American-Eurasian J. Agric. & Environ. Sci., 16 (1): 70-84, 2016
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2016.16.1.12786

Sustainable Agriculture and Innovation Adoption in a Small-Scale Food Production System: the Case of Yam in Rotation with Intercropping *Mucuna pruriens var utilis* and Maize in the Guinea-Sudan Zone of Benin

[1]Raphiou Maliki, [2]Brice Sinsin, [3]Laurent Parrot, [3]Jacques Lançon, [4]Anne Floquet and [5]NeBambi Lutaladio

[1] Institut National des Recherches Agricoles du Bénin (INRAB), P.O. Box: 2128, Calavi, Benin
[2]Faculté des Sciences Agronomiques de l'Université d'Abomey-Calavi (FSA/UAC), P.O. Box: 01-526, Cotonou, Benin
[3]Centre De Coopération Internationale En Recherche Agronomique Pour le Développement (CIRAD), P.O. Box: 34398, Montpellier Cedex 5, France
[4] Centre Béninois Pour L'environnement, Le Développement Economique et Social (CEBEDES), P.O. Box: 02-331, Cotonou, Benin
[5] Food and Agriculture Organisation of the United Nations (FAO), P.O. Box: 00100, Roma, Italy

Abstract: Slash-and-burn and shifting cultivation systems lead to the deforestation, soil degradation and depletion in Sub-Saharan Africa. Sedentary yam-based cropping systems with herbaceous legumes are promoted in Benin. Crop rotations with herbaceous legumes are of interest in Sub-Saharan Africa because improving the soil fertility where long-fallows are no longer feasible. This study investigate the adoption of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in the Guinea-Sudan zone of Benin. Results from logistic regression analysis suggeste that contact with researchers and extension workers, population density in zone, credit service, gender, land, farm household and livestock sizes were identified as major discriminating factors. The adoption was more significant in the area with denser population. It was also more significant in Research and Development sites. Women, who have little land rights, were more prone to adopt yam-based cropping with *Mucuna* than men. In addition, the study highlights advantages, constraints, adaptations of technology and implications for the international applications.

Key words: Adaptation · Adoption · Constraints · Herbaceous legume · Logit · *Mucuna pruriens* var *utilis* · Yam

INTRODUCTION

Yam *(Dioscorea* spp.*)* is a tuber crop that is widely cultivated in the humid and sub-humid lowland regions of West Africa and the Caribbean [1]. More than 90% of world yam production (40 million metric tons of fresh tubers/year) comes from West Africa [2] and especially from the countries located between Ivory Coast and Nigeria [3]. Traditionally, yam is cultivated as a pioneer crop after forest or after a long fallow. In these conditions, it yields about 10 metric tons of fresh tuber/hectare/year [4]. However, the potential yield of *D. alata*, one of the most important species, can reach 60 to 75 metric tons per hectare and per year [5, 6].

Benin is the world's fourth ranking producer, after Nigeria, Côte d'Ivoire and Ghana. Yam production increased from 1 285 858 tons on an estimated 117 255 ha harvested area in 1995 to 1 802 944 tons in 2008 on 204 683 ha [7]. This 40% increase in production was obtained thanks to a 74% increase in land under yam, indicating

Corresponding Author: Raphiou Maliki, Institut National des Recherches Agricoles du Bénin- (INRAB), Research and Development unit. Permanent address: P.O. Box: 2128, Calavi, Benin. Cell: +229 21 03 92 47.

that intensification was limited. Smallholder farmers grow yam. Nowadays in Benin, it is impossible for farmers to practice long fallow periods and yam is cultivated in 1 or 2-year herbaceous fallow–yam or maize-yam rotations with manual incorporation of residues into the soil.

With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes (*Mucuna pruriens* var *utilis)*. On the basis of the results of this on-farm research, yam based systems including herbaceous legume with *Mucuna* were diffused.

Very few practical results are currently available on sedentary yam-based cropping systems with herbaceous legumes in western Africa. However, in the past decade, the beneficial effect of *Mucuna* as a green manure and as a short-duration fallow has been intensively demonstrated in West Africa, on maize for example [8, 9]. Legumes improve soil fertility thanks to their ability to fix N_2 and to produce N-rich residues that can be returned to the soil [10]. Nitrogen fixation can help provide a growing population with a nutritious, environmentally friendly, sustainable food supply. In Benin, preliminary studies revealed a positive effect of herbaceous legumes on yam yield and an income increase for smallholders [11, 12].

With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes (*Mucuna pruriens* var *utilis*). On the basis of the results of this on-farm research, yam-based systems in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize were diffused in the Guinea-Sudan zone of Benin. However, studies on the adoption of the technology in a Small-Scale Food Production System are lacking.

It is generally agreed that farmers adopt an innovation if they expect it to contribute to better achieving their goals with, which may include economic, social and environmental aspects, while considering risk-related issues at the same time [13, 14]. In this paper, we intend to identify factors that may explain the adoption of yam-based systems that use herbaceous legume with *Mucuna* for soil conservation and sustainable yam production. We explore several demographic or institutional factors in view of providing relevant pointers for more effective and efficient public policies as regards the dissemination of yam-based systems including the mixed intercropping *Mucuna* and maize for sustainable production. In section 1, we present the study area in the Guinea-Sudan zone of Benin, the yam-based systems recommended to farmers and the process of diffusion and adoption implemented. In section 2 we describe the survey methodology and adoption model used for assessment. In sections 3 and 4, results are exposed and discussed.

MATERIALS AND METHODS

Study Area: The study was carried out in the Guinea-Sudan transition zone of Benin in a low (Savalou, Bantè, Savè and Ouessè) and in denser population zone (Dassa-Zoumè, Glazoué). This area lies between the latitudes 7°45 ' and 8°40' North and longitudes 2°20 ' and 2°35 ' East. The climate is the transitional climatic Guinea-Sudan type with a gradient from bimodal to monomodal rainfall distribution from the south and the north of Benin respectively. Annual rainfall in the study area varies from 1, 100 mm to 1, 200 mm with unequal distribution [15].

The soils are plinthosols and luvisols. The soil physical properties vary according to their clay content [16]. Vegetation is a degraded woody savannah type. Maize, yam, cassava and groundnut are annual cropping systems and the cash crops are cotton and soybean.

Yam-Based Systems in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize: The itinerary of the yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize (TMM) is as follows: smallholder farmers planted maize (spacing 80 × 40 cm) in April of the first year. *M. pruriens* seeds (25 kg ha^{-1}) were sown at (spacing 80 × 40 cm) in May six weeks after the maize. In the improved yam-based system (TMM), smallholder farmers applied or no on maize 100 kg ha^{-1} NPK fertilizer (14% N, 10% P, 11.7% K) in April and 50 kg ha^{-1} urea (46% N) in June. The maize was harvested in July. The grainless *M. pruriens* crops were mowed 140 days after planting. Organic matter was incorporated in moulds in October and then yam was planted directly on these mounds, without mineral fertilization.

