Contingent Constraints of Soil Conservation Innovations: Case of Yam-Based Systems with Herbaceous Legumes in the Guinea-Sudan Transition Zone of Benin

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Abstract: One of the most serious problems of farming systems in West Africa is the excessive reduction of agricultural productivity related to the "slash and burn" and shifting cultivation systems. With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes (*Aeschynomene histrix* and *Mucuna pruriens* var *utilis*). This study examines with end-users in the framework of focus group and individual surveys in 306 farm households, constraints degree of severity of yam-based cropping systems and participatory solutions in order to improve policy transacting in rural areas for sustainable yam-production. The results showed significantly high constraint degree of severity for herbaceous legumes biomass incorporation (52% and 46%) for *Mucuna* and *Aeschynomene* respectively during individual survey and 82% during focus group for both legumes. Crop competitions, field access (with *Mucuna*), animal divagation, fertilizer cost, biomass burn, seed consumption, market and grains harvest (with *Aeschynomene*) were additional constraints as well as in low and relatively high population density zone. On the seed production plot, the biomass of *Aeschynomene* at senescence could be shaken within basins to collect easily the seeds and avoid lost. The mixture of *Aeschynomene* seeds with dry sand (3/4 sand - 1/4 seeds) solves the problem of planting small seeds. Before the legumes reach the physiological maturity, three-quarters of biomass could be manually incorporated into the soil before the dry season during ridging and the remaining biomass could be left on the surface as mulch in order to reduce the workload related to the biomass incorporation into the soil. The practice of fire wall and fire of reference around the plot is necessary to avoid the burn of the mulch in the dry period. *Mucuna* seeds valorisation occurred to generate additional incomes for smallholders' households. The animal nutrition with *Mucuna* grains deserves to be more investigated. The crop-livestock integration with these herbaceous should be an opportunity for yam production because of agro pastoral potential in the GuineaSudan transition zone of Benin.

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Key words: *Dioscorea rotundata* % Herbaceous legumes % Constraint degree of severity % Contingent ranking

INTRODUCTION

Yam (*Dioscorea* spp.) is a tuber crop that is widely cultivated in the humid and sub-humid lowland regions of West Africa and the Caribbean [1]. More than 90% of world yam production (40 million metric tons of fresh tubers/year) is in West Africa [2]. Yam is grown in traditional cropping systems as the first crop after virgin forest or after a long fallow period yielding about 10 t of fresh tubers ha^{-1} year^{-1} [3]. But when the soil fertility is high, the potential yield of species *Dioscorea. rotundata* (*D. rotundata*) can easily reach 25-30 t ha^{-1} [4]. The increase in yam production has been due more to land expansion than to crop improvement potential [5]. For example, the yield increase of 7.6% in West Africa was

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mainly due to an increase in area of 7.2% and only 0.4% was due to an improvement in crop productivity itself [5].

Yam is a demanding crop in terms of organic matter and soil fertility [6], especially the most appreciated and market-valued cultivars (early maturing *D. rotundata*) used for the popular dish called *Fufu* (pounded yam) [7]. Yam cultivation in West Africa is now confronted with the scarcity of fertile soil available for clearing [8]. In Benin nowadays, farmers hardly have the possibility to rely on long duration fallow and yam is being cultivated in 1 or 2-year herbaceous fallow-yam or maize-yam rotation systems with manual incorporation of residue into the soil [9]. Smallholder farmers removed important quantities of nutrient from their soil without applying sufficient quantity of manure or fertilizer to replenish the soil [10]. constraints of agricultural innovations for conservation [11-14]. Nevertheless, such techniques have been generally grain-oriented (cereals, legumes) and very little has been done on root and tuber crop based systems [15].

