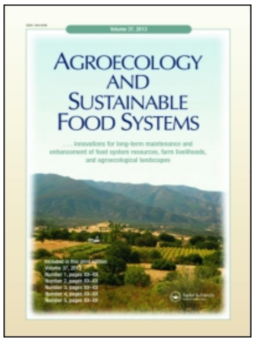

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Sedentary yam-based cropping systems in West Africa: Benefits of the use of herbaceous cover-crop legumes and rotation—lessons and challenges

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ABSTRACT
New farming technologies such as improved fallow of herbaceous legumes have been developed over the last 20 years as alternatives to traditional yam cropping systems in areas where shifting cultivation is no more possible. One aim of this research was to analyze actual adoption by smallholders of such a technology and influencing factors in the Southern Guinea Savannah in Benin (West Africa). On the other hand, a second objective was to measure agronomic and economic performances of the innovative yam-based cropping systems in comparison with the usual ones under producers' natural and socioeconomic circumstances in order to discuss the technology potential for large scale adoption. Smallholders with limited land access now develop as usual cropping systems a one-year fallow of Andropogonon gayanus–yam rotation or a maize–yam rotation. Innovative sedentary yam-based systems consist of an Aeschynomene histrix intercropped with maize–yam rotation or a Mucuna pruriens intercropped with maize–yam rotation. Factors potentially affecting adoption were included in a polynomial logit model. Agronomic and economic performances were assessed by the multiple regression and net present value of the 4-years double rotation. Ranking matrix was used to highlight constraints that may impede adoption. Benefits, lessons, and challenges are discussed in this article.

KEYWORDS
Adoption; contingent ranking matrix; economic intensification; herbaceous legumes; sustainable agriculture

1. Introduction

More than 90% of the yam (*Dioscorea* spp.) world production (40 Mt fresh tubers/year) is produced in West Africa, especially in five coastal countries: Ivory Coast, Ghana, Togo, Benin, and Nigeria (FAOSTAT 2015).

Yam is a demanding crop in terms of organic matter and nutrients, especially the most appreciated and market-valued cultivars (early maturing white yam *Dioscorea cayenensis* subsp. *rotundata*) used for the popular dish called "fu-fu" (pounded yam). Yam is an autochthonous crop in West Africa and as such has been integrated in traditional shifting cultivation systems. As

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already well assessed by Nye and Greenland (1960), shifting cultivation maintains soil qualities as long as short rotations alternate with long fallow periods; 2–4 years of cultivation followed by at least a 10 years fallow allowing for accumulation of easily degradable organic matter maintain soil fertility (Gaiser et al. 1999; Salako et al. 2001; Hauser 2006; Igué et al. 2008). Shifting cultivation and long fallow are conditioned by low population pressure.

Yam cultivation remains a major cause of the deforestation of the last forests in the West African yam belt that expands over five countries. In this area, settlers are joined by migrants from both northern and southern densely populated and depleted parts of these countries in clearing forest lands. At the same time, yam cultivation is increasingly confronted with the scarcity of fertile forest land (Doumbia 2005). In many parts of the yam growing areas, farmers are unable to leave their lands fallow for long periods and depend on 1–2 years of herbaceous fallows. Farmers also practice rotation with maize or sorghum. In addition, cereal stalks serve as stakes for trailing yam vines and as crop residue to replenish the soil (Maliki 2006).

In Benin, yam rarely takes advantage of yield improving technologies as has been the case for maize, cassava, and recently, rice. When producers are obliged to plant yam on older fields, they have to switch to less demanding and less valued ecotypes and landraces such as "kokoros" and they expect yield decline (Vernier and Dossou 2003).

A few researchers have been working with farmers since the 1990s to design alternative cropping systems for sedentary yam cultivation that maintain soil quality and cope with a wide range of yam ecotypes, including the most demanding ones. Some cropping systems mimic a woody fallow using fast growing legume shrubs in alleys (Raintree and Warner 1986), while others try to replace natural fallow with herbaceous cover crops; both systems may also be combined. Participatory experiments have been conducted over the last 20 years. Two yam plantation variants have also been tested in Benin, yam being planted as usual on mounds after incorporation of the biomass or installed by zero tillage in mulch (Cornet et al. 2009). The latter option produced small tubers less appreciated by farmers. The purpose of this article is to discuss the potential for adoption of these herbaceous cover crops in yam-based cropping systems.

Prior experiences with cover crops have revealed that even after a significant adoption, dis-adoption may also happen. In Honduras, Buckles and Triomphe (1999) and Neill and Lee (2001) analyzed how an apparently successful maize–Mucuna system that had been widely adopted was abandoned when land availability further decreased. In Benin, Honlonkou, Manyong, and Tchetche (1999) assessed the economic outcomes and perceptions of the maize–Mucuna technology and were optimistic about the potential adoption of this system; however, it was very soon dis-adopted at the end of project-induced promotion campaigns.

In this article, the agro-economic performance of cover crop technology in smallholders' farms is discussed, as well as its potential stability. The possibility for smallholders to overcome actual constraints and shortcomings of the new system is weighed with and without additional policy interventions. The benefits of incorporating cover crops in the yam-based cropping system, compared to other intensification technologies, are highlighted.

2. Materials and methods

Two types of data have been used for this article: data from an adoption survey of a cover crop in two zones covering gradients of densely and less densely populated environments, and data from on-farm trials with two cover crops in four villages representing these two zones.

2.1. Study area

Research was carried out in the Southern Guinea Savannah zone of Benin (bimodal rainfall) and in its transition to the Northern Guinea Savannah (monomodal rainfall), within latitude ranges 7°45′–8°40′N and longitude ranges 2°20′–2°35′E, in sites located in a lower population density area in the northern zone (11–49 inhabitants km^{-2}) and in a more degraded permanent cultivation area in the South (50–89 inhabitants km^{-2}). All these sites belong to the same administrative province (Collines). In each area, experimentation was conducted on four research and development (R&D) sites, respectively (Akpéro, Gbanlin, Miniffi, and Gomè), where technical staff was permanently posted to monitor on-farm trials.

This area is located in a so-called transition zone between a two rainy seasons and a one season pattern. Annual rainfall during the study period was 1,052 mm (2002), 1,386 mm (2003), 983 mm (2004), and 797 mm (2005).

2.2. Choice of cover crops species

The objective was to obtain similar effects as from a forest long fallow; therefore, cover crops rather than edible legumes were chosen. After screening, cover crops selected were *Mucuna pruriens* (L.) DC. and *Aeschynomene histrix* Poiret. *M. pruriens* is an annual legume, also called "velvet bean." Its fast-growing vines have a good ability to cover the soil and smother weeds in the rainy season as well as to produce a thick mulch in the dry season. *Mucuna* spp. can be installed in a short cycle crop such as maize, provided the main crop is sown first and granted a good start before *Mucuna* spp. begins its own development. Seeds are heavy beans, with a high protein content; their consumption has been discouraged because of their toxins (L-DOPA) that require special treatment. The plant and especially the pods can cause itching. Several subspecies have been tested in Benin since the 1980s. In most cases, producers used it to control spear grass *Imperata cylindrica* and abandoned it later. *A. histrix* has been more recently selected as a perennial, semi-erect legume that can also be installed in association with a crop and can be used as forage and cover crop; its ability to suppress *Striga* sp. germination is valued.

Both species have been tested in yam-based cropping systems as cover crops producing mulch, in which yam has been planted twice in 2003 and 2005. In the 2005 adoption survey, only *Mucuna* spp. is quoted by producers, whereas *Aeschynomene* is still in the test phase.

2.3. Farming system research and extension activities

Most of the experiments developed since 2000 in the study area have been conducted on the four R&D sites mentioned above. However, farmers from surrounding villages and districts have been visiting the trials, either informally or at the instigation of a few extension and NGO officers. In spite of the fact that extension has not been systematic, some diffusion could be observed. Therefore, an adoption survey was conducted in 2005 in the "Collines" Province by 75 R&D on-site (25%) and 231 off-site producers (75%) located in 27 villages in both low and relatively high population density areas (Table 1).

Sampling was proportional to population size. In each village, sampling was conducted along a transect in order to maximize agroecological diversity. The survey identified adopters and non-adopters of yam-based cropping system in rotation with intercropping *Mucuna* and maize. Adopters planted maize (at 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 6 weeks after the maize. They applied or no on maize 100 kg ha^{-1} NPK fertilizer in April and 50 kg ha^{-1} urea in June. The maize was harvested in July. The grainless *M. pruriens* crops were mowed 140 days after planting. Organic matter was incorporated in mounds in October, and then yam was planted directly on these mounds, without mineral fertilization. Among non-adopters, producers could be found who had never adopted as well as some who had dropped the technology after its test (Tables 2 and 3).

2.4. Adoption assessment of yam-based cropping systems with herbaceous legumes

2.4.1. Qualitative appraisal of the technologies

Focus groups of about 30 male and 20 female farmers discussed the main constraints and advantages of the yam-based cropping system in rotation with intercropped *Mucuna* spp. in maize in both low and high population density areas. Prioritization and contingent ranking matrices were built to

Table 1. Sample size for household-level survey in the Guinea–Sudan transition zone of Benin.

