improved field irrigation techniques, have a positive impact on the level of technical efficiency of farms. Adjustment of the agricultural calendar is more effective than irrigation and intensive use of fertilizers.

The negative sign of the coefficient assigned to the age of the farmer reflects the fact that this variable positively affects the technical efficiency of the farms in the sample. Thus, older farm managers are more efficient than younger ones. This result ties with those of Sibiko et al. (2013), and can be explained by the experience (learning by doing) of the older farmers in the agricultural activity. This experience is averagely more than 17 years in the sample. On the other hand, it is in contradiction with those obtained by Coelli and Fleming (2004). For the latter, younger farmers are more effective than older ones because they are more willing to integrate new technologies and popularization.

Membership in a farmer organization positively affects technical efficiency. In Cameroon, since the crisis of the 1980s, the State has encouraged farmers to organize themselves. This is the only way for farmers to benefit from government supervision, subsidies and advice (through programs such as PNVRA and ACEFA) as well as from NGOs. This result confirms the findings of the literature that community organization helps solve labour problems and access to credit, which are important factors in improving technical efficiency (Audibert et al., 1999; Helfand and Levine, 2004; Nuama, 2006).

With respect to gender, female farmers are more efficient than male farmers. likewise, more educated farmers are likely to be more efficient than their less or uneducated counterparts. Plausible reasons for a positive correlation could be their better skills, access to information, and good farm planning as shown by Coelli and Battese (1996) and Bravo-Ureta et al. (1997). However, our results indicate that the education level of the farm manager is not significant.

The cultivated area is positively and significantly related to the technical efficiency of farms. This indicates that there is room to increase the productivity of the farm.

Heads of households with another income generating activity are on average more efficient than those without. One might think that this activity generates additional disposable income that allows them to finance agricultural activities.

Conclusion and recommendations

We attempted to examine the impact of climate change on the technical efficiency of farms in four regions of Cameroon, namely: Adamawa, North, West and South. Not only are yields per hectare low, but these regions are increasingly witnessing a fluctuations in temperature and rainfall patterns as well as extreme occurrences (drought, floods, strong winds). Our contribution consisted in integrating into the analysis the climatic factors that can have an influence on technical efficiency, such as the date of the beginning of the rainy season and the length of the rainy season, as well as some adaptation strategies to climate change.

We used a two-stage methodology. The first stage focussed on the use of a DEA model to rate the technical efficiency scores of farms. The efficiency scores obtained were then used in a Tobit model to estimate the influence of climatic and other control variables on the technical efficiency of farms. The results reveal that the technical efficiency of farms is low overall (0.46). This efficiency is lower in the two regions of the North (Adamawa, North) than in the West and South regions, with the West region having the best technical efficiency score (0.51). On the other hand, disruptions in the start dates of the rainy season and the average temperature levels of the rainy season negatively and significantly impact the technical efficiency of farms. In addition, adjustment of the agricultural calendar, intensive use of fertilizers and the use of advanced irrigation techniques significantly improve technical efficiency and can thus constitute strategies for mitigating the adverse effects of climate change.

In light of the results obtained, some recommendations could be made to reduce the effect of the changes on agriculture and, in turn, on agricultural technical efficiency.

Actions to reduce climatic disturbances. Several actions will have to be undertaken in order to reduce temperature and seasonal variations that are detrimental to agricultural activities. Among others, we can mention: (i) the introduction of a high tax on the most polluting activities in Cameroon such as those related to the import of used vehicles and second-hand equipment (polluter pays principle), in order to increase their opportunity cost; (ii) the integration of a full-fledged teaching unit (with a high coefficient) on environmental preservation practices in all school and university curricula; and (iii) the fight against deforestation through the prohibition of the importation of non-manufactured wood packing, the multiplication of protected forest areas as well as the establishment of a national civic program called "*one citizen, one tree planted every month*".

Actions for the production and dissemination of climate forecast documents. In order to enable farmers to better plan their agricultural activities, for example, making shifts or selecting short-duration seeds according to weather forecasts; the political authorities must produce and disseminate reliable climate forecasting documents (climate forecasts, crop calendars, ten-day climate early warning bulletins). This includes the installation of meteorological stations in all strategic corners of the national triangle as well as the modernization of meteorological equipment in the cities that already have them. This is an extremely costly investment that the State can realize in a progressive way by relying on pollution tax. This tax will also make it possible to finance the large-scale dissemination of climate forecasts through local channels (community radios, community centres, traditional chieftainships, peasant organizations).

