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ARTICLE

The Economic Profitability of Cereal Production Systems in the Context of Adaptation to Climate Change: the Case of Millet

Abdoul Azizou Oumarou Dan-Baki[1*] Mamane Tarno[2]

1 UFR/SEG of Ouaga 2 University of Burkina Faso
2 Faculty of Economic Sciences and Management, Abdou Moumouni University of Niamey, Niger

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ABSTRACT

This article studies the economic profitability of the millet production in a context of adaptation to climatic changes by considering the techniques of adaptation to soil protection, namely, low wall girdles tree and half-moon in order to determine their impact on the economic profitability of the production of this cereal.
The economic model of profitability developed by Gnanglé and al. [15] is used to analyze this effect. The data used in this paper is obtained from the ministry of agriculture of Niger (ECVM/A 2015) and consists of 3,985 households from two regions of Niger, namely, the Maradi and Diffa regions. The results show that the techniques of "belt of tree" and "half-moon" increase the economic profitability of the millet production and that the effects are, respectively, 0.19 and 0.054 in the two areas. The econometric results show that these techniques are profitable in both areas. Given the effectiveness of these techniques, this study suggests that producers increase these practices in order to mitigate the effects of climate change on the millet production in Niger. Lastly, the government must popularize these techniques and support their use for a better adaptation of agriculture in these zones to climate change.

1. Introduction

Cereals are the main sources of food in the world [1], of which more than 50% of the production come from the developing countries [2]. These crops are confronted to climatic challenges which make their productions unpredictable.

Niger is a sub-Saharan country in Africa where the basic foodstuff is mainly cereals (millet, sorghum, rice, etc.) and is characterized by a hot and dry climate [3]. Niger's geographical position exposes it to all kinds of natural shocks, especially with the threat of the fast expansion of the desert. This situation deserves to be analyzed carefully to find solutions adapted to these various climatic shocks.

Today, the impact of climatic change, especially on agricultural development, is the topic intense debate in the world and Sub-Saharan Africa is far from being spared [4]. It is a planetary problem which should be integrated in agricultural decision-making processes. Climatic change is generally characterized by an increase in the temperature and an irregularity of rainfall [5, 6]. According to Rwanyisiri and Rugema [7] the rise in temperature and the irregularity of rainfall cause an important decrease in rice productivity. To that issue are added a loss of biodiversity

**Corresponding Author:*
Abdoul Azizou Oumarou Dan-Baki,
UFR/SEG of Ouaga 2 University of Burkina Faso
Email: abdoulazizoumarou62@yahoo.fr

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and shifting seasons [8]. Climatic change, thus, has a negative impact on agriculture which is the main activity of the Sub-Saharan population [9]. These countries are most vulnerable to climatic change because of their low capacity of adaptation to it [10]. The latter causes a significant decrease in cereal output which in turn leads to chronic food insecurity.

Indeed, the proportion of households with great vulnerability increased in Africa by 7.8% between 2009 and 2013 [11]. This increase shows how climate change undoubtedly makes producers more vulnerable with no end in sight. To face these challenges, Jiri and al. propose the use of the techniques of adaptation to the climate [12].

Climate change is the result of multiple causes. Among these are increases temperature, a reduction in pluviometry, the irregularity of rainfall, and the impoverishment of the soil, to quote a few. Our research focuses on the last cause, that is, the impoverishment of the soil caused by erosion.

Erosion is defined as the impoverishment of the soil [13]. There are two categories of erosion, namely, wind erosion and hydrous erosion. Niger, which is ¾ desertic is plagued by hydrous erosion. This situation causes the loss of the fertility of the soil [14] and, consequently the fall of agricultural outputs. To face this major problem which threatens Niger's agricultural system, the adoption of techniques that mitigate the effects of climate change is necessary.

The great disaster caused by this natural plague and the techniques that producers use to mitigate it led us to raise the following research question:

2. Do the Techniques of Protection of Soil Increase the Economic Profitability of the Systems of Production of the Millet in the Areas of Maradi and Diffa?

The main objective of this research is to of analyze the economic profitability of the systems of cereal production in a context of adoption of the techniques of protection of the soil. It aims to determine the most effective techniques to attenuate the impoverishment of the soil. Specifically, this research has the followings goals:

(1) To analyze the effect of the techniques of protection of the soil on the economic profitability of cereals.

(2) To determine the sociodemographic characteristics influencing the economic profitability of the millet.

3. Methodology

In this section, we present the model of economic profitability in the form of a Cobb-Douglas function. This model is used by Gnanglé and al. [15] to analyze the economic profitability of Shea production systems in the context of climate change adaptation in northern Benin.

