Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Impact of Water Collection and Management techniques (CGE) combined to microdose and to warrantage system on cowpea productivity in North and East Center of Burkina Faso

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ABSTRACT

The current study conducted on a sample of hundred and eighty (180) women aims to analyze the relative contribution of the micro dose, the rainwater collection and management techniques (CGE) and the warrant age system on cowpea productivity through econometric tools.

The estimation of the Cobb-Douglas production function shows that the CGE techniques, the micro dose and the warrant age, significantly increase the cowpea productivity. Among the various techniques of CGE, zai is the most appropriate in average rainfall situation while in the conditions of insufficient rainfall the combination of zai with the stony cord seems to be best suited.

Promotion strategies of massive adoption of the joint use of the micro dose with appropriate CGE techniques based on climate conditions then constitute the best alternative to anticipate climate impacts and improve food availability in arid and semi-arid areas. The extension and the strengthening of the warrant age system not only will improve the food security situation but also break the cycle of poverty of farmers.

KEY WORDS: Micro dose, Water Management, Warrant age, Burkina-Faso.

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1- INTRODUCTION

The analysis of the relative productivity of the production factors is a very important aspect of the production economics [1]. It comes from the neoclassical production ideology, which states that the producer seeks to maximize his utility function, within the constraints imposed by limited resources in production factors and by the technical production possibilities[2]. The constraints are characterized by the production function which links the produced quantities to the quantities of factors used under possible techniques [3]. The utility function reflects the preferences or the producer objectives which may for instance be the maximization of income [4].

The most predominant factors of productivity are usually land, labor and capital so that the most important forms of productivity are those relating to these factors [5]. However, rainwater collection and management technologies (CGE) play a relevant role in agricultural productivity in semi-arid areas. On bare soil in adverse weather conditions, they are considered as one of the most suitable alternatives to expect production [6]. Their introduction into production functions could then enrich the empirical productivity study. But the agronomic effectiveness of these technologies is improved with the addition of organic manure and mineral fertilizers that improve the physical-chemical parameters of soil, ensuring then good productivity [7]; [8]. Although the agronomic gain of the combined use of these two fertilizers is proved, mineral fertilizers are lowly used [9] in the northern and East-Centre regions of Burkina Faso because of their high cost, their low availability in local area and associated risks faced by producers in bad seasons [10]. It is in order to conciliate the economic difficulties of producers and edaphic requirements to increase productivity that microdose technology was developed through research. The microdose, a mineral fertilizer at low doses, favors the efficiency of fertilizers' use and therefore constitutes a real productivity determinant while protecting the environment [11] ; [12]. Furthermore, this technique seems to be better valued with improved seeds due to their high agronomic potential [13]. Women in North and East Center region of Burkina Faso (providing 75% of the subsistence production) [14] combine a large number of soil fertility management technologies to boost cowpea production, their main crop. But, to the best of our knowledge, there is quite no study on estimating a production function to analyze the relative productivity issues of production factors in order to make predictions and provide substantial opportunities to sustainably increase yields. In this paper we have tested not only the influence of the CGE techniques, the microdose and the warrantage system but also the effect of organic manure, the labor and improved varieties of cowpea productivity. In addition, the effects of the different CGE techniques were compared. The paper aims to answer the following question: are CGE technologies, microdose and warrantage system relevant in cowpea productivity?

2. MATERIALS AND METHODS

2.1. *Study area*

The study is conducted in the Kouritenga province in the East- Centre region, between 11° 48' and 12° 34' North latitude and 0°20' and 0° 38' west longitude and in Zondoma in the northern region between northern latitudes 12° 38' and 14° 18' and between 1°33' and 2°55’ west longitude. Kouritenga’s province belongs to the north Sudanese agro-climatic area and between 600 and 900 mm of water isohyets. Soils are generally shallow and not very fertile. As for the province of Zondoma, the climate is dry continental and Sudano-Sahelian type. The annual rainfall average is between 600 and 800 mm of water with scarce rainfall, erratic and unequally distributed in time and space. Soils are less transformed and very low fertile [15]. The population of the province is dominated by women, who represent 54.49% and the majority practices the cowpea farming. Agriculture is the main economic activity in the both provinces and is based on food crops (sorghum, millet, maize and rice) and cash crops (cowpeas, groundnuts, Bambara groundnut and sesame). Poor soils and adverse climatic conditions have imposed the restoration and conservation of water and soils by the zai technique, stone bunds, half-moons etc. These areas have benefited from many projects for the application of water and soil conservation techniques as well as the project "AGRA" on microdose and warrantage system. Hence, producers have some experience in the implementation of technologies. This constitutes an advantage to promote the adoption of the combination of CGE technologies, organic fertilizers and microdose if indeed these technologies are relevant in the improvement of the production.

