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# Effect of sustainable land management (SLM) measures disseminated by the climate change resilience through sustainable land management project on the economic efficiency of maize producers in the communes of Malanville and Kouandé in northern Benin

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**Soil degradation is increasingly becoming a problem for agricultural production due to poor production practices. The search for solutions to this phenomenon has led producers to adopt sustainable land management (SLM) strategies proposed by projects and programs. This study aims to evaluate the effect of SLM measures on the economic efficiency of maize producers who are beneficiaries of the Projet de Résiliences aux effets des ChangementsClimatiquespar la Gestion Durable des Terres au Nord Bénin (Project of Climate Change Resilience through Sustainable Land Management in Northern Benin PRCC-GDT). Economic efficiency was estimated using stochastic frontier models and dual cost function with the Cobb-Douglas specification, respectively. Socio-economic data were collected through a survey of a random sample of 152 producers, including 73 beneficiaries and 79 non-beneficiaries in the communes of Kouandé and Malanville. The results obtained show that pigeon pea, mucuna, soil fertility management, crop association, crop rotation, direct seeding, perpendicular plowing, the use of improved plants, and the use of drought-tolerant seeds are the measures most applied in maize production. The technical, allocative, and economic efficiencies are respectively on average 0.4419; 0.9887 and 0.4369 for the PRCC-GDT beneficiaries and 0.4110; 0.9887 and 0.4059 for the non-beneficiaries. Pigeon pea, crop rotation, mucuna, and the use of drought-tolerant seeds are the measures that ensure the economic efficiency of beneficiaries. Agricultural policies must be put in place to promote the adoption of SLM measures that are most effective in ensuring sustainable agriculture.**

**Key words:** Efficiency, sustainable management, maize production, Benin.

## INTRODUCTION

Most developing countries are seeing their population growth rates increase exponentially. As a consequence of this population growth rate, the demand for food products is increasing (Kendo, 2012). This excess demand for food products is heavily dependent on agriculture, which is the mainstay of Benin's economic development, accounting for 36% of gross domestic product (GDP), 88% of export earnings, and 15% of government revenue (Fawaz and Adéchinan, 2018). In this sector, food crops and vegetable crops are complementary and play a key role in food security with different functions. Cereal crops, particularly maize, are the most widely grown and consumed foodstuff in Benin after yams and cassava, far ahead of rice and sorghum (Aminou et al., 2018). Thus, the market garden production that accompanies these cereals in the diet of the population is a guarantee of food security and poverty reduction for households, especially women (Vodouhê and Davo, 2018). The importance of one or the other of these crops is no longer to be demonstrated on the economic and social levels. Given their importance, these two crops have been identified and retained by the Beninese government among the twelve priority sectors in the Strategic Plan for the Development of the Agricultural Sector (SPDAS, 2017). However, these crops have been vulnerable in recent years to the adverse effects of climate, which affect not only yields, but also soil fertility and the agricultural environment. The highly affected food and, vegetable crops, therefore, deserve special attention if Benin aspires to ensure food self-sufficiency (Katé, 2016; Azontonde, 2016). Several strategies were developed by producers to reduce the decline in soil fertility and increase yields in turn their income to improve their living conditions. These strategies combined, among others, tillage, short-term allow, the use of organic manure, and other initiatives such as improved fallow introduced by environmental protection projects and programs (Yabi et al., 2016). However, the adaptation methods that have emerged since the 1970s as the only alternative for reducing the vulnerability of rural populations have sometimes shown their limitations due to the lack of initial assessment (Tidjani and Akponikpe, 2012). The evaluation of SLM measures disseminated by the Climate Change Resilience Project on maize production is important in the promotion of the latter for possible improvement. Many studies focus on the effect of climate change adaptation strategies (Yegbemey et al., 2014) on the economic efficiency of maize farmers (Mamam et al., 2018; Fawaz and Adéchinan, 2018) and better on the economic profitability of SLM measures in maize production (Yabi et al., 2012). In contrast to these studies, this paper evaluates the comparative effect of SLM measures disseminated by the PRCC_SLM on the economic efficiency of maize producers to analyze the adequacy of these measures in improving agricultural yields in northern Benin.

## MATERIALS AND METHOD

### Study area

The PRCC_GDT project was tested in the communes of Kouandé and Malanville. These two communes are located respectively in the departments of Atacora and Albori. The commune of Kouandé is an area of high agricultural production and covers an area of 4,500 km$^2$. It belongs to an agro-ecological zone characterized by rainfall that varies between 900 and 1100 mm per year with a peak in August. The average temperature is 27°C with a harmattan regime, a cold and dry wind that blows between November and mid-March and sometimes causes a thermal amplitude of 9.5°C. The commune is endowed with soils that are not very developed and tend to be ferruginous, soils that are not very leached, and soils that are leached. There are ferralitic and ferrugino-tropical soils, but also lateritic soils and undergrowth soils are available in small areas in the northern zone of the commune. These soils are favorable for market garden crops such as chili, tomato, cabbage, lettuce, and onion (Figure 1). The commune of Malanville, extends between 11.5° and 12° latitude from North to South over 50 km and from East to West over 60 km. It covers an area of 3,016 km² of which 8000 ha are cultivable. The prevailing wind is the harmattan, which blows from November to January in all directions, with temperature varying between 16 and 25°C. The city is built on a sandy site that can be flooded in some places during the flood season. The upper bed of the Niger, which extends the city to the north, is a flat area where rice cultivation is developed. The soils in the commune of Malanville are mostly of the gneissic type, but in the Niger valley and its tributaries, one encounters sandy clay and ferruginous soils that are very favorable for market gardening (Kinhou, 2019).

