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Original Paper

Economic Performance of Soil and Water Conservation Practicesin Burkina Faso

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Abstract

The continuous degradation of agroecosystems is a major concern for Sub-Saharan African countries, particularly Burkina Faso. To fight against this problem, various research projects and programs have implemented Soil and Water Conservation practices (SWC) in Northern Burkina Faso. The objective of this study was to assess the economic performance of stone rows, grass strips, zaï, filtering dikes, half-moons and agroforestry on agricultural production in this part of Burkina Faso. Stochastic Frontier Analysis was used to estimate SWC's technical efficiency. Results indicated that the cost for SWC construction did not influence white sorghum and pearl millet yield. However, an increase of 1% in the investment for SWC implementation results in a 0.42% increase in groundnut yield and 0.19% in cowpea yield. Although, the half-moon technique had a positive effect on the farmer's technical efficiency, the effects of stone rows, filtering dikes, zaï and grass strips were not significant. Given the tremendous efforts that farmers develop to implement these anti-erosion practices, one recommendation is that policy makers strengthen the technical, financial and equipment supports to farmers for efficient implementation of SWC techniques to ensure sustainability of agricultural production systems in Northern Burkina Faso.

Keywords

technical efficiency, Cobb Douglas function, production frontier, Yatenga Province, zaï, half-moons, stone rows, grass strips

1. Introduction

Burkina Faso, like most countries in Sub-Saharan Africa, is facing a continuous degradation of its ecosystem. In most situations, this degradation of ecosystems is cause stagnation or even a decrease in crop yields, biomass availability for livestock and the availability of ligneous and harvesting products (Palé et al., 2019a, 2019b).

In 2006, results from a study conducted by the Permanent Secretariat of the National Council for the Environment and Sustainable Development (SP/CONEDD) indicated that about 11% of the country's land was greatly degraded and 34% considered moderately degraded.

Factors affecting the land degradation are mainly the very strong human population grow and economic pressure, the use of unsustainable production practices such as no application of organic as well as mineral fertilizers, overexploitation of natural resources around cities and villages and low use of SWC practices. This leads to a shortening of fallow duration, a decrease in crop yields and a degradation of soil properties (Roose et al., 2017).

To fight against this degraded situation, SWC such as stone rows, grass strips, zaï, filtering dikes, half-moons and agroforestry (Figure 1) had been introduced in the Yatenga Province several decades ago in Northern Burkina Faso.

Fig. 1.1

Fig. 1.2

Fig. 1.3

Fig. 1.4

Fig. 1.5

Fig. 1.6

Figure 1. Some SWC Techniques Introduced in the Yatenga Province

Note. Fig. 1.1: Stone row (*Source*: Agrintalk, 2016); Fig. 1.2: Zaï (*Source*: SPONG, 2012). Fig. 1.3: Half-moons (*Source*: Souka, 2011). Fig. 1.4: Filtering dikes (*Source*: Rabdo, 2007); Fig. 1.5: Grass strip of *Andropogon gagnanus* (*Source*: Rabdo, 2007). Fig. 1.6: Agroforestry (*Source*: FAO, 2019).

After decades of SWC practice, the impact of these different techniques in terms of the level of adoption by farmers and the effects on crop yields and livestock production merit study. Literature indicated that little work has been done to assess the economic performance of the SWC techniques in the country (Da, 2008). Therefore, a study on the influence of these anti-erosion techniques on crop yields in Northern Burkina Faso particularly in the Yatenga Province was needed.

Through an econometric approach based on the estimation of production frontiers and the analysis of technical efficiency, the present study attempts to respond to the question of how the use of SWC techniques could improve the agricultural performance of farmers' productions in the northern Region of Burkina Faso. More specifically, the study aims to assess the effects of SWC techniques on farmers' efficiency.

2. Methodological Approach

2.1 Study Area

The survey was conducted in four villages in Yatenga Province with the capital Ouahigouya (13°35'00'North and 2°25'00'West) having a total population of 762,041 in 2019 (INSD, 2019). The four villages covered by the survey are Tougou, Bogoya, Aorèma and Ziga and are located 23, 5, 15 and 25 km from Ouahigouya (Figure 2). These villages have benefited from the SWC projects that enabled the introduction of SWC techniques, particularly stone rows, zaï, half-moons, filtering dikes, grass strips and agroforestry which were selected for the study.