Process of Diffusion and Adoption of Innovations: Herbaceous legume such as *Mucuna pruriens* var *utilis* was introduced in 1990 in the Guinea-Sudan zone of Benin to improve farming systems. The technology was transferred to smallholder farmers by way of participatory training, farmer field schools (FFS) and visits in close

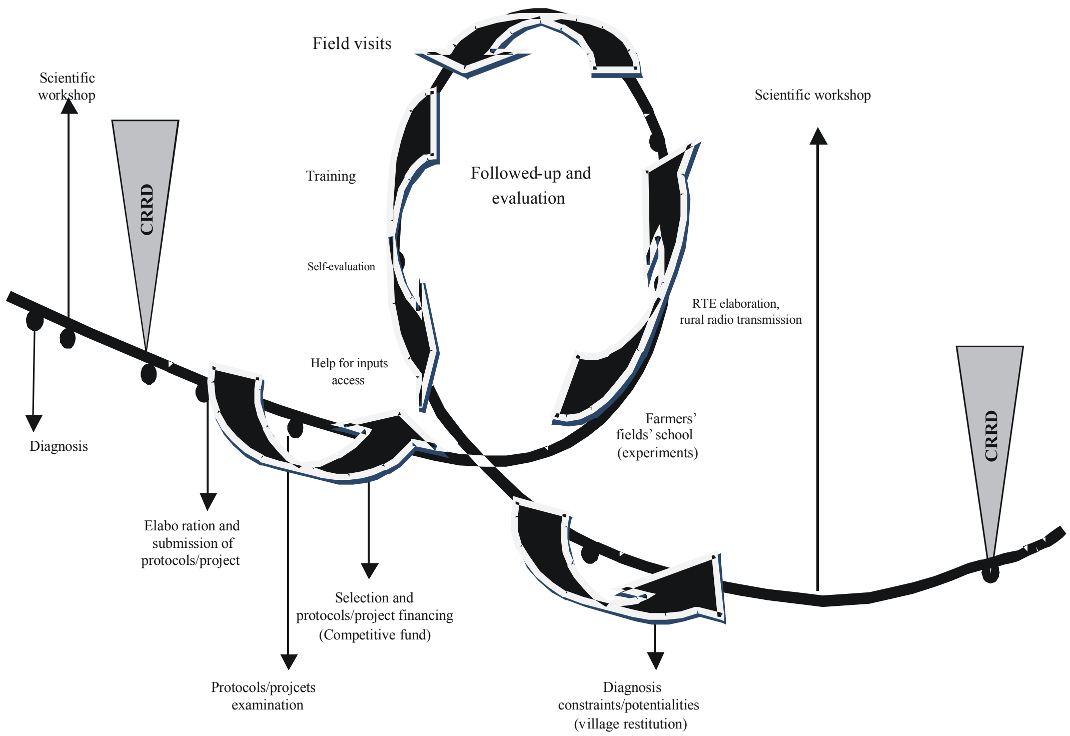

Fig. 1: Annual cycle of Research and Development (R&D) for yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in the Guinea-Sudan zone of Benin

partnership with extension workers. The results of research are presented in the framework of village restitution. Successful outcomes observed by each farmer in a particular field help to increase participation by the remaining farmers. Field training and visits are organized to document different points of view by farmers, extension workers and researchers. A scientific workshop is organized for researchers from the National Agricultural Research System (SNRA), who present and discuss the results of their research [17] (Fig. 1). Major research findings are communicated to the Regional Research and Development Committee (CRRD), the main link in the agricultural research management cycle in Benin. Some 50% of farmers and end users of the technologies are members of the CRRD, the remaining 50% being researchers, intermediate users such as the Regional Centre for Agricultural Development (CeRPA), NGOs, development partners and political decision makers. The research results are presented in simple and accessible form during the forum and are discussed with the participation of farmers. The CRRD forum can transfer the best and most affordable results in terms of technical and economic performance to extension services for widespread promotion of the adopted technologies. After fine-tuning of the technologies, a manual is drafted in a multi-field and multiinstitutional approach in collaboration with farmers, researchers and the extension structures. The document proposes a technical road map with illustrations, comments and discussion of the economic issues. This technical and economic reference (RTE) was produced for farmers, agricultural professionals, extension workers and researchers for the dissemination and promotion of the technology.

Survey Methodology and Model of Adoption

Theoretical Model of Adoption: The dependent variable, adoption of soil conservation innovation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize for subsequent yam, is dichotomized by assigning a value of one if a farmer is an adopter and zero otherwise. Because the dependent variable is dichotomous, the regression is non-linear in form and ordinary least squares will not provide useful estimators [18]. Instead a dichotomous logistic model technique is used to regress adoption on a set of explanatory variables. Many studies have used the logistic analysis approach to examine similar issues in various geographical regions and for different technologies [19, 20, 21].

$$y_i^* = \beta' x_i + u_i \quad (1)$$

where y_i^* unobservable variable, but determined by the dummy variable y defined by.

$$y = 1 \; if \; y_i^* > 0 \quad (2)$$

$y = 0$ otherwise

From equations (1) and (2), the probability that y = 1 a particular farmer will adopt soil conservation innovations with the mixed intercropping *Mucuna* and maize for increasing yam productivity is:

$$\text{Prob}\,(y = 1) = \text{Prob}\,(u_i > -\beta' x_i) = -F(-\beta' x_i) \quad (3)$$

and the probability that y = 0 that the farmers will not adopt, is:

$$\text{Prob}\,(y = 0) = \text{Prob}\,(u_i < \beta' x_i) = F(-\beta' x_i) \quad (4)$$

where in equation (3) and (4), F is the cumulative distribution function. We assume that u is independent of X, the vector of characteristics associated with smallholder farmers and has a standard logistic distribution (Wooldridge, 2000) and β is the vector of estimated coefficients. A combination of equations (1) and (2), yields the probability that a smallholder farmer will adopt the technology as:

$$1 - F(-\beta' x_i) = \frac{\exp(\beta' x_i)}{1 + \exp(\beta' x_i)} = A(\beta' x') \quad (5)$$

and the likelihood (Maddala, 1983) is:

$$L = \prod_{y_i \to 0} F(-\beta' x_i) \prod_{y_i \to 1} \left[1 - F(-\beta' x_i)\right] \quad (6)$$

The confidence interval is another goodness-of-fit measure. After estimating the $\hat{a}$s, confidence intervals (CI), a statistical inference for the model parameters can be performed to help judge the magnitude of the significance [22]. A confidence interval only has the specified probability of containing the parameter if the sample data on which it is based is the only information available about the value of the parameter by using the formula in equation (7).

$$\beta \pm z_{\alpha/2}(ASE) \quad (7)$$

where ASE is the asymptotic standard error and z is the $\alpha/2$ critical value from a t- distribution with (n/k) degrees of freedom.

The magnitude of changes in the probability of adoption as the regressor changes is best captured by the marginal effect, usually evaluated at its mean of the explanatory variable. Following [23], we denote the logistic cumulative function by A(-) which is between zero and one. Substituting A(-) as the standard logit in equation (3), we find the marginal effects of the regressors on the probability as:

$$A(1-A)\beta \quad (8)$$

The derivatives of the likelihood estimates of the coefficients yield the probability of being in one of the dichotomous groups, an adopter or non-adopter. This will give the measure of strength of response for the independent variables. However, the change in the probability can be expressed in percentage change by multiplying with 100.