### Sampling and data collection

The units of observation are the maize producers. In collaboration with the field facilitators, a list of the beneficiary and non-beneficiary producers by village was obtained. The study focused specifically on the villages of Guéné-centre, Goun-goun, Bodjécali and Monkassa in the commune of Malanville, and the villages of Kouandé-centre, Boré, Sékogourou and NiékénéBansou in the commune of Kouandé. In both communes, 152 producers were selected as beneficiaries and non-beneficiaries of the project. These lists served as the sampling frame. Next, simple random sampling was used to select 152 maize farmers in the two communes, 72 in Kouandé and 80 in Malanville. Thus, 73 beneficiary and 79 non-beneficiary producers were surveyed. The data collected are related to socio-economic characteristics (gender, age, level of education, etc.), producers, applications of SLM measures disseminated in the context of mitigating the effects of climate change in northern Benin, inputs, and outputs, production, are planted, etc. Data will be collected in November 2020 and analyzed using STATA 13 software.

### Theoretical model

Theoretically, several approaches have been debated in scientific research on the adoption of innovation dissemination, sustainable land management measures, and economic efficiency. In agricultural economics, the theory of efficiency has been applied to make efficient in the rational use of production factors (input) to maximize yield (output). The starting point for this theory is a large number of observations that have shown that firms with identical technical characteristics can have very large differences in production costs. This appears to be in complete contradiction with neoclassical theory. For the latter, the sole objective of all firms is to

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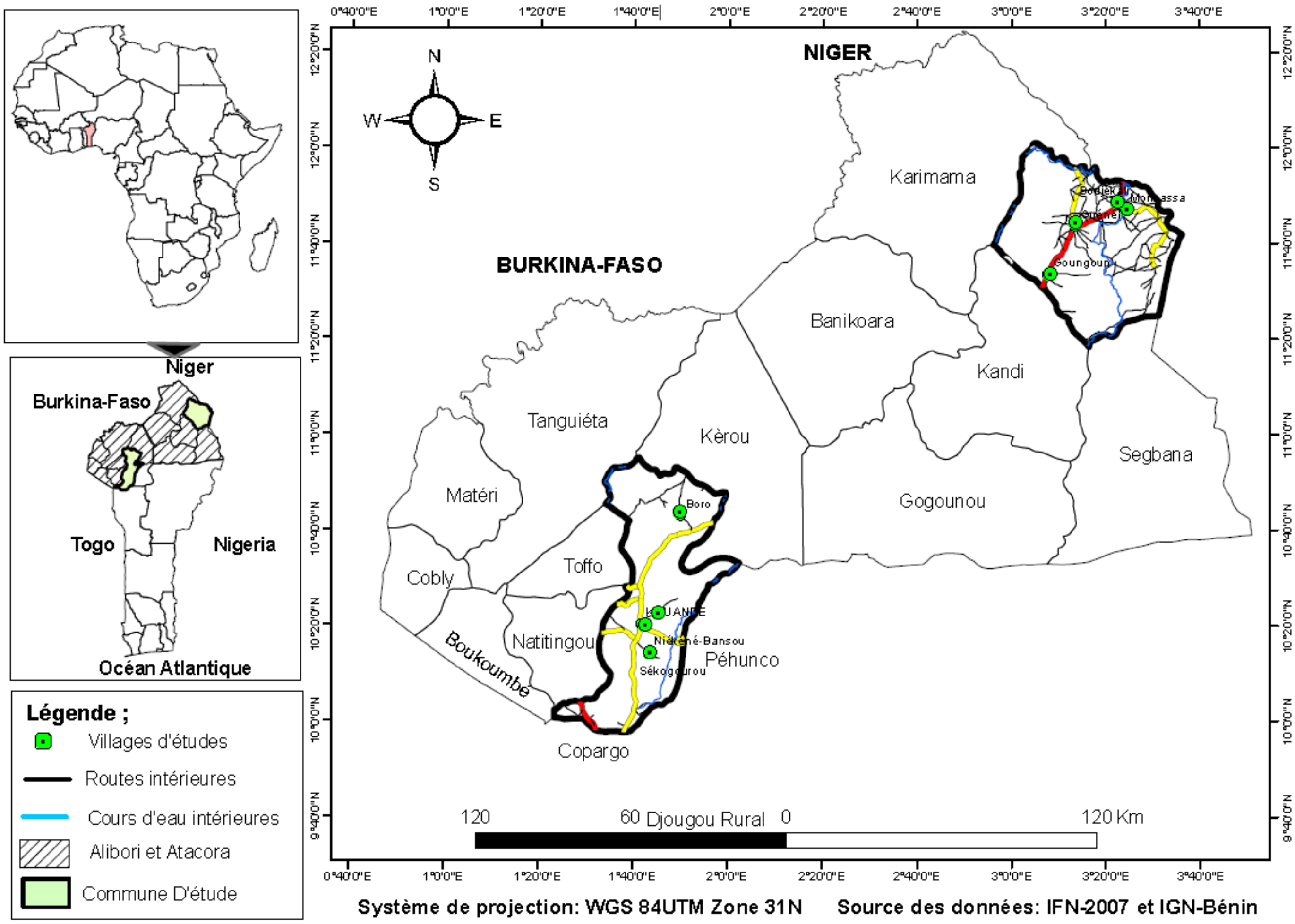