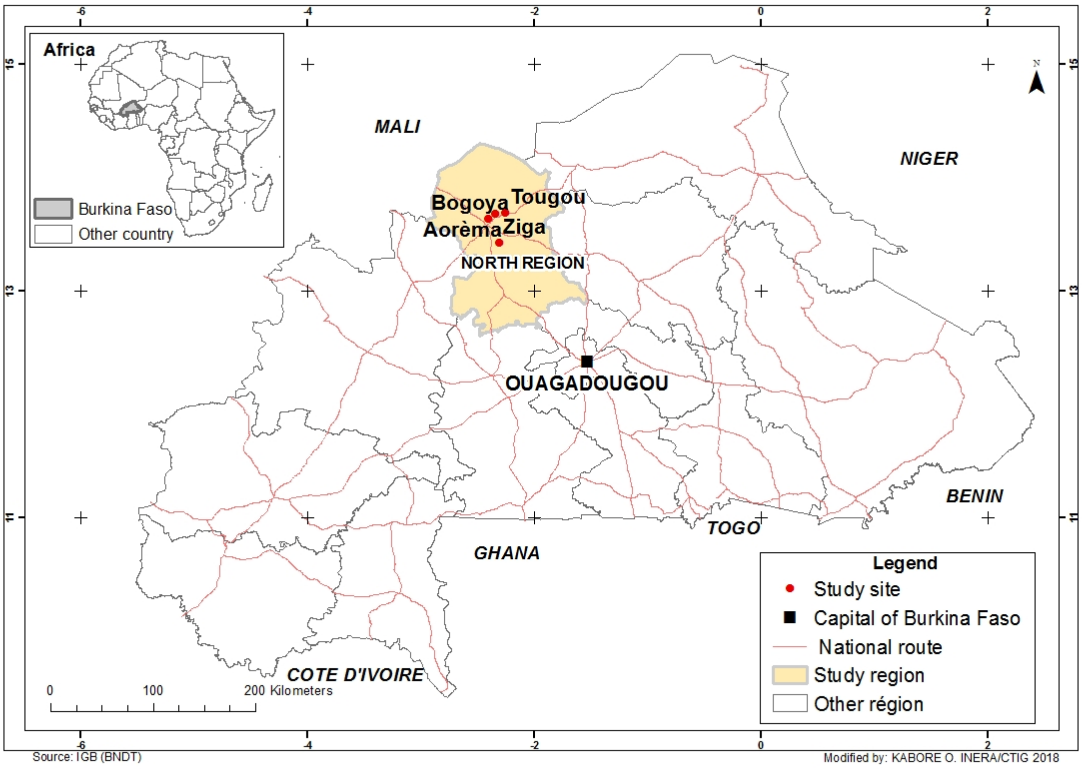

Figure 2. Map of Burkina Faso Showing the Province of Yatenga and the Four Survey Villages

Source: Geographic Institute of Burkina Faso (IGB); adapted by the Teledetection and Geographic Information Unit (CTIG) at the Institute of Environment and Agricultural Research (INERA), Burkina Faso, 2018.

2.2 Data Collection

The data were collected through a questionnaire and from farmers in the four villages covered by the survey. The unit of observation for this was each household and the respondent was the farmer, responsible of all decisions to be taken in farm management.

Due to the absence of a population data basis giving the list of all farmers practicing SWC techniques in the 4 villages, the sample size was set at thirty (30) farmers per village from different households. The choice of farmers was made taking into account criteria such as the diversity in village populations. An identification of farmers practicing SWC techniques was first carried out with the participation of Village Development Committees (VDC). The VDC helped divide farmers into three random groups. Thirty (30) farmers were selected from each of the 3 groups to give a representative final sample size of 120 total respondents.

The crop species used for the analysis were white sorghum [(*Sorghum bicolor* (L.) Moench)], pearl millet [*Pennisetum* glaucum (L.) R. Br.], cowpea [(*Vigna unguiculata* (L) Walp)] and groundnut (*Arachis Hypogaea* L.). These species were the main food crops in these four villages. Indeed, the survey showed that 95% are white sorghum farmers, 95% pearl millet farmers, 89% cowpea farmers and 75% groundnut farmers.

2.3 Data Analysis

Three categories of variables were selected for the model analyses: (1) output or production, (2) inputs, and (3) variables likely influencing farmer's efficiency. The inputs considered were the three basic factors of production: land, labor and capital (or cost of implementation). Fifteen (15) explanatory variables to technical efficiency were selected (Table 1).

Table 1. Summary of Explanatory Variables to Technical Efficiency

Variables	Nature	Definition
Sex	Qualitative	Farmer's sex taking the value 1 for male and 0 if not
Age	Quantitative	Age of farmer given in number of years
Level of education	Qualitative	Farmer's level of education set to 1 if educated and 0 if not
Use of stone rows	Qualitative	Use of stone rowsset to 1 if used and 0 if not
Use of filtering dikes	Qualitative	Use of filtering dikesset to 1 used and 0 if not
Use of zaï	Qualitative	Use of zaï set to 1 if used and 0 if not
Use of half-moons	Qualitative	Use of half-moons set to 1 used and 0 if not
Use of grass strip	Qualitative	Use of Grass strips to 1 if used and 0 if not
Use of combined SW techniques	Qualitative	Use of at least 2 SW techniques combined set to 1if used and 0 if not
Financial or Equipment support	Qualitative	Financial or Equipment support set to 1 if received and 0 if not
Cattle	Qualitative	Cattle set to 1 if bred and 0 if not
Training on SWCSDRSWC	Qualitative	Training on SWC set to 1 if received and 0 if not
Use of agroforestry	Qualitative	Use of Agroforestry set to 1 if used and 0 if not
Main Activity	Qualitative	Main activity set to 1 for farmer practicing only crop or livestock production, and 0 if practicing both activities
Member of farmer organization	Qualitative	Member of farmer organization set to 1 if member and 0 if not.

Source: Authors from the study.

Data analyses were performed Excel, Stata (Stata Corp LP, 2015), Text Mining with R (R Core Team, 2018) and SPSS software (IBM Corp, 2015). SPSS was used to confirm the tests performed with Stata.

