

# Econometric Analysis of the Determinants of Adoption of Yam-Based Cropping Systems in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize in the Guinea-Sudan Zone of Benin

Raphiou Maliki\*, Brice Sinsin, Laurent Parrot, Jacques Lançon, Anne Floquet and NeBambi Lutaladio

\*Corresponding author email id: malikird@yahoo.fr

**Abstract** – In West Africa, yam cultivation is now facing increasing scarcity of fertile soils because of the “slash and burn” and shifting traditional cultivation systems highlighted by the excessive reduction of agricultural productivity. With the aim of designing more sustainable yam cropping systems, alternative systems with *Aeschynomene histrix* are promoted in the Guinea - zone of Benin. This paper, aims at identifying factors that may explain the adoption of yam-based system in rotation with the mixed intercropping *Aeschynomene histrix* and maize for soil conservation and sustainable yam production. 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. As results: Contact with researchers and extension workers, credit service, population density in zone, gender, and farm household size 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 were more prone to adopt yam-based cropping with *Aeschynomene* than men. In addition, the study highlights disadoption, advantages, constraints, adaptations of technology and implications for the international applications.

**Keywords** – Adaptation; Adoption; *Aeschynomene histrix*; Constraints; Disadoption; Herbaceous Legume; Logit; Yam.

## I. INTRODUCTION

Current yam-based cropping systems, which involve shifting cultivation, slash-and-burn or short fallow, often result in deforestation and soil nutrient depletion [1]. As long as population pressure was low, the cropping phase was short compared to the fallow period. Three or four years of cultivation followed by ten years or more of fallow, for example allows the accumulation of easily degradable organic matter to regenerate soil fertility [2]-[3]. Where population increases, available land per inhabitant is reduced and fallow periods shorten. Traditional long-fallow shifting cultivation can no longer continue in most of humid sub-Saharan Africa. Increasing population densities are posing a serious threat to natural resources and agricultural production. Farmers' response to higher food demand has been either an increase in cultivated area or/and a reduction of fallow period. The minimum fallow duration to maintain crop production was estimated at 12 years [4]. Fallow periods in most of the humid zone of West and Central Africa are actually between 5 and 2 years [5], reinforcing the need to seek alternative food production systems [4].

Yam is a demanding crop in terms of organic matter and soil fertility, especially the most appreciated and market-valued cultivars (early maturing *Dioscorea rotundata*) used for the popular dish called “fu-fu” (pounded yam) [6]. According to [6], harvest of 1 t of yam fresh tubers takes up to 3.8 kg of nitrogen, 0.39 kg of phosphorus and 4.2 kg of potassium. The amount of nutrients removed in the yam tuber harvest could, however, depend on growth rate and yield which in turn depends on climate, soil fertility conditions and variety. The quantities of soil N supply would depend on the yield potential of yam on a particular soil and of the soil's ability to supply N. Levels of N decline rapidly once cropping commenced [7]. Nitrogen supplied from the breakdown of inherent organic matter must be supplemented from other sources. Yam cultivation in West Africa is now confronted with the scarcity of fertile soil available for clearing [1]. In degraded zones where long duration fallow periods were no longer available, market-oriented yam production either strongly decreased, or evolved toward more tolerant but also less profitable varieties such as late maturing *D. rotundata* or *D. alata* better adapted to poor soils [8].

Therefore, there is a dire need to economically assess in farmers' conditions the performance of sustainable cultivation techniques. Ongoing soil degradation could be mitigated by the adoption of the new farming techniques such as improved fallow of herbaceous leguminous plants [9]-[10]. This will serve an alternative solution to maintain the potentials of the land resources under the various prevailing economic, social and political environment. Where smallholders' access to N fertilizer is limited, legume-based fallows, which, through symbiotic N-fixation, appear capable to provide more N than the natural fallow, allowing sole maize crops at high plant densities. Legumes improve soil fertility because of their ability to fix N<sub>2</sub> and produce N-rich residues that may be returned to the soil [11]-[12]-[13].

With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes (*Aeschynomene histrix*). On the basis of the results of this on-farm research, yam based systems in rotation with the mixed intercropping *Aeschynomene histrix* 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 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 [14]-[15]. In this paper, we intend to identify factors that may explain the adoption of yam-based system in rotation with the mixed intercropping *Aeschynomene histrix* and maize 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 the improved yam-based cropping systems. 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.