The equation used to estimate the parameters is:

$$E(y_i) = \alpha + \beta_1 ZONE + \beta_2 SUDISP + \beta_3 GENDER + \beta_4 NBOUCH + \beta_5 FTRAV + \beta_6 ORIGIN + \beta_7 CONTACT + \beta_8 CREDIT + \beta_9 NIVELEV$$

Socioeconomic Analysis: Empirical Model of Adoption: Choice of Sites: The choice concerned the Research and Development (R&D) sites where the systems were generated and off R&D sites, implying certain heterogeneity in the agro-ecological, socioeconomic and cultural level [24]. Districts were located in the relatively high and low population density zones (Table 1).

To establish the base of the survey, the results from the "third population census" [24] and other relevant documents were analyzed [25]. Statistical data concerning the yam smallholder farmers from several villages in the "Collines Department" were also used. Total sample of 306 farm households in six districts of the "Collines Department" in the study area were surveyed including 25% and 75% of the sample for the R&D and off R&D sites respectively. In each village, sampling was conducted along a transect that accounted for agro-ecological diversity with the aim of including maximum possible of variability. This made it possible to calculate the total number of yam smallholders in the study area and the number of yam smallholder farmers in each site or village for the survey.

Table 1: Sampling size for individual survey in the Guinea-Sudan zone of Benin

Zone	Site	Commune	Household sampling size	Percentage per site(%)
Low population density zone	R&D site	Ouessè	36	12
	Off R&D site	Savè	21	
		Ouessè	40	
		Savalou	39	
		Bantè	50	49
Relatively high population density zone	R-D site	Dassa	20	
		Glazoué	19	13
	Off R&D site	Dassa	41	
		Glazoué	40	26
Total			306	100

Legend: N: Sampling size of farm households for the survey; R&D site: Research and Development site where yam based-systems with herbaceous legumes were promoted; Off R&D site

Twenty-seven villages investigated in different Communes according to R&D and Off R&D sites are as follows:

Table 2: Statistical description of adoption factors in the study zone in the Guinea-Sudan zone of Benin (n = 306 farm household surveyed)

Acronym of variable	Description of variable and value	Mean	Standard deviation
ZONE	Demographic zone/population density (1=yes; 0=no)	0.39	0.49
SUPDISP	Household land surface available per ha	8.25	7.61
SEXE/GENDER	Male or female (1=yes; 0=no)	0.82	0.38
NBOUCH	Household' size	7.63	4.88
FTRAV	Household' labor size	2.66	2.39
ORIGIN	Owner status: indigenous or immigrant (1=yes; 0=no)	0.83	0.38
CONTACT	Contact with the change agents (1=yes; 0=no)	0.59	0.49
CREDIT	Access to credit (1=yes; 0=no)	0.06	0.24
NIVELEV	Livestock size (sheep, goat and cow)	4.53	12.05

Legend:

ZONE: population density in zone; SUPDISP: land surface available in farm household, GENDER: sex (male or female) of the smallholder farmer; NBOUCH: Farm household size; FTRAV labour force within the households; ORIGIN: owner status (indigenous or immigrant); CONTACT: smallholder farmers' contacts with the research or extension workers; CREDIT: formal financial credit for inputs; NIVELEV: livestock size.

Survey: Twenty-seven villages in the "Collines Department" with low and relatively high population densities were surveyed including adopters and non-adopters (never adopted and disadopter) of yam-based cropping system in rotation with the mixed intercropping *Mucuna* and maize.

A checklist was used for the socio-economic investigations and data collection at the level of the farm household. Fifty explanatory variables were considered for the study. Out of fifty explanatory variables, nine independent variables more meaningful were selected with the correlation analysis and included in the model. ZONE (population density in zone), SUPDISP (land availability), GENDER (sex), NBOUCH (Farm household size), FTRAV (labour availability), ORIGIN (owner status: indigenous or immigrant), CONTACT (contacts with external services for advice), CREDIT (formal financial credit), NIVELEV (livestock size).

Justifications, methods, and predicted signs for each independent variable in the models are discussed (Table 2).

The variable ZONE expresses the geographical diversity of social, cultural and ecological constraints linked with demography, land pressure and, as a consequence, soil degradation [26, 27]. In zones where soils are degraded, smallholders could be more inclined to adopt new systems. This variable takes value 1 in denser population zone and 0 otherwise. SUPDISP is the land availability for yam cropping systems. Land security is useful for the soil fertility investment. Land availability could lead farmers to clear new woody fallow for yam production (traditional shifting cultivation system) versus improved yam-based systems in rotation with the mixed intercropping *Mucuna* and maize. A negative sign is expected for this variable. GENDER is the variable sex. Many studies were carried out on gender analysis about new technologies [28-31]. Generally, unfavourable land status attributed for women could be prejudicial for adoption of innovative technologies. GENDER is a dummy variable which takes value 1 for men and 0 otherwise. NBOUCH is the farm household size supposed positively correlated to the adoption of new technologies. FTRAV is the variable relative to household labour availability. Importance of labour for adoption of new technologies is reported [32, 33]. This variable is expected to influence positively adoption of improved yam-based systems. ORIGIN is the farm owner social status. We supposed that indigenous farmers will be more prone to adopt improved yam-based system than immigrant. In fact, the loan is particularly practiced by immigrants in the study area which is unfavourable for long term soil fertility investment [34]. This variable takes value 1 if the owner is indigenous and 0 otherwise. CONTACT identifies farmers who have connections and dealings with the external agents (researcher, extension agent). It is an important variable for diffusion and adoption of innovations [35, 36]. This variable could influence positively the adoption of improved yam-based systems in rotation with the mixed intercropping *Mucuna* and maize. The variable takes value 1 if the smallholder farmer ties contacts with the external structures (at least one contact per month) and 0 otherwise. CREDIT expresses the access to the formal credit. The use of innovative yam-based system requires inputs purchase (seeds or seedlings and mineral fertilizers for maize). Difficulties of cash limit farmers' investments [29, 35]. Access to credit can raise this constraint and support adoption. This variable takes value 1 if the farmer obtains formal credit and 0 otherwise. NIVELEV is the livestock size (sheep, goat and cow). The natural pasture is the endogenous practice for providing forage to ruminants. In crop/livestock integration system, herbaceous legumes established in dynamic of rotation can provide forage for animal feeding and the field is useful for subsequent crops as yam. This variable is supposed to influence positively the adoption of improved yam-based system.

SPSS was used for the descriptive analysis and correlation of the independent variables. LIMDEP version 7.0 was used for the empirical model [37].

RESULTS

Multivariate Analysis of Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize: Adoption of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize (TMM) was 34% (Table 3).

The percentage of adopter's women was 9% whereas 25% were recorded for men that fit with the size sample investigated (54 women against 252 men). The models had rather good predictive and estimated properties. The χ^2 test was highly significant ($p<0.01$). The percentage of correct prediction was high (77%).

Results of Student's test revealed that seven variables determined the adoption of TMM: "CONTACT" with external agents, population density in "ZONE", "CREDIT", GENDER, SUPDISP, NBOUCH and NIVELEV.

The rate of adoption of TMM was higher in the relatively high population density zone (20%) than in the low-density zone (14%). This was also higher in the Research and Development (R&D) sites (18%), where smallholder farmers had much more in contact with research and extension than in the other sites (16%) (Table 4).