2.4 Theoretical Approaches for Estimating the Production Frontier

Two methods were used to estimate the production frontier: the Stochastic Frontier Analysis (SFA) as a parametric approach (Aigner et al., 1977; Battesse & Coelli, 1995) and the Development Envellope Analysis (DEA) as a non-parametric approach. The choice between the two approaches must be based on one's knowledge about the technology of the sector studied (case of the agricultural sector for example), the estimation of production frontiers is preferable (Bosman & Frecher, 1992). Thus, based on literature (Bosman & Frecher, 1992) and the random nature of agricultural sector, the SFA approach being more appropriate for estimating production frontiers was used. The estimation of the production function parameters was based on the maximum likelihood method. Once the coefficients of the production frontier are estimated, the variances of the errors σ2 and γ are calculated according to equation 1.

Eq. 1: $\sigma^2 = \sigma_u{}^2 + \sigma_v{}^2 \text{ et } \gamma = \frac{\sigma_u{}^2}{\sigma_u{}^2 + \sigma_v{}^2}$,

where γ, an important estimate in the analysis of technical efficiency, represents the part of the deviation between the observed production and the potential production which is explained by the inefficiency of the farmer. A value of γ equals zero means that the deviation from the production frontier is entirely due to random factors (not dependent on the farmer); a value of γ equals 1means that the deviation from the production frontier is entirely due to the efficacity of the farmer.

The technical efficiency index (Tei) used to dissociate the contribution due to technical inefficiency from the purely random contribution in the term εi in the case of stochastic production frontiers (Jondow et al., 1982) is obtained from Eq. 2.

Eq. 2: $TEi = E(\exp(-ui|\varepsilon i) = \exp(-\mathrm{ui} + 0.5\, \sigma^2 *)\frac{\phi(\frac{ui}{\sigma *} - \sigma *)}{\phi(\frac{ui}{\sigma *})}$

The estimates of ui and σ* vary with the distribution of the term inefficiency:

If ui follows a semi-normal law then $\mathrm{u} * \mathrm{i} = \frac{-\sigma u^2 * \varepsilon i}{\sigma u^2 + \sigma v^2}and\sigma * = \frac{\sigma u^2 * \sigma v^2}{\sigma u^2 + \sigma v^2}$

If ui follows a truncated normal law then $\mathrm{u} * \mathrm{i} = \frac{\sigma v^2 * \mu - \sigma u^2 * \varepsilon i}{\sigma u^2 + \sigma v^2}$ et $\sigma * = \frac{\sigma u^2 * \sigma v^2}{\sigma u^2 + \sigma v^2}$

If ui follows an exponential law then $\mathrm{u} * \mathrm{i} = -\, \varepsilon i + \frac{\sigma v^2}{\sigma u^2}$ et $\sigma * = \sigma v$

2.5 Choice of Production Technology

The literature distinguishes two production frontier specifications: Cobb Douglas type function and Translog type function. The first one only gives the main effect of each single input on the output, while the second gives both main effect of each input and interaction effect of combination of inputs on the output. That's why, in the case of Cobb Douglas function, coefficients estimated can be interpreted directly. But, in the case of Translog function, partial elasticities (eki) obtained by Eq. 3 give better interpretations.

Eq. 3: $e_{ki} = \frac{\partial \text{ Ln } y_i}{\partial \text{ Ln } x_{ki}} = \beta_k + \sum_{l=1}^{m} \beta_{kl} \text{Ln } x_{li}$

Thus, interpreting the effect of the production factor xk on production y is done by interpreting the average effect of its partial elasticities obtained by equation 4 (Eq. 4).

Eq. 4: $e_k = \frac{1}{N}\sum_{i=1}^{N} e_{ki}$

The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were used to make a choice between Cobb Douglas and Translog production functions. The model using Cobb

Douglas function was the one that minimized the AIC and BIC criteria for white sorghum and pearl millet. So, Cobb Douglass production function was used for the white sorghum and pearl millet productions and Translog function which minimized the selection criteria and being more appropriate for estimating the production function of groundnut and cowpea was used for these two crops (Table 2).

Table 2. Selection Criteria for Cobb Douglas and Translog Functions

Model	AIC	BIC
White sorghum		
Cobb Douglas	309.48	367.31
Translog	442.59	511.43
Pearl millet		
Cobb Douglas	396.07	448.39
Translog	417.70	486.54
Groundnut		
Cobb Douglas	417.82	463.21
Translog	265.59	310.98
Cowpea		
Cobb Douglas	504	557.64
Translog	450.2	501.16

Note. AIC: Akaike information criterion; BIC: Bayesian information criterion.

Source: Estimates from Authors.