## II. METHODOLOGY

### A. Study Area

The study was carried out in the Guinea-Sudan zone of Benin in a low (Savalou, Bante, Save and Ouesse) and in a relatively high population density zone (Dassa-Zoume, Glazoue). 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 [16].

The soils are plinthosols and luvisols. The soil physical properties vary according to their clay content [17]. Vegetation is a degraded woody savannah type. Maize, yam, cassava and groundnut are annual cropping systems and the cash crops are cotton and soybean.

### B. Yam-Based Systems in Rotation with the Mixed Intercropping *Aeschynomene Histrix* and Maize

Smallholder farmers planted maize (spacing 80 × 40 cm) in April of the first year. *A. histrix* seeds (7 kg ha<sup>-1</sup>) were sown two weeks after the maize. In the improved yam-based system (TMA), smallholder farmers applied or no on maize 100 kg ha<sup>-1</sup> NPK fertilizer (14% N, 10% P, 11.7% K) in April and 50 kg ha<sup>-1</sup> urea (46% N) in June. The maize was harvested in July. The grainless *A. histrix* crops were mowed 180 days after planting. Organic matter was incorporated in mounds in October, and then yam was planted directly on these mounds, without mineral fertilization.

### C. Theoretical Model of Adoption

The dependent variable, adoption of soil conservation innovation with the mixed intercropping *Aeschynomene histrix* 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

$$y = 1 \text{ if } y_i^* > 0 \quad (2)$$

$$y = 0 \text{ otherwise}$$

From equations (1) and (2), the probability that  $y = 1$  a particular farmer will adopt soil conservation innovations with the mixed intercropping *Aeschynomene* 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 [22], and  $\beta$  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:

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

and the likelihood [19] is:

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

The confidence interval is another goodness-of-fit measure. After estimating the  $\beta$ s, confidence intervals (CI), a statistical inference for the model parameters can be performed to help judge the magnitude of the significance [23]. 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 [24], 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:

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

#### D. Empirical Model of Adoption

Table 1 shows the sampling size for individual 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	Ouesse	36	12
		Save	21	
	D site	Ouesse	40	49
		Savalou	39	
		Bante	50	
Relatively high population density zone	R-D site	Dassa	20	13
		Glazoue	19	
	Off R & D site	Dassa	41	26
		Glazoue	40	
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.

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" [25] and other relevant documents were analyzed [26]. 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.

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 [27]-[28]. 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 [29]-[30]-[31]-[32]. 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 [33]-[34]. 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 [35]. 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 [36]-[37]. 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 [30]-[36]. 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 [33].

### III. RESULTS

#### A. Multivariate Analysis of Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize

Adoption of yam in rotation with the intercropping *Aeschynomene histrix* and maize (TMA) was 22% (Table 3).

The percentage of adopter's women was 4% whereas 18% were recorded for men. The models had rather good predictive and estimated properties. The  $\chi^2$  test was highly significant ( $p < 0.01$ ). The percentage of correct prediction was high (79.74%). Results of Student's test revealed that seven variables determined the adoption of TMA: "CONTACT" with external agents, "CREDIT", population density in "ZONE", GENDER and NBOUCH.

Further, the rate of adoption of TMA was higher in denser zone (13%) than in the low-density zone (9%). The rate of adoption was also higher in the Research and Development (R & D) sites (13%), where farmers had much more in contact with research and extension than in the other sites (9%). (Table 4).

#### B. Advantages and Constraints of Yam in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize in the Guinea-Sudan Zone of Benin

*Aeschynomene* was appreciated for its capacity to increase crop yield (yam) and supplemented the animal feeding according to farmers' opinions. However, smallholder farmers highlighted some constraints that limiting adoption. *Aeschynomene* biomass incorporation appeared as most of important constraints in yam-based system with *Aeschynomene histrix* (TMA) with 21% and 84% in relatively high population density zone (ZA) and low population density zone (ZB:) (Table 5).