Zone	Site	District	Village	Household sampling size	Percentage per village (%)	Percentage per site (%)
Low-population density zone	Site R&D	Ouèssè	Gbanlin	16	5	12
		Ouessè	Akpéro	20	7	
	Off-site R&D	Savè	Gbée	11	4	49
		Savè	Ouoghi	10	3	
		Ouèssè	Malété	11	4	
		Ouèssè	Yaoui	9	3	
		Ouèssè	Zogbatrékou	10	3	
		Ouèssè	Tchogodo	10	3	
		Savalou	Logozohè	10	3	
		Savalou	Mondji	10	3	
		Savalou	Monkpa	9	3	
		Savalou	Lahotan	10	3	
		Bantè	Akpassi	10	3	
		Bantè	Agoua	10	3	
		Bantè	Ikoko	10	3	
		Bantè	Kouloubou	10	3	
		Bantè	Ilélakou	10	3	
Relatively denser population zone	Site R&D	Dassa	Miniffi	20	7	13
		Glazoué	Gomè	19	7	
	Off-site R&D	Dassa	Iléma	9	3	26
		Dassa	Yonkpingnon	11	4	
		Dassa	Odo-Ochéré	10	3	
		Dassa	Gankpétin	11	4	
		Glazoué	Haya	9	3	
		Glazoué	Yagbo	12	4	
		Glazoué	Zaffé	9	3	
		Glazoué	Agouagon	10	3	
Total				306	100	100

R&D: Research and development.

compare the relative importance of a constraint (IR) and its degree of severity (DS) as developed by Deffo et al. (2004). The relative importance of a constraint (IR) is the score that the end users gave to a constraint. Participants freely established the notation. The maximum score corresponded to the constraint that the group considered most important. The minimum score was selected equal to zero for the group. The degree of a constraint severity (DS) is the percentage of the note given to a constraint compared to the maximum score. Technology constraints were also assessed by frequency analysis during the farm–household survey (among 120 and 186 households) in low and relatively high population density, respectively.

2.4.2. Quantitative assessment and adoption model

A dichotomous logistic model was 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

Table 2. Status of adopters and non-adopters of yam-based technologies with intercropped *Mucuna pruriens* var. *utilis* and maize in the R&D sites (Guinea–Sudan zone of Benin).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
Household characteristics		n = 33 (10.8%)	n = 6 (2.0%)	n = 4 (1.3%)	n = 27 (8.8%)	n = 12 (3.9%)	n = 0 (0%)
Age	Average hold (year)	45	35	49	49	41	–
	Standard deviation	11.2	5.9	2.2	9.0	7.9	–
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 of years of experiment	Year	21	12	22	24	20	–
	Standard deviation	13.5	5	10.8	7.1	8.2	–
Households' size	Number	6	5	6	8.5	5	–
Economic factors							
Average farm income	FCFA	271.0	278.0	290.0	618.4	4,200.0	–
Number of farm manpower	Number	2	1	4	3	2	–
	Standard deviation	2.3	1.3	1.8	2.5	1.5	–
Arable land surface available	ha	5	3.6	4.8	9.5	9.2	–
	Standard deviation	3.1	2.5	1.7	3.9	6.1	–
Land surface per manpower	ha	2.5	3.6	2.1	3	4.6	–
Dependence rate	Ratio	2	4	0.5	1.8	1.5	–
Socioecological factors							

(*Continued*)

Table 2. (Continued).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
Population density	inhabitants/km^2	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 status	% 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	–
Participation in village restitution	% of farmers taking place to village restitution	77	20	100	96	25	–

(*Continued*)

Table 2. (Continued).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
	% 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	–
Organization membership	% of farmers belong to organization	57	40	50	21	8	–
	% of farmers without organization	43	60	50	79	92	–
Household functional characteristics							
Average yam land surface	ha	0.5	0.1	0.2	0.9	0.7	–
	Standard deviation	0.3	0.0	0.0	0.7	0.6	–
Average cassava land surface	ha	0.2	0.5	0.7	1.5	1.4	–
	Standard deviation	0.1	0.1	0.1	0.4	1.0	–
Average maize land surface	ha	0.4	0.8	1.1	2.3	1.1	–
	Standard deviation	0.2	0.1	0.2	0.6	0.5	–
Average groundnut land surface	ha	0.5	0.5	0.6	2.8	1	–
	Standard deviation	0.3	0.1	0.1	1.4	0.6	–
Average soybean land surface	ha	0.6	0.2	0.3	0.0	0	–
	Standard deviation	0.4	0.0	0.0	0.0	0.0	–
Average cowpea land surface	ha	0.7	0.2	0.2	0.4	0.8	–
	Standard deviation	0.3	0.0	0.0	0.2	0.3	–
Average rice land surface	ha	0.4	0.1	0.1	0.1	0.3	–
	Standard deviation	0.4	0.0	0.0	0.1	0.2	–

(*Continued*)

Table 2. (Continued).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
Average cotton land surface	ha	0.8	0.2	0.2	0.1	0	–
	Standard deviation	0.2	0.0	0.0	0.0	0.0	–
Average cashew tree land surface	ha	0.3	0.9	1.2	5.5	2.9	–
	Standard deviation	0.1	0.2	0.2	0.8	1.2	–
Average teak land surface	ha	0.1	0.1	0.1	0.4	0.4	–
	Standard deviation	0.1	0.0	0.0	0.2	0.4	–
Average herbaceous leguminous land surface	ha	0.1	0.0	0.0	0.4	0.0	–
	Standard deviation	0.1	0.0	0.0	0.3	0.0	–
Livestock size (sheep, goat, and cow)	Number	6	3.0	4.0	9.5	5	–
	Standard deviation	8.2	0.8	1.1	6.2	3.1	–

Table 3. Status of adopters and non-adopters of yam-based cropping system in rotation with intercropped *Mucuna prurien*s var. *utilis* and maize off the R&D sites (Guinea–Sudan zone of Benin).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
Household characteristics		*n* = 25 (8.2%)	*n* = 47 (15.4%)	*n* = 3 (1.0%)	*n* = 18 (5.9%)	*n* = 131 (42.8%)	*n* = 0 (0%)
Age	Average hold (year)	45	49	49	41	45	–
	Standard deviation	12.6	16.85	12.7	13.8	10.7	–
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	18.0	23.3	12.8	10.6	–
Households' size	Number	9	7.6	7.7	8	7	–
Economic factors							
Average farm income	FCFA	256.8	381.1	475.0	921.2	672.1	–
Number of farm manpower	Number	4	3	5	2	2	–
	Standard deviation	5.1	2.3	3.6	5.8	1.7	–
Arable land surface available	ha	6	4.6	4.5	17.3	9.6	–
	Standard deviation	5.5	1.9	1.9	15.3	7.8	–
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	–
Socioecological factors							
Population density	inhabitants km^{-2}	49	49	49	25	25	–

(*Continued*)

Table 3. (Continued).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
Land tenure	% of land owner	88	98	100	85	83	–
	% of non-land owner	12	2	0	15	17	–
Soil fertility status	% 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	–
Abandonment rate of tests	% of farmers	0	–	100	0	–	–
Participation to village restitution	% of farmers taking part 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	–
Organization membership	% of farmers belong to organization	47	23	50	30	67	–
	% of farmers without organization	53	77	50	70	33	–

(Continued)

Table 3. (Continued).

Variable	Description	Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
			Never adopted	Disadopter		Never adopted	Disadopter
Household functional characteristics							
Average yam land surface	ha	0.3	0.2	0.3	0.8	0.5	–
	Standard deviation	0.4	0.02	0.0	0.4	0.3	–
Average cassava land surface	ha	0.2	0.3	0.4	0.5	0.5	–
	Standard deviation	0.1	0.0	0.1	0.3	0.3	–
Average maize land surface	ha	0.5	1.1	1.6	1.1	0.8	–
	Standard deviation	0.3	0.1	0.2	0.6	0.3	–
Average groundnut land surface	ha	0.7	0.6	0.9	1.2	0.9	–
	Standard deviation	0.4	0.1	0.1	0.4	0.5	–
Average soybean land surface	ha	0.7	0.4	0.5	0.0	0.0	–
	Standard deviation	0.2	0.1	0.1	0.0	0.0	–
Average cowpea land surface	ha	0.5	0.3	0.4	0.4	0.7	–
	Standard deviation	0.4	0.0	0.1	0.2	0.3	–
Average rice land surface	ha	0.4	0.2	0.3	0.1	0.3	–
	Standard deviation	0.3	0.0	0.0	0.1	0.2	–
Average cotton land surface	ha	0.2	0.1	0.2	0.0	0.0	–
	Standard deviation	0.1	0.0	0.0	0.0	0.0	–
Average cashew tree land surface	ha	0.6	1.2	1.8	3.7	4.0	–
	Standard deviation	0.4	0.2	0.2	0.2	0.8	–
Average teak land surface	ha	0.2	0.2	0.3	0.2	0.6	–
	Standard deviation	0.1	0.0	0.0	0.2	0.4	–
Average herbaceous leguminous land surface	ha	0.0	0.0	0.0	0.2	0.0	–

(*Continued*)

Table 3. (Continued).