Characteristics of Adopters and Non-adopters of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize: Adopters profile is as follows: to be man or woman, young person or adult, to be farm households' head and having experience in agriculture around 22 years with an households size of 7, to have the right of ownership on the land, to be educated (at least 6 years of formal education), to have regular contacts with the changes agents (at least one contact per month), to have access to information, to be trained on new technologies, to have access to credit and to belong to a village organization (Tables 5 and 6).

Globally, soil depletion problem was expressed as well as by adopters and non-adopters. Land is available and allocated to crops with more surfaces attributed for cereal (maize) and grain legumes (groundnut and beans). Livestock size of adopters was higher as well as in R&D and off R&D sites. The woody for combustion and fodder for animal feeding were available in farm household.

Advantages and Constraints of Yam in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize in the Guinea-Sudan Zone of Benin: *Mucuna* was appreciated for its capacity to restore the soil fertility, to maintain soil humidity and to control weeds as well in low (ZB) as in relatively high population density (ZA) zones.

Table 3: Econometric model of the discriminating factors affecting adoption of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in the Guinea-Sudan zone of Benin

Acronym of variable	Estimated β	T test
ZONE	0.244	4.792***
SUPDISP	0.009	2.836**
GENDER	-0.179	-3.294***
NBOUCH	0.011	2.284**
FTRAV	-0.012	-1.146
ORIGIN	-0.032	-0.55
CONTACT	0.382	7.868***
CREDIT	0.353	3.544***
NIVELEV	0.003	1.948**
Log-probabilities		-143.08
χ^2		104.74***
% of prediction		77

Legend: **p<0.05 and ***p<0.01 represent significant level at 5% and 1% respectively;

β is the vector of estimated coefficient for each independent variable

ZONE: population density in zone; SUPDISP: land surface available in farm household, GENDER: sex (male or female) of the smallholder farmer; NBOUCH: Farm household size; FTRAV labour force within the households; ORIGIN: owner status (indigenous or immigrant); CONTACT: smallholder farmers' contacts with the research or extension workers; CREDIT: formal financial credit for inputs; NIVELEV: livestock size

Table 4: Adoption and non-adoption rates of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize as part of site and population density in the Guinea-Sudan zone of Benin

Site type	Population density	Adoption type	Categories	Number of smallholder farmers surveyed	Rate of adopters (%)	Rate of non adopters (%)	Rate of adoption on R-D sites (%)	Rate of adoption on off R-D sites (%)	Rate of adoption in denser population (%)	Rate of adoption in low population density (%)
R-D sites	Denser population	Adopter	Adopter women	8	3		3		3	
			Adopter men	25	8		8		8	
		Non-adopter	Never adopted	6		2				
			Disadopter	4		1				
	Low population density	Adopter	Adopter women	7	2		2			2
			Adopter men	20	7		7			7
		Non-adopter	Never adopted	12		4				
			Disadopter	0		0				
Off R-D sites	Denser population	Adopter	Adopter women	8	3			3	3	
			Adopter men	17	6			6	6	
		Non-adopter	Never adopted	47		15				
			Disadopter	3		1				
	Low population density	Adopter	Adopter women	3	1			1		1
			Adopter men	15	5			5		5
		Non-adopter	Never adopted	131		43				
			Disadopter	0		0				
	Total			306	34	66	20	14	19	15

R-D sites: Research-Development sites; off R-D sites: Off Research-Development sites

Mucuna in intercropping with maize increased yam yield and supplemented the animal feeding according to smallholder farmers' viewpoints. However, some constraints limit the adoption of yam-based system with *Mucuna*. Biomass incorporation difficulty in yam-based technology with *Mucuna* (TMM) was the first constraint reported with 43 and 67%, respectively in the ZA and ZB, followed by the problem of competition between *Mucuna* and the pattern crop with 25% (ZA) versus 9% (ZB). Smallholders highlighted the problem of *Mucuna* seeds edibility with 18 and 19% and damages caused by the animal (cattle) divagation (16 and 17%) in ZA and ZB respectively (Table 7).

Table 5: Characteristics of adopters and non-adopters of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in Research and Development sites in the Guinea-Sudan zone of Benin

		Relatively high population density zone			Low population density zone		
			Non-adopter			Non-adopter	
Variable	Description	Adopter	Never adopted	Disadopter	Adopter	Never adopted	Disadopter
Household characteristics		n=33 (11%)	n=6 (2%)	n=4 (1%)	n=27 (9%)	n=12 (4%)	n=0(0%)
Age	Average hold (year)	45	35	49	49	41	-
	Standard deviation	11.2	5.85	2.21	9.02	7.89	-
Education	% of educated	63	60	75	46	50	-
	% of non-educated	37	40	25	54	50	-
Gender	% of male	73	80	100	79	83	-
	% of female	27	20	0	21	17	-
Origin	% of native	90	40	100	92	83	-
	% of immigrants	10	60	0	8	17	-
Matrimonial situation	% of married	100	100	100	100	100	-
	% of single	0	0	0	0	0	-
Position in the household	% of head of household	73	80	100	75	83	-
	% of non-head of household	27	20	0	25	17	-
Number years of experiment	Year	21	12	22	24	20	-
	Standard deviation	13, 5	5	10.75	7.1	8.2	-
Households' size	Number	6	5	6	8.5	5	-
Economic factors							
Average farm income	FCFA	270, 500	258, 000	29, 000	618, 417	4, 161, 000	-
Number of farm manpower	Number	2	1	4	3	2	-
	Standard deviation	2.31	1.3	1.77	2.53	1.51	-
Arable land surface available	ha	5	3.6	4.75	9.5	9.2	-
	Standard deviation	3.1	2.5	1.7	3.94	6.07	-
Land surface per manpower	ha	2.5	3.6	2.05	3	4.6	-
Dependence rate	ratio	2	4	0.5	1.8	1.5	-
Socio-ecological factors							
Population density	inhabitants /km²	49	49	49	25	25	-
Land tenure	% of land owner	93	100	75	96	91	-
	% of non-land owner	7	0	25	4	9	-
soil fertility state	% of farmers (poor soil)	40	100	75	17	33	-
	% of farmers (fertile soil)	60	0	25	83	77	-
wood availability	% of farmers (wood problem)	3	80	25	13	8	-
	% of farmers (without wood problem)	97	20	75	87	92	-
Fodder availability	% of farmers (fodder problem)	13	33	50	0	8	-
	% of farmers (available fodder)	87	67	50	100	92	-
Institutional factors							
Information on new technologies	% of farmers informed	100	20	0	100	17	-
	% of farmers non-informed	0	80	100	0	83	-
Contact with change agents	% of farmers have contacts	83	20	75	100	50	-
	% of farmers without contact	17	80	25	0	50	-
Training	% of trained farmers	80	20	50	96	8	-
	% of non- trained farmers	20	80	50	4	92	-
Test	% of tester farmers	100	0	100	100	0	-
	% of non-tester farmers	0	100	0	0	100	-
Abandonment rate of tests	% of farmers	0	-	100	0	0	-
Village restitution	% of farmers taking place to village restitution	77	20	100	96	25	-
	% of farmers having ever participated	23	80	0	4	75	-
Credit	% of farmers with credit	37	20	0	4	0	-
	% of farmers without credit	63	80	100	96	100	-
Belong to organisation	% of farmers belong to organisation	57	40	50	21	8	-
	% of farmers without organisation	43	60	50	79	92	-
Household functional characteristics							
Average yam land surface	ha	0.48	0.13	0.17	0.9	0.69	-
	Standard deviation	0.325	0.021	0.028	0.667	0.581	-
Average cassava land surface	ha	0.18	0.51	0.67	1.5	1.37	-
	Standard deviation	0.11	0.082	0.108	0.354	0.991	-
Average maize land surface	ha	0.37	0.80	1.06	2.3	1.05	-
	Standard deviation	0.164	0.129	0.170	0.616	0.543	-
Average groundnut land surface	ha	0.45	0.47	0.62	2.76	1	-
	Standard deviation	0.29	0.076	0.100	1.367	0.579	-
Average Soya land surface	ha	0.55	0.21	0.27	0.000	0	-
	Standard deviation	0.428	0.033	0.044	0.000	0.000	-

