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LAND TENURIAL SYSTEMS AND THE ADOPTION OF *MUCUNA* PLANTED FALLOW IN THE DERIVED SAVANNAS OF WEST AFRICA

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ABSTRACT

In 1987, an improved resource management system that incorporates velvet bean (*Mucuna pruriens* var. *utilis*) to address soil fertility and weed (*Imperata cylindrica*) infestation was introduced to the small-scale farmers in a densely populated area of the derived savannas in Benin Republic (West Africa). Six years later, an adoption study was conducted to assess factors driving the adoption process. Four types of land tenure systems based on mode of access to land were identified: divided inheritance, purchasing, gifts, and sharecropping/renting. The first three provide long-term security over land, and together, they represent about 76 percent of the survey fields. Results from three variants of a probit model indicated that security over land was among the factors that significantly affect the adoption of the technology, with a high marginal effect on the probability of adoption, while gender did not have a significant effect. The most important determinant for adoption is the number of times a field is weeded during a cropping season (a proxy for the amount of labor required to tend a crop for better yields). High weeding requirements favorably affect the adoption of velvet bean only if farmers have full security on the degraded (weedy) land. The predominance of land tenure systems that provide secure property rights, namely the traditional acquisition of land through inheritance or gift mode and the gradual development of a land market, facilitated a quick spread of the *Mucuna* planted fallows in the study region.

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Victor M. Manyong[*] and Victorin A. Houndékon[H]

1. INTRODUCTION

Over time, the vital role land plays in sustaining life for human beings has led societies to establish arrangements concerning the ownership and use of land, usually referred to as land tenure. Land tenure involves the rules and procedures governing the rights, duties, liberties, and exposure of individuals and groups in the use of and control over such basic resources as land and water (Matlon 1994).

The possible effects of indigenous land-right systems on the efficiency of input use and on incentives to adopt land-improving technologies in sub-Saharan Africa are generating increased interest among researchers and policy makers (Versteeg and Koudokpon 1991; Place and Hazell 1993; Matlon 1994; Lawry et al. 1994; Biaou 1996; Dvorák 1996; Gavian and Fafchamps 1996; Manyong et al. 1996). Concern has been heightened by the observed low level of use of modern inputs by farmers in many developing countries, and by the observed increasing degradation of natural resources. However theories and empirical evidence on the role of land tenure are mixed.

In many African countries, national legislation has formally provided for legal title to be granted to landholders to register ownership and land transfers. In practice,

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formal land titling, commercial land exchange, and the use of land as collateral are typically effective only in urban areas (Matlon 1994). In rural areas of tropical agriculture where land is abundant, these practices tend to be either nonexistent (Binswanger and McIntire 1987) or just emerging. The most common land tenure system found in sub-Saharan Africa is community-based ownership of land where individuals belonging to a particular community have access and use rights to land which is held in trust by the community. Rights to different types of land are typically accorded to individual households or groups. Private ownership rights, which include the right to sell one's land, are still limited, particular in West Africa. Modes through which individuals have access to land in West Africa include inheritance, gift, purchasing, renting, pledging, sharecropping, and renting (Lawry, Stienbarger, and Jabbar 1994).

This paper describes the existing land tenure systems in a rural area of West Africa and analyzes the effects of those systems on the adoption of *Mucuna*, a land-improving annual technology that was newly introduced to the farmers in late 1980s. In the literature, views have not been unanimous on the importance of tenurial arrangements on the adoption decision. The working hypothesis for this paper proposes a weak linkage between property rights and the adoption of the *Mucuna* planted fallow technology because it is an annual crop that does not last too long in a plot although the land-improving qualities last for a longer period (see Knox, Meinzen-Dick, and Hazell in this volume).

The following section describes the study area, the cropping systems prevailing in the study area, the technology farmers are adopting, and existing tenurial arrangements found in the study. The third section presents the methodology especially the sampling procedure and the empirical model for the econometric analysis. The fourth section discusses the effects of property rights on the adoption of the technology, and the last summarizes the findings and highlights the policy implications for the future.

2. STUDY AREA AND AGRICULTURAL PRACTICES

STUDY AREA

The study was conducted in 1993 in the southern part of Benin Republic in West Africa using a survey methodology designed for econometric applications. The prevailing agroecological zone is the derived savanna, although small parts of the coastal savannas are found along the sea. The study area represents about 10 percent of the land but holds about 54 percent of the total population and about 60 percent of the rural population of the country (INRAB 1995). Therefore farming systems are intensive in the use of land. Soil degradation and the resulting low