Actions for the production and use of organic fertilizers. We have seen above that the intensive use of fertilizers improves the technical efficiency of the sample farms. Given the availability of household waste and human and animal excrement, and in the interest of preserving the environment, the State must develop and implement a training program on techniques for producing fertilizers from organic waste. This training should be operationalized by relying on the technicians of the Ministry in charge of agriculture.

Finally, it is worth noting the limitations of our study.

- We did not include the amount of credit obtained by the farmer in the analysis. However, the possibility of obtaining a large amount of credit may be a determining factor in the acquisition of seeds or the adoption of advanced technologies.
- We did not take into account the possibility of polyculture. In reality, however, farmers tend to improve the technical efficiency of their farms by diversifying crops on the same plot.
- The study took into account 4 of the 10 regions of Cameroon. The study of the other 6 regions can help to highlight the similarities as well as the particularities of each region.
- Other coping strategies can be examined such as changing the type of crop, pooling resources at the group level, and changing the cropping technique.

These limitations may be the subject of future research.

References

Abatania L.N., Hailu A., Mugera A.W. (2012). Analysis of farm household technical efficiency in Northern Ghana using bootstrap DEA. In Proceedings of the 56th Annual Conference of the Australian Agricultural and Resource Economics Society, 33p.

Abdelradi F. & Yassin D. (2020). Climate Impact on Egyptian Agriculture: An Efficiency Analysis Approach. In Climate Change Impacts on Agriculture and Food Security in Egypt (pp. 603-624). Springer, Cham.

Akamin A., Bidogeza J.C., Minkoua N.J.R., Afari-Sefa V. (2017). Efficiency and productivity analysis of vegetable farming within root and tuber-based systems in the humid tropics of Cameroon. Journal of integrative agriculture, 16(8): 1865-1873.

Amara N., Romain R. (2000). Mesure de l'efficacité technique : Revue de la littérature. Série Recherche des cahiers du CREA. Centre de recherche en économie agroalimentaire. Faculté des Sciences de l'agriculture et de l'alimentation- Université Laval.

Amougou J.A., Abossolo S.A., Tchindjang M., Batha R.A.S. (2015). Variabilité des précipitations à Koundja et à Ngaoundéré en rapport avec les anomalies de la température de l'Océan Atlantique et El Nino. Revue Ivoirienne des Sciences et Technologie, 25 : 110-124.

Atkinson S.E., Christopher C. (1994). Parametric estimation of technical and allocative inefficiency with panel data. International Economic Review (1994): 231-243.

Audibert M., Mathonnat J., Nweyimana I., Henry M.C. (1999). The determinants of health care demand amongst the Senoufo of the Cote d'Ivoire. Health and System Science, 2 (12): 111-126

Bagamba F., Ruben R., Rufino M. (2007). Determinants of banana productivity and technical efficiency in Uganda. In Smale, M., and Tushemereirwe W.K. (Eds), An economic assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania, pp.109-128.

Banda, F. (2014). Le changement climatique en Afrique : Guide à l’intention des journalistes, Organisation des Nations Unies pour l’éducation, la science et la culture, 7, place de Fontenoy, 75352 Paris 07 SP, France.

Battese G.E., Coelli T.J. (1995). Un modèle pour les effets d'inefficacité technique dans une fonction de production de frontière stochastique pour les données de panel. Économie empirique, 20 (2), 325-332.

Bifarin J.O., Alimi T., Baruwa O.I, Ajewole O.C. (2010). Determinant of technical, allocative and economic efficiencies in the plantain production industry in Ondo State, Nigeria. Proceeding of International Conference on Banana & Plantain in Africa, Edited by Dubois T, et al. Acta Hort, 879:199-210.

Binam J.N., Tonye J., Wandji N., Nyambi G., Akoa M. (2004). Factors affecting the technical efficiency among smallholder farmers in a slash and burn agriculture zone of Cameroon. Food Policy, 29(5): 531-545.

Bravo-Ureta, B. E., Solís, D., Moreira López, V. H., Maripani, J. F., Thiam, A., & Rivas, T. (2007). Technical efficiency in farming: a meta-regression analysis. *Journal of productivity Analysis*, *27*(1), 57-72.