Table 5: Continued

Average bean land surface	ha	0.65	0.17	0.22	0.35	0.75	-
	Standard deviation	0.332	0.027	0.036	0.179	0.287	-
Average rice land surface	ha	0.35	0.10	0.14	0.11	0.25	-
	Standard deviation	0.427	0.017	0.022	0.052	0.166	-
Average cotton land surface	ha	0.75	0.17	0.22	0.05	0	-
	Standard deviation	0.219	0.027	0.036	0.025	0.000	-
Average cashew tree land surface	ha	0.25	0.94	1.24	5.5	2.9	-
	Standard deviation	0.147	0.152	0.200	0.791	1.241	-
Average teak land surface	ha	0.12	0.09	0.12	0.35	0.45	-
	Standard deviation	0.061	0.015	0.020	0.175	0.351	-
Average herbaceous leguminous land surface	ha	0.09	0.00	0.00	0.45	0.000	-
	Standard deviation	0.073	0.00	0.00	0.336	0.000	-
Livestock size (sheep, goat and cow)	Number	6	3.00	4.00	9.5	5	-
	Standard deviation	8.21	0.82	1.10	6.19	3.1	-

Table 6: Characteristics of adopters and non-adopters of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in off Research and Development sites in the Guinea-Sudan zone of Benin

		Relatively high population density zone			Low population density zone		
			Non-adopter			Non-adopter	
Variable	Description	Adopter	Never adopted	Disadopter	Adopter	Never adopted	Disadopter
Household characteristics		n=28(9%)	n=47 (15%)	n=3 (1%)	n=18(6%)	n=131 (43%)	n=0(0%)
Age	Average hold (year)	45	49	49	41	45	-
	Standard deviation	12.58	16.85	12.72	13.76	10.66	-
Education	% of educated	53	40	50	55	28	-
	% of non-educated	47	60	50	45	72	-
Gender	% of male	56	85	2	70	92	-
	% of female	44	15	98	30	8	-
Origin	% of native	87	83	100	55	83	-
	% of immigrants	13	17	0	45	17	-
Matrimonial situation	% of married	100	100	100	90	99	-
	% of single	0	0	0	10	1	-
Position in the household	% of head of household	66	87	50	80	94	-
	% of non- head of household	34	13	50	20	6	-
Number years of experiment	Year	26	28	29	19	19	-
	Standard deviation	14.5	17.96	23.33	12.8	10.6	-
Households' size	Number	9	7.6	7.7	8	7	-
Economic factors							
Average farm income	FCFA	256, 750	381, 129	475, 000	921, 212	672, 060	-
Number of farm manpower	Number	4	3	5	2	2	-
	Standard deviation	5.12	2.28	3.55	5.84	1.72	-
Arable land surface available	ha	6	4.6	4.5	17.3	9.6	-
	Standard deviation	5.53	1.87	1.87	15.35	7. 76	-
Land surface per manpower	ha	1.5	1.5	2.1	8.7	4.8	-
Dependence rate	ratio	1.3	1.7	0.5	1.6	2.5	-
Socio-ecological factors							
Population density	inhabitants /km²	49	49	49	25	25	-
Land tenure	% of land owner	88	98	100	85	83	-
	% of non-land owner	12	2	0	15	17	-
soil fertility state	% of farmers (poor soil)	41	89	100	90	32	-
	% of farmers (fertile soil)	59	11	0	10	68	-
wood availability	% of farmers (wood problem)	0	51	0	10	0	-
	% of farmers (without wood problem)	100	49	100	90	100	-
Fodder availability	% of farmers (fodder problem)	6	30	50	15	6	-
	% of farmers (available fodder)	94	70	50	85	94	-
Institutional factors							
Information on new technologies	% of farmers informed	100	45	100	100	24	-
	% of farmers non-informed	0	55	0	0	76	-
Contact with change agents	% of farmers have contacts	84	36	100	75	48	-
	% of farmers without contact	16	64	0	25	52	-
Training	% of trained farmers	56	19	50	30	4	-
	% of non-trained farmers	44	81	50	70	96	-
Test	% of tester farmers	97	0	100	94	0	-
	% of non-tester farmers	3	100	0	6	100	-

Table 6: Continued

Abandonment rate of tests	% of farmers	0	-	100	0	-	-
Village restitution	% of farmers taking place to village restitution	31	6	50	70	5	-
	% of farmers having ever participated	69	94	50	30	95	-
Credit	% of farmers with credit	8	2	0	5	1	-
	% of farmers without credit	92	98	100	95	99	-
Belong to organisation	% of farmers belong to organisation	47	23	50	30	67	-
	% of farmers without organisation	53	77	50	70	33	-
Household functional characteristics							
Average yam land surface	ha	0.35	0.17	0.25	0.55	0.50	-
	Standard deviation	0.44	0.024	0.034	0.42	0.33	-
Average cassava land surface	ha	0.16	0.31	0.44	0.50	0.45	-
	Standard deviation	0.11	0.042	0.060	0.31	0.30	-
Average maize land surface	ha	0.48	1.12	1.58	1.05	0.75	-
	Standard deviation	0.29	0.153	0.216	0.63	0.29	-
Average groundnut land surface	ha	0.65	0.62	0.88	1.20	0.85	-
	Standard deviation	0.39	0.085	0.120	0.36	0.47	-
Average Soya land surface	ha	0.72	0.37	0.53	0.000	0.000	-
	Standard deviation	0.18	0.051	0.072	0.000	0.000	-
Average bean land surface	ha	0. 50	0.27	0.39	0.35	0.70	-
	Standard deviation	0.44	0.037	0.053	0.18	0.34	-
Average rice land surface	ha	0.40	0.19	0.25	0.11	0.32	-
	Standard deviation	0.30	0.025	0.035	0.11	0.16	-
Average cotton land surface	ha	0.25	0.12	0.18	0.000	0.000	-
	Standard deviation	0.10	0.017	0.024	0.000	0.000	-
Average cashew tree land surface	ha	0.55	1.24	1.75	3.70	4.00	-
	Standard deviation	0.43	0.170	0.240	0.15	0.83	-
Average teak land surface	ha	0.17	0.19	0.25	0.22	0.55	-
	Standard deviation	0.13	0.025	0.035	0.16	0.43	-
Average herbaceous leguminous land surface	ha	0.05	0.00	0.00	0.22	0.000	-
	Standard deviation	0.03	0.00	0.00	0.13	0.000	-
Livestock size (sheep, goat and cow)	Number	13.00	2.00	4.00	5.00	4	-
	Standard deviation	20.45	0.27	0.55	5.16	12.73	-