2.6 Empirical Model Presentation and Estimation Procedure

Based on the Battesse and Coelli model (1995), the empirical model described by Eq. 5.

$$Eq.5{:}Ln\ y_i = \beta_0 + \beta_1 \ln field\ size_i + \beta_2\ ln\ labor\ size_i + \beta_3 \ln SWC\ cost_i + 0.5 * \beta_{11} (\ln field\ size_i)\char`^2 + 0.5 * \beta_{22} (\ln labor\ size_i)\char`^2 + 0.5 * \beta_{33} (\ln SWC\ cost_i)\char`^2 + 0.5 * \beta_{12} \ln field\ size_i * \ln labor\ size_i + 0.5 * \beta_{13} \ln field\ size_i * ln\ SWC\ cost_i + 0.5 * \beta_{23} \ln labor\ size_i * \ln SWC\ cost_i + \mathrm{v_i} - \mathrm{u_i}$$

$$\begin{aligned} ui = {} & \delta 0 + \delta 1(\text{Sex}) + \delta 2(\text{Age}) + \delta 3\,(Farmer\ organisation) + \delta 4(\text{Main Activity}) + \delta 5\,(Education\ Level) \\ & + \delta 6\,(\text{Stone rows}) + \delta 7\,(\text{Filtering Dikes}) + \delta 8(\text{Zaï}) + \delta 9\,(\text{Half} - \text{moons}) \\ & + \delta 10\,(\text{Grass Strip}) + \delta 11\,(\text{Association of SWC}) \\ & + \delta 12\,(\text{Financial and Equipment Support}) + \delta 13\,(\text{Cattle}) + \delta 14\,(\text{Training}) \\ & + \delta 15\,(\text{Agroforestery}) + \mathrm{w_i} \end{aligned}$$

3. Results and Discussion

3.1 Estimation of Production Frontiers for White Sorghum and Pearl Millet

3.1.1 White Sorghum

For the white sorghum production, the value of γ estimated by the Cobb Douglas type function was 0.69 (Table 3) indicating a technical inefficiency for white sorghum farmer. This γ value also shows that the difference between the observed production and the potential production related to the frontier is explained by 69% of farmer's inefficiency. The fact that a white sorghum farmer does not produce maximum yield from the total amount of inputs used, is explained at 69% by his inefficiency and 31% by uncontrolled random effects. It is important to indicate that all the estimated coefficients of the production function are significant at the critical p-value of less of equal to 5%, except for the β3 coefficient associated with the total cost of SWC construction. In fact, 1% increase in field size leads to 0.61% increase in white sorghum production. Similarly, an increase of 1% in labor size led to an increase of 0.29% in white sorghum production. Thus, to increase their productions, white sorghum farmers have to increase their labor size and field size rather than increase the cost of SWC construction.

3.1.2 Pearl Millet

For pearl millet production, the value of γ estimated according to Cobb Douglas type function is 0.33 (Table 3). In other words, the fact that a white sorghum farmer is not located on the production frontier is explained at 33% by his inefficiency. As found in white sorghum production, the estimated coefficients for pearl millet are all significant at the critical p-value of less of equal to 5% with the except for the one associated with the cost of SWC construction. Thus, an increase of 1% in pearl millet field size results in 1.19% increase in pearl millet production; an increase of 1% in farm labor size leads to an increase of 0.59% in pearl millet production. Therefore, to increase their production, pearl millet farmers have to increase their field size or labor size.

Table 3. Cobb Douglas Stochastic Frontier Parameters Estimated Using the Method of Maximum Likelihood for White Sorghum and Pearl Millet Production

		White sorghum		Pearl millet	
Variable	Coefficient	F-Value	P-value	F-Value	P-value
Constant	β_0	5.93	0.000	4.48	0.000
Ln (Field size)	β_1	0.61	0.000	1.19	0.000
Ln (Labor size)	β_2	0.29	0.020	0.59	0.006
Ln (Cost of SWC construction)	β_3	0.0025	0.837	0.01	0.549
Variance parameters					
Variance	σ^2	0.66		0.60	
Gamma ratio	γ	0.69		0.33	
Log maximum likelihood		-133.74		-179.04	
Technical efficiency variables					
Constant	δ_0	-0.78	0.680	-1.63	0.013
Sex	δ_1	-1.30	0.057	-4.34	0.057
Age	δ_2	0.04	0.094	0.16	0.025
Member of farmer organization	δ_3	0.53	0.420	-0.53	0.620
Main activity	δ_4	-1.06	0.172	-1.29	0.334
Level of education	δ_5	1.74	0.020	-0.51	0.635
Use of stone rows	δ_6	0.11	0.911	-1.13	0.451
Use of filtering dikes	δ_7	-5.95	0.512	-1.10	0.638
Use of zaï	δ_8	-1.40	0.182	-0.93	0.494
Use of half-moons	δ_9	2.81	0.014	-3.44	0.828
Use of grass strips	δ_{10}	-1.19	0.393	0.19	0.891
Use of combined SWC techniques	δ_{11}	0.41	0.684	0.16	0.913
Financial and equipment support	δ_{12}	-2.03	0.016	-1.47	0.495
Cattle	δ_{13}	-2.42	0.008	-1.10	0.349
Training on SWC	δ_{14}	0.03	0.970	-0.96	0.520
Use of agroforestry	δ_{15}	0.77	0.291	-0.57	0.543
Model significance					
Number of observations	116			116	
Wald chi-square	29.95			1.02e+06	
P-value	0.000			0.0000	

3.2 Estimation of Production Frontiers for Groundnut and Cowpea

3.2.1 Groundnut

For groundnut production, the value of γ estimated is 0.20 depending on the Translog function used for the estimation (Table 4). In other words, the fact that a groundnut farmer is not located on the production frontier is explained at 20% by his inefficiency and 80% by uncontrolled random effects.