3.1 Specification of Model

The model of economic profitability can be written as follows:

$$\pi_i = e^{\alpha_0} SUP_i^{\alpha_1} LABOR_i^{\alpha_2} CAPI_i^{\alpha_3} \left(\prod_{k=1}^{m} ADAPT_{ki}^{\beta_k}\right) \left(\prod_{p=1}^{n} Z_{pi}^{\delta_p}\right) e^{\varepsilon_i} \quad (1)$$

Where π_i is the profit of producer i.

Re-expressing equation (1) in logarithmic form, we get:

$$\ln(\pi_i) = \alpha_0 + \alpha_1 \ln(SUP_i) + \alpha_2 \ln(LABOR_i) + \alpha_3 \ln(CAPI_i) + \sum_{k=1}^{m} \beta_k ADAPT_{ki} + \sum_{p=2}^{n} \delta_p Z_{pi} + \varepsilon_i \quad (2)$$

SUP_i = area in ha. $LABOR_i$ = familial labor in man/day; $CAPI_i$ = total quantity of capital used in FCFA (agricultural inputs. Market labor. Farm equipment. etc.). $ADAPT_i$ = Variables related to the strategies of adaptation to the climatic changes, and Z_{pi} = variables related to the social-economic, demographic and geographical characteristics of producer i.

The annual profit RN_j can be written as follows:

$$RN_j = PBV_j - CT_j = PBV_j - CV_j - CF_j \quad (3)$$

where PBV_j is gross product in value or total revenue. CV_j = the variable costs related to activity j; CF_j = Fixed costs related to the activity j.

From (3), the profit can be written as:

$$\pi_i = \sum_{j=1}^{n} RN_{ij} \qquad \text{with j = 1. 2. 3.... n} \quad (4)$$

The following section is related to the empirical model.

3.2 Empirical Model

We adapt this model in the following way:

$$\ln(\pi_i) = \alpha_0 + \alpha_1 \ln(SUP_i) + \alpha_2 \ln(LABOR_i) + \alpha_3 \ln(CAPI_i) + \sum_{k=1}^{3} \beta_k ADAPT_{ki} + \sum_{a=1}^{3} \partial_z MODAP_{zi} + \sum_{p=1}^{9} \delta_p Z_{pi} + \varepsilon_i \quad (5)$$

With $MODAP_i$ = mode of appropriation of the grounds and $z = 1, 2 \text{ and } 3$. Thus we have:

$$Lnprofit_i = \alpha_0 + \alpha_1 Lnarea_i + \alpha_2 Lnsize_i + \alpha_3 lncapi_i + \beta_1 lowwell_i + \beta_2 girdletree_i + \beta_3 halfmoon_i + \partial_1 ownland_i + \partial_2 hiredland_i + \partial_3 borrowland_i + \delta_1 status_i + \delta_2 gender_i + \delta_3 age_i + \delta_4 titledeed_i + \delta_5 credit_i + \delta_6 c_{vulga_i} + \delta_7 Diffa_i + \delta_8 Maradi_i + \delta_9 \text{educ}_i + \varepsilon_i \quad (6)$$

4. Zone of Study and Data

4.1 Zone of Study

Niger covers a surface of 1,267,000 km^2 and is populated of almost 20 million inhabitants of which 90% are farmers [3].

However. We specifically focused analysis on the area of Diffa and Maradi (see graph of Niger) because of the availability of the data. These two areas are located in the Southern band of Niger. The region of Maradi makes border with Nigeria and Diffa with Nigeria and Tchad. The main activity of the inhabitants of these areas is agriculture.

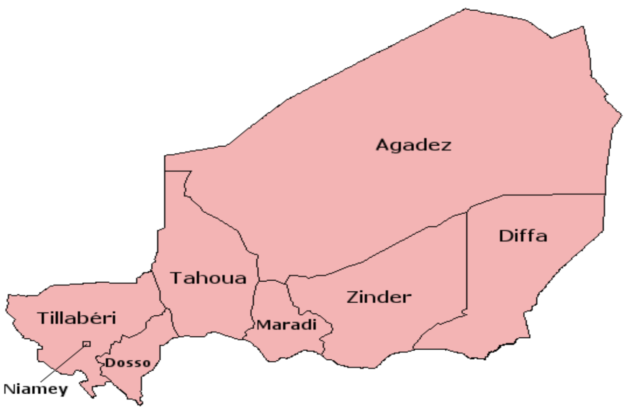

Figure 1. Graph of Niger

4.2 Data

The data used in this study is taken from the National survey of the Living conditions of Households and Agriculture (ECVM/A) of 2015. This database is compiled by the National Institute of Statistics (INS) of Niger with technical and financial assistance from the World Bank. It contains multiple variables which detail the life of the population of Niger in the year 2015. The sample size is 3,985 households for the two regions. Table 1 lists the variables used in this study.