Table 7: Constraints of adoption of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in the Guinea-Sudan zone of Benin (Farm household level)

	ZA (N=186)		ZB (N=120)				
Constraints	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	OI
Biomass incorporation	80/186	43	80/120	67	160/306	52	1
Competition	47/186	25	11/120	9	58/306	19	2
Seeds consumption	33/186	18	23/120	19	56/306	18	3
Animal divagation	30/186	16	20/120	17	50/306	16	4
Reptile refuge	9/186	5	11/120	9	20/306	7	5
Fertilizer cost	9/186	5	8/120	7	17/306	6	6
Plot maintenance	9/186	5	-	-	9/306	3	7
Vegetation burn	-	-	5/120	4	5/306	2	8
Seeds marketing	4/186	2	-	-	4/306	1	9

N= sampling size; ZA: relatively high population density zone; ZB: low population density zone; OI: importance order

DISCUSSION

Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize in Denser and Low Population Density Zone: Adoption of yam-based system in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize (TMM) is highly expressed in the zone with denser population compared to the low population density zone. In the denser zone, land pressure is relatively high with an increasingly scarcity of fertile soils for yam production and smallholder farmers look relatively inclined to develop more sustainable and more productive systems. Most smallholder farmers could already appreciate the ability of *Mucuna* for increasing yam productivity, maintain soil humidity, control weeds (*Imperata cylindrica* in particular) and restore soil fertility [8, 38]. *Mucuna* stover showed the high dry matter (DM) amount whatever the year and this can reach 10 t ha^{-1} [8]. Because *Mucuna* grows rapidly and close. Generally, studies revealed that the incorporation of the biomass gets more nitrogen to the succeeding crop than the mulch application on the soil because the decomposition of organic matter is more rapid after incorporation. Decomposition data indicated that

6 weeks after incorporation of biomass only 30% of *Mucuna* remained [9]. This would be related to faster decomposition of *Mucuna* residue biomass and nutrients release for subsequent plants growth. Furthermore, *Mucuna* recycled macronutrients (N, P and K) with moderate rates of decomposition [39]. Legumes fallows with *Mucuna,* are known especially for improving the quantity of available P fractions in the soil for subsequent crops. Nevertheless, it depends on the inherent P levels in the soils. *Mucuna* transports P from lower soil layers and improves available P in arable surface that is crucial for yam. TMM significantly increased yam yields to about 15 t ha^{-1} (fresh matter) in the study area. In Benin and Togo, [11] studied the effect on the yam crop of short fallows based on *Mucuna pruriens* var *utilis, Aeschynomene histrix,* or *Pueraria phaseoloides* and reported that a 1-year fallow planted with *M. pruriens* led to a significant increase in yam yields.

Studies conducted by [26] in the Bamiléké area, Cameroun, or [40] in the vicinity of Kano, Nigeria, corroborates the feeling that land scarcity is a major incentive to switch to intensive agriculture. In northern Benin, where the population density is lower than 100 inhabitants per km², intensive agriculture is much less frequent than it is in the south where the population density frequently exceeds 200 inhabitants per km². However, study carried out by [21] on Agroforestry system in Cameroon showed that adoption is lower for farmers in areas with very high population pressure. Because alley cropping requires that farmers set aside a part of their land for growing trees, the cultivable areas under food crops have to be reduced. Smallholder farmers in villages where land pressure is very high may view tree planting as competing with food crops, thus reducing incentives to adopt alley cropping [41] found that farmers facing very high land pressure and exhausted fields opted for short fallow with *Mucuna* as a soil fertility management option instead of alley cropping.

Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize in the Research and Development and off Research and Development Sites: The highest adoption in the Research and Development (R&D) sites than Off Research and Development sites (off R&D) was probably due to more frequent interactions between smallholder farmers and the R&D research team through demonstration plots, training and field visits, village meetings at which results of research were presented showing the advantages of innovations based on a specific farmer's field, information exchange between farmers and knowledge production [12]. Contacts are especially helpful in the early stages of technology experimentation, where technology abandonment rates are usually higher [42, 41]. [43] argued that a landholder's probability of making a good decision increases over time with increasing knowledge of and perhaps experience with, the practice or technology. They report that land managers go through a typical sequence of acquiring and applying new knowledge, beginning with becoming aware of the technology or innovation. The land managers progress through a (non-trial) evaluation stage, where they collect information and begin to assess its usefulness in their own context, followed by a stage of small-scale trials. And then, if this is successful, adoption, review and modification and finally either fully adopting or abandoning the innovation. It has also been shown that land managers who participate in property management planning activities have a greater capacity to adopt more sustainable land management practices, indicating a link between knowledge and skills and the capacity to change [43].

The formal credit supports inputs and could be an additional benefit for adoption of innovative yam-based systems as well as on R&D and off R&D sites. Smallholder farmers in majority were often in prone to financial difficulties because of their low incomes and purchasing power. This situation limited inputs acquisition (equipments, mineral fertilizers, seeds...). Past research indicated that financial constraints were self-reported by land managers as an important barrier to the adoption of changed management practices [14, 44-48]. For example, a study of land manager attitudes in the Burdekin Dry Tropics region in northern Queensland found that operational and financial constraints were perceived as the most important impediments to the adoption of natural resource management activities or changed practices [14]. Similar surveys in the Burnett Mary and Queensland Murray Darling regions found that 76 and 81% of respondents, respectively identified cash flow as the highest rated constraint. But nevertheless, studies showed that financial resources may not be the main limiting factor when land managers consider adopting new technologies or changed practices. For example, ……. [49] suggested that where it can be shown that farm family income exceeds \$50, 000 per year then the constraints for undertaking changed practices were not necessarily financial. One suggestion is that land managers may be constrained by the perception that improved practices provide greater benefit to society at large than to the individual.

Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize According to the Gender: The negative sign of the β parameters estimated for the variable gender shows that the women have much more preference for yam-based system in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize than the men. Women who have more insecure land rights are more prone to adopt TMM than men. This situation was observed on R&D sites and should be related to external structures effects through contacts, trainings and advices. In addition, the effect of herbaceous legumes (*Mucuna*) should be expressed in short-term period with low labour requirement and generate immediate incomes for farm household. On the contrary, [21] former work showed that male farmers are more likely to adopt than women agroforestry in Cameroon. The authors argue that sustainable agricultural systems targeted to women farmers must be compatible with their land and tree tenure. Where women do not have secure rights to land, technologies which require that land be put under trees for a long period of time are unlikely to be adopted by women farmers. In such areas, short season improved fallow systems may be more appropriate for women farmers. Yam-based systems with herbaceous legumes will bring a higher present value than traditional systems (maize or 1-year *Andropogonon gayanus* fallow–yam) in the first 4 years and appeared attractive for land, labour and cash productivities [39].

Adaptations of Yam-Based System in Rotation with the Mixed Intercropping *Mucuna pruriens* Var *Utilis* and Maize and Implications for the International Applications: For the important constraint related to the biomass incorporation, smallholder farmers adapted the technology with the practice of both mulching and biomass incorporation into the soil. Three-quarters of biomass could be manually incorporated into the soil in October-November during ridging and the remaining biomass could be left on the surface as mulch in order to reduce workloads related to the incorporation. The practice of fire wall and fire of reference around the plot was necessary to avoid the burning of the mulch in dry periods. The mulch will contribute to protect seed yam from solar radiations, to improve soil humidity and earthworms' activity. Nevertheless, the seed production plot is needed in order to induce plant material availability.