This study examines constraints degree of severity of improved yam-based systems with herbaceous legumes with the prospect of identifying ways to improve policy transacting in rural area. By exploring the relevant constraints in the demographic (population density of zone) and gender context, the paper is an empirical contribution to the constraints literature and provides valuable pointers for the design of effective and efficient public policies for on-farm yam-based systems including herbaceous legumes for sustainable production. In section 1, we present the study area in the Guinea-Sudan

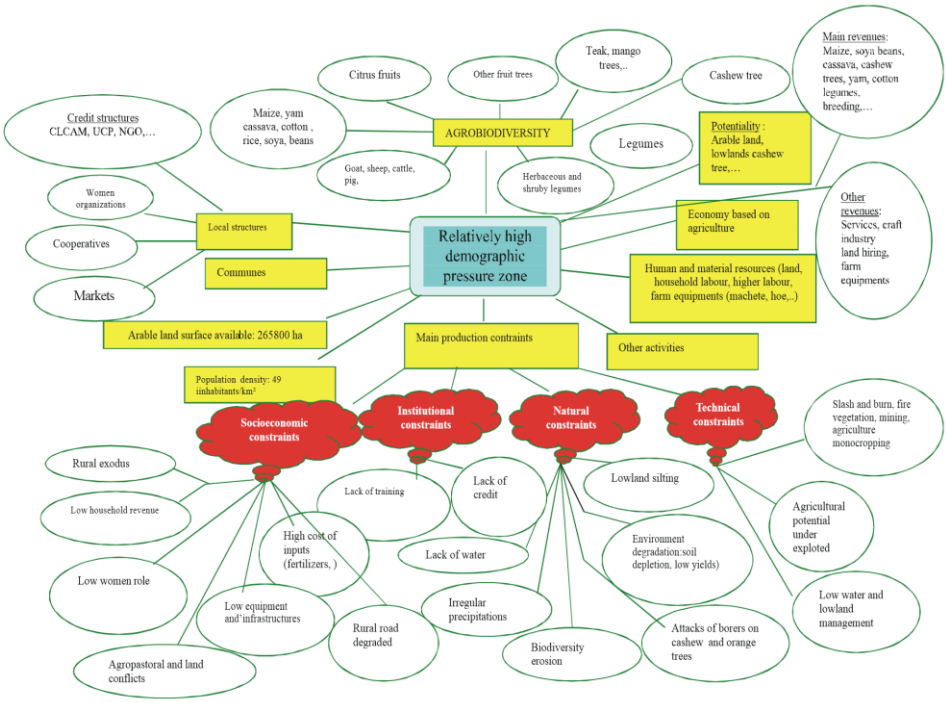

Fig. 1: Characteristics of the relatively high demographic pressure zone in the central part of Benin