		Relatively denser population zone			Low-population density zone		
		Adopter	Non-adopter		Adopter	Non-adopter	
Variable	Description		Never adopted	Disadopter		Never adopted	Disadopter
	Standard deviation	0.0	0.0	0.0	0.1	0.0	–
Livestock size (sheep, goat and cow)	Number	13.0	2.0	4.0	5.0	4	–
	Standard deviation	20.4	0.3	0.6	5.2	12.7	–

Table 4. Statistical description of adoption factors in the study zone in the Guinea–Sudan zone of Benin (*n* = 306 farm–households surveyed).

Acronym of variable	Description of variable and value	Mean	Standard deviation
ZONE	Demographic zone/population density (1 = yes; 0 = no)	0.4	0.5
SUPDISP	Household land surface available per ha	8.3	7.6
SEXE/GENDER	Male or female (1 = yes; 0 = no)	0.8	0.4
NBOUCH	Household size	7.6	4.9
FTRAV	Household labor size	2.7	2.4
ORIGIN	Owner status: indigenous or immigrant (1 = yes; 0 = no)	0.8	0.4
CONTACT	Contact with the change agents (1 = yes; 0 = no)	0.6	0.5
CREDIT	Access to credit (1 = yes; 0 = no)	0.1	0.2
NIVELEV	Livestock size (sheep, goat, and cow)	4.5	12.1

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: labor 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.

technologies (Adesina et al. 2000; Ayuk 1997). The logistic analysis is used to estimate the probability for a phenomena to occur given a set of properties.

The observed dependent variable is the adoption of a cover crop in a yam-based cropping system. Independent variables to survey and to include in the model were chosen ex ante on the basis of credible hypotheses by the research team.

A questionnaire was designed for the socioeconomic farm household survey for the estimation of 50 potentially explanatory variables related to site characteristics, farm household requirements and resources, producer's profile, field management, and access to external markets and resources.

Predicted signs for each independent variable in the potential models were discussed. Out of these 50 explanatory variables, 9 independent variables were finally selected as relevant and uncorrelated with each other for inclusion in the model. These variables were ZONE (population density in zone), SUPDISP (land availability), GENDER (sex), NBOUCH (Farm household size), FTRAV (labor availability), ORIGIN (owner status: indigenous or immigrant), CONTACT (contacts with external services for advice), CREDIT (formal financial credit), and NIVELEV (livestock size). SPSS was used for the descriptive analysis (Table 4) and the correlation analysis of the independent variables. LIMDEP version 7.0 was used for the empirical model.

2.5. On-farm experiments

2.5.1. Experimental design

The experiment was conducted with eight farmers in each of the four selected sites over a period of 2 years, first in 2002–2003, and repeated in 2004–2005 using the local, late maturing *D. cayenensis rotundata* cv. "Kokoro." The cultivar was selected based on its popularity with farmers and suitability for storage and processing (Vernier and Dossou, *op.cit.*). The plot size per farm was 1,600 m^2 made up of four crop rotation treatments replicated four times and arranged in a randomized complete block design (Table 5 and Figure 1).

Treatments were T0, TM, TMA, and TMM:

- In T0 (Control 1), yam was cultivated in the second year after a 1-year natural fallow of *Andropogon gayanus*, a common practice in the area.
- In TM (Control 2), yam was cultivated in the second year after maize, also a common practice in the area. Maize was planted (at 80 cm × 40 cm) in April of the first year.
- In TMA, yam was cultivated in the second year after *A. histrix* intercropped with maize in the first year. Maize was planted (at 80 cm × 40 cm) in April of the first year. *Aeschynomene* seeds (7 kg ha^{-1}) were mixed with dry sand (3/4 sand–1/4 seeds) and sown 2 weeks after maize in a 2-cm deep furrow on the side of the maize row.
- In TMM, yam was cultivated in the second year after *M. pruriens* intercropped with maize. Maize was planted (at 80 cm × 40 cm) in April of the first year. *Mucuna* spp. seeds (25 kg ha^{-1}) were sown in May, 6 weeks after sowing maize seeds, and on the maize row, at the rate of two seeds per hole (at 80 cm × 40 cm).

Table 5. Design of a farmer-managed experiment comparing four yam-based cropping systems with herbaceous legumes, maize, and short grass fallow in the 2002–2003 and 2004–2005 cropping seasons, 32 farmers, 4 village sites (Miniffi, Gomè, Gbanlin, and Akpéro), Benin.

Treatment	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)	Year 4 (2005)
T0 (control 1), 1-year natural fallow–yam rotation	Fallow of *A. gayanus*	Yam	Fallow of *A. gayanus*	Yam
TM (control 2), maize–yam rotation	Maize + $N_{14}P_{23}K_{14}$ + urea: 100 kg ha^{-1} NPK fertilizer (14% N, 10% P, 11.7% K) + 50 kg ha^{-1} urea (46% N)	Yam	Maize + $N_{14}P_{23}K_{14}$ + urea: 100 kg ha^{-1} NPK fertilizer (14% N, 10% P, 11.7% K) + 50 kg ha^{-1} urea (46% N)	Yam
TMA (*Aeschynomene histrix*/Maize intercropping–yam rotation)	*Aeschynomene histrix*/Maize intercropping + $N_{14}P_{23}K_{14}$ + Urea	Yam	*Aeschynomene histrix*/Maize intercropping + $N_{14}P_{23}K_{14}$ + Urea	Yam
TMM(*Mucuna pruriens*/Maize intercropping–yam rotation)	*M. pruriens*/Maize intercropping + $N_{14}P_{23}K_{14}$ + urea	Yam	*M. pruriens*/Maize intercropping + $N_{14}P_{23}K_{14}$ + urea	Yam

Plot sizes: 10 m × 10 m; Number of farmer per site: 8; Yam variety tested: "Kokoro" (late maturing (*D. cayenensis* subsp. *rotundata*); Number of treatment: 4; Number of replication: 4.

T0: 1-year fallow–yam rotation; TM: maize–yam rotation; TMA: *A. histrix/*maize intercropping–yam rotation; TMM: *M. pruriens/*maize intercropping–yam rotation.

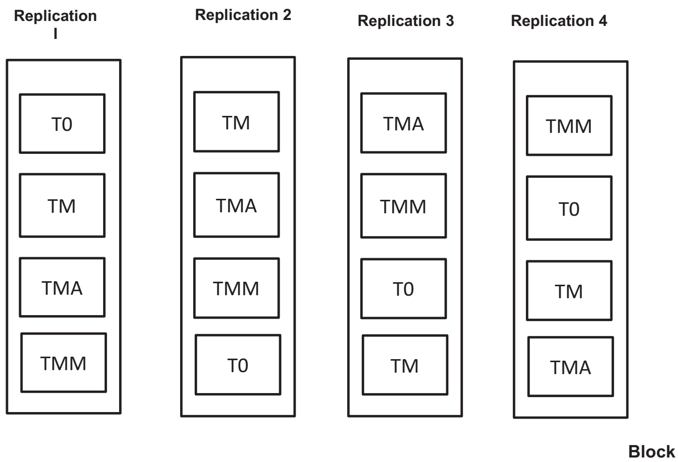

Figure 1. Design of yam-based cropping systems with herbaceous legume intercrops, with maize, and short fallow in the farmer-managed experiment: 2002–2003 and 2004–2005 cropping seasons, 4 cropping system treatments, 4 village sites (Miniffi, Gomè, Gbanlin, and Akpéro), 32 farms, Benin. Number of replications: 4; treatment plot sizes: 10 m × 10 m; number of farmers per site: 8.T0 (Control 1): 1-year fallow–yam rotation; TM (Control 2): (maize + 100 kg $N_{14}P_{23}K_{14}$ + 50 kg urea)–yam rotation; TMA: (*Aeschynomene histrix*/maize intercropping + 100 kg $N_{14}P_{23}K_{14}$ + 50 kg urea)–yam rotation; TMM: (*Mucuna pruriens*/maize intercropping + 100 kg $N_{14}P_{23}K_{14}$ + 50 kg urea)–yam rotation.

In treatments TM, TMA, and TMM, NPK fertilizer (14% N, 10% P, and 11.7% K) was applied to maize at 100 kg ha^{-1} followed by 50 kg of urea ha^{-1} (46% N) in June. Maize was harvested in July. *Mucuna* spp. and *Aeschynomene* crops were slashed down 140 and 180 days after planting, respectively, and before seed maturity. Yam mounds were built early at the end of the rainy season in October in order to ensure organic matter decay before planting yams in the next year. Organic material (from natural *Andropogon* fallow, maize, *Mucuna* spp., and *Aeschynomene* residues) was manually incorporated into the mounds. A small portion of the remaining biomass was used to mulch the top of the mounds as usually performed in order to protect yam seeds and sprouts from heat and desiccation. Yam was planted in these mounds without fertilizer application as usually performed by producers, who attribute tuber quality losses to mineral fertilizer application.

Experimental data [yam yields fresh matter (t ha^{-1})] were analyzed using both variance and regression analysis.