**Figure 1.** Study area.
Source: Study area

maximize their profit, which implies in particular the minimization of costs. To explain this contradiction, it is necessary to analyze not the firm but the individuals who compose it and whose rationality islimited in the sense of Simon who stipulates that the rational individual is and must be an organized and institutionalized individual (Simon, 1947). The neo-classical theory presents the economy as a competitive regime; the game of market entries and exits carries within it the mechanisms for restoring the competitiveness of firms. To maximize profit, farmers ensure an optimal allocation of their resources and an efficient use of production factors (Djimasra, 2009a). Thus, the farmers who do well are those who combine the factors of production in the best possible way (Ngasseu, 2013). Furthermore, with all the constraints associated with current farming, farmers will only be effective through the adoption of Sustainable Land Management measures and the division of innovations. Several authors have disseminated these innovations from process to practice. The model of the process of adoption and diffusion of innovations, which emerged in the 1960s, was subsequently modified and adjusted in the various editions of Rogers' book *Diffusion of Innovations* and his subsequent research. Rogers' sociologically based model initially focused on the diffusion of agricultural technological innovations and social innovations (Maddux and Rogers, 1983). Subsequently, Rogers' model has become an anchor for many researchers interested in the adoption and diffusion of any form of innovation, whether it is an innovative idea, a technical object, software, or technology.

Also, since the 1970s, climate change adaptation measures (TDM measures) have been the subject of propaganda in the agricultural world. The acceptance and adoption of these measures are partly related to the characteristics of producers (Cimmyt, 1993). Recently, several authors have promoted these SLM measures (Yabi et al., 2012; Biaou et al., 2016; Koudougou et al., 2017; Assogba et al., 2017). It is in this context that the Laboratory for Analysis and Research on Economic and Social Dynamics (LARESD) worked in 2018 to promote and support maize and vegetable farmers in the practice of SLM measures. To evaluate the effect of SLM measures on the economic efficiency of maize farmers, it was necessary to collect all the information deemed important. This information relates to socio-economic characteristics, the characteristics of cultivation techniques, production inputs and outputs, and the various sustainable management measures adopted. It should be noted that the calculation of work time was done by choosing the man/day as the basic unit. For this purpose, the weighting coefficients applied by the FAO were used. These coefficients are expressed in man/day equivalents. Thus, the working time of women is multiplied by 0.75; for children under 15 the coefficient is 0,5. Then, the working time in man/day is determined by dividing the total number of hours worked by 8 (one man/day is equivalent to 8 hours of work per day).

## Empirical model

### *Estimating the technical and allocative efficiency of corn farmers*

In the literature, there are several methods or approaches to evaluate the performance or economic efficiency of producers (Leibenstein,1966). In this paper, we illustrate the notion of efficiency through a production function. Let Q = f (K, L) be the production function of a firm with Q being the output, K and L being capital and labor, respectively. According to this author's definition, a firm is technically efficient when it is on the frontier of production possibilities, in other words, with a given quantity of factors, it obtains the highest level of production possible (Djimasra, 2009a). For this author, producer inefficiency is the type of inefficiency caused primarily by the misuse of resources on the farm. Leibenstein contrasts overall economic efficiency with the general process of resource allocation within the farm. According to Djimasra, (2009b) this theory differs from the views of classical economics, according to which for a given quantity of resource, the producer achieves optimal production, or by setting her level of production, she uses the minimum quantity of resource to achieve it. For the proponents of this theory, the productive inefficiency of a producer can be explained by several factors, but the main variable remains the effort, which is a function of the degree of motivation in effect in the operation. First, the technical, allocative, and economic, efficiency indices are estimated. The stochastic frontier approach is used. The Cobb-Douglas functional form is tested based on Fisher's F statistical tests of the likelihood ratio to choose the one that gives the best estimates. The first functional form gives the following model:

$$Ln(rendAi) = \alpha 0 + \alpha 1 Ln(qsemAi) + \alpha 2 Ln(qnpkAi) + \alpha 3 Ln(qureeAi) + \alpha 4 Ln(qherbAi) + \alpha 5 Ln(MOAi) + Vi - Ui \quad (1)$$

*Where, $i$: represents the corn producer $i$; qsem : the quantity of seed used (kg/ha); qnpk: the total amount of NPK used (kg/ha); quree: the total amount of urea used in (Kg/ha); qherb: the total amount of herbicide used in L/ha; MO: the total amount of labor used in man-days/ha; Rend: output;* A$i$: maize farmers $i$; Vi: random variables outside the control of the producers and are assumed to be independently and identically distributed according to a normal distribution of zero mathematical expectation and variance $\sigma^2 V[Vi \approx N(O, \sigma^2 u$ independent of the $U_i$ *s* $UiS$; Ui: are technical inefficiency random variables and are assumed to be independently and identically distributed as nonnegative random variables, obtained by truncation at zero, of the distribution of type $N(\mu, \sigma u^2)$ The $\alpha, \mu$ et $\sigma^2$ are the parameters to be estimated by the maximum likelihood method at the model level. These parameters are the coefficients of the production frontier whose residuals have been used to determine the technical efficiency indices and more precisely by the following formula defined by Coelli et al. (1998): $\exp(TEi) - Ui$

### *Estimation of allocative efficiency indices*

The stochastic frontier approach was used. The Cobb-Douglas functional form was tested based on statistical tests of the likelihood ratio to select the one that gives the best estimates.