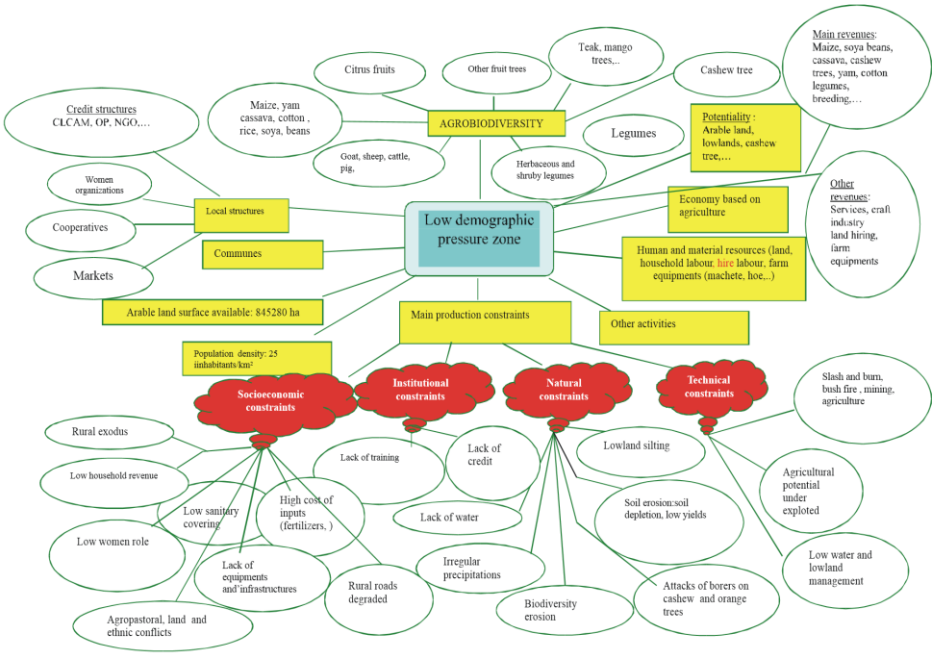

Fig. 2: Characteristics of low demographic pressure zone in central Benin

transition zone of Benin, the yam-based systems recommended to farmers. In section 2 we describe the survey methodology. In sections 3 and 4, results are exposed and discussed.

Background

Study Area: The study was carried out in 2005 in the Guinea-Sudan transition zone of Benin in a low (Savalou, Bantè, Savè and Ouessè) and in a relatively high population density zone (Dassa-Zoumè, Glazoué) (Figs. 1 and 2). This area in central Benin lies between the latitudes 7°45 ' and 8°40' North and longitudes 2°20 ' and 2°35 ' East. The climate is the transitional climatic GuineaSudan 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].

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.

Yam-Based Systems with Herbaceous Legumes:

- Intercropped *Aeschynomene histrix* with maize-yam rotation (TMA): smallholders planted maize (spacing 80 × 40 cm) in April of the first year. *Aeschynomene* seeds (7 kg haG^{1}) were sown two weeks after the maize (Fig. 3).
- Intercropped *Mucuna pruriens* with maize-yam rotation (TMM): smallholders planted maize. *Mucuna* seeds (25 kg haG^{1}) were sown at (spacing 80 × 40 cm) in May six weeks after the maize (Fig. 4).

In both improved yam-based systems (TMA and TMM), some smallholders applied 100 kg haG^{1} NPK fertilizer (14% N, 10% P, 11.7% K) in April and 50 kg haG^{1} urea (46% N) in June. The maize was harvested in July. Biomass of *Mucuna* and *Aeschynomene* crops were mowed and manually incorporated into the soil in October-December during ridging and then the main yam crop was planted in moulds, without mineral fertilization.

Fig. 3: Preceding *Aeschynomene histrix* and maize for yam production at Ouessè (Central Benin)

Fig. 4: Focus group at village level on the preceding *Mucuna pruriens* var *utilis* and maize for yam production (Dassa-Zoumè in central Benin)

MATERIALS AND METHODS

Individual Survey at Household Level: The individual survey was conducted in 2005 in 306 farm households (120 and 186) in low and relatively high population density in the Guinea-Sudan transition zone of Benin (Table 1). Technologies constraints evaluation was determined during individual surveys by the frequency and percentage analysis. The frequency is the number of end-users' response for the constraint within the sampling size.

Focus Group at Village Level: Various socioprofessional groups took part at different villages in the constraints evaluation in the zone with low and relatively high population density. They were groups of men (30-65 years

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

Zone	Village	Household sampling size	Percentage per zone (%)

Low population density zone	Savè	21	
	Ouessè	76	
	Savalou	39	
	Bantè	50	61
Relatively denser population zone	Dassa	61	
	Glazoué	59	39
Total		306	100

old) and women (25-55 years old). The maximum size of the groups was an average of 30 per village (Fig. 4). Advantages of yam-based technologies with herbaceous legumes were discussed with end-users. The prioritization matrix at village level and the contingent ranking matrix (synthesis matrix at regional level) were used for constraint degree of severity [14]. Following parameters were considered in the data analysis:

Relative Importance of a Constraint (IR): Is the score that the end-users group gave to a constraint. The participants freely established the score notation. The maximum score corresponded to the constraint that the socioprofessional group considered most important or the sum of maximum when the synthesis matrix was concerned. The minimal score was selected equal to zero for the options of no importance for the group.