2.5.2. Soil and biomass data collection on the experimental plots

In each farmer field, composite soil samples were collected at 0–20 cm depth along plot transects before the beginning of the experiment in 2002 (32 farm fields × 4 plots × 1 depth = 128 samples) and at the beginning of 2004 in order to determine soil characteristics.

Prior to building yam mounds in both cropping seasons, the aboveground biomass was collected in a 1 m^2 quadrat replicated four times within each plot, in October and November 2002 and 2004 for herbaceous legumes and fallow, and after maturity of the maize for its stover. Biomass samples were dried at 60°C until constant weight was reached and then dry weight was determined with a balance. Fresh yam tuber weight was estimated on each plot in December 2003 and 2005.

2.5.3. Selection of variables potentially affecting yam yields

An explanatory (linear regression) yield model was designed ex ante including predictable variables related to soil fertility (clay, silt and sand contents; soil organic matter; total nitrogen and phosphorus; biomass N, P, and K), crop management (crop cycle duration and density, mound height, weeding number), field characteristics such as plot position in the toposequence and land use intensity. It also took into account climate variables (especially cumulative amounts of rainfall in the five first months of the yam growth, yam water requirements being especially high after crop germination and between the fourteenth and twentieth weeks of growth) (Dansi et al. 2003). Climatic data were collected at the national meteorological station and the other variables on the experimental plots. The model was tested and elasticity was calculated to estimate the overall change in the dependent variable for a marginal change in each significant explanatory variable.

2.5.4. Analyses of variance to test site, year, and treatment effects on yam yield

Analyses of variance (ANOVA) using the general linear model (GLM) procedure was applied to yam yield, using a partial nested model with five factors: Year, Replicate, Farmer, Site, and Treatment. Random factors were "Year," "Replicate," and "Farmer." Farmer was considered as nested within "Site," and "Replicate" nested within "Farmer." Fixed factors were "Treatment" and "Site." Sites were considered as fixed based on certain criteria such as landscape (lowland, plateau), soil type, and initial soil fertility. Yield values were logarithmically transformed to normalize the data and to stabilize population variance. The GLM was computed to assess the interactions between the factors involved. Treatment effects were determined by variance analysis using computer package SPSS version 11 (SPSS Inc. 2002). Significance was considered at $p \leq 0.05$.

2.6. Economic appraisal of the cropping systems

A simple financial analysis was performed to evaluate the profitability of each average yam-based cropping system using the net present value (which represents the cumulative expected values of incomes discounted for the future). A 4-year time frame (2002–2005) was considered and, as the choice of discount rate has always been debated among economists, a sensitivity analysis was conducted with discount rates ranging from 0% to 50%.

3. Results

3.1. Adoption of herbaceous cover crops observed in yam-based systems

Adoption rate of herbaceous legumes in yam-based cropping observed during the survey was 14% off-site and 20% on R&D sites, where producers had either been exposed more intensively to the technologies or had participated in the technology development (Table 6). Off-site adoption is higher in the high land use intensity area (8%) than in the low intensity area (6%). Adoption is also higher among men (25%) than women (9%).

3.2. Profitability of yam-based cropping systems with herbaceous legumes

Yam is a labor demanding (140 MD ha^{-1} after the grass fallow), but profitable, crop. Even where yam has been grown after a short *Andropogon* fallow, its net income is positive in both years and across treatments and sites.

In the cropping systems with herbaceous legumes, the total income was fairly improved as compared to grass fallow, in spite of higher labor costs. Labor requirements are around 210 MD ha^{-1} after a cover crop, 33% and 35% higher as compared with T0 (Table 7).

Yam-based systems with cover crops (TMM and TMA) consistently reached higher land, labor, and investment returns over sites and years. Average investment returns over the four sites reached 169% in 2002–2003 and 190% in 2004–2005 for the *Mucuna* spp. treatment against 70% and 40% for the maize treatment and 118% and 86% for the natural fallow in 2002–2003 and 2004–2005 cropping seasons, respectively.

Cover crop supply of additional biomass positively increased yam yields; intercropping, however, negatively affected maize yields.

When the cropping systems are considered over 4 years, total NPV per hectare (10% discount rate) was nearly US $4,000 for *Mucuna* spp.–yam, US $3,700 for Aeschynomene–yam, and only US $1,500 for a short natural fallow–yam and less than US $1,000 for maize–yam. Therefore, even when considering the loss of income incurred in the first year from setting up a planted fallow, farmers with a 4-year planning horizon are still better off when investing in a cover crop rather than planting maize

Table 6. Adopters and non-adopters of yam in rotation with herbaceous legume (case of the mixed intercropping *Mucuna pruriens* var. *utilis* and maize) in the Guinea–Sudan transition zone of Benin.

Site type	Population density	Adoption type	Categories	Number of smallholder farmers surveyed	% of adopters/non-adopters per site	Rate of adopters/ non-adopters (%)	Rate of adoption in denser population/in low population density (%)	Rate of adoption on R&D/off R&D sites (%)
R&D sites	High population density	Adopter	Adopter women	8	18.6	3		
			Adopter men	25	58.1	8		
		Non-adopter	Never adopted	6	14.0	2		
			Disadopter	4	9.3	1		
		Subtotal		43	100.0	–	11	
	Low population density	Adopter	Adopter women	7	8.5	2		
			Adopter men	20	24.4	7		
		Non-adopter	Never adopted	12	14.6	4		
			Disadopter	0	0.0	0		
		Subtotal		82	100.0	–	9	20
Off R&D sites	High population density	Adopter	Adopter women	8	10.7	3		
			Adopter men	17	22.7	6		
		Non-adopter	Never adopted	47	62.7	15		
			Disadopter	3	4.0	1		
		Subtotal		75	100.0	–	8	
	Low population density	Adopter	Adopter women	3	2.0	1		
			Adopter men	15	10.1	5		
		Non-adopter	Never adopted	131	87.9	43		
			Disadopter	0	0.0	0		
		Subtotal		149	100.0	–	6	

(*Continued*)

Table 6. (Continued).

Site type	Population density	Adoption type	Categories	Number of smallholder farmers surveyed	% of adopters/non-adopters per site	Rate of adopters/ non-adopters (%)	Rate of adoption in denser population/in low population density (%)	Rate of adoption on R&D/off R&D sites (%)
	Subtotal off sites			224		–		14
R&D sites	Low and high population density	Adopter	Adopter women	15	18.3	5		
			Adopter men	45	54.9	15		
		Non-adopter	Never adopted	18	22.0	6		
			Disadopter	4	4.9	1		
		Subtotal		82	100	–	20	
Off R&D sites	Low and high population density	Adopter	Adopter women	11	4.9	4		
			Adopter men	32	14.3	10		
		Non-adopter	Never adopted	178	79.5	58		
			Disadopter	3	1.3	1		
		Subtotal		224	100	–	14	
Both R&D and Off R&D sites	Low and high population density	Adopter	Adopter women	26	8.5	9		
			Adopter men	77	25.2	25		
		Non-adopter	Never adopted	196	64.1	64		
			Disadopter	7	2.3	2		
		Total both		306	100	100		34

R&D: Research and development.

Table 7. Estimated cost of production, gross revenue, return on investment, and labor productivity of different yam-based systems in the 2002–2005 cropping seasons.