2.2. *Data collection*

Four (04) villages in Kouritenga and 3 in Zondoma villages were randomly selected from the villages in which demonstration tests on microdose were applied. To take into account the agro-climatic and economic diversity in each province, a sample of 90 women was randomly selected among cowpea women producers giving a sampling rate of 40% in Kouritenga and 30% in Zondoma. The sample is composed, for each technology, of women who used it in their production activities and those who do not use it. The analysis of the relative productivity of technologies requires the administration of a questionnaire to women. The questions are related to the allocated areas to the cowpea, productions and quantities of used inputs especially labor, mineral and organic fertilizers. Similarly, qualitative information such as the types of seed, the application mode of mineral fertilizers and adopted technologies were collected

2.3. Estimation of the Cobb-Douglas production function

Two specifications are generally used in the estimation of production functions. These are Cobb-Douglas and Translog production functions but the Cobb-Douglas production function serves as the basis of many empirical works on the productivity of factors of production [1] because of the ease to estimate its parameters [16].

Noting K, the capital or asset; L, the quantity of labor and Y, the quantity produced (output), the theoretical general form of Cobb-Douglas production function for two factors according to [1], is as follows for K>0 and L>0: $Y = y(K, L) = AK^{\alpha} L^{\beta} e^{\mu}$ (1)

Where Y is output per unit of area, $0 < \alpha < 1$et $0 < \beta < 1$and μ and the error term

A logarithmic transformation of this function provides a more simplified and easy form to interpret

$LnY = Lny(K, L) = LnA + \alpha LnK + \beta LnL + \mu$ (2)

The α and β are the elasticities of inputs production and α+βis the degree of homogeneity. So,

$$\alpha = \varepsilon_{Y/K} = \frac{\delta LnY}{\delta LnK} = \frac{\delta Lny(K, L)}{\delta LnK} \quad (3)$$

and $\beta = \varepsilon_{Y/L} = \frac{\delta LnY}{\delta LnL} = \frac{\delta Lny(K, L)}{\delta LnL}$ (4)

To specify the model, the explanatory variables (Table 1) were introduced into the theoretical model (3) according to regions where data were collected.

Two models were estimate d for each province. The first was used to estimate the effect of technologies on cowpea productivity and the second was used to identify the CGE technique that provides the maximum of yield. For this second model, the test or control sample, we mean women who do not realize any CGE technique were not taken into account when estimating. The Zai which is considered by many authors as a best technology in terms of yield improvement has been considered the reference and the effect of other CGE technologies were compared to the one of zaï. The Songretenga villages, the driest in East Centre and the village Raguèguemale the most flooded in the North, were considered as references respectively in Kouritenga and in Zondoma regions. The effect of each factor or technique has been tested by the Student t test. The estimation of regression coefficients have been performed by the ordinary least squares method after a logarithmic transformation of quantitative variables. The Fisher F statistic was used to test the models' global significance to assess their explanatory power.