The first functional form gives the following model:

$$Ln(CTAi) = \beta 0 + \beta 1 Ln(rendAi) + \beta 2 Ln(punqsemAi) + \beta 3 Ln(punqnpAi) + \beta 4 Ln(punqureeAi) + \beta 5 Ln(CFAi) + B6 Ln(punherbAi) + (Vi + Ui) \quad (2)$$

Where: $i$*: represents the corn producer* $i$; *-CT: represents the total cost of maize production in (FCFA/ha); -Physical production of corn (kg/ha); -punqsem: the unit price of corn seed in (FCFA/kg); -punqnpk: the unit price of the quantity of NPK in (FCFA/kg); -Punquree: the unit price of the quantity of urea in (FCFA/kg); -CF: the fixed cost of maize production (FCFA/ha).-punherb: the unit cost of the herbicide;* A$i$: maize farmers $i$;$Vi$: error term; $Ui$: allocative inefficiency term

The $\beta$, are the parameters to be estimated by the maximum likelihood method at the model level. These parameters are the coefficients of the production frontier whose residuals were used to determine the allocative efficiency indices and more precisely by the following formula defined by Coelliet al. (1998):

$$\exp(TEi) = -Ui$$

### *Estimation of economic efficiency indices*

Economic efficiency (EE) is therefore the product of technical efficiency (TE) and allocative efficiency (AE) given by the formula: $EE = ET * EA$

## RESULTS

## Socio-economic characteristics of producers

The majority of producers in the PRCC-GDT intervention zone are men (86.84% of those surveyed). It should be noted that 48.03% of the producers in the study area have benefited from the PRCC-GDT actions that is 9.59% of women and 90.41% of men (Table 1). The majority of producers are married (86.08% of non-beneficiaries and 90.41% of beneficiaries) and very few (8.55%) of them are single (6.85% of beneficiaries and 10.13% of non-beneficiaries). Table 1 shows that 22.37% of the producers surveyed had reached primary school level (23.29% of PRCC-GDT beneficiaries and 21.52% of non-beneficiaries), 15.13% had reached secondary school level that is 21.92% of beneficiaries and 8.86% of non-beneficiaries. Very few (1.32%) of the sampled producers have reached university level. The beneficiaries of the PRCC-GDT have achieved this level more than the non-beneficiaries (Table 1). In addition, 22.67% of producers can read and write in their local language, including 29.17% of PRCC-GDT beneficiaries and 16.67% of non-beneficiaries. Table 1 shows that the rate of producers who have benefited from agricultural credit is low (17.11%). PRCC-GDT beneficiaries have more access to credit (21.92%) than non-beneficiaries (12.66%). It should be noted that 48.68% of producers

**Table 1.** Summary of qualitative socio-economic variables of producers.

| Variable | Terms and conditions | Beneficiaries of the PRCC-GDT (%) | | | Chi 2 test |
|---|---|---|---|---|---|
| | | Non Beneficiaries | Beneficiaries | Total | |
| Gender | Male | 83.54 | 90.41 | 86.84 | $\chi^2$ = 1.565; ddl = 1; p= 0.211 |
| | Female | 16.46 | 9.59 | 13.16 | |
| Marital status | Single | 10.13 | 6.85 | 8.55 | $\chi^2$ = 0.819; ddl = 3; p=0.845 |
| | Divorced | 1.27 | 1.37 | 1.32 | |
| | Married | 86.08 | 90.41 | 88.16 | |
| | Widow(er) | 2.53 | 1.37 | 1.97 | |
| Level of education | No | 69.62 | 52.05 | 61.18 | $\chi^2$ = 8.405; ddl = 3; p=0.038 |
| | Primary | 21.52 | 23.29 | 22.37 | |
| | Secondary | 8.86 | 21.92 | 15.13 | |
| | Superior | 0.00 | 2.74 | 1.32 | |
| Literacy in local language (Reading and writing) | Yes | 16.67 | 29.17 | 22.67 | $\chi^2$ = 3.337; ddl =2; p=0.068 |
| | No | 83.33 | 70.83 | 77.33 | |
| Membership in a cooperative or group | Yes | 50.63 | 67.12 | 58.55 | $\chi^2$ = 4.251; ddl =1; p=0.039 |
| | No | 49.37 | 32.88 | 41.45 | |
| Access to agricultural credit | Yes | 12.66 | 21.92 | 17.11 | $\chi^2$ = 2.294; ddl =1; p=0.130 |
| | No | 87.34 | 78.08 | 82.89 | |
| Contact with tension service | Yes | 45.57 | 52.05 | 48.68 | $\chi^2$ = 0.638; ddl =2; p=0.424 |
| | No | 54.43 | 47.95 | 51.32 | |

Source : Field survey results(2020).