Sites/ Systems	2002–2003 cropping seasons Eco. y. (t ha^{-1}) Yam	Maize	T. Rev. (US $)	Cost P. (US $) Land	Input	Labor	T. cost (US $)	N. Rev.	.Inv R. (%)	Lb (man-day ha^{-1})	Lb Pro. (US $)	2004–2005 cropping seasons Eco. y. (t ha^{-1}) Yam	Maize	T. Rev. (US $)	Cost P. (US $) Land	Input	Labor	T. cost (US $)	N. Rev. (US $)	R. Inv. (%)	Lb (man-day ha^{-1})	Lb Pro. (US $)
Akpéro																						
T0	11.8	–	2.2	47.6	476	350	874	1.4	157	139	10	9.6	–	1.8	47.6	476	350	874	963	110	139	7
TM	9.1	1.9	2.3	47.6	541	582	1.2	1.1	94	209	5	6.5	2.0	1.8	47.6	541	582	1.2	646	55	209	3
TMA	17.4	1.6	3.7	47.6	548	578	1.2	2.6	219	213	12	19.3	1.6	4.1	47.6	548	578	1.2	3.0	252	213	14
TMM	18.1	1.4	3.9	47.6	552	573	1.2	2.7	228	208	13	19.3	1.6	4.1	47.6	552	573	1.2	3.0	252	208	14
Gbanlin																						
T0	10.4	–	2.0	57.1	476	352	885	1.1	124	140	8	8.5	–	1.6	57.1	476	352	885	742	84	140	5
TM	7.0	1.9	1.9	57.1	541	584	1.2	686	58	211	3	5.4	2.0	1.6	57.1	541	584	1.2	406	34	211	2
TMA	13.6	1.6	3.1	57.1	548	582	1.2	1.9	158	214	9	15.3	1.5	3.3	57.1	548	582	1.2	2.1	181	214	10
TMM	13.7	1.3	3.0	57.1	552	578	1.2	1.8	151	209	9	15.6	1.4	3.4	57.1	552	578	1.2	2.2	184	209	10
Miniffi																						
T0	10.7	–	2.0	66.7	476	354	897	1.1	127	140	8	7.1	–	1.3	66.7	476	354	897	446	50	140	3
TM	9.1	2.1	2.3	66.7	541	585	1.2	1.1	95	212	5	4.3	1.9	1.4	66.7	541	585	1.2	172	14	212	1
TMA	15.9	1.6	3.5	66.7	548	583	1.2	2.3	191	215	11	12.3	1.5	2.8	66.7	548	583	1.2	1.6	131	215	7
TMM	15.8	1.4	3.4	66.7	552	579	1.2	2.2	185	210	11	12.1	1.3	2.7	66.7	552	579	1.2	1.5	122	210	7
Gomè																						
T0	7.9	–	1.5	76.2	476	356	908	593	65	142	4	9.5	–	1.8	76.2	476	356	908	899	99	142	6
TM	5.5	1.9	1.6	76.2	541	587	1.2	368	31	213	2	8.0	1.9	2.1	76.2	541	587	1.2	853	71	213	4
TMA	10.8	1.6	2.5	76.2	548	585	1.2	1.3	109	216	6	16.6	1.5	3.6	76.2	548	585	1.2	2.4	197	216	11
TMM	11.0	1.3	2.5	76.2	552	581	1.2	1.3	103	211	6	17.2	1.4	3.7	76.2	552	581	1.2	2.5	204	211	12
All sites																						
T0	10.2	–	1.9	61.9	476	353	891	1.1	118	140	7.5	8.7	–	1.7	61.9	476	353	891	763	86	140	5
TM	7.7	1.9	2.0	61.9	541	585	1.2	820	70	211	3.8	6.0	1.9	1.7	61.9	541	585	1.2	519	44	211	3
TMA	14.4	1.6	3.2	61.9	548	582	1.2	2.0	169	215	9.5	15.9	1.5	3.5	61.9	548	582	1.2	2.3	190	215	11
TMM	14.7	1.3	3.2	61.9	552	578	1.2	2.0	167	210	9.8	16.0	1.4	3.4	61.9	552	578	1.2	2.3	191	210	11

US \$190.5 t^{-1} for yam fresh weight; US \$285.7 t^{-1} for maize; \$1 USD = 524.98 FCFA from May 24, 2010.

t: Ton; T0: 2-year fallow–yam rotation; TM: maize–yam rotation; TMA: *A. histrix*/maize intercropping–yam rotation; TMM: *M. pruriens*/maize intercropping–yam rotation; Eco. y.: economic yield (t ha^{-1}); T. Rev.: total revenue (US \$); Cost. P.: cost of production (US \$), Lb: Laborl (man-day ha^{-1}); T. Cost: total cost (US \$); N. Rev.: net revenue (US \$); R. Inv.: return on investment (%); Lb Pro: labor productivity (US \$).

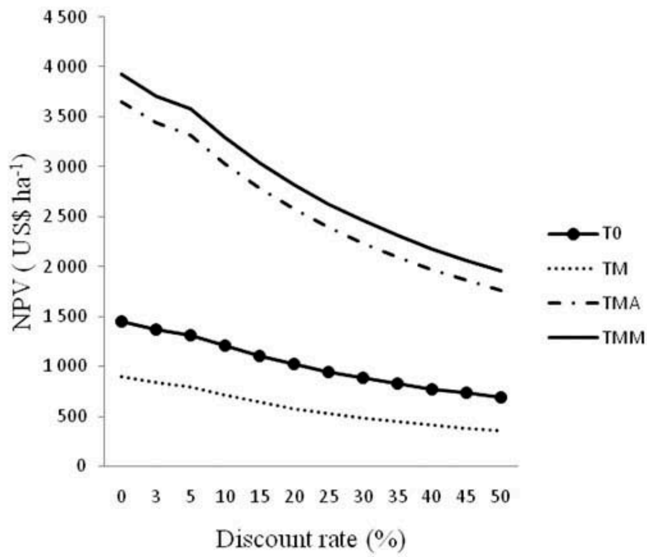

Figure 2. Profitability of yam-based cropping systems with herbaceous legumes in comparison with traditional systems (time horizon: 4 years) in the transitional zone of Benin. T0 (control 1): 1-year fallow–yam rotation; TM (control 2): maize–yam rotation; TMA: intercropped *A. histrix* with maize–yam rotation; TMM: intercropped *M. pruriens* with maize–yam rotation; NPV: net present value.

or waiting for 1 year. This holds for a large range of discount rates and therefore for a range of alternative investment opportunities (Figure 2).

In the second trial in 2004–2005, gross returns had decreased for T0 and TM and increased for TMA and TMM and so had returns to production factors. Longer term experiments would have been necessary to better capture such additive effects.

3.3. Adoption model

An adoption model was developed with a good predictive ability and estimated properties (Table 8). The χ^2 test was highly significant ($p < 0.01$). The percentage of correct prediction was high (77%).

Out of the nine independent explanatory variables finally kept in the adoption model, seven (frequent contacts with external agents, a high land use intensity, access to formal credit, gender, farmland availability, household size, and importance of livestock) had significant influence on cover crop adoption in a yam-based cropping system. “Contacts” here are often related to the participation in on-farm activities with researchers and this participation exerted a major influence on adoption. A high “land-use intensity” (correlated with lower availability of fallow land and higher soil degradation) created as expected an incentive to adopt. However, producers with lower

Table 8. Econometric model of the factors affecting adoption of *Mucuna pruriens* var. *utilis* in yam-based cropping systems in the Guinea–Sudan transition zone of Benin.

Acronym of variable	Estimated β	*t*-Test
Population density in zone (ZONE)	0.2	4.8**
Land surface available in farm household (SUPDISP)	0.0	2.8*
Sex (male or female) of the smallholder farmer (GENDER)	−0.2	−3.3**
Farm household size (NBOUCH)	0.0	2.3*
Labor force within the households (FTRAV)	−0.0	−1.2
Owner status (indigenous or immigrant) (ORIGIN)	−0.0	−0.6
Smallholder farmers' contacts with the research or extension workers (CONTACT)	0.4	7.9**
Formal financial credit for inputs (CREDIT)	0.4	3.5**
Livestock size (NIVELEV)	0.00	2.0*
Log-probabilities	−143.1	
χ^2	104.7**	
% of prediction	77	
Rate of adoption	34%	

*$p < 0.05$ and **$p < 0.01$ represent significant levels at 5% and 1%, respectively.
β is the vector of estimated coefficient for each independent variable.

land availability were less prone to adopt than better endowed ones. Even if the first ones suffer more from higher pressure, they may be too constrained to take the risk of being among the early adopters. Access to credit and family size also positively affect adoption. Livestock may use cover crops as a fodder and their ownership encourages adoption; indirectly, livestock is also correlated with wealth. In the end, early adopters belong to the rather wealthy and better endowed farmers, who are eager to work with researchers and may take the risk of a failure. What the more constrained smallholders will do, and what will happen at the end of the research program, cannot be predicted out of the model.

3.4. Agronomic outcomes of the crop rotation with cover crops

Cover crops significantly affected yam yields as assessed in the ANOVA partial nested model ($p < 0.05$) (Table 9). Yam yields differed significantly depending on the treatment; interactions Year × Farmer ($p < 0.001$), Year × Site × Treatment ($p < 0.05$), Year × Treatment ($p < 0.01$), Year × Site ($p < 0.001$) were also significant.

After *Mucuna* spp. and *Aeschynomene* (TMA and TMM), yam yields were similar and significantly higher than in the traditional cropping systems with natural or no fallow (T0 and TM). Yam yields from *Mucuna* spp. and *Aeschynomene* rotations (14.40 t ha^{-1} in 2003 and 16.04 t ha^{-1} in 2005) were significantly higher than in the traditional cropping systems with natural or no fallow (7.67 t ha^{-1} in 2003 and 6.04 t ha^{-1} in 2005) (Table 10). However, there were high variations in yields from site to site and among farmers within a site. Therefore, yield instability is an issue.

How may management affect yam production? In both cropping seasons, four variables significantly affected yam yields in linear form: Year × Treatment

Table 9. ANOVA in a partial nested model of the effect of the four treatments on logarithmic transformed yields values of "Kokoro" yam (*D. cayennensis* subsp. *rotundata*) in 2002–2003 and 2004–2005 (4 sites, 32 farmers, Benin).

Source	DF	Adj. SS	Adj. MS	*F*	*p*
Site	3	13.9	4.6	0.5	0.7
Farmer (Site)	28	28.3	1.0	1.8	0.7
Replicate (Farmer)	96	9.6	0.1	1.2	0.1
Year	1	0.6	0.6	0.1	0.8
Treatment	3	125.2	41.7	18.8	0.0
Site × Treatment	9	0.9	0.1	0.6	0.8
Treatment × Farmer (site)	84	5.8	0.1	0.8	0.9
Year × Farmer (site)	28	15.9	0.6	6.7	0.0
Year × Treatment	3	6.7	2.2	12.3	0.0
Year × Site	3	24.5	8.2	12.3	0.0
Year × Site × Treatment	9	1.6	0.2	2.1	0.0
Error	756	64.2	0.1		
Adjusted *R*-square (%)			70.8		

DF: Degree of freedom; Adj. SS: adjusted sums of squares; Adj. MS: adjusted mean squares; *F*: Fisher's test; *p*: Fisher's probability test.