End-users would undoubtedly adopt yam-based technologies with *Mucuna* if there was a market for the flow of seeds. The farmers assured about the marketing of their products would increase adoption. The existence of a market contributes to the adoption of improved technologies for high yields and farm household incomes [50, 51].

Mucuna seeds valorisation would generate additional incomes for smallholders' households. In fact, the seeds of *Mucuna* contains 3-(3, 4-dihydroxyphenyl)-L-alanine, known as L-Dopa which makes difficult *Mucuna* grains consumption. Human consumption of unprocessed beans can cause intoxication, but the toxins can be removed by boiling and soaking the seeds in several changes of water [52]. The L-Dopa content of Mucuna ranges from 4.7 to 6.4% [41]. The end-users would undoubtedly grant more credit to yam-based technologies with *Mucuna*, if in addition to its fertilizing role, the seeds were edible. In spite of the research undertaken by several organisations on this issue, *Mucuna* grain consumption remained difficult.

Animal feeding with *Mucuna* seeds deserves to be further investigated. The crop-livestock integration with this herbaceous legume should be an opportunity for yam production or other crops in dynamic of rotations, because of agropastoral potential in the Guinea-Sudan zone of Benin. Integration of forage legumes into the traditional fallow management can help improving both forage supply at a time of feed scarcity and soil fertility. Corralling contracts in the fence-based cropping systems with forage legumes inside the fence are important form of crop-livestock interaction during the dry season and could contribute to manures supply and nutrient cycling for the benefit of crops and soil. This practice returns both manure and urine to soil and can conserve nutrients.

A detailed attention deserves to be given to the technical, institutional and political problems facing end-users and more information, as well as advices are required in order to improve the level of adoption of yam-based technologies with herbaceous legumes.

The application of this technology will allow to natural resources better preserved, chemical pollution of the environment to be reduced and agricultural production to be diversified. Furthermore, this could contribute to plant biodiversity to be better conserved, bio fuel to be promoted, access of smallholders to land resources to be improved, as well as their capacity to manage these resources. This influence may be strengthened by suitable organizational arrangements to popularize adapted technologies, involving researchers, extension workers and farmers.

CONCLUSION

The study highlights that seven main factors determine adoption of yam in rotation with the mixed intercropping *Mucuna pruriens* var *utilis* and maize in the Guinea-Sudan zone of Benin. Contact with researchers and extension workers, population density zone, credit service, gender, land availability, farm household size and livestock size were identified as major discriminating factors for adoption. Adoption was more significant in the area with denser population. It was also more significant in Research and Development sites. Formal financial credit for inputs is significant for smallholder farmers and supports adoption. Women were more prone to adopt the yam-based system with *Mucuna* than men. Although this system is currently not yet widely used by smallholders, we predict that it will be adopted as soon as land pressure increases. We then propose to promote durable and replicable yam-based system, through a favourable legislative, economic and political environment to support local initiatives. Collaborations between research, development and extension structures should also be favoured to support the development and dissemination of innovations.

ACKNOWLEDGEMENTS

The authors express their sincere appreciation for the financial support received from the French Agency for Development (AFD) in the framework of the Support Project for Farm Household development (PADSE), the Development Project for Roots and Tubers (PDRT), the Food and Agriculture Organisation of the United Nations (FAO) in the framework of project TCP/BEN 3002 (A) “Sustainable production of yams adapted to the markets”, the International Centre for Cooperation in Agronomic Research for Development (CIRAD), the Cooperation Project for Academic and Scientific Research (CORUS) and the French Embassy in Benin.

REFERENCES

1. Onwueme, I.C. and J.A. Haverkort, 1991. Modelling growth and productivity of yams (*Dioscorea* spp.): Prospects and problems. Agricultural Systems, 36: 351-367.
2. FAOSTAT, http://apps.fao.org (accessed on February 13th 2009).
3. Lev, L.S. and A.L. Shriver, 1997. A trend analysis of yam production, area, yield and trade (1961-1996). In L’igname plante séculaire et culture d’avenir. Actes du séminaire international, 3-6 juin 1997, Eds., Berthaud, J., N. Bricas and J. Marchand, CIRAD, INRA, ORSTOM, CORAF, Montpellier (France), pp: 11-20.
4. Carsky, R.J., N. Wolo, V.M. Manyong and G. Tian, 2001. Understanding soil factors limiting the potential yield of yam (*Dioscorea spp*.). Proceedings of the 7th Triennal Symposium of the International Society for Tropical Root Crops-Africa Branch, Cotonou, Benin. Eds., Akoroda M.O. and J.M. Ngeve, pp: 198-209.
5. Martin, F.W., 1974. Tropical Yams and their Potential. Part 3. *Dioscorea alata.* Washington, USDA, Agriculture Handbook Nr. 495., pp: 39.
6. Zinsou, C., 1998. Physiologie et morphogénèse de l’igname (*Dioscorea spp.*). In ‘Actes du Séminaire International sur l’igname, Montpellier, France. Eds., Berthaud J., N. Bricas and J.L. Marchand, pp: 213-222.
7. FAOSTAT, 2010. Crop data. [On-line] [2011-05-15] <URL: http://faostat.fao.org/site/567/default.aspx# ancor >.
8. Carsky, R.J., S.A. Tarawali, M. Becker, D. Chicoye, G. Tian and N. Sauplaga, 1998. *Mucuna*-herbaceous cover legume with potential for multiple use, IITA. Ress. Crop. Manag. Resea. Monog. N° 25, pp: 52.
9. Adjei-Nsiah, S., T.W. Kuyper, C. Leeuwis, M.K. Abekoe and K.E. Giller, 2007. Evaluating sustainable and profitable cropping sequences with cassava and four legume crops: Effects on soil fertility and maize yields in the forest/savannah transitional agro-ecological zone of Ghana. Field Crops Research, 103: 87-97.
10. Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. 2nd Ed. CAB International, Wallingford, UK.
11. Sodjadan, P.K., A.M. Toukourou, R.J. Carsky and P. Vernier, 2005. Effets des précédentes plantes de couverture sur la production de l'igname en zone de savane au Bénin et au Togo. African Journal of Root and Tuber Crops, 6(1): 34-40.
12. Maliki, R., 2006. Sédentarisation de la culture de l’igname et gestion durable des ressources naturelles au centre du Bénin: développement participatif, contraintes, adoption et diffusion des technologies. Mémoire du DEA en Aménagement et Gestion des Ressources Naturelles (AGRN), Faculté des Sciences Agronomiques de l'Université d'Abomey Calavi, pp: 312.