belong to a cooperative or an agricultural production group. Among these producers, 52.05% are beneficiaries of the PRCC-GDT and 45.57% are non-beneficiaries. Few (48.68%) of the respondents are in contact with an extension service. The beneficiaries of the PRCC-GDT (52.05%) are more in contact with one of the extension services than the non-beneficiaries (45.57%). The PRCC-GDT beneficiaries still have the support of other extension services such as the communal cells of the Territorial Agricultural Development Agencies (ATDA) and the members of the multidisciplinary teams of the Departmental Directorates of Agriculture, Livestock and Fisheries (DDAEP), NGOs, projects, etc. Table 2 presents the average age, experience, household size and a number of agricultural assets of maize producers who are beneficiaries of the PRCC project and non-beneficiaries of the sustainable land management in the face of climate change in northern Benin, The average age of beneficiaries is 41 years (±10.44) compared to 37 years (±10.39) for non-beneficiaries, Agriculture being the main activity of almost all research units (beneficiaries and non-beneficiaries), the experience in agriculture of beneficiaries is 11 years (±8.78 and 13 years (±9.55) for non-beneficiaries, the average household size for beneficiaries and non-beneficiaries is 8 persons respectively, the average number of agricultural workers is 5 persons respectively for beneficiaries and non-beneficiaries in their respective households, The average number of men and women in the households varies from one respondent to another (Table 2). For educated respondents, the average number of years of schooling is 2.62 (±3.73) years. This number of years for beneficiaries is higher than for non-beneficiaries (Table 2).Table 2 provides information on yields according to the crops grown on the areas planted by project beneficiaries and non-beneficiaries. Analysis of Table 2 shows that the average area sown to maize is 3.45 ha, that is 4.22 ha for beneficiaries and 2.73 ha for non-beneficiaries. The average maize grain yield obtained is 3298.47 kg/ha. The average yield of grain maize for beneficiaries (3596.06 kg/ha) is higher than that of non-beneficiaries (3023.49 kg/ha).

## Land management and climate change adaptation measures in maize production

In the implementation of the PRCC-GDT in northern

**Table 2.** Summary of quantitative socio-economic variables of producers.

| Variable | Beneficiaries of the PRCC-GDT | | | t-Student test |
|---|---|---|---|---|
| | Non-beneficiaries | Beneficiaries | Total | |
| Age | 37.17 (±10,39) | 41.27 (±10.44) | 39.14 (±10.58) | t = -2.42; ddl =150; p<0.001 |
| Total number of years of schooling | 1.64 (±2.64) | 3.68 (±4.41) | 2,625 (±3.73) | t = -3.48; ddl =150; p<0.001 |
| Experience in corn production and/or market gardening | 10.92 (±8,785) | 12.60 (±9.55) | 11.75 (±9.18) | t = -1.11; ddl =1; p= 0.13 |
| Number of men | 2.86 (±2.74) | 2.86 (±2.43) | 2.86(±2.59) | t = -0.005; ddl =150; p= 0.49 |
| Number of women | 2.07 (±1.51) | 2.41 (±2.02) | 2.23 (±1.78) | t = -1.15; ddl =150; p= 0.12 |
| Number of children | 3.012(±2.85) | 2,49 (±2.30) | 2.76 (±2.61) | t = 1.227; ddl = 150; p= t = 1.22 |
| Household size | 7.94 (±5.85) | 7,76 (±5.04) | 7.86 (±5.46) | t = 0.20; ddl = 150; p= 0.581 |
| Number of active men | 2.30 (±2.45) | 2,17 (±1.91) | 2.24 (± 2.20) | t = 0.35; ddl =150; p= t = 0.35 |
| number of working women | 1.51 (±1.38) | 1.78 (±1.48) | 1.64 (±1.43) | t = -1.12; ddl =150; p= 0.13 |
| number of active children | 1.24 (±1,90) | 0.78 (±1.73) | 1.02 (±1.73) | t = 1.58; ddl = 150; p= 0.94 |
| Household assets | 5.06 (±4.63) | 4.75 (±3.34) | 4.91 (±4.05) | t = 0.46; ddl = 150; p= 0.31 |
| Corn area (ha) | 4.229 | 2.737 | 3.453 | t = -1.802, ddl = 150, P= 0.036 |
| Corn yield (Kg/ha) | 3596.063 | 3023.49 | 3298.476 | t = -0.657, ddl = 150, P= 0.255 |

Source: Field survey results (2020).

**Table 3.** Rate of implementation of measures disseminated by the PRCC-GDT in Malanville and Kouandé.

| Land management and climate change adaptation strategies | The study area (%) | | | $Chi^2$ test |
|---|---|---|---|---|
| | Kouandé | Malanville | Total | |
| Use of Mucuna | 93.33 | 5000 | 68.06 | $\chi2$ = 15.11; ddl = 1; p<0.01 |
| Crop association | 93.75 | 100.00 | 97.33 | $\chi2$ = 2.76; ddl = 1; p= 0.09 |
| Crop rotation and crop rotation | 90.00 | 100.00 | 95.83 | $\chi2$ = 4.38; ddl = 1; p= 0.03 |
| Crop residue management | 63.33 | 97.62 | 83.33 | $\chi2$ = 14.84; ddl = 1; p<0.01 |
| Pigeon pea | 100.00 | 97.62 | 97.62 | $\chi2$ = 1.46; ddl = 1; p= 0.22 |
| Semi-direct | 100 | 100 | 100 | No test |
| Perpendicular ploughing | 100 | 100 | 100 | No test |
| Installation plowingeaks | 16.67 | 2.38 | 8.33 | $\chi2$ = 6.28; ddl = 1; p= 0.043 |
| Use of improver plants | 58.54 | 97.96 | 80.00 | $\chi2$ = 21.68; ddl = 1; p< 0.01 |
| Confession of the filtering dikes | 0.00 | 10.00 | 5.88 | $\chi2$ = 2.97; ddl = 1; p= 0.08 |
| Forage plot | 0.00 | 95.24 | 55.56 | $\chi2$ = 64.32; ddl = 1; p< 0.01 |
| Use of cow's purse | 6.67 | 100.00 | 61.11 | $\chi2$ = 64.14; ddl = 1; p< 0.01 |
| Organic manure | 6.67 | 0.00 | 2.78 | $\chi2$ = 2.88; ddl = 1; p= 0.09 |
| Use of drought tolerant seeds | 65.85 | 93.88 | 81.11 | $\chi2$ = 1.56; ddl = 1; p= 0.21 |
| making and spreading of compost | 26.83 | 4.08 | 14.44 | $\chi2$ = 11.44; ddl = 1; p<0.01 |
| Spreading seedlings | 0.00 | 16.33 | 8.89 | $\chi2$ = 7.34; ddl = 1; p< 0.01 |