Table 1: Description of the variables introduced in the production functions

Variables		Type of variables	Description of variables	Expected effet
yield=Rdt		Quantitative dependent	Yield per unit of area (kg/ha)	
Labor=MO		Quantitative	Labor quantity in man-day for one hectare of cowpea	Positive
Organicmanure=FO		Quantitative	Quantity of organic manure(kg/ha)	Positive
Insecticide=Ins		Quantitative	Quantity of insecticide (kg/ha)	Positive
Microdose= Micro		Qualitative	Application of fertilizers in low dose. It takes the value 1 if yes and 0 if not	Positive
CGE technique = Tech		Qualitative	Practice of at least one soil fertility management technique. This binary variable takes the value 1 if yes and 0 if not	Positive
Warrantsge=Warran		Qualitative	Practice of warrantage system: 1 if the woman did it and 0 if not	Positive
Improvedseed=Sem		Qualitative	Using of cowpea improved seed. This dichotomous variable takes the value 1 if yesand 0 if not	Positive
Kouritenga'sstudy villages	Ronsin=Ron	Dichotomousdummy	1 if the woman is of Ronsin and 0 if not	Positive
	Kabeiga=Kab	Dichotomousdummy	1 if the woman is of Kabeiga and 0 if not	Positive
	Tensobtenga=Ton	Dichotomousdummy	1 if the woman is of Tensobtenga and 0 if not	Positive
Zondoma'sstudy villages	Boussou=Bou	Dichotomousdummy	1 if the woman is of Boussou and 0 if not	Positive
	Kagapessogo=Kag	Dichotomousdummy	1 if the woman is of Kagapessogo and 0 if not	Positive
Types of CGE techniques	Stonycord=CP	Dichotomousdummy	It takes the value 1 if the woman did the stony cord and 0 if not	Negative
	Half-moon=DL	Dichotomousdummy	It takes the value 1 if the woman did half-moon and 0 if not	Positive
	grassed strip =BE	Dichotomousdummy	It takes the value 1 if the woman did grassed strip and 0 if not	Negative

	Combination of zaï and stony cord=ZCP	Dichotomousdummy	Realization of in the arranged plots with stony cords. It takes the value 1 if yes and 0 if not	Positive
	Combination of zaï and grassed strip =ZBE	Dichotomousdummy	Realization of in the arranged plots with grassed strip. ZBE=1 if yes and 0 if not	Positive
	Mulching=Paille	Dichotomousdummy	Protection of the plot by the straw. Couverture de la parcelle avec de la paille. It takes the value 1 if yes and 0 if not	Negative

Source: Authors' specifications

3. RESULTS

3.1. Women practices intensifications

Women perform various soil fertility and water management practices that the main ones are CGE techniques, use of mineral fertilizers and organic manure (Table 2). The rate of practicing CGE technologies vary between 46.6% and 93.3% depending on the region. As regards to organic manure, its adoption rate is between 46.7 and 66.7%. Mineral fertilizers are used in microdose by 18.9% to 43.3% of women according to the provinces. Cowpea cropping system is dominated by local varieties and only 13.3% to 17.8% of women cultivate improved cowpea seed. The average quantity of labor, organic manure, fertilizer and insecticide per hectare of cowpea are respectively 39 man-days, 143.33 kg, 18 kg and 0.2 liter in East Centre. On the other hand, in the north, women devote to the average labor quantity per hectare, 64 man-days to achieve a hectare of cowpea and bring156.78 kg of organic manure, 48.33 kg of mineral fertilizers and 0.89 liter of insecticide. The yields from these cropping systems vary between 418.89 kg / ha and 654.81 kg / ha depending on the region.

3.2. Effect of the microdose, CGE and warehouse receipt system techniques on the cowpea productivity

The results of the Cobb-Douglas estimation function using the ordinary least squares method indicate that the models are specified at 0.01% level (Tables 3 and 4).

In the East Centre, the Student t test indicates that the qualitative variables coefficients, the microdose (Micro), CGE technology (Tech), warrantage system (Warran) and improved seed (Sem) are positive and significant at the level of5% as all probabilities are less than 0.05. These different variables influence positively cowpea productivity, thus corresponding to the expected effect. In addition to these factors, the coefficients of variables such as labor and the study site are significant.

Table 2: Descriptive statistics of variables introduced in the Cobb-Douglas function

Variables	**Kouritenga**	**Zondoma**
Yield kg/ha	654,81	418,89
Quantity of laborin man-day/ha	39	64
Quantity of organic manure in kg/ha	143,33	156,78
Quantity of fertilize in kg/ha	18	48,33
Quantity of insecticide in l/ha	0,2	0,89
	Percentage	**Percentage**
CGE Technique	46,7	93,3
Microdose	18,9	43,3
Warrantage system	30	0
Improvedseed	17,8	13,3

Source : Authors' specifications

In the North, if the coefficients of the variables microdose (Micro) and improved seed (Sem) are significant at 1% and positive, the one CGE technique is not statistically different ofzero and has a negative sign. The coefficients of the dummy variables,Boussou (Bou) and Kagapessogo (Kag) are also significant and positive at 1%.