Constraint Degree of Severity (DS): Is the percentage of the note given to a constraint compared to the maximum score. A constraint degree of severity of 100% would be that showed most important by the participants.

RESULTS

Constraints of Yam-Based Systems with Herbaceous Legumes at Household Level: Biomass incorporation difficulty in yam-based technology with *Mucuna* (TMM) was the first constraint expressed with 43% and 67% respectively in the relatively high (ZA) and low population density zone (ZB), followed by the problem of competition between *Mucuna* and the pattern crop with 25% (ZA) versus 9% (ZB) (Table 2). Smallholders highlighted the problem of *Mucuna* seeds edibility with 18% and 19% and damages caused by the animal (bovine) divagation (16% and 17%) in ZA and ZB, respectively.

Aeschynomene biomass incorporation appeared also as the first constraints in yam-based system with *Aeschynomene histrix* (TMA) with 21% and 84% in both zones (Table 2). In addition, *Aeschynomene* seeds harvest, the concerns more particularly 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.

Constraints of Yam-Based System with Herbaceous Legumes at Village Level: Focus groups' discussions at village level and the contingent ranking matrix analysis at regional level, show as the first constraint the herbaceous biomass incorporation followed by the field access difficulties. In fact, biomass incorporation into the soil and field access difficulties was highly expressed with constraints degree of severity of 82 and 68% for both zones (Table 3). Constraints of which in particular the difficulty of harvest, animal divagation, marketing and seeds consumption, fertilizer costs, vegetation burn and the reptile refuge under the biomass were mentioned with constraint degree of severity ranged from 18 to 59%.

According to the gender analysis per zone, results show that the biomass incorporation for both legumes (100%), the harvest difficulty (67%) and the animal divagation (50%) were the preoccupation of women group in ZA versus the biomass incorporation, seeds marketing, the animal divagation and seeds harvest difficulties with constraints degree of severity ranged (100%; 100%, 90% and 75%) respectively from the men group. Women and men groups in ZA drew particularly attention on high fertilizer costs (97% and 100%), respectively. Both groups in ZB expressed the field access difficulty (100%). Women and men groups focussed attention on the biomass incorporation (83%) and the vegetation burn (83%) respectively in ZB. Animal divagation was expressed as well by women (50%) and by men (43%) in ZB. Therefore, the gender analysis per zone shows that all these constraints were important with degree of severity (>40%).

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Table 2: Constraints of yam-based technologies with herbaceous legumes (Farm household level)

		ZA (N=186)		ZA (N=120)				
	Constraints	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	OI
TMM	Biomass incorporation	80/186	43	80/120	67	160/306	52	1

	Competition	47/186	25	11/120	9	58/306	19	2
	Seeds consumption	33/186	18	23/120	19	56/306	18	3
	Animal divagation	30/186	16	20/120	17	50/306	16	4
	Reptile refuge	9/186	5	11/120	9	20/306	7	5
	Fertilizer cost	9/186	5	8/120	7	17/306	6	6
	Plot maintenance	9/186	5	-	-	9/306	3	7
	Vegetation burn	-	-	5/120	4	5/306	2	8
	Seeds marketing	4/186	2	-	-	4/306	1	9
TMA	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
	Ferilizers cost	9/186	5	3/120	3	12/306	4	6
	Plot maintenance	9/186	5	-	-	9/306	3	7

Legend: 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 3: Contingent ranking matrix on constraints in yam-based systems with herbaceous legumes (Focus groups level)

	ZA				ZB						
	GW		GM		GW		GM		Prioritisation		
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