Source: Field survey results (2020).

Benin, several Sustainable Land Management (SLM) and Climate Change Adaptation (CCA) measures are disseminated to beneficiary producers. Table 3 provides information on the rate of application of the measures disseminated by the commune. Table 3 shows that the beneficiaries of the PRCC-GDT in the commune of Malanville have applied the techniques of crop association (100%), crop rotation (26.60%), crop residue management (97.62%), the use of improving plants (97,96%), the use of filtering bunds (10%), the installation of fodder plots (95.24%), the use of cow dung (100%), the use of drought-tolerant seeds (93.88%) and sowing (16.33%) than the beneficiaries in the commune of Kouandé. On the other hand, techniques such as the use of mucuna (93.33%), pigeon pea (100%), the installation of windbreaks (16.67%), the spreading of organic fertilizer (6.67%), and the making and spreading of compost (26.83%) are more widely applied by

**Table 4.** Estimation of the parameters of the stochastic corn production frontier.

| Variable | Coefficients | Standard errors |
|---|---|---|
| Quantity of seeds (Kg/ha) | 1.502359*** | 0.1114023 |
| Amount of NPKA (Kg/ha) | 0.4448168*** | 0.0783336 |
| Quantity of urea (Kg/ha) | -0.1598779** | 0.082001 |
| Quantity of cow dung (Kg/ha) | 0.2826007*** | 0.0794921 |
| Total amount of herbicide (L/ha) | -0.543025*** | 0.1551661 |
| Amount of selective herbicide (L/ha) | 0.0516015 | 0.097328 |
| Quantity of labor (h,d) | -0.3133276 | 0.0998305 |
| constant | 2.638332 | 0.3853705 |
| /lnsig2v ($\sigma_v^2$) | 0.2645959 | 0.1824795 |
| /lnsig2u ($\sigma_v^2$) | 0.8460649*** | 0.3038478 |
| sigma_v ($\sigma_v$) | 1.141448 | 0.1041454 |
| sigma_u ($\sigma_u$) | 1.526584 | 0.2319246 |
| sigma2 ($\sigma^2$) | 3.633363 | 0.5703644 |
| Lambda (λ) | 1.337409 | -0.3130653 |
| Number of observation | | 255 |
| Wald chi2(7) | | 1210.22*** |
| Prob>chi2 | | 0.0000 |
| Log-likelihood | | -457.24946 |
| Likelihood-ratio test of sigma_u=0: chibar2(01) | | 6.88 |
| Prob>=chibar2 | | 0.004 |

Source : Field survey results(2020).

beneficiaries in the commune of Kouandé than those in the commune of Malanville. It should be noted that the "perpendicular plowing and direct seeding" techniques are applied by all PRCC-GDT beneficiaries in both communes (Table 3).

## Effects of applied measures on the economic efficiency of producers

### *Estimating the efficiencies of corn producers*

The analysis of technical efficiency shows that the model is globally significant ($p< 0.01$). However, the efficiency terms follow a truncated normal distribution since μ is not statistically different from zero. The presence of technical inefficiency or not was analyzed through the efficiency parameter γ. Which parameter γ (ratio of σ^2 and σ_u) that measures the contribution of the error due to economic inefficiency (γ) is estimated to be 0.6414. This indicates that 64.14% of the variation in the quantities of maize production inputs introduced into the model is due to the allocative inefficiency of producers and 35.96% of this variability is then attributed to random factors (Table 4). From this, the variation in observed quantities of maize production is partly due to producer inefficiency effects. Thus, resources are not well allocated in terms of price in the maize production systems in our study area.