3.2.2 Cowpea

For cowpea production, the value of γ estimated is 0.55 depending on the Translog function used for the estimation (Table 4). In other words, the fact that a cowpea farmer is not located on the production frontier is explained at 55% by his inefficiency and 45% by uncontrolled random effects.

Table 4. Translog Stochastic Frontier Parameters Estimated Using the Method of Maximum Likelihood for Groundnut and Cowpea Production

		Groundnut		Cowpea	
Variables	Coefficients	F-Value	P-Value	F-Value	P-Value
Constant	β_0	3.91	0.214	3.03	0.187
Ln (Field size)	β_1	-2.05	.0.297	0.14	0.960
Ln (Labor size)	β_2	3.18	0.335	1.29	0.555
Ln (Cost of SWC construction)	β_3	-0.49	0.093	-0.01	0.946
Ln (Field size)^2	β_{11}	-3.08	0.038	-8.17	0.000
Ln (Labor size)^2	β_{22}	-2.04	0.237	-0.14	0.904
Ln (Cost of SWC construction)^2	β_{33}	0.041	0.205	-0.01	0.815
Ln (Field size) *Ln (Labor size)	β_{12}	2.95	0.001	1.02	0.671
Ln (Field size) *Ln (Cost of SWC construction)	β_{13}	0.36	0.034	0.81	0.016
Ln (Labor size) *Ln (Cost of SWC construction)	β_{23}	017	0.207	-0.05	0.631
Variance parameters					
Variance	σ^2	0.44		0.58	
Gamma ratio	γ	0.20		0.55	
Log maximum likelihood		-114.79		-206.10	
Technical efficiency variables					
Constant	δ_0	-2.42	0.211	-1.16	0.576
Sex	δ_1	-4.57	0.005	-3.70	0.000
Age	δ_2	0.15	0.000	0.19	0.000
Member of farmer organization	δ_3	-0.51	0.758	-1.38	0.705
Main activity	δ_4	0.29	.0.092	-2.01	0.184

Level of education	δ_5	-0.84	0.246	-0.53	0.536
Use of stone rows	δ_6	-1.36	0.544	-0.76	0.595
Use of filtering dikes	δ_7	0.72	0.191	0.32	0.883
Use of zaï	δ_8	-1.90	0.154	-1.10	0.452
Use of half-moons	δ_9	-2.50	0.420	0.17	0.123
Use of grass strips	δ_{10}	-0.22	0.950	-1.27	0.346
Use of combined SWC techniques	δ_{11}	0.16	0.932	-0.30	0.826
Financial and equipment support	δ_{12}	-0.66	.0.524	-4.58	0.128
Cattle	δ_{13}	-1.55	0.349	-0.88	0.332
Training on SWC	δ_{14}	-0.27	0.883	-1.28	0.885
Use of agroforestry	δ_{15}	-0.85	0.731	-0.21	0.465
Model significance					
Number of observations		92		108	
Wald statistics estimate (chi-square (3))		1.02e+06		1.28e+07	
P-value		0.0000		0.0000	

For better interpretations, in the case of Translog function, it's necessary to calculate the partial elasticities for each farmer. The average partial elasticities for groundnut are shown in Table 5. Table 5 indicates that an increase of 1% in the groundnut field size results in 5.46% increase in groundnut production; an increase of 1% in the farm labor size leads to 2.03% increase in groundnut production and that 0.42% increase in groundnut production occurs when the total cost of SWC construction was increased by 1%. The average partial elasticities for cowpea are shown in Table 5. Table 5 indicates that an increase of 1% in the cowpea field size results in 5.70% increase in cowpea production; an increase of 1% in the farm labor size leads to 0.98% increase in cowpea production and that 0.19% increase in cowpea production occurs when the total cost of SWC construction is increased by 1%.

Table 5. Average Partial Elasticities for Groundnut and Cowpea Production

	Groundnut	Cowpea
Field size	5.46	5.70
Labor size	2.03	0.98
Cost of SWC construction	0.42	0.19

3.3 Technical Efficiency Scores

All farmers therefore produce below the production frontier, which corroborates the existence of inefficiencies. The results from the calculation of technical efficiencies (Table 6) indicate that on average white sorghum farmers have a technical efficiency of 66%. In other words, these farmers produce on average 66% of the maximum possible production and lose 34% of their potential production due to their inefficiency and uncontrolled random effects. For pearl millet, results show an average technical efficiency scores of 61%. In other words, pearl millet farmers lose on average 39% of their potential production due to inefficiency. For groundnut and cowpea farmers, have an average technical efficiency of 74% and 49.5%, respectively. These average technical efficiencies indicate that these groundnut and cowpea farmers produce on average 74% and 50% of the maximum possible production, respectively.

Table 6. Farmers' Technical Efficiency (TE) Scores

Variable	Mean	Standard deviation	Minimum	Maximum
White sorghum TE	0.6574366	0.2524799	0.0009966	0.9824254
Pearl millet TE	0.6148428	0.2259154	0	0.9604982
Groundnut TE	0.7415643	0.2083064	0	0.971709
Cowpea TE	0.495104	0.2755447	0	0.9861348

After completion of the efficiency score analysis, it is important that the factors affecting the different technical inefficiencies be analyzed.