3. Results

This part is divided into two sub-sections. The first sub-section presents the descriptive statistics of the variables of the model followed by the econometric results and the second sub-section interprets the empirical results.

3.1 Descriptive Statistics

The descriptive statistics are provided in the following table 2. These results show that most of the producers own their own land (90.31%) without land titles (94.35%) and are men (92.77%), married (92.67%), not well-educated (98.97%), and adopt the belt of trees (98.40%) technique. In the Maradi region, these owners are a majority (51.37%) without access to credit (65.47%) and have not had the

Table 1. List of variables

Variables	Variable Type	Code	Modality	Expected Signe
Net annual Profit (in fcfa)	Continuous	Profit	---	
Area (in ha)	Continuous	Area	---	+
Capital (in fcfa)	Continuous	Capi	---	+
Family labor (in men/day)	Continuous	Size	---	+
Matrimonial Status	Dummy	Status	0=not married. 1=married	+
Gender of the household head	Dummy	gender	0=female. 1=male	+
Age of the household head (in year)	Continuous	age	---	+
Education level	Dummy	educ	0=not well-educated. 1=well-educated	+
Own land	Dummy	ownland	0=no. 1= yes	+/-
Hired land	Dummy	hiredland	0=no. 1= yes	+/-
Borrowed land	Dummy	borrowland	0=no. 1= yes	+/-
Title deed	Dummy	titledeed	0=no. 1= yes	+/-
Low well	Dummy	lowwell	0=no. 1= yes	+
Girdle tree	Dummy	girdletree	0=no. 1= yes	+
Half moon	Dummy	halfmoon	0=no. 1= yes	+
Region of Diffa	Dummy	Diffa	0=no. 1= yes	+/-
Region of Maradi	Dummy	Maradi	0=no. 1= yes	+/-
Access to credit	Dummy	credit	0=no. 1= yes	+/-
Contact with vulgarization services	Dummy	c_vulga	0=no. 1= yes	+/-

Source: author from literature review

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visit of the vulgarization services (76.24%).

Table 2. Descriptive statistics of model's qualitative variables

Variables	Modality	Proportions
Matrimonial Status	Married	92.67
	Not-married	7.33
Gender of the household's head	Male	92.77
	Female	7.23
Instruction level	well-educated	1.03
	Not well-educated	98.97
Title deed	Yes	5.65
	Non	94.35
Land ownership	Own land	90.31
	Hired land	5.34
	Borrowed land	4.35
Technical adaptation	Low well	81.50
	Girdle tree	98.40
	Half moon	28.07
Region	Diffa	48.63
	Maradi	51.37
Access to credit	Yes	34.53
	No	65.47
Vulgarization	Yes	23.76
	No	76.24

Source : estimation of ECVM/A 2011 with STATA

The results of Table 3 show that the households are headed by individuals whose average age is 44 years and the average number of labor used by these households is 4.62 men/day. The average area used is 240.32 ha with an average capital of 23,033.58 FCFA.

Table 3. Descriptive statistics of quantitative variables

Variables	mean	minimum	maximum
Family labor (in man/day)	4.62	1	29
Area (in hectare)	240.32	2	241.5
Capital used (in FCFA)	23,033.58	1,600	300,000
Age of the household's head (in year)	44	15	98

Source: estimation of ECVM/A 2015 with STATA

The matrix of adoption of the techniques of protection of soil is presented in table 4 below.

It shows that the most adopted technique is the "low well" with a percentage of 98.40% (18.05% + 80.35%). Moreover, the most adopted combination of the two techniques of protection is the "low wall" and the "girdle trees" with a percentage of 80.35% of the total adoption. Thus, there is only 22.20% of the households which practice the three techniques at the same time and only 0.33% of them do not practice any techniques of protection of the soil. Then, 13.57% (0.12% + 0.85% + 12.60%) is the percentage of households adapting only one technique. Lastly, 63.90% (0.30% + 5.45% + 58.15%) indicates the percentage of households adapting two techniques.