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

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

Site type	Population density	Adoption type	Categories	Size 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	4	1		1		1	
			Adopter men	19	6	6	6			
	Non-adopter	Never adopted	9		3					
		Disadopter	6		2					
Low population density	Adopter	Adopter wome	4	1		1			1	
		Adopter men	14	5	5	5			5	
	Non-adopter	Never adopted	19		6					
		Disadopter	0		0					

Acronym of variable	Description of variable and value	Mean	Standard deviation
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.

Table 3. Econometric model of the discriminating factors affecting adoption of yam in rotation with the mixed intercropping *Aeschynomene histrix* and maize in the Guinea-Sudan zone of Benin

Acronym of variable	Estimated $\beta$	T test
ZONE (Demographic zone/population density)	0.098	2.107**
SUPDISP (Household land surface available)	-1.98E-04	-0.064
GENDER (Male or female)	-0.136	-2.732**
NBOUCH (Household' size)	0.012	2.813**
FTRAV (Household' labor size)	0.013	1.354
ORIGIN (Owner status: indigenous or immigrant)	-0.026	-0.493
CONTACT (Contact with the change agents)	0.257	5.799***
CREDIT (Access to credit)	0.434	4.768***
NIVELEV (Livestock size (sheep, goat and cow))	4.34E-04	0.244
Log-probabilities	-144.01	
$\chi^2$	44.01***	
% of prediction	79.74	

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

$\beta$  = 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.

Site type	Population density	Adoption type	Categories	Size 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 (%)
Off R-D sites	Denser population	Adopter	Adopter women	3	1			1	1	
			Adopter men	15	5			5	5	
		Non-adopter	Never adopted	53		17				
	Disadopter		6		2					
	Low population density	Adopter	Adopter women	2	1			1		1
			Adopter men	7	2			2		2
Non-adopter		Never adopted	145		47					
	Disadopter	0		0						
Total				306	22	78	13	9	13	9

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

Table 5. Constraints of yam in rotation with the mixed intercropping *Aeschynomene* and maize (Farm household level)

Constraints	ZA (N=186)		ZB (N=120)		Frequency	Percentage (%)	OI
	Frequency	Percentage (%)	Frequency	Percentage (%)			
Biomass incorporation	39/186	21	101/120	84	140/306	46	1
Grains harvest	39/186	21	38/120	32	77/306	25	2
Animal divagation	29/186	16	35/120	29	64/306	21	3
Seeds marketing	30/186	16	-	-	30/306	10	4
Reptile refuge	-	-	14/120	12	14/306	5	5
Seeds consumption	9/186	5	5/120	4	14/306	5	5
Fertilizers cost	9/186	5	3/120	3	12/306	4	6
Plot maintenance	9/186	5	-	-	9/306	3	7

ZA: relatively high population density zone; ZB: low population density zone; OI: importance order. Smallholder farmers revealed the problem of *Aeschynomene* seeds harvest such as the small size of seeds (21% and 32%), the animal divagation (16% and 29%) in the ZA and ZB and the inexistence of the flow market (16%) in ZA.

#### IV. DISCUSSION

##### A. Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize in Denser and Low Population Density Zone

Adoption of yam-based system in rotation with the mixed intercropping *Aeschynomene histrix* and maize (TMA) 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 farmers look relatively inclined to develop more sustainable and more productive systems.

Studies conducted by [27]. In the Bamileke area, Cameroun, 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 km<sup>2</sup>, intensive agriculture is much less frequent than it is in the south where the population density frequently exceeds 200 inhabitants per km<sup>2</sup>.

##### B. Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Aeschynomene histrix* 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. Contacts are especially helpful in the early stages of technology experimentation, where technology abandonment rates are usually higher [38]-[39]. [40] 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 (disadoption). 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 [40].

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 [41]-[42]-[43]-[44]-[15]-[45]. 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 [15]. 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, [46] 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.

#### C. Adoption of Yam-Based System in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize According to the Gender

The negative sign of the  $\beta$  parameters estimated for the variable gender shows that the women have much more preference for yam-based system in rotation with the mixed intercropping *Aeschynomene histrix* and maize than the men. Women who have more insecure land rights are more prone to adopt TMA 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 (*Aeschynomene histrix*) 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 [47].