3.3 Influence of the different CGE techniques on the cowpea productivity

To evaluate the effect of the different CGE techniques in order to identify the most appropriate technique to women production conditions in each province, the women who realize none of these techniques have been removed from the analysis. The results of the descriptive statistics (Table 5) shows that the grass strip and the zai are respectively the water and soil conservation practices the most used. Among women who apply the CGE techniques, a proportion of 27.4 to 57.1% applies the grass strip according to the region and 33.3% practice *the* zai technique.

Table 3: Results of the evaluation model of the microdose, CGE and warrantage system techniques' on the yield

Variables	Dependant Variable =Lnrend		
	Coefficients	**T-statistics**	**Probabilities**
Constant	5,031	27,884	0,000
Tech	0,204	2,169	0,033
Micro	0,277	2,262	0,026
Warran	0,391	3,312	0,001
Sem	0,392	2,950	0,004
LnFO	0,032	1,222	0,225
LnMO	0,103	1,807	0,075
LnIns	0,094	0,549	0,584
Son	0,552	2,859	0,005
Ten	0,704	4,195	0,000
Ron	0,607	1,951	0,055
F	43,154 (ddl= 10 ; 79)		
R^2	0,845		0,000

Source: Authors' estimations

Table 4: Results of the evaluation model of the microdose effect, CGE and warrantage system techniques' on the yield

Variables	Dependant variable: Ln Rend		
	Coefficients	T-statistics	Probabilities
Constant	4,420	13,879	0,000
Tech	-0,001	-0,021	0,983
Micro	0,302	2,806	0,006
Sem	0,438	2,884	0,005
LnFO	0,005	0,254	0,800
LnMO	0,102	1,348	0,182
InIns	0,072	0,532	0,596
Bou	0,744	5,421	0,000
Kag	1,395	8,721	0,000
F	30,039 (ddl= 8 ; 81)		
R^2	0,748		0,000

Source: Authors' estimations

3.4. Result of the production function

The results of the production functions show that the models are generally significant at 0.1% (Table 6and 7).

In Kourritenga, the Student t test indicates that the coefficient of the dummies variables grassed strip(BE), stony cord (CP) and the combination of zaï and the stony cord technique (ZCP) are significant at 10%. All of the coefficients of the CGE techniques are negative except the (ZCP) which displays the same positive signs. These signs correspond to the expected effects for each of the technologies. Thus, the combination of zaï with stony cord technique increases the performance more than does the zaï that is better than the stony cord and grass strip technique.

Table 5: Results of the descriptive statistic of the CGE techniques

Sites	CGE Techniques	Absolutefrequencies	Relative frequencies
Kouritenga	Zaï	14	33,3
	CP	3	7,1
	BE	24	57,1
	ZCP	1	2,4
Zondoma	Zaï	28	33,3
	CP	19	22,6
	BE	23	27,4
	ZCP	14	16,7

Source: Authors' estimations

In the other hand, in the north, the coefficients of all the techniques of CGE, the combination of zai with stony cords show a negative sign. This means that the grass strip (BE), the stony cord (CP) and the combination zaï and stony cord (ZCP) improve less significantly the cowpea yield than thezai.

Table 6: Estimation of the model'sevaluation of the different CGE techniques effect on the productivity in Kouritenga

Variables	**Variable dépendante= LnRend**		
	Coefficients	T-statistics	Probabilities
Constant	6,624	27,801	0,000
BE	-0,215	-2,007	0,053
ZCP	0,545	1,968	0,058
CP	-0,262	-1,761	0,088
Sem	0,214	1,510	0,141
LnMO	-0,049	-0,909	0,370
LnFO	0,017	0,676	0,504
LnIns	0,106	0,998	0,326
Warran	0,343	3,664	0,001
Micro	0,294	2,897	0,007
F	12,657		
R^2	0,781		0,000

Source: Authors' estimations

Table 7: Estimation of the model's evaluation of the different CGE techniques effect on the productivity in Zondoma