Legend: 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

DISCUSSION

End-Users' Perception about Effects of Herbaceous Legumes in Yam-based Cropping Systems: Herbaceous legumes (*Mucuna* in particular) used for yam production was appreciated by end-users for its capacity to restore the soil fertility, maintain soil humidity and control weeds (*Imperata cylindrica* in particular) as well as in low and relatively high population zones. Furthermore, *Mucuna* increased yield (yam) and supplemented the ruminant's food. This confirmed former works. Because *Mucuna*, compared with *Aeschynomene* in the study area, grows more rapidly and close. Generally, studies revealed that soils. *Mucuna* root exudates could solubilize P increasing its availability that is crucial for yam [19]. In Benin and Togo, [20] studied the effect on the yam crop of short the incorporation of the biomass gets more nitrogen to the succeeding crop than the mulch application on the soil because the decomposition of organic matter is more rapid after incorporation [18]. Decomposition data indicated that 6 weeks after incorporation of biomass only 30% of *Mucuna* remained [11]. This should be related to faster decomposition of *Mucuna* residue biomass and nutrients release for subsequent plants growth. Furthermore, *Mucuna* recycled more macronutrients (N, P, K) than *Aeschynomene* [19]. Legumes fallows with *Mucuna*, are known especially for improving the quantity of available P fractions in the soil for subsequent crops [18]. Nevertheless, it depends on the inherent P levels in the End-users would undoubtedly adopt yam-based technologies with herbaceous legumes if there is a market for the flow of seeds. The farmers assured to sell their

fallows based on *Mucuna pruriens* var *utilis*, *Aeschynomene histrix*, or *Pueraria phaseoloides* and reported that a 1-year fallow planted with *Mucuna* led to a significant increase in yam yields.

End-Users' Perceptions about Constraints in Yam-based Systems with Herbaceous Legumes:

Biomass incorporation into the soil was expressed in both zones as well as by women and men for *Mucuna* and *Aeschynomene* with highest constraint degree of severity and highlighted the importance of this constraint for yam-based cropping systems with herbaceous legumes.

Seeds consumption constraint was expressed in both zones and confirms former works [13]. In fact, the seeds of *Mucuna* contains 3-(3,4-dihydroxyphenyl)-L-alanine, known as L-Dopa which makes difficult *Mucuna* grains consumption. Human consumption of unprocessed beans can cause intoxication, but the toxins can be removed by boiling and soaking the seeds in several changes of water [21]. The L-Dopa content of Mucuna ranges from 4.7 to 6.4% [22]. The end-users would undoubtedly grant more credit to yam-based technologies with *Mucuna*, if in more of its fertilizing role, the seeds were edible. In spite of the research undertaken by several institutions for animals and the human food, *Mucuna* grain consumption remained difficult. This constraint raises the problem of the *Mucuna* seeds valorisation.

Fig. 5: Animal divagation contributing to crops damage and herbaceous biomass remove (Ouessè in central Benin)

production cycle. Nevertheless, in yam-based cropping systems with herbaceous legumes, the mineral fertilizer is applied on the preceding crop (maize) and yam could profit from the residual effect. In fact, there is often a products would look for increasing production. The existence of market supports the adoption of improved technologies for high yields and household farmers' revenue [23, 24].

Animal divagation was expressed as well by women and men in both zones (ZA and ZB). In fact, livestock have long been an integral part of West African farming systems. The communal and extensive grazing of natural pastures continues to be the predominant feeding strategy in the Guinea-Sudan transition zone of Benin (Fig. 5). This practice leads to the lack of high quality fodder especially during the dry season and the use of crop residues in the fields for livestock's feeding. The ruminant (bovine) passage through the landscape lead to biomass remove, plants and crop residues damage [25]. There is an urgent need to replace this destructive cycle with economically and ecologically viable farming systems.