#### D. Adaptations of Yam-Based System in Rotation with the Mixed Intercropping *Aeschynomene histrix* and Maize and Implications for the International Applications

*Aeschynomene* was appreciated for its capacity to increase crop yield (yam) and supplemented the animal feeding according to farmers' opinions. However, smallholder farmers in the study area expressed constraints for *Aeschynomene* used as more particularly the small size of seeds and the problem of the management of seeds during planting, lignified stems of *Aeschynomene* after two years of plant growth and the problem of the *Aeschynomene* biomass incorporation, crop competition,

animal divagation, high fertilizers cost, legumes burning, and absence of markets for seed.

For the important constraint related to the lignified stems of *Aeschynomene* after two years growth and the biomass incorporation, smallholder farmers adapted the technology with the practice of early incorporation after one year of biomass production or conducting both mulching and biomass incorporation into the soil (Figure 1). 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 is 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. However, the small size of seeds and the problem of the management of seeds during planting and harvesting were evocated. During the harvest on the seed production plot, the biomass of *Aeschynomene* at senescence was shaken within basins to collect easily the seed (Figure 2). About the problem of *Aeschynomene* seed sowing, smallholder farmers planted maize in April of the first year. *Aeschynomene* seeds ( $7 \text{ kg ha}^{-1}$ ) were mixed with dry sand  $21 \text{ kg/ha}$  ( $3/4 \text{ sand} - 1/4 \text{ seeds}$ ) and sown two weeks after the maize in order to avoid grains losses during planting.

The crop-livestock integration with *Aeschynomene* should be an opportunity for yam production in dynamic of rotations, because of agro pastoral 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. Corraling contracts in the fence-based cropping systems with forage legumes 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.

## V. CONCLUSION

The study highlights that six main factors determine adoption of innovative yam in rotation with the mixed intercropping *Aeschynomene histrix* and maize in the Guinea-Sudan zone of Benin. Contact with researchers and extension workers, credit service, population density in zone, gender, and farm household size were identified as major discriminating factors for adoption. The 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 adopt

the yam-based cropping system with *Aeschynomene* than men. Although these systems are currently not yet widely used by smallholders, we predict that they will be adopted as soon as land pressure increases. We then propose to promote durable and replicable yam-based systems with *Aeschynomene*, 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.

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Fig. 1. Both mulching and *Aeschynomene histrix* biomass incorporation into the soil with the ridges in the yam-based system with the mixed intercropping *Aeschynomene histrix* and maize in the Guinea-Sudan zone of Benin Three-quarters of *Aeschynomene histrix* biomass manually incorporated into the soil in October-November during ridging, and the remaining quarter left on the surface as mulch in order to reduce the workload related to the biomass incorporation in the soil



Fig. 2. *Aeschynomene histrix* seeds harvesting in the Guinea-Sudan zone of Benin On the seed production plot, the biomass of *Aeschynomene* at senescence is shaken within basins to collect easily the seed.



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## AUTHOR'S PROFILE



**Raphiou Maliki** is an Agronomist, with a PhD in Natural Resource Management and Conservation in West Africa. He is Coordinator of Research and Development (R-D) in INRAB (National Agricultural Research Institute of Benin). Interim Director of CRA-Centre (Agricultural Research Center) of INRAB, and Administrative and Technical Chief of CRA-Centre. ICRA Expert 1999 (International Center in Agricultural Research for Development), National consultant FAO (Food and Agriculture Organization of the United Nations) of the Project TCP/BEN/3002 (A). Winner of The national Energy Globe Award Benin 2014 awarded to the project ("Solar Systems for Energy Self-Sufficient Households"), member of PAEPARD and CGIAR networks. Roots and Tubers Expert for the Green Innovations Center (CIVA) of AfricaRice/IITA Benin (International Institute of Tropical Agriculture). Worked in close relationship with CIRAD (International Centre for Cooperation in Agronomic Research for Development). Author of several articles in the Integrated Soil Fertility Management and Conservation, speaks French and English. Fields of research (agroforestry systems, sedentary-based cropping systems, cover cropping systems, organic/biological/ecological agriculture, cashew plant breeding and management systems, Agro pastoral conflicts prevention and management, Climatic Changes, Green/Renewable Energy, Value Chains Productivity).