Variables	**DependantVariable : LnRdt**		
	Coefficients	t-statistics	Probabilities
(Constant)	4,214***	10,583	0,000
LnMO	0,203**	2,216	0,031
LnFO	0,027	0,860	0,394
LnIns	0,225	1,160	0,252
Micro	0,271*	1,929	0,059
Sem	0,670**	2,552	0,014
BE	-0,238	-1,116	0,270
CP	-0,308**	-2,074	0,043
ZCP	-0,480**	-2,284	0,027
Bous	0,617***	2,915	0,005
Kag F	0,964** 7,433(ddl=10,49)	2,153	0,036 0,000
R^2	0,603		

Source : Authors' specifications

4- DISCUSSION OF RESULTS

From the results of descriptive statistics, it comes out that the average of women's cowpea yields is low compared to the provincial averages. Women grow on marginal lands likely to affect the agronomic effectiveness of CGE techniques and management of soil fertility. Furthermore, the difficulties of control and respect of technical itineraries related to lack of training and financial problems affect a lot the productivity. To these factors is added the low utilization of production factors as highlighted [14].

The results of the econometric analysis shows that exogenous variables introduced into the models together contribute significantly to explain the performance of cowpea productivity. Models show that, 84.5% and 74.8% of yield variations are explained by changes in explanatory variables respectively in Kouritenga and in Zondoma, ceteris paribus.

The variable CGE technique positively influences cowpea productivity. Indeed, these techniques not only improve soil moisture through the downturn and the capture of rainwater but also enhance soil fertility by capturing plant debris and reducing the degradation of topsoil [12]. Earlier authors [8, 17] have shown that CGE technologies play a relevant role in increasing agricultural productivity in semi-arid area and may induce increase of average yields up to 100% depending on the crop. But the results of this study suggest that the impact of these technologies on yield depends on rainfall conditions since in the northern region, the effect is not only insignificant but also negative. This area has experienced significant variability intra-annual rainfall in 2012 marked by floods especially on plots were CGE techniques were applied. This discussion is shared by [8]. According to them, the efficacy of CGE technical performance depends on rainfall and the effect of these techniques compared to the control sample is more important in a year of poor rainfall. This finding is confirmed by the comparative analysis of the CGE techniques effect where the performance of the different techniques varied depending on the site. While the combination of stone barriers with the zai is the best CGE practice to significantly increase cowpea yields in insufficient rainfall conditions, zai is the best technological option in fairly good rainfall conditions. In fact, the combination of the two techniques improves soil moisture through the capture and the storm water slowing. Furthermore, it reinforces soil fertility through the concentration of organic fertilizers in the zai holes and sedimentation of organic matter upstream of stone bunds. But when the rainfall conditions are fairly good, this combination can lead to excess water and result in crop losses. The important effect of the zai compared to the grass strip and cord stony would be linked to the supply of fertilizers in the zai holes. [17] mentioned the importance of zai in increasing yield relative to the cord stony. As for the low mineral fertilization dose, it significantly increases the productivity of cowpea. The application of fertilizer at the foot of the plants improves the efficiency of fertilizers by restricting competition between crop and weeds and in reducing loss of minerals by leaching. In addition, it limits the volatilization of nitrogen. This result is consistent with those of [18] that found that the application of mineral fertilizers in microdose greatly increases agricultural productivity. These authors have obtained cowpea yield increases from 77% to 120% depending on rainfall years with 3g / seed hole NPK 15-15-15. The same effects have been found by [19] at the dose of 0.3g in Mali, which led to increase yields from 34% to 74% depending on the crop and sites. The contribution of 20kg of P_2O_5 and 30kg / ha of Nitrogen resulted in microdose yields gains of 140 to 180 kg / ha for the millet in Burkina Faso, Mali and Niger [20]. Furthermore, [13] have obtained cereal grain yield increasing from 30% to 60% or even 100% in different areas of West Africa. The practice of the warrantage significantly increases the yield of cowpea. Despite the low productivity of crops that limits the quantities stored, women who practice warrantage manage to have a little money early in the season for the purchase of inputs. Furthermore, the availability of food in the lean season through this system improves labor productivity. This discussion is shared by [21] and [22]. According to them, warrantage system enables producers to acquire fertilizer and improve their production. In addition to CGE techniques, microdose and warrantage system, improved seeds and areas of study also affect cowpea productivity. In fact, improved seeds significantly increase the yield of cowpea. Most new varieties are short-cycle seeds adapted to the rainfall conditions. In addition, they have high agricultural potential which results in production on marginal lands. This result is consistent with the theory of the determinant role of improved varieties in increasing yields as shown by the study of [23]; [24]; [13]. The influence of the villages of studies on productivity can be explained by the variability in rainfall conditions. Indeed, the control villages were marked either by the floods (in the north) or accentuated by droughts pockets (in the East Centre).