13. Battershill, M.R.J. and A.W. Gilg, 1997. Socio-economic constraints and environmentally friendly farming in the south-west of England. Journal of Rural Studies, 13(2): 213-228.
14. Greiner, R., L. Patterson and O. Miller, 2008. Motivations, risk perceptions and adoption of conservation practices by farmers. Agricultural Systems (in press).
15. Zannou, A., 2006. Socio-economic, agronomic and molecular analysis of yam and cowpea diversity in the Guinea-Sudan transition zone of Benin. PhD Thesis, Wageningen University, pp: 246.
16. Agossou, V. and I. Mouïnou, 2002. Caractérisation des sols des sites de recherche développement du CRA-Centre: classification dans la base de référence mondiale et actualisation de leur niveau de dégradation, Atelier scientifique Centre (1ére édition) 18 au 19 Déc.2002 au CRA- Centre, INRAB/MAEP, Savè, Bénin.
17. Arodokoun, D., A.M. Matthess, B. Agbo, P. Akondé, M. Adomou, H. Hodonou, G. Agbahungba and J. Sagbohan, 2004. Manuel du cycle de gestion de la recherche agricole au Bénin. MAEP, Cotonou, pp: 103.
18. Maddala, G.S., 1983. Limited Dependent and Quantitative Variables in Econometrics. Econometric Society Monograms 3. Cambridge University Press, Cambridge.
19. Alavalapati, J.R.R., M.K. Luckert and D.S. Gill, 1995. Adoption of agroforestry practices: a case study from Andhra Pradesh, India. Agrofor. Syst., 32: 1-14.
20. Ayuk, E.T., 1997. Adoption of agroforestry technology: the case of live hedges in central plateau of Burkina Faso. Agric. Syst., 54: 189-206.
21. Adesina, A.A., D. Mbila, G.B. Nkamleu and D. Endamana, 2000. Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon. Agriculture, Ecosystems and Environ., 80: 255-265.
22. Agresti, A., 1996. An Introduction to Categorical Data Analysis. John Wiley & Sons, New York.
23. Greene, W.H., 2000. Econometric Analysis. Prentice Hall, Upper saddle River, New Jersey. ICRAF, 1996. Agroforestry for Sustainable Rural Development in the Zambezi Basin. Project Management Plan. International Center for Research in Agroforestry, Nairobi, Kenya.
24. Rgph3, 2004. Cahier des villages et quartiers de ville: département des Collines. MPPD/INSAE, Cotonou, Bénin.
25. Lares, 2001. La problématique de l'intercommunauté dans le fonctionnement des communes, 253p, LARES, Cotonou, Bénin.
26. Dongmo, 1978. Farm land space use and development in tropical Africa: farmers'perception and technical rationality, Ouagadougou workshop 4–8 December 1978, Orstom.
27. Parrot, L., C. Dongmo, M. Ndoumbé and C. Poubom, 2008. Horticulture, livelihoods and urban transition in Africa: evidence from South-West Cameroon. Agricultural Economics, 39: 245-256.
28. Bonnard, P. and S. Scherr, 1994. Within gender differences in tree management: is gender distinction a reliable concept? Agroforestry Systems, 25: 71-93.
29. Adesina, A.A., O. Coulibaly, V.M. Manyong, P.C. Sanginga, D. Mbila, J. Chianu and D.G. Kamleu, 1999. Policy shifts and adoption of alley farming in West and Central Africa. IITA annual report, Ibadan, Nigeria, pp: 50.
30. Cameron, L.A., 1999. The importance of learning in the adoption of high-yielding variety seeds. American Journal of Agricultural Economics, 81: 83-94.
31. Neill, S. and D. Lee, 2002. Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in northern Honduras. Economic Development and Cultural Change, 49: 793-820.
32. Celis, R. and C. Holleman, 1991. The effects of adopting technology on the household use of labor. In Adopting Improved Farm Technology: A Study of Smallholder Farmers in Eastern Province, Zambia. IFPRI, Washington, DC, Eds., Celis, R., J.T Milimo and S. Wanmali.
33. Moser, C.M. and C.B. Barrett, 2002. The disappointing adoption dynamics of a yield increasing, low external-input technology: the case of SRI in Madagascar. Journal of Agricultural Systems, 76: 1085-1100
34. Maliki, R., F. Amadji, I. Adje and C. Englehart, 2000. Quelques options de gestion de la fertilité des sols et de stabilisation des rendements dans la zone des savanes au centre du Bénin: Constraintes à leur adoption. Bulletin de la Recherche Agronomique du Bénin, 28: 1-15.
35. Adégbola, P. and A. Arouna, 2004. Déterminants socio-économiques de l'adoption des technologies de gestion de la fertilité des sols au Sud du Bénin: une analyse avec un modèle logit multinominal. Communication À L'atelier Scientifique National, pp: 9.

36. Saka, J.O., V.O. Okoruwa, B.O. Lawal and S. Ajijola, 2005. Adoption of Improved Rice Varieties among Small-Holder Farmers in South-Western Nigeria. World Journal of Agricultural Sciences, 1(1): 42-49.
37. Greene, H.W., 1995. Limdep version 7.0, Manual. Econometric Software Incorporated, USA.
38. Honlonkou, N.A., 1999. Economic impact of techniques of soil fertilization: Case of *Mucuna* fallow in south of Benin. Thesis in rural economy, CIRES, University of Cocody, Abidjan, Ivory Coast, pp: 188.
39. Maliki, R., M. Toukourou, B. Sinsin and P. Vernier, 2012. Productivity of yam-based systems with herbaceous legumes and short fallows in the Guinea-Sudan transition zone of Benin. Nutrient Cycling in Agroecosystems, 92(1): 9. DOI: 10.1007/s10705-011-9468-7.
40. Snrech, S., 1995. West african agriculture processing, evolution 1960-1990. Challenge for Future, Implications for Sahalian Countries, pp: 39.
41. Versteeg, M.N. and V. Koudokpon, 1993. Participative farmer testing of four low external input technologies, to address soil fertility decline in Mono province (Benin). Agric. Syst., 42: 265-276.
42. Atta-Krah, A.N. and P.A. Francis, 1987. The role of on-farm trials in the evaluation of composite technologies: the case of alley farming in southern Nigeria. Agric. Syst., 23: 133-152.
43. Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay and R. Wilkinson, 2006. Understanding and promoting adoption of conservation technologies by rural landholders. Australian Journal of Experimental Agriculture, 46: 1407-1424.
44. Besley, T. and A. Case, 1993. Modeling technology adoption in developing countries. American Economic Review 83 (May), pp: 396-402.
45. Zeller, M., 1994. Determinants of credit rationing: a study of informal lenders and formal credit groups in Madagascar. World Development, 22: 1895-1907.
46. Foster, A. and M. Rosenzweig, 1995. Learning By doing and learning from others: human capital and technical change in agriculture. Journal of Political Economy.
47. Cary, J., T. Webb and N. Barr, 2002. Understanding land managers' capacity to change to sustainable practices: insights about practice adoption and social capacity for change, Bureau of Rural Sciences, Canberra.
48. Byron, I., A. Curtis and J. MacKay, 2004. Providing social data to underpin catchment planning in the Queensland Murray-Darling region, Bureau of Rural Sciences, Canberra.
49. Rendell, R., P. O'Callagan and N. Clark, 1996. *Families, Farming & the Future*. Agriculture Victoria, Bendigo.
50. Boserup, E., 1970. Land use systems evolution and démographic pressure; Eds Flammarion, Paris.
51. Braun, V.E. and J. Kennedy, 1986. Commercialization of subsistance agriculture: Income and nutritional effects in developing countries, In Binswanger H.P. and V.J. Braun.
52. Kay, D., 1979. Food legumes. Tropical Products Institute, London, UK. Crop and Product Digest No. 3, pp: 435.