Variables such as quantities of seeds, NPK, and cow dung are significant and positive at the 1% level. While the quantities of total herbicides and family labor are negatively significant at the 1% level and the quantity of urea is also significant and negative at the 10% level. Thus, maize farmers in the study area are 99.96% efficient in optimizing maize production quantities. The resources are very well allocated taking into account their quantity in the market gardening production systems in our study area. It can therefore be concluded that an increase in the quantities of seed, NPK, and cow dung by 1% increases the technical efficiency of maize producers by 1.50; 0.44; 0.28 respectively. On the other hand, an increase in the quantities of urea, total herbicide, and family labor by 1% decrease the technical efficiency of maize producers by 0.159; 0.543; and 0.31 respectively. This shows that variations in the quantities of inputs such as the total herbicide, urea, and labor negatively influence the use that producers make of these inputs. Table 5 shows the average technical, allocative, and economic efficiencies of producers by status in the study area. The comparison test used to compare the average efficiency reveals that the average technical efficiency scores of maize producers are 0.41 and 0.44 for non-beneficiaries and beneficiaries of the PRCC-GDT respectively. The average allocative efficiency scores of

**Table 5.** Average scores of the efficiency parameters.

| Efficiency parameter | Categories of producers | | | Test of t-student |
|---|---|---|---|---|
| | Beneficiaries | Non-beneficiaries | Set | |
| Allocative efficiency | 0.9886959 (0.000103) | 0.9886935 (O.0000979) | 0.9886947 (0.0001001) | t = -0.15; ddl = 150; P= 0.44 |
| Technical efficiency | 0.4419858 (0.0168532) | 0.4110241 (0.1426596) | 0.4258938 (0.0116529) | t = -1.33; ddl = 150; P= 0.09 |
| Economic efficiency | 0.4369863 (0.1424652) | 0.4059494 (0.1410993) | 0.4208553 (0.1421404) | t = -1.348; ddl = 150; P= 0.08 |

Source: Field survey results (2020).

**Table 6.** Average efficiencies for each measure.

| Land management and climate change adaptation strategies | Scores of the efficiency indices | | |
|---|---|---|---|
| | Techniques | Allocatives | Economic |
| Use of Mucuna | 0.440014 (±0.1466516) | 0.9886926 (±0.0001031) | 0.4349275 (±0.1450215) |
| Crop association | 0.4212762 (±0.1470709) | 0.9886902 (±0.0001042) | 0.4162308 (±0.1455291) |
| Crop rotation and crop rotation | 0.440727 (0.1433662) | 0.9886839 (0.0000999) | 0.4357534 (±0.1420868) |
| Crop residue management | 0.427008 (±0.1385723) | 0.9886658 (±0.0001134) | 0.4219231 (±0.1374924) |
| Pigeon pea | 0.5464035 (±0.1129341) | 0.988688 (±0.0001754) | 0.54 (±0.1131371) |
| Use of improver plants | 0.440998 (±0.1428192) | 0.9886899 (±0.0001025) | 0.4359722 (±0.1415474) |
| Use of cow dung | 0.3884361 (±0.111195) | 0.9887249 (±0.0000591) | 0.3825 (0.1100325) |
| Use of drought tolerant seeds | 0.4446925 (±0.1302559) | 0.9886915 (±0.0001005) | 0.4395506 (0.1290077) |
| Making and spreading of compost | 0.4380446 (±0.1335014) | 0.9886678 (±0.0000872) | 0.4330769 (±0.1329401) |

Source: Field survey results (2020).

beneficiaries are slightly higher than the average score of non-beneficiaries (Table 5). The average economic efficiency scores are 0.40 and 0.43 for non-beneficiaries and CCRP-GDT beneficiaries respectively. We note that the average economic efficiency score for beneficiaries is 0.43, which explains why project beneficiaries are more economically efficient than non-beneficiaries. Technically, the average efficiency score of beneficiaries is higher (0.44) than that of non-beneficiaries (0.41). This means that the technical efficiency of the beneficiaries depends on the SLM practices they received from the project. The same table reveals that the average allocative efficiency scores of beneficiaries are higher than those of non-beneficiaries. This result shows that beneficiaries are more allocatively efficient than non-beneficiaries. This is because beneficiaries appropriately adopt fertility measures that reduce their cost of production and increase their yield to

### *Economic efficiency of producers according to SLM/CCA measures*

Table 6 presents the results of the averages of the technical, allocative, and economic efficiencies of the different measures most adopted (Use of Mucuna, Cultivation association, Crop rotation and rotation, Crop residue management, Pigeon pea, Use of improvement plants, Use of cow dung, Use of drought tolerant seeds, Compost making and spreading). The results obtained show that the average technical efficiency of the most adopted measures varies from 0.38 to 0.54. It is noted that the technical efficiency index score of beneficiaries using pigeon pea (0.54) is higher than the technical efficiency index score of other measures while the technical efficiency index of beneficiaries using cow dung (0.38) is lower than the technical efficiency index scores of other SLM measures (Table 6). This would mean that technical efficiency is higher among pigeon pea adopters than adopters of other measures. This would be explained by the fact that the adoption of pigeon pea increases maize yield more and contributes to soil fertilization compared to the other measures. From an allocative perspective, producers using cow dung have almost the same levels of allocative efficiency, with the average allocative efficiency for the cow dung measure being 0.9887249 and higher than the average allocative efficiency scores for the other measures. The allocative efficiency of the TDM measures implemented under the CCRP-TDM is proportionally equal. This analysis suggests that producers are not adequately applying the measures disseminated by the project in the study area. The use of these measures could reduce the amount of fertilizer used in maize production to improve yields. The average economic efficiency for the adoption of pigeon pea is 0.54. This average is higher than the average of the economic efficiencies of measures such as the use of Mucuna, crop association, crop rotation, crop residue management, the use of plant improvers, the use of cow dung, the use of drought-tolerant seeds, and compost application. This explains why adopters of this measure are more economically efficient than adopters of the other measures. The difference between the levels of economic efficiency is not significant in the two communes. The adoption of pigeon pea in maize production is an innovation disseminated by the project in the study area.