Mineral fertilizer application appeared to be essential particularly in ZA, but the high cost of inputs limits their application. Smallholders use fertilizers on maize on depleted soils depending on cash and inputs availability. Consumers' requirements for the quality of taste often slowed down the direct application of chemical fertilizers on yam because of their "presumed negative effect" on the quality of pounded yam [7]. For this reason, farmers avoid applying mineral fertilizers during the yam

CONCLUSION

The study highlights on farm research with yam-based cropping systems. Participatory diagnosis

problem of NPK equilibrium for tuber production: too much nitrogen and not enough K, resulting in tubers with too high water content, with consequences on tuber conservation and on fufu preparation. Further information is needed to end-users in this way for sustainable yam production.

evaluates constraints degree of severity of yam-based systems with herbaceous legumes. As a whole, the herbaceous legumes gave satisfaction for the problem of soil fertility. *Mucuna* in particular was appreciated for its capacity to restore the soil fertility, to maintain soil humidity and to control weeds as well as in low and

Fig. 6: 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 (Central Benin)

The practice of fire wall and fire of reference around the plot is necessary to avoid the burn of the mulch in dry period

Fig. 7: Late burn of *Aeschynomene histrix* biomass in dry period at Ouessè (Central Benin)

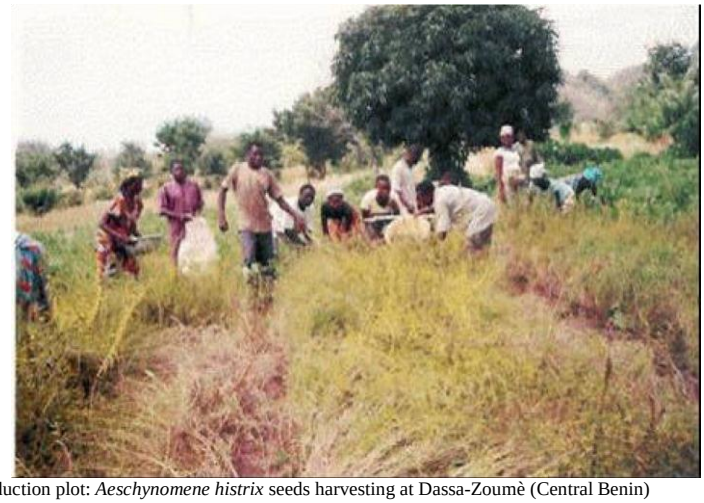

Fig. 8: Seed production plot: *Aeschynomene histrix* seeds harvesting at Dassa-Zoumè (Central Benin)
On the seed production plot, the biomass of *Aeschynomene* at senescence is shaken within basins to collect easily the seeds

relatively high population density zones. Herbaceous legumes increased crop yield (yam) and supplemented the ruminant's food according to farmers' opinions. Results show significantly high constraint degree of severity for herbaceous legumes biomass incorporation (52% and 46%) for *Mucuna* and *Aeschynomene* respectively during individual survey and 82% during focus group for both legumes. Crop competitions, field access (with *Mucuna*), animal divagation, fertilizers cost, legumes burn, seed consumption, market and legume grains harvest in particular with *Aeschynomene* were additional constraints as well as in low and relatively high population density zone.

We thus, suggest the early-reduced biomass incorporation into the soil. Three-quarters of biomass could be manually incorporated into the soil in October-November during ridging and the remaining biomass could be left on the surface as mulch in order to reduce workloads related to the incorporation (Figure 6). The practice of fire wall and fire of reference around the plot is necessary to avoid the burn of the mulch in dry period (Figure 7). 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. On the seed production plot, the biomass of *Aeschynomene* at senescence is shaken within basins to collect the seeds (Figure 8).

Mucuna seeds valorisation occurred to generate additional incomes for smallholders' households. The animal nutrition with *Mucuna* grains deserves to be more investigated.

The crop-livestock integration with these herbaceous legumes should be an opportunity for yam production in dynamic of rotations, because of agropastoral potential in the Guinea-Sudan transition zone of Benin. Integration of forage legumes into the traditional fallow management can help improving both forage supply at a time of feed scarcity and soil fertility. Corralling contracts in the fence-based cropping systems with forage legumes 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 needs toward end-users for more information, advices in order to impel a dynamics for the adoption of yam-based technologies with herbaceous legumes.

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