Charnes A., Cooper W., Rhodes E. (1978). Measuring the efficiency of decision making units. European Journal of operational Research, Elsevier, vol.2(6), 429-444.

Chiona S. (2011). Technical and allocative efficiency of smallholder maize farmers in Zambia. Master of Science Thesis in Agricultural Economics. University of Zambia, Lusaka.

Coelli T.J., Battese G.E. (1996). Identification of factors which influence the technical inefficiency of indian farmers. Australian Journal of Agricultural Economics, vol.40 (2), 103-128.

Coelli T.J., Fleming E. (2004). Économies de diversification et efficacité de la spécialisation dans un système de production mixte d'aliments et de café en Papouasie-Nouvelle-Guinée. Économie agricole, 31 (2-3): 229-239.

Coelli T.J., Rao D.S.P., Battese G.E. (1998). *An introduction to efficiency and productivity analysis*. Kluwer Academic Publishers, Boston.

Dontsi (1994). "La théorie HOS et le paradoxe de la situation des pays de l'Afrique au Sud du sahara", Revue Mondes en Développement, Vol. 22, No 86.

Ekou Nuama (2006). Mesure de l'efficacité technique des agricultrices de cultures vivrières en Côte d'Ivoire. Economie Rurale, vol.6(296), 39-53.

Farell M.J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society: Series A (General). vol.120(3), 253-281.

Heidari M.D, Omid M, Akram A (2011). Aplication of artificial neural network for modeling benefit to cost ratio of broiler farms in tropical regions of Iran. Research Journal of Applied Sciences, Engineering and Technology, 3 (6):546-522

Helfand S.M., Levine E.S. (2004). Farm size and the determinants of productive efficiency in the Brazilian Center-West. Agricultural Economics, 31(2-3): 241-249.

Jouve P. (1992). Le diagnostic du milieu rural : de la région à la parcelle. Approche systémique des modes d'exploitation agricole du milieu. In : L'appui aux producteurs. Paris : Ministère de la Coopération et du Développement.

MINADER (2020), Base de données sur la production agricole au Cameroun, Republic of Cameroon.

MINEPAT (2016). Stratégie de Développement du Secteur Rural : Le secteur rural, un important moteur de l'économie nationale. Republic of Cameroon, 84 pp.

Molua E.L., Lambi C.M. (2007) The Economic impact of climate change on agriculture in Cameroon. Policy research working paper series 4364, The World Bank.

Mukete N., Li Z., Beckline M., Patricia B. (2018). Cocoa production in Cameroon: A socioeconomic and technical efficiency perspective. International Journal of Agricultural Economics, 3(1): 1-8.

Mulwa R., Kabubo-Mariara J. (2017). Productive Efficiency and Its Determinants in a Changing Climate. A Monotonic Translog Stochastic Frontier Analysis. *Environment for Development Discussion Pape*r - Resources for the Future (RFF) 2017 No.17-06 pp.33 pp. ref.50

Nankap S. A. and Dontsi (2022). "Déterminants de la non-conformité des produits agricoles subsahariens aux normes internationales", *Revue Région et Développement*, *No 56.*

Njikam O. & Alhadji H.A. (2017). Technical efficiency among smallholder rice farmers: a comparative analysis of three agro-ecological zones in Cameroon. African Development Review, 29(1): 28-43.

Ogundari K., Onyeaghala R. (2021). The effects of climate change on African agricultural productivity growth revisited. Environmental Science and Pollution Research, 28: 30035-30045

ONACC (2020), *Base de données sur les changements climatiques*, République du Cameroun.

Singh A.K., Narayanan K.G.S., Sharma P. (2019). Measurement of technical efficiency of climatic and non-climatic factors in sugarcane farming in Indian states: Use of stochastic frontier production function approach. *Climate Change*, 5(19): 150-166.

Sibiko, K. W., Owuor, G., Birachi, E., Gido, E. O., Ayuya, O. I., & Mwangi, J. K. (2013). Analysis of determinants of productivity and technical efficiency among smallholder common bean farmers in eastern Uganda. *Current Research Journal of Economic Theory*, *5*(3), 44-55.

Tabe-Ojong Jr M.P., Molua E.L. (2017). Technical efficiency of smallholder tomato production in semi-urban farms in Cameroon: A stochastic frontier production approach. *Journal of Management & Sustainability*, 7(4): 27-35.