## DISCUSSION

The results of this study revealed that crop association, crop rotation, pigeon pea, mucuna, crop residue management, direct seeding, plowing perpendicular to the slope, installation of windbreaks, use of ameliorating plants, construction of filtering bunds installation of fodder plots, use of cow dung, organic fertilizer, use of drought-tolerant seeds, making and spreading compost, and staggered sowing are soil fertility management measures used by PRCC-DGT beneficiaries in maize production. Pigeon pea, mucuna, soil fertility management, crop association, crop rotation, no-till, plowing perpendicular to the slope, use of planting materials, and use of drought-tolerant seeds are the most used measures in maize production under soil fertilization. This result explains that for a good maize yield, it is necessary to have fertile soil and the use of measures such as pigeon pea, mucuna, and, crop rotation is effective in soil fertilization. This result is confirmed by (Azontondé (1991) who showed that the use of mucuna as a cover crop improves maize yields. Also, studies conducted by Aklamavo and Mensah (1997) showed that mucuna cultivation improves the fertility and/or physical structure of soils for maize production and reduces the chiendens population to a level that can be easily controlled by the producer. Sogbedji et al. (2005) found that in West Africa, maize yields increased by 32.1% using pigeon pea as a cover crop. Results from (Vissoh et al. (2004), showed that in Benin, pigeon pea is used as a cover crop in weed control, particularly the Japanese bloodroot weed called *Imperatacylindrica (quackgrass)*. Crop rotation allows the farm to derive maximum benefit from these types of practices, and their assessment from the point of view of both efficiency and sustainability makes it possible to propose ways of improving the management of farmland (Djenontin et al., 2003). In addition, the average of the technical efficiency indices for beneficiaries, non-beneficiaries, and the whole is 0.4419; 0.4110; 0.4258 respectively. The comparison test performed is significant at the 10% level. As for the indices of allocative efficiency, the average of beneficiaries is 0.9886959, that of non-beneficiaries is 0.9886935 and that of all producers is 0.9886947. The mean of the allocative efficiency index of beneficiaries is higher than that of non-beneficiaries but statistically insignificant from the perspective of the Student t-test. The average of the economic efficiency indices for beneficiaries, non-beneficiaries, and all producers is 0.4369; 0.4110; 0.4208 respectively. We note that the average economic efficiency index of beneficiaries is higher than that of non-beneficiaries. The comparison test carried out for this effect is significant at 10%. This explains why beneficiaries are more efficient than non-beneficiaries. This is justified by the fact that beneficiaries adopt SLM measures more than non-beneficiaries for maize production. The level of technical efficiency observed in rice production in Senegal by (Ngom et al. (2014) is 0.70 and is higher than the level of technical efficiency obtained in our study area as a whole which is 0.4258. Similarly, our result is below that achieved in Benin by Amoussouhoui et al. (2012) which is 0.72. The technical efficiency is negatively significant at 10%. This could be explained by the fact that beneficiaries allocate more resources efficiently to maize production than non-beneficiaries (Agalati et al., 2017). The effective use of SLM measures disseminated by the CCRP-SLM reduces production costs and increases yield for beneficiaries. This result is contrary to (Huynh and Mitsuyasu 2011), who found that soybean farmers in Vietnam achieve more technical efficiency (TE) but poor allocative efficiency (AE). Our study reveals that the average economic efficiency of producers is 0.42. This result is similar to that of Adékambi et al. (2010) who estimated an economic efficiency index of 0.42 for cashew nut production units in Benin, with the average varying from 0.41 to 0.60 between classes. These results are generally influenced by access to credit, the number of years of experience in agricultural production, and contact with extension services. These results, which are close to ours, confirm that African producers are generally averagely efficient, and that improving their economic production efficiency requires strengthening credit services and increasing training in good production practices, such as made the PRCC-GDT

## Conclusion

This study on the "*Effect of Sustainable Land Management (SLM) measures disseminated by the Climate Change Resilience through Sustainable Land Management Project on the economic efficiency of maize producers in the communes of Malanville and Kouandé in northern Benin*" made it possible to determine the adoption of SLM measures disseminated by the PRCC-SLM and their effect on the economic efficiency of beneficiaries. The combination of several data collection and analysis methods made it possible to assess the level of adoption of SLM measures disseminated by the PRCC-SLM and to evaluate their analyzed effects on the economic efficiency of beneficiaries. The results obtained reveal that the use of Mucuna, crop association, crop rotation, crop residue management, pigeon pea, direct seeding, plowing perpendicular to the slope, installation of windbreaks, and use of ameliorating plants. The use of cow dung, organic fertilizer, drought-tolerant seeds, composting, and sowing are the measures adopted by the beneficiaries among those disseminated by the PRCC-GDT. Pigeon pea, mucuna, soil fertility management, crop association, crop rotation, no-till, perpendicular plowing, use of planting materials, and use of drought-tolerant seeds are the measures most applied in maize production under soil fertilization. Pigeon pea, crop rotation, mucuna, and the use of drought-tolerant seeds are the measures that ensure the economic efficiency of the beneficiaries. It was noted that beneficiaries are more economically efficient than non-beneficiaries. Indeed, agricultural policies must be put in place to promote the adoption of SLM measures that are the most efficient to ensure sustainable agriculture accompanied by a strategy to combat coastal erosion and soil degradation.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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