Table 10. Yam yields as affected by cropping systems with herbaceous legumes and short fallow in the 2003 and 2005 cropping seasons.

	Yam yield (t ha^{-1})	
Treatment	2003	2005
1-year fallow–yam rotation (T0)	10.2b	8.7b
Maize–yam rotation (TM)	7.7c	6.0c
Aeschynomene histrix/maize intercropping–yam rotation (TMA)	14.4a	16.0a
M. pruriens/maize intercropping–yam rotation (TMM)	14.7a	16.0a
LSD 5%	0.4	0.4
SD	5.3	6.2

Means with the same letter within column are not significantly different ($p > 0.05$).

interaction ($p < 0.001$), land use intensity ($p < 0.001$), soil organic matter ($p < 0.001$), and soil phosphorus ($p < 0.001$); in 2002–2003, additional variables were soil silt content ($p < 0.05$) and position on the toposequence; in 2004–2005, additional variables were rainfall ($p < 0.05$), crop duration, soil nitrogen ($p < 0.01$), soil potassium ($p < 0.05$). R^2 coefficients were high and the models captured a large part of the yield variability (Table 11).

Effects of the treatments on yam yields are directly related to the amount of biomass dry matter supplied. These ranged from 2.3 to 5 t ha^{-1} in traditional yam-based systems (T0 and TM) and 7.3 to 11.4 t ha^{-1} in sedentary yam-based systems (TMA and TMM) and allowed for a change in the soil organic matter content. Higher soil organic matter contents (average value of 1.59%), as well as a higher clay content (respectively a lower silt content) in these sandy soils (83% sand and 6.5% clay in average) also positively affect yam yields. A change of 10% in the soil organic matter content increased yam yields by 79% during the cropping season 2002–2003 and by 110% in 2004–2005. Organic matter content has the highest elasticity coefficient and its effects even offset those of mineralized nitrogen, available phosphorus, and soluble potassium in the soil. Soil clay also positively affect yam yields, a 10% increase improving yields by 28% and 52% in both cropping seasons.

A longer vegetative period consecutive to early planting also tends to improve yields as expected (312 days on average from the seed yam plantation to the harvest ranged, with large variations, between 275 and 396 days). Higher rainfall during the first 5 months of the yam growing period, 229 mm (184–276 mm) and 259 mm (228–296 mm) in the 2002–2003 and 2004–2005 cropping seasons, exerted a positive effect in 2004–2005 but a negative one in 2002–2003, respectively. Rainfall distribution was more important than quantities (Tables 11, 12, and 13). Land position in uplands and lowlands did not affect yields consistently either, as a location in lowlands may not only improve water availability but also increase it up to water logging.

The number of weeding operations (on average three weeding operations are required [two to four]), did not significantly affect yam yields. Density as well as mound size effects are low and unclear, attesting to the flexibility of the crop. In all, management variables other than fallow type had low effects.

In all, cover crops are very efficient options for improving yam yields, especially when combined with a site selection of soils with a high clay content. However, yam yields react in a rather unpredictable way to rainfall and toposequence so that cultivation on several contrasted sites is advisable.

3.5. Constraints of yam-based systems with herbaceous legumes

Cultivation is performed manually. Individual surveys reveal that biomass incorporation of both cover crops is seen as a main constraint. This was reported by 52% and 46% of the respondents for *Mucuna* spp. and *A. histrix*, respectively. Competition between *Mucuna* spp. and the associated crop is also an issue for 19% of the respondents but was not quoted for *Aeschynomene* (Table 14). Smallholders also evoked the *Mucuna* spp. seed inedibility (18% of respondents), the difficulty of *Aeschynomene*'s small-sized seed harvest (25%), and the damage caused by roaming cattle attracted by the *Mucuna* spp. vines or residues (16%) as well as by the high-quality *Aeschynomene* fodder (21%).

Women are particularly affected by the hardship of biomass incorporation of both legumes (100%) as well as of seed harvest (67%) and by roaming cattle (50%). Both women and men in the high population density zone (ZA) are concerned by high fertilizer costs (97% and 100%), a constraint reflecting their dependency on external inputs in this depleted area and by the lack of access to credit mentioned in the adoption survey. In the low population

Table 11. Relationship and awaited signs between yam maturing Kokoro (*D. cayenensis* subsp. *rotundata*) yield and independent variables (2002–2003 and 2004–2005 cropping seasons, 4 village sites, 32 farms, Benin).

Dependent variable *Y*	Explanatory variable *X*	Unit	Relationship *Y–X*	Awaited sign	Mean value	Minimum	Maximum
Yam yield in 2003 (Y_2003)		t ha^{-1}			11.7	2.7	22.4
	Year × Treatment	Number	Linear	+	2.4	2	2.6
	Rainfall	mm	Linear	±	229	184	276
	Organic matter	%	Linear	+	1.6	1.1	2.6
	Nitrogen	%	Linear	±	0.1	0.1	0.1
	Phosphorus	ppm	Linear	±	11.5	6.7	22
	Potassium	me/100 g	Linear	±	0.1	0.1	0.2
	Clay	%	Linear	+	6.5	5.5	7.4
	Silt	%	Linear	–	10.1	5.5	17.5
	Sand	%	Linear	–	83.4	71.1	96.9
	Crop duration	Number	Linear	+	312	275	396
	Crop density*	(mounds ha^{-1})	Quadratic	+	8,537	6,667	10,000
	(Crop density)^2	(mounds $ha^{-1})^2$	Quadratic	–	74,676,811	44,444,444	100,000,000
	Mound size	m	Linear	–	0.5	0.3	0.9
	Weeding	Number	Linear	±	3	2	4
	Land position	Number	Linear	–	2	1	3
	Land use intensity	Number	Linear	–	3	1	4
Yam yield in 2005 (Y_2005)		t ha^{-1}			11.7	1.8	22.9
	Year × Treatment	Number	Linear	+	2.3	1.7	2.7
	Rainfall	mm	Linear	±	259	228	296
	Organic matter	%	Linear	+	1.6	1.1	2.6
	Nitrogen	%	Linear	±	0.1	0.1	0.1
	Phosphorus	ppm	Linear	±	11.5	6.7	22
	Potassium	me/100 g	Linear	±	0.1	0.1	0.2
	Clay	%	Linear	+	6.5	5.5	7.4
	Silt	%	Linear	–	10.1	5.5	17.5
	Sand	%	Linear	–	83.4	71.09	96.9
	Crop duration	Number	Linear	+	312	275	396
	Crop density	Mounds ha^{-1}	Quadratic	+	8,537	6,667	10,000
	(Crop density)^2	(Mounds $ha^{-1})^2$	Quadratic	–	74,676,811	44,444,444	100,000,000
	Mound size	Number	Linear	+	0.5	0.3	0.9

(*Continued*)

Table 11. (Continued).

Dependent variable *Y*	Explanatory variable *X*	Unit	Relationship *Y*–*X*	Awaited sign	Mean value	Minimum	Maximum
	Weeding	Number	Linear	±	3	2	4
	Land position	Number	Linear	–	2	1	3
	Land use intensity	Number	Linear	–	3	1	4

*Variables in linear and quadratic form.

Rainfall: Cumulative amount of rainfall (mm) in the fifth month of the yam growing period; crop duration is the plant production cycle between yam planting and harvesting; crop density is the number of the mounds of yam per hectare (mounds ha^{-1}); mound size: in meter; $(\text{crop density})^2$: square of crop density; land position: land position is the field crop position through the landscape (bottom of the slope, plateau, top of the slope with 3, 2, and 1 affected values, respectively); weeding: number of weeding; land use intensity is the intensity of land utilization indicating the number of cultivated fields around the four sides of the experiment plot (1–4); Year × Treatment: interaction between treatments and year.

Table 12. Regression coefficients of explanatory variables and their level of significance (2002–2003 and 2004–2005 cropping seasons, 4 village sites, 32 farms, Benin).