3.4 Factors Affecting Technical Efficiencies

Results from the analysis of factors that explain the level of technical inefficiency of white sorghum farmers (Table 3) indicate that only the coefficients associated with the farmer's education level, the use of half-moon technique, the financial and technical support received, and the breeding of cattle are significant at the critical p-value of less of equal to 5%. In other words, only these variables significantly influence the levels of inefficiency. Indeed, the fact of having received equipment by technical or financial support in combination of livestock production in the farm have a positive effect at the critical p-value of less or equal to 5%. In contrast, the education level of farmers and the practice of half-moons have a negative effect on the efficiency level of white sorghum farmers. For pearl millet farmers, only the coefficient associated with farmer's age significantly influenced farmers' technical efficiencies (Table 3). The positive sign of this coefficient indicates farmer's age has a negative effect on his technical efficiency. For groundnut and cowpea, only the coefficients associated with farmer's sex and age have a significant effect on technical efficiency (Table 4). Since the coefficients have the same sign, this indicates that being a man has a positive effect on the efficiency of groundnut and cowpea farmers. However, farmer's age has a negative effect on his technical efficiency.

4. Discussion

Results from the study show that no farmer is on the production frontier thus confirming the existence of technical inefficiencies in the farms in the villages of Tougou, Aorema, Bogoya and Ziga. However, it should be noted that, on average, groundnut farmers were the most efficient. Indeed, with an average technical efficiency score of 74%, they outperform compared to white sorghum farmers who have an average technical efficiency score of 66% and pearl millet farmers who have an average efficiency score of 61%. On average, cowpea farmers are the least technical efficiencies (49.51%). Compared to findings from Combary and Savadogo (2014) who indicated that except for cowpea farmers, white sorghum, pearl millet and groundnut farmers in the four study villages recorded higher technical efficiency levels than cotton farmers whose level in 2008 was about 60%. However, only groundnut farmers are more efficient than rice farmers in the Senegal River Valley and in small farms in Mauritius. Results from study conducted by Ngom et al. (2016) indicated an average technical efficiency of 70% for rice farmers in the Senegal River Valley and Ndiaye (2018) reported an average efficiency level of 72.6% for the small farm holders in Mauritius. From the conclusion reported by Audibert (1997) who indicated an average technical efficiency of 52% for pearl millet and white sorghum farmers in Mali, one can state that pearl millet and white sorghum farmers in the Northern Region of Burkina Faso have better efficiency scores.

The practice of SWC techniques has a mixed effect on the farmer's efficiencies. For white sorghum farmers, only half-moons practice has a significant effect farmer's efficiency at the critical p-value of less of equal to 5%. Indeed, coefficients corresponding to the practice of stone rows, filtering dikes, zaï and grass strips are all insignificant. The non-significant effect of filtering dikes on the technical efficiency of white sorghum farmers is contrary to the results from study conducted by Vlaar and Wesselink (1990) who found that filtering dikes increased white sorghum yields between 0.5 and 1.5 t ha^{-1}, with a larger increase in relatively dry years. Zougmoré (2003) also found that in good rainy season, the use of stone rows does not significantly improve yields. For pearl millet, groundnut and cowpea farmers, it is clear that none of the SWC techniques had a significant effect on the farmer's technical efficiency. SWC techniques were therefore not efficient since they did not have a significant positive effect on the farmer's efficiency. This result seems to contradict farmers' perception. However, it should be noted that farmers find the techniques more efficient compared to the fields where no SWC technique is applied, and argue that crop productions are improved with application of those techniques (Coulibaly, 2018). However, the model indicates that if the SWC techniques implemented in the village were efficient, then their application would result in higher crop yields. This contradictory result could also be explained by the fact that farmers were not trained enough to efficiently use the introduced SWC techniques.

In fact, the implementation of the SWC requires some technical level that can be ensured by training to improve farmers' capacities since most of them have a low education level. Results indicates that the age of white sorghum farmer does not influence his technical efficiency significantly. In contrast, for pearl millet, groundnut and cowpea farmers results indicate a negative effect of the farmer's age on his technical efficiency at the critical p-value of less of equal to 5%. One could think that older farmers who have more experience in farming be more efficient than youngers but unfortunately, they are not. Nevertheless, these results could be attributed to the continuous decrease in power for these old farmers whereas the construction of SWC techniques such as stone rows and particularly zaï, are very physical effort demanding. Therefore, in a situation of highly degraded soils, young farmers would be more efficient because they still have physical capacity to better implement SWC techniques. The level of education has a positive effect on the farmers' technical efficiency. However, for white sorghum farmers, the level of education affects negatively these farmers' efficiencies. White sorghum farmers with very low levels of education are more efficient than those with higher levels. In contrast, results indicate that pearl millet, groundnut and cowpea farmers' technical efficiencies are rather not influenced by the farmer's level of education. This result for white sorghum farmers seem a bit paradoxical and contrary to that of Coelli and Flemming (2004), as educated farmers are supposed to be those who have got high technical skills for using improved production techniques. However, Audibert et al. (1999) came to the same conclusion for farmers in Ivory Coast. According to these scientists, the higher educated farmers are more attracted by prestigious jobs and activities that provide rapid and high incomes than farming, thus they do not devote great time on agricultural activities (Nuama, 2010).