Thiam A., Bravo-Ureta B.E., Rivas T.E. (2001). Technical efficiency in developing country agriculture: a meta-analysis. *Agricultural Economics*, 25(2-3): 235-243.

UNCTAD (2021). *Trade and development, From recovery to resilience: the development dimension*, Report by the secretariat of the United Nations Conference on Trade and Development.

Vigh E., Ferto I., Fogarasi J. (2018). Impacts of climate on technical efficiency in the Hungarian arable sector. Studies in Agricultural Economics 120: 41- 46

Annexes

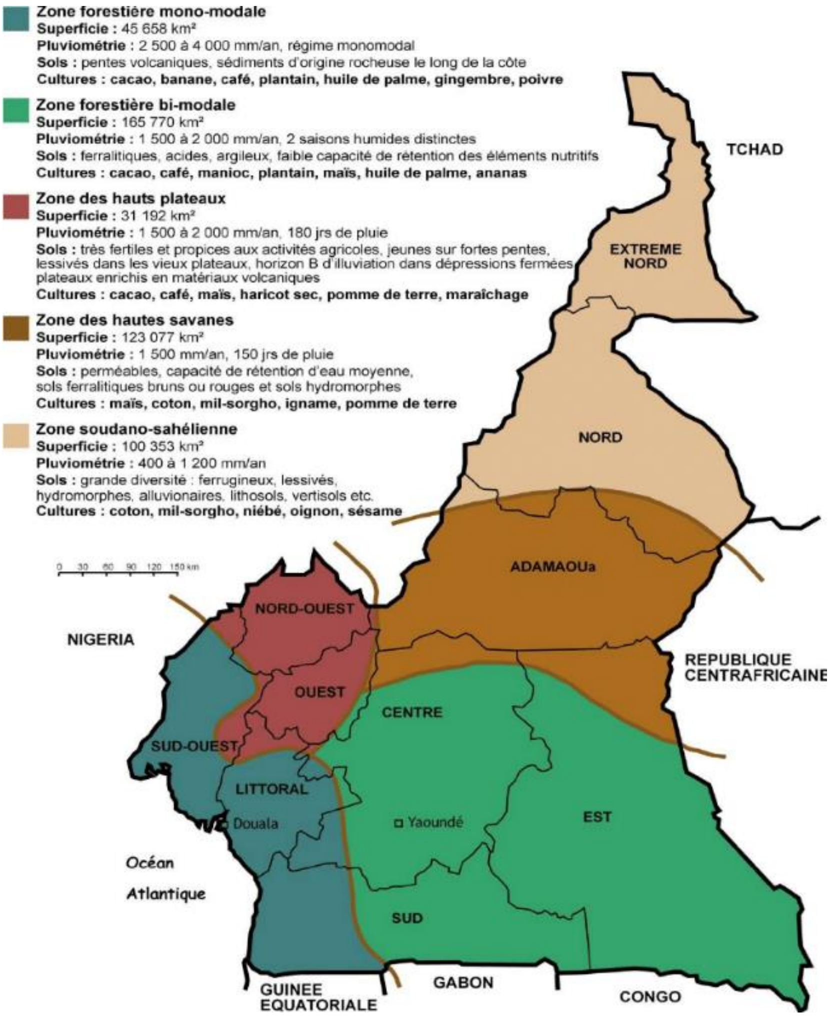
Table 2: Summary of studies analyzing the technical efficiency of small farms

References	Area/country studied	Sample	Efficiency factors	Inefficiency factors
Abdelradi and Yassin (2020)	Egypt	(Wheat, rice, corn)		The increase in maximum temperature and average humidity
Mulwa and Kabubo-Mariara (2017)	Kenya	3933 households from 22 districts	Increased rainfall, level of education, age of household head, membership in farming groups	Rising average temperatures, household size
Singh et al (2019)	India	Panel data at the level of 14 states of India during 1971-2014 (sugar cane)		Maximum temperature and minimum precipitation
Vigh et al (2018)	Hungary	Agricultural data for the period 2002-2013	Temperature increase during the seeding period (April, May and June)	The increase in temperature during the vegetative period (July and August), the decrease in the level of precipitation
Tabe-Ojong and Molua (2017)	Cameroon	80 tomato producers in the municipality of Buea in Cameroon	Education, age, adoption of agronomic techniques, area cultivated, amount of improved seed used	Proximity to the extension agent
Njikam and Alhadji (2017)	Cameroon	Survey data from 1141 Cameroonian smallholder rice farmers	The age of the head of the household, the increase in land ownership, the experience of the farmer, the distance of the plot from the village, and agricultural training.	
Akamin et al (2017)	Cameroon	71 farmers covering 8 villages	The distance of the plot from the village, agricultural training, gender (women), education level	The increase in farm size
Mukete et al (2018)	Cameroon			Aging cocoa trees and farmers, lack of adaptive capacity, lack of government subsidies and credit programs.
Ndiaye and Diallo (2022)	Senegal	2115 family farms covering 21 Divisions	Age, gender, land tenure, life span of materials, use of organic manure and plant protection	