Dependent variable *Y*	Predictor	Coefficient *β*	SE of *β*	*T*	*p*
Yam yield in 2003 (Y_2003)					
	Constant	−90.4	63.9	−1.4	0.2
	Year × Treatment	10.8	0.8	13.8	0.0
	Rainfall	0.3	0.2	1.3	0.2
	Organic matter	58.2	20.9	2.8	0.0
	Nitrogen	−38.0	215.7	−0.2	0.9
	Phosphorus	−4.1	1.2	−3.5	0.0
	Potassium	−125.4	151.9	−0.8	0.4
	Clay	5.1	12.5	0.4	0.7
	Silt	−2.5	1.1	−2.3	0.0
	Sand	−0.5	0.9	−0.6	0.6
	Crop duration	0.0	0.0	1.3	0.2
	Crop density	0.0	0.0	0.9	0.4
	(Crop density)^2	−0.0	0.0	−0.8	0.4
	Mound size	−1.5	5.4	−0.3	0.8
	Weeding	0.1	0.5	0.1	0.9
	Land position	−1.4	0.7	−2.0	0.1
	Land use intensity	−1.8	0.4	−4.7	0.0
	R-Sq. (%)				74.2
	Adj *R*-Sq. (%)				70.5
	Pred *R*-Sq. (%)				66.1
	Fisher Coeff.				19.9
	F-sig. level				0.0
Yam yield in 2005 (Y_2005)					
	Constant	166.8	94.4	1.8	0.1
	Year × Treatment	10.2	0.4	24.1	0.0
	Rainfall	−0.6	0.2	−2.4	0.0
	Organic matter	81.3	17.8	4.6	0.0
	Nitrogen	−538.6	184.6	−2.9	0.0
	Phosphorus	−2.959	1.0	−2.9	0.0
	Potassium	−558.8	251.3	−2.2	0.0
	Clay	9.3	9.5	1.0	0.3
	Silt	−1.3	0.9	−1.4	0.2
	Sand	−1.2	0.7	−1.8	0.1
	Crop duration	0.0	0.0	1.9	0.1
	Crop density*	0.0	0.0	0.8	0.4
	(Crop density)^2	−0.0	0.0	−0.7	0.5
	Mound size	4.2	4.8	0.9	0.4
	Weeding	−0.5	0.5	−1.0	0.3
	Land position	−0.2	0.6	−0.4	0.7
	Land use intensity	−1.22	0.3	−3.7	0.0
	R-Sq. (%)				86.7
	Adj *R*-Sq. (%)				84.8
	Pred *R*-Sq. (%)				82.3
	Fisher Coeff.				45.4
	F sig. level				0.0

*Variables in linear and quadratic form; *R*-sq: *R*-square; Adj *R*-Sq. (%): adjusted *R*-square; Pred. *R*-sq: predicted *R*-square; Fisher Coeff.: Fisher coefficient; *F* sig. level: Fisher significance level.

density area (ZB), both men and women are concerned by field inaccessibility (100%); remoteness also increases the risk of bush fire (83%) and of damage from roaming cattle [reported by both women (50%) and men (43%)] (Table 15).

Table 13. Elasticity of yam yield and explanatory variables (2002–2003 and 2004–2005 cropping seasons, 4 village sites, 32 farms, Benin).

Dependent variable Y	Explanatory variable X	Unit	Mean Y	Mean X	(Mean X/ mean Y)	Coefficient β	Elasticity**
Yam yield in 2003 (Y_2003)		t ha^{-1}	11.7				
	Year × Treatment	Number		2.4	0.2	10.8	2.2
	Rainfall	mm		229.3	19.6	0.3	4.9
	Organic matter	%		1.6	0.1	58.2	7.9
	Nitrogen	%		0.1	0.0	−38.0	−0.3
	Phosphorus	ppm		11.5	1.0	−4.1	−4.0
	Potassium	me/ 100 g		0.1	0.0	−125.4	−1.4
	Clay	%		6.5	0.6	5.1	2.8
	Silt	%		10.1	0.9	−2.5	−2.2
	Sand	%		83.4	7.1	−0.5	−3.5
	Crop duration	Number		312.4	26.7	0.0	0.6
	Crop density*	(hillocks ha^{-1})		8,537	729.7	0.0	0.2
	(Crop density)^2	(hillocks ha^{-1})^2		74,676,811	6,382,633.4	0.0	
	Mound size	m		0.5	0.0	−1.5	−0.1
	Weeding	Number		2.6	0.2	0.0	0.0
	Land position	Number		2.0	0.2	−1.3	−0.2
	Land use intensity	Number		3.3	0.3	−1.8	−0.5
Yam yield in 2005 (Y_2005)			11.7				
	Year×Treatment	Number		2.3	0.2	10.2	2.0
	Rainfall	mm		259.1	22.1	−0.6	−12.5
	Organic matter	%		1.6	0.1	81.3	11.1
	Nitrogen	%		0.1	0.0	−538.6	−3.7
	Phosphorus	ppm		11.5	1.0	−3.0	−2.9
	Potassium	me/ 100 g		0.1	0.0	−558.8	−5.1
	Clay	%		6.5	0.6	9.3	5.2
	Silt	%		10.1	0.9	−1.3	−1.1
	Sand	%		83.4	7.1	−1.2	−8.5
	Crop duration	Number		312.4	26.7	0.0	0.7
	Crop density*	(hillocks ha^{-1})		8,537.2	729.7	0.0	0.3
	(Crop density)^2	(hillocks ha^{-1})^2		74,676,811.4	6,382,633.5	0.0	
	Mound size	Number		0.5	0.0	4.2	0.2
	Weeding	Number		2.6	0.2	−0.5	−0.1
	Land position	Number		2.0	0.2	−0.2	−0.0
	Land use intensity	Number		3.3	0.3	−1.2	−0.3

*Variables in linear and quadratic form.
**Elasticity for the variable and its quadratic part.

4. Discussion

4.1. Propensity to adoption

Most smallholder farmers did appreciate the ability of *Mucuna* spp. to increase yam productivity, maintain soil humidity, control weeds (*I. cylindrica* in particular), and restore soil fertility. Adoption of yam-based system with *M.*

Table 14. Constraints of yam-based technologies with herbaceous legumes (farm household level).

		High density zone (ZA) (*N* = 186)		Low density zone (ZB) (*N* = 120)		Both zones (*N* = 306)		
	Constraints	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	OI
	Cover-crop biomass incorporation	80/186	43	80/120	67	160/306	52	1
TMM	Competition with associated crop	47/186	25	11/120	9	58/306	19	2
	Seeds inedibility	33/186	18	23/120	19	56/306	18	3
	Roaming cattle	30/186	16	20/120	17	50/306	16	4
	Reptile refuge	9/186	5	11/120	9	20/306	7	5
	Fertilizer costs	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
	Lack of seed market	4/186	2	–	–	4/306	1	9
TMA	Biomass incorporation	39/186	21	101/120	84	140/306	46	1
	Tedious seed harvest	39/186	21	38/120	32	77/306	25	2
	Roaming cattle	29/186	16	35/120	29	64/306	21	3
	Lack of seeds market	30/186	16	–	–	30/306	10	4
	Reptile refuge	–	–	14/120	12	14/306	5	5
	No seed consumption	9/186	5	5/120	4	14/306	5	5
	Fertilizer cost	9/186	5	3/120	3	12/306	4	6
	Plot maintenance	9/186	5	–	–	9/306	3	7

N: Sampling size; TMA: intercropped *Aeschynomene histrix* with maize–yam rotation; TMM: intercropped *Mucuna pruriens* with maize–yam rotation; ZA: relatively high population density zone; ZB: low-population density zone; OI: importance order.

Table 15. Contingent ranking matrix on constraints in yam-based systems with herbaceous legumes (focus groups level).

	ZA				ZB						
	GW		GM		GW		GM		Prioritization		
Constraints	IR	DS	IR	DS	IR	DS	IR	DS	IRT	DS	OI
Biomass incorporation	30	100	20	100	25	83	15	50	90	82	1
Field access	15	50	0	0	30	100	30	100	75	68	2
Grains harvest	20	67	15	75	15	50	15	50	65	59	3
Animal divagation	15	50	18	90	15	50	13	43	61	55	4
Seeds marketing	15	50	20	100	20	67	0	0	55	50	5
Seeds consumption	15	50	10	50	15	50	10	33	50	45	6
Fertilizer cost	29	97	20	100	0	0	0	0	49	45	6
Vegetation burn	0	0	0	0	10	33	25	83	35	32	7
Reptiles refuge	0	0	10	50	10	33	0	0	20	18	8

IR: relative importance of constraint; IRT: total relative importance of constraint; IRT max = 110 (maximum relative importance of constraint); DS: constraint degree of severity; OI: importance order; GW_: group of women; GM: group of men; ZA: relatively high population density zone; ZB: low population density zone.

pruriens var. *utilis* was higher in the higher population density zone. Because of fertile soil scarcity, smallholders are more inclined to develop more productive systems. Studies conducted by Jouve (2006) in the Bamiléké area, Cameroun, and by Adams and Mortimore (1997) in Kano, Nigeria, corroborate that land scarcity may be a major incentive for switching to intensive agriculture, as also stated in maize-based systems in Benin by Honlonkou, Manyong, and Tchetche (1999). When land use intensity becomes so high that many smallholders can only cultivate one plot, even cover crops are difficult to adopt, as observed in southeastern Benin (Manyong et al. 1996), (Carsky, Becker, and Hauser 2001), and in Honduras (Neill and Lee 2001). This is not yet the case in the study area.

4.2. Profitability of legume cover-crops in yam-based cropping systems

In the present research combining on farm experiments with surveys, we could assess that including a cover crop in a yam-based cropping system may be a highly profitable option for smallholders across sites and years. However, it may not always be assessed as the best option by producers. For very poor smallholders, intercropping of maize in *Mucuna* spp. reduces maize yield and if such farmers are "impatient consumers," they may prefer immediate though much lower income from traditional yam-based cropping to future higher income from the yam-based cropping systems with herbaceous legumes. For better-off farmers, preference may be to invest money in activities that will bring the highest returns of cash. In the study area where cash is scarce and credit rarely available, such activities are numerous (processing, informal trade, etc.) and may be assessed by farmers as lower risk activities than farming.