5. Conclusion and Involvement of Political Authorities

The objective of this research was to assess the economic performance of the SWC techniques in the Northern Region of Burkina Faso. To achieve this, the SFA approach was used to estimate production frontiers. Results show that no farmer is located on the production frontier. The analysis of production functions indicated that the cost of SWC implementation has a mixed effect on agricultural production. A 1% increase in the total cost of SWC construction leads to an increase of 0.42% in groundnut production and 0.19% in cowpea production. However, no significant effects are observed on white sorghum and pearl millet productions. The results also show that the combination of different SWC techniques by farmers does not have the same effects on the farmers' technical efficiency. Indeed, except for the half-moon practice that has a significant and positive effect on the technical efficiency of farmers, none of the other techniques including stone rows, filtering dikes, zaï and grass strips has influenced farmers' technical efficiencies. On the basis of these results, the authorities in charge of the making and implementation of agricultural policies should define appropriate training programs to enhance farmers' technical capacities, provide financial and equipment supports to farmers for an efficient use implementation of SWC techniques to ensure sustainability of their production systems.

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References

Agrintalk. (2016). *Technique de réalisation des cordons pierreux*. Retrieved June 15, 2018, from http://www.agrintalk.com/technique-realisation-des-cordons-pierreux/

Ahmadou, C., Ngom, B., Sarr, F., & Fall, A. A. (2016). Mesure de l'efficacité technique des riziculteurs du bassin du fleuve Sénégal (Estimating the technicalefficiency of ricefarmers in the Senegal River valley). *Économie rurale*, *355*(2016), 91-105. https://doi.org/10.4000/economierurale.5021

Aigner, D. (1977). Formulation and Estimation of Stochastic Frontier Production Functions. *Journal of Econometrics*, *6*, 21-37. https://doi.org/10.1016/0304-4076(77)90052-5

Audibert, M. (1997). Technical Inefficiency Effects among Paddy Farmers in the Villages of "Office du Niger", Mali, West Africa. *Journal of Productivity Analysis*, *8*(4), 379-394. https://doi.org/10.1023/A:1007767508848

Audibert, M., Mathonnat, J., Henry, J. M. C., & Nzeyimana, I. (1999). Rôle du paludisme dans l'efficience technique des producteurs de coton dans le nord de la Côte d'Ivoire (Effect of malaria in the technicalefficiency of cottonfarmers in Northern Ivory Coast). *Revue d'Économie du Développement*, *4*, 121-148. https://doi.org/10.3406/recod.1999.1010

Battese, G., & Coelli, T. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, *20*, 325-332. https://doi.org/10.1007/BF01205442

Bosman, N., & Frecher, F. (1992). Une étude comparative de l'efficacité technique du secteur de la santé au sein des pays de l'O.C.D.E (Comparative study of technicalefficiency in healthsector in the countries of O.C.D.E). *Working Paper*, *92/08*, CIRIEC, 13.

Coelli, T., & Fleming, E. (2004). Diversification Economies and Specialization efficiencies in a Combined Food and Coffee Smallholder Farming System in Papua New Guinea. *Agricultural Economics*, *31*, 229-239. https://doi.org/10.1111/j.1574-0862.2004.tb00260.x

Combary, S., & Savadogo, K. (2014). Les sources de croissance de la productivité globale des facteurs dans les exploitations cotonnières du Burkina Faso (Factorsinfluencing global growth of cottonproductivity in Burkina Faso). *Revue d'économie du développement*, *22*(4), 61-82. https://doi.org/10.3917/edd.284.0061

Coulibaly, Z. C. T. S. (2018). Technologies locales deconservation des eaux et des sols /défense et restauration des solset perception paysanne sur leurefficacité dans l'amélioration des productions agricoles dans laprovince du Yatenga au Burkina Faso. Mémoire de fin de cycle pour l'obtention du diplôme d'Ingénieur des Travaux Statistiques (ITS). In *Ecole Nationale dela Statistique et deL'Analyse Economique, Dakar, Sénégal* (p. 106).

CTIG (Cellule de télédétection et d'Information Géographique). (2018). Map of Burkina Faso showing the province of Yatenga and the four survey villages. In *CTIG, INERA* (p. 1). Burkina Faso.

Da, C. (2008). Impact des techniques de conservation des eaux et des sols sur le rendement du sorgho au Centre-nord du Burkina Faso (Impact of soil and water conservation techniques on sorghumyield in North-central Burkina Faso). In *Les Cahiers d'Outre-Mer. Revue de géographie de Bordeaux* (p. 15). https://doi.org/10.4000/com.3512

Dugué, P. (1994). Stratégies des producteurs et gestion des ressources naturelles en Afrique soudano-sahélienne (Farmers' strategies and naturalresource management in Sudano-Sahelian Zone of Africa). In *Cahiers de la Recherche-Développement* (pp. 73-84).

FAO (Food and Agriculture Organization of the United Nations). (2019). *Agroforestry*. Retrieved July 14, 2019, from http://fao.org/forestry/agroforestry/en/

Greene, W. (1980). Maximum likelihood estimation of econometric frontier functions. *Journal of econometrics*, *13*, 27-56. https://doi.org/10.1016/0304-4076(80)90041-X

IBM Corp. (2015). *IBM SPSS Statistics for Windows, version 23.0*. IBM Corp, Armonk, New York, USA.