			products, terrain	
Ndiaye (2018)	Maurice	200 randomly selected farmers	Gender of the farmer, area of land cultivated, and wages of the labor force	
Fawaz and Aminou (2021)	Benin	203 corn producers from 06 districts	Gender of the farmer, use of improved seeds, selling price, off-farm income, contact with an NGO, access to finance	

Annexes

Appendix 1: Agro-ecological zones of Cameroon

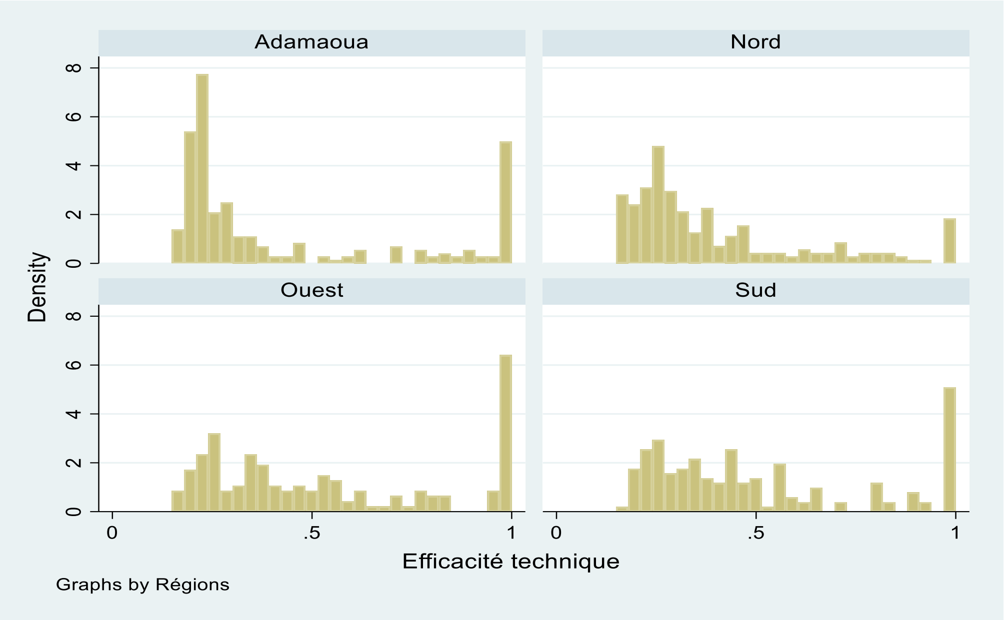


Source: ONACC (2015)

Appendix 2: Correlation matrix between technical efficiency score and climate variables

Correlation Probability	EFFICACITE...	DATE_DEB...	LONGUEU...	PRECIPITAT...	TEMPERAT...	SUPERFICI...
EFFICACITE_TEC...	1.000000 -----					
DATE_DEBUT_SA...	-0.159488 0.0000	1.000000 -----				
LONGUEURSAIS...	0.014493 0.6836	0.002429 0.9456	1.000000 -----			
PRECIPITATIONS...	0.061954 0.0812	-0.232990 0.0000	0.870424 0.0000	1.000000 -----		
TEMPERATURESA...	-0.133554 0.0002	0.584695 0.0000	-0.317839 0.0000	-0.505115 0.0000	1.000000 -----	
SUPERFICIE_EXP...	-0.321823 0.0000	0.529871 0.0000	-0.028880 0.4167	-0.188134 0.0000	0.339791 0.0000	1.000000 -----

Appendix 3: Distribution of technical efficiency scores of farms



Appendix 4: Mustache boxes