Table 4. Matrix of adoption of the techniques of protection of soil

Half-moon	Low well and Girdle tree				Total
	No		Yes		
	No	Yes	Non	Yes	
No	13 (0.33)	34 (0.85)	502 (12.60)	2,317 (58.15)	2,866 (71.93)
Yes	5 (0.12)	12 (0.30)	217 (5.45)	885 (22.20)	1,119 (28.07)
Total	18 (0.45)	46 (1.15)	719 (18.05)	3,202 (80.35)	3,985 (100.00)

Proportion in brackets
Source: Author from ECVM/A 2015 with tab3way command on STATA

3.2 Econometric Results

The model is overall significant at the 1 percent level. Furthermore, the model's variables explain the net annual profit of the producers by 54%.

The results of the annual profit of the households by the method of ordinary least squares presented in table 5 show that the variables, capital used, family labor, matrimonial status, gender, age, own land, girdles trees, half-moon, regions (Diffa or Maradi) and contact with the services of the vulgarization are the main determinants of the level of annual profit of the households.

Table 5. Determinants of the net annual profit of producers

variables	Coefficient	t-stat
lnarea	-0.197	-1.45
lncapi	0.097***	6.85
Lnsize	0.176***	7.76
status	0.112*	1.68
gender	0.340***	5.03
age	0.003***	3.79
educ	-0.092	-0.67
ownland	0.089*	1.66
hiredland	0.051	1.49
borrowland	0.085	1.30
titledeed	0.076	1.19
lowwell	0.007	0.21
girdletree	0.190*	1.73
halfmoon	0.054*	1.75
Diffa	0.389***	7.61
Maradi	0.217***	7.12
credit	-0.006	-0.21
c_vulga	0.124***	3.71
constant	7.980***	10.22
Dependent Variable = Logarithm of net annual profit of producers		
Number of observation		3,957
F (18; 3,938)		22.79***
Prob> F		0.000
R-squared		0.54

*=significant at 10%. ***=significant at 1%
Source : estimation of ECVM/A 2015 with STATA

4. Discussion

This section discusses the variables used in the empirical estimations and their implications for our research.

4.1 Geographic Variables

The production of millet is profitable in the two areas (Maradi and Diffa) we study. The effects obtained are positive and statistically significant. These effects are of 0.217 for Maradi and of 0.389 for Diffa. These results imply that millet production is more profitable in Diffa than in Maradi. It can be explained by the fact that, the soil of Diffa is richer than that of Maradi which is almost sandy.

4.2 Social-economic and Technical Variables

The results show that the following characteristics of the households have a positive impact on the economic profitability of the production of millet in the two regions: gender (0.34), age (0.003), matrimonial status (0.112), contact with vulgarization services (0.124), land ownership (0.089), amount of capital used (0.097), and the quantity of family labor used (0.176). A farmer who fulfills these criteria or possesses these characteristics is more likely to produce more.

4.3 Technical Variables of Soil Protection

The variable "girdle tree" is statistically significant at the 10% level, implying that it positively impacts producers' annual profits. Specifically, our findings show that an increase of one unit in this variable causes the annual profit of the producer to increase by 19%. Thus, this technique leads to highly profitable production. Consequently, this technique should be encouraged in order to preserve the fertility of the soil because of its capacity of protection against erosion.

The technique of protection "half-moon" has a positive and statistically significant effect at the 10% level. The results show that if the variable half-moon increases by one unit, the annual profit of the producer increases by 5.4%. That proves that this technique increases the economic profitability of production of millet. However, this technique is less effective than the "girdle tree" approach.

These results of technical climate change adaptation align with findings of Jiri and al. [12]. They also confirm the beneficial effects of the proactive adaptation of climate changes reported by Smit and al. [16].

5. Conclusion and Recommendations

This study isolates the most profitable techniques among most practices of soil protection in the regions of Diffa and Maradi of Niger. An analysis of these techniques reveals that the application of the techniques "girdle trees" and "half-moon" in the two areas increases the annual net profit of the producers of millet. Consequently, these techniques are the protection of the soil in the two regions. The populations of these areas must practice these techniques with the aim of increasing their productivity.

Variables such as the amount of capital utilized, family labor, matrimonial status, gender of the household's head, age of the household's head, land ownership, "girdle trees", "half-moon", region (Diffa or Maradi), and the contact with the vulgarization services are the main determinants of the level of annual profit of the households.

Considering the impact of these techniques on millet production, we offer the following recommendations:

• Encourage the use of the techniques of "half-moon" and "girdle trees";

• Abandon or reform the technique of "low wall" in order to increase its effectiveness;

• Raise the awareness of the population on the importance of these techniques on the production;

• Conceive and implement large-scale investment projects in order to vulgarize these techniques.

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