INSD (Institut National de la Statistique et de la Démographie). (2019). *Annuaire statistique 2018 de la région du nord du Burkina Faso: Enquête conduite par l'INSD* (2018 statisticalyear-book for NorthernRegion of Burkina Faso:Surveyconducted by INSD, p. 270). INSD, Ouagadougou, Burkina Faso.

Jondrow, J. M., Knox Lovell, C. A., Materov, I. S., & Schmidtal, P. (1982). On the estimation of technical inefficiency in the Stochastic Frontier Production Function Model. *J. Econometrics*, *19*, 283-294. https://doi.org/10.1016/0304-4076(82)90004-5

Meeusen, W., & Van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production function with composed error. *International Economic Review*, *18*, 435-444. https://doi.org/10.2307/2525757

Mietton, M. (1981). Lutte antiérosive et participation paysanne en Haute-Volta (Controlling soilerosion with farmers' participation in Haute-Volta.). *Géo-Eco-Trop*, *5*(1), 57-72.

Ndiaye. (2018). Analyse de l'efficacité technique des exploitations agricoles familiales à l'Ile Maurice (Analyzing technical efficiency of small-holder farmers in Mauritius). In *SHS, LARES* (pp. 143-160). https://doi.org/10.19044/esj.2018.v14n9p143

Nuama, E. (2010). L'efficacité technique des riziculteurs ivoiriens: La vulgarisation en question (Technical efficiency rice farmers in Ivory Coast: Extension in question). In *Économie Rurale* (pp.

39-47). https://doi.org/10.4000/economierurale.2598

Palé, S., Sermé, I., Taonda, S. J. B., Ouattara, K., Mason, S. C., & Sohoro, A. (2019a). Sorghum and groundnut yields as influenced by tillage, cropping system and soil amendment in the Sudanian Agroecological Zone of Burkina Faso. *Journal of Agricultural Science and Food Technology*, *5*, 109-116.

Palé, S., Sermé, I., Taonda, S. J. B., Ouattara, K., Mason, S. C., & Sohoro, A. (2019b). Pearl millet and cowpea yields as influenced by tillage, soil amendment and cropping system in the Sahel of Burkina Faso. *International Journal of Sciences*, *8*, 56-64. https://doi.org/10.18483/ijSci.2136

R Core Team. (2018). *A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Rabdo, A. (2007). Inventaire des techniques de lutte anti érosive dans le degré carré de Ouahigouya au Burkina Faso. Université de Ouagadougou. In *Mémoire Online* (p. 15). Retrieved from https://www.memoireonline.com/12/13/8264/m_Inventaire-des-techniques-de-lutte-anti-erosive-dans-le-degre-carre-de-Ouahigouya-au-Burkina-Faso4.html

Roose, E., Zougmoré, R. B., Stroosnijder, L., Dugué, P., & Bouzou, M. I. (2017). Techniques traditionnelles de restauration de la productivité des sols dégradés en régions semi-arides d'Afrique occidentale. In Eric (Ed.), *Restauration de la productivité des sols tropicaux et méditerranéens: Contribution à l'agroécologie. Roose* (Marseille: IRD Éditions, pp. 491-517). https://doi.org/10.4000/books.irdeditions.24435

Souka, F. Y. (2011). La sécurité alimentaire dans la région du Centre Ouest du Burkina Faso dans un contexte de changements climatiques: Quelles stratégies d'adaptations pour la production agricole? In *We ADAPT* (p. 44). Retrieved from https://www.weadapt.org/placemarks/plain/view/630

SP/CONEDD (Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable). (2006). *Revue scientifique sur l'état de la dégradation des terres au Burkina Faso: Une étude réalisée dans le cadre du programme de gestion durable des terres* (Scientific review on the status of degradedsoil in Burkina Faso: Study conducted by the Sustainable Soil Management Programme, p. 115). Ouagadougou, Burkina Faso.

SPONG. (2012). Fiches techniques des bonnes pratiques de gestion durable des terres, d'adaptation aux changements climatiques et de conservation de la biodiversité. In *Programme de renforcement des Capacités des OSC* (p. 112). Union Européenne. Retrieved from https://fr.search.yahoo.com/search?p=SPONG+%282012%29.+Fiches+techniques+des+bonnes+pratiques+de+gestion+durable+des+terres/

Stata Corp, L. P. (2015). *Stata Statistical Software: Release 14*. College Station, Texas City, USA.

Stevenson, R. (1980). Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics*, *13*, 57-66. https://doi.org/10.1016/0304-4076(80)90042-1

Vlaar, J., & Wesseünk, A. (1990). *Aménagement de Conservation des Eaux et des Sols par Digues Filtrantes: Expérimentations dans la Région de Rissiam, Burkina Faso, 1986-1989. Tome 1:*

Aspects techniques et agronomiques (Soil and water conservation through filteringdike simple mentation. Experiments conducted in the Rissiam Region, Burkina Faso, 1986-1989. Volume 1: technical and agronomic aspects). Ouagadougou: WAU Wageningen/CIEH.

Zougmoré, R. B. (2003). *Integrated water and nutrient management fort sorghum production insemi-arid Burkina Faso* (Ph.D Thesis, p. 205). Wageningen University & Research, The Netherlands.