CONCLUSION

From the analysis, the microdose, CGE and warrantage system techniques significantly increase the cowpea productivity. But, it seems that the effect of the CGE techniques depends on rainfall years. While the zai alone is more effective in the conditions of average rainfall, the combination of stony cord and zaï is better in situations of poor rainfall. But in addition of the microdose, CGE techniques and warrantage system, factors such as improved seeds and labor also contribute to the improvement of cowpea productivity. Finally, cowpea performance is also function of the sites. Thus, a large-scale adoption of microdose, improved seeds, CGE techniques adapted to the physiognomy of each crop year and strengthening of the warehouse receipt system could reduce food insecurity and improve the welfare of rural households.

ACKNOWLEDGMENTS

The authors address their sincere thanks to the project Integrated Management of Nutritional Elements for a Sustainable Agricultural Production in the Sahel for funding this study.

RESUME

La présente étude menée auprès de cent quatre-vingt femmes vise à analyser la contribution relative de la microdose, des techniques de collecte et gestion des eaux de pluie (CGE) et le système de warrantage sur la productivité du niébé à travers des outils économétriques.

L’estimation des fonctions de production Cobb-Douglas montrent que les techniques de CGE, la microdose et le warrantage augmentent significativement la productivité du niébé. Parmi, les différentes techniques de CGE, le zaï est la plus appropriée en situation de pluviométrie moyenne alors que dans les conditions de pluviométrie insuffisante l’association zaï et cordon pierreux semble être la mieux adaptée.

Des stratégies de promotion d’une adoption massive de l’utilisation conjointe de la microdose avec des techniques de CGE appropriées en fonction des états de nature constitueront alors la meilleure alternative pour anticiper les incidences climatiques et améliorer la disponibilité alimentaire dans les zones arides et semi-arides. L’extension et le renforcement du système de warrantage pourrait non seulement améliorer la situation alimentaire mais aussi rompre le cercle vicieux de pauvreté des exploitants agricoles.

***Mots clés* :** microdose, gestion eaux, warrantage, Burkina-Faso

REFERENCES

1. Stadelmann, D. La fonction de production Cobb-Douglas, illustration de ses propriétés mathématiques importantes pour l'analyse économique. Travail de séminaire. 2005; 25.
2. Brossier, J. Apport des théories sur l'exploitation agricole dans une perspective de gestion. In : Gafsi M., Dugué, P., Jamin, J. Y., Brossier, J. (Eds), *Exploitations agricoles familiales en Afrique de l'Ouest et du* 2007 ; *Centre.* Versailles Cedex:Quae 2007; 87-103.
3. Cueva, S., Heyer, E. Fonction de production et degrés d'utilisation du capital et du travail : une analyse économétrique. *Economie & prévision,* 1997; (131) : 93-111.
4. Adegbidi, A. B. E. A. Elaboration du plan de production agricole en milieu paysan dans l'agriculture pluviale du Bénin. Une analyse de l'incidence de la pluviométrie dans la zone cotonnière du Nord-Bénin ; cas du village de Bagou, Thèse de Ph.D, Center for Development Studies, Université de Groningen, Pays-Bas. 2003;350.
5. Campbell, B. M. S., Overton, M., Heffer, J., Béaur, G. Production et productivité dans l'agriculture anglaise, 1086-1871. *Histoire &Mesure*, 1996;11 (3-4), 255-297.
6. Zougmoré, R., Zida, Z., Kambou, F. N. Réhabilitation des sols dégradés : rôles des amendements dans le succès des techniques de demi-lune et de zaï au Sahel. *Bulletin Réseau Erosion,*1999; (19), 536-550.
7. Zougmoré, R., Zida, Z., Kambou, N. F. Role of nutrient amendments in the success of half-moon soil and water conservation practice in semiarid Burkina Faso. *Soil & Tillage Research*,2003; (71):143-149.
8. Sawadogo, H., Bock, L., Lacroix, D., Zombré, N. P. Restauration des potentialités des sols dégradés à l'aide du Zaï et du compost dans le Yatenga (Burkina Faso). *Biotechnol. Agron. Soc. Environ.,*2008 ;12(3) : 279-290.
9. Ouédraogo, S. Intensification de l'Agriculture dans le plateau central du Burkina Faso : une analyse des possibilités à partir des nouvelles technologies, Thèse de Doctorat. 2005 ;317.
10. Doumbia, M., Berthé, A., Aune, J. B. La gestion intégrée de nutriments végétaux au Mali. Rapport récapitulatif de 1998-2004, 2005.
11. Palé, S., Mason, S. C., Taonda, S. J. B. Water and fertilizer influence on yield of grain sorghum varieties produced in Burkina Faso. *S. Afr. J. Plant Soil,* 2009; 26 (2): 91-97.