Adjei-Nsiah et al. (2007) reported on a 3-year experiment that the cropping sequence "Mucuna–maize–Mucuna/maize with N fertilizer application to maize" compares well to maize–maize–maize and grass fallow–maize; however, cowpea–maize–maize/cowpea obtains net revenues and returns to investment similar to Mucuna–maize–Mucuna/maize. Cassava–maize and pigeon pea–maize even produced higher net revenues and returns than maize–maize–maize and grass fallow–maize. In absence of higher performances due to higher effects or of additional gross revenues from the cover crop, producers will prefer edible legumes or cassava, as long as these crops may scavenge nutrients from the soil. It has to be kept in mind that the so-called control does not always adequately reflect the range of alternatives producers may face and that this leads them not to rely on cover crops but on other alternatives. Concerning yam, however, cover crops have specific abilities that cannot be produced to a similar extent by other alternatives and may positively affect their attractiveness.

4.3. Cover crop ability to sustain yam yields at a high level

In our research area, yam yields after a 1-year grass fallow reached 9.4 t on average (7.9–11.8 t across high and low population density sites and 14.4–16 t ha^{-1}after a cover crop. Both legumes improved subsequent yam yields compared to a maize crop in spite of its mineral fertilization or to a natural grass fallow. This confirms former results obtained in Benin and Togo by Sodjadan et al. (2005), who studied the effects on yams of cover crops (*M. pruriens* var. *utilis*, *A. histrix*, or *Pueraria phaseoloides*) and reported that a 1-year *Mucuna* spp. cover led to a significant increase in yam yields. However, cover crops also require minimum conditions in order to produce high biomass quantities and improve yields consistently. In the Northern Guinea Savanna for example, a range of legumes installed without fertilizer did not improve the following maize significantly, which was explained by a low phosphorus soil content (Carsky, Oyewole, and Tian 1999, 2001).

Part of the positive effect of the cover crop may be explained by its effect on the soil nutrient balance. *Mucuna* spp. recycles macronutrients (N, P, K) with moderate rates of decomposition (Maliki et al. 2012). *Mucuna* spp. fallows are well known as improving the quantity of nitrogen through fixation as well as the available P fractions in the soil for subsequent crops. *Mucuna* spp. root exudates seem to be particularly effective in making phosphorus available for subsequent crops (Salako and Tian 2003).

Yam itself often has a poor response to mineral fertilizer applications and little research has been conducted so far to improve this response. Under similar conditions to the present research (rainfall, *kokoro* landrace), Srivastava, Dagbenonbakin, and Gaiser (2010) did not find any significant response to mineral fertilizer nor manure application on yam cultivated in the central part of Benin (low population density). Similar lack of response was found in both forest transition and savannah areas in Nigeria after application of a range of mineral and organic fertilizers (Ajayi, Akinrinde, and Asiedu 2006). In Ghana in a forest transition zone where farmers typically plant yam on newly cleared fields, fertilizer applied in several splits did increase tuber yields by 22% and improved moderately the net benefit of the crop without reducing the sensory quality of the product (Ennin et al. 2014). Considering our own results, response seems to be higher and safer when fertilizer is applied to a previous crop intercropped with a cover crop, so that yam takes advantage from multidimensional mulch effects. However, fertilizer application on maize and nutrient mobilization in the soil by *Mucuna* spp. may not be sufficient to compensate for yam nutrient exports, which are considerable. Harvest of 1 t of yam fresh tubers removes up to 3.8 kg of nitrogen, 0.39 kg of phosphorus, and 4.2 kg of potassium from the soil (Vernier and Dossou 2003). Soil K content has decreased significantly with cultivation in the study area (Igué 2000) and smallholders may then not be able to apply a sufficient quantity of manure or fertilizer to replenish the soil, especially as long as specific fertilizers adapted to tubers are not available in the country (Saïdou 2006). In this experiment, time has been too short to assess mid and long-term effects but at least, biomass recycled from legumes, stover, and yam vines has been considerably higher than in both controls.

Cover crop by-product markets would constitute an additional incentive for producers. *Mucuna* spp. seeds, which are particularly difficult to collect, are also underused. L-DOPA content of *Mucuna* spp. ranges from 4.7% to 6.4% so that consumption by non-ruminants may cause intoxication and research on efficient and economically sound processing (ensiling) is still going on worldwide. However, they do have a high value as cattle feed but are not used as such.

In a near future, nematicide properties of *Mucuna* spp. seeds may also become an important asset in sedentary yam-based cropping systems, which are more susceptible to nematode-related yield losses. Recent experiments in Ghana revealed that an application of *M. pruriens* seed powder results in significant population reduction of the economically most important nematode pests (Osei et al. 2013). It had already been tested that *Mucuna* spp. roots installed as an intercrop also smother some of the nematode infestation (Adegbite et al. 2005).

Additional uses as well as seed and fodder markets development would be major incentives for producers not to dis-adopt as soon as initial yield improvement and weed control have been reached, as it had been the case with *Mucuna* spp. in a maize-based cropping system that was said to have been adopted massively by farmers and can hardly be found on farms nowadays (Vissoh et al. 1996).

4.4. Specific constraints and potential of cover crops

Both legume-based systems tested displayed good performances so that farmers may choose the species they prefer according to their intended uses. However, some constraints and specific incentives to adoption still have to be considered. As earlier concluded by Hauser et al. (2006), planted fallow has to be specifically designed for farm households and crops and no "one-fit-for-all" system should be expected. Attention should not be only focused on soil conservation but also on weeds and pests control, income, food supply, labor requirements, and risk reduction.

In the yam-based system with cover crop, legumes are not difficult to install as they are sowed in relay in maize on the same row and require little additional labor in the early stages. Management constraints appear at harvest time due to the tedious incorporation of biomass into mounds and ridges, seed harvest, and risks of bush fire or cattle damage. Local learning processes may partly leverage such constraints; farmers participating in the experiments for example did adjust the time of slashing the cover crop in order to reduce its hardship and as a prevention of bush fire. Equipment could also be tested that helps either cutting the stems and vines or planting into the mulch; zero tillage may in the long run replace yam cultivation in mounds, provided the soil has become soft and porous and is locally loosened, as tested by Cornet et al. (2005, 2009). In all these situations, insertion in networks where farmers can exchange about difficulties and how to cope with them, as well as receive adequate training and timely access to inputs, was a main asset for adoption.

Both legumes are good fodder as formerly assessed by Tarawali (1994) and Versteeg et al. (1998). In this study, farmers raising livestock have been more prone to adopt cover crops. However, this aptitude to provide high-quality fodder is also a constraint as long as roaming cattle are difficult to control. An increasing competition between livestock keepers and farmers, especially in the dry season, when animals are on their seasonal move, makes it difficult to prevent damage in open fields. Livestock keepers also set bush fire on in order to have young grass shoots, which causes bush fires to spread into the dry cover crop mulch. In the end, this constraint may turn into an opportunity. Agro-pastoralists might become interested in fodder cultivation and pastoralists in purchase of high-quality fodder in times of draught.

5. Conclusions

Farmers adopt an innovation if they expect it to contribute to better achieving their goals, which may include economic, social, and environmental aspects, while considering constraints and risk-related issues at the same time. Legume cover crops in yam-based systems improve yam harvest, incomes and returns to labor for slightly higher labor and cash demands. Additional labor requirements may not be a limiting factor, actually smaller plots may be cultivated for the same harvest as after grass fallow, but appropriation of the new skills needed for managing the important additional biomass is. In R&D sites, frequent interactions between smallholders have been facilitated by the research team through demonstration plots, training and field visits, or village evaluation meetings. Such contacts are essential in the early stages of technology experimentation, where technology abandonment rates are usually high. New adopters off-site will have to collect information, especially from early adopters, and begin to assess its usefulness in their own context, followed by a stage of small-scale trials. If this is successful, adoption, review and modification, and finally either full adoption or abandonment of the innovation will follow. Promotion of such acquisition and exchanges of experiences would increase the speed of adoption.

Producers may need several years before they acquire sufficient skills and knowledge about such new technologies. Additional income from new valuable products derived from the cover crop itself (seeds, fodder) would therefore be incentives to adoption and help overcome the tediousness of the technology appropriation period.

Land use security also conditions access to the technology of both women and new settlers especially. In the absence of binding contracts with landowners, they cannot take the risk of improving the soil fertility of their field and see it requested by the landowner before they can obtain the benefit from their efforts. All these issues will require new research as well as decision makers' involvement in order to sustain efforts toward extension, farmers' networks, land tenure security, and new markets emergence.

Cover crops seem promising options for yam-based systems, yam responding particularly well to additional biomass application, especially when compared to usual yam-based systems, the performances of which are known to be in decrease. However, producers may assess cover crops in comparison to other economic opportunities, including yam or not. In order to increase the attractiveness of cover crops, additional options should be considered to enhance their profitability. Exchanges also are required among producers and with researchers and extension agents for the development of the new required skills and the adoption of the innovation up to a scale where they become standard practices.

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