12. Liniger, H. P., Mekdaschi, Studer, R., Hauert, C., Gurtner, M. La pratique de la gestion durable des terres. Directives et bonnes pratiques en Afrique subsaharienne. TerrAfrica, Panorama mondial des approches et technologies de conservation (WOCAT) ; 2011.
13. Bationo, A., Sogodogo, D., Taonda, J. B. S., Mamane, S., Mahamadou, G. Le microdosage de l'engrais minéral : Espoir des paysans des zones soudano sahéliennes de l'Afrique de l'Ouest et un potentiel de transformation de cette zone du gris au vert. 2012;11.
14. MPF. Document de la politique nationale du genre du Burkina Faso. 2012 ;56.
15. Ganou I. Programme Sahel Burkinabé. Projet de Gestion des Ressources Naturelles dans le Séno-Yagha. In Lyyke A., Reenberg A. et Nielson I. (éds). The Sahel. Nature and Society : Researchers Perspective Political Dimensions of the Implementation Process Danida's Regional Activities. Proceedings 11thDanish Sahel Workshop, 5-7 January 1999. SEREIN Occasional Paper n°10: 79-85.
16. Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. An introduction to efficiency and productivity analysis. Springer Science & Business Media.2005.
17. Botoni, E., Reij, C. La transformation silencieuse de l'environnement et des systèmes de production au Sahel : Impacts des investissements publics et privés dans la gestion des ressources naturelles. Burkina Faso, 2009 ; 61.
18. Taonda, S. J. B., Yagho, E., Soubeiga, J., Kabré, A. Projet « transfert de la technologie de fertilisation par micro dose et des variétés tolérantes à la sécheresse pour la prospérité des petits producteurs agricoles du Sahel ». Burkina Faso, Rapport final, 2005-2008, 66.
19. Aune, J. B., Doumbia, M., Berthé, A. Micro fertilizing sorghum and pearl millet in Mali Agronomic, economic and social feasibility.*Agriculture*, 2007; 36(3): 199-203.
20. Bakayogo, M., Maman, N., Palé, S., Sirifi, S., Taonda, S. J. B., Traoré, S., Mason, S. C. Microdose and N and P fertilizer application rates for pearl millet in West Africa. *African Journal of Agricultural Research*, 2011; 6(5) : 1140-1150.
21. Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., &Nykvist, B.. A safe operating space for humanity. nature, 2009 ; 461(7263) : 472-475.
22. Somda, M. D., Kaboré, C., Bastard, G., Broutin, C. Etude de cas sur l'expérience de warrantage dans le Sud -ouest du Burkina Faso. Rapport final de l'atelier régional de formation sur le renforcement de capacités des organisations de producteurs à répondre à l'évolution de l'agriculture moderne. 2010 ; 28.
23. Palé, S., Mason, S. C., Taonda, S. J. B. Water and fertilizer influence on yield of grain sorghum varieties produced in Burkina Faso. *S. Afr. J. Plant Soil*, 2009; 26 (2):91-97.

24. Twomlow, S., Rohrbach, D., Dimes, J., Rusike, J., Mupangwa, W., Ncube, B., ... &Mahposa, P. Micro-dosing as a pathway to Africa's Green Revolution: evidence frombroad-scale on-farm trials. *NutrientCycling in Agroecosystems*, 2010 ;*88*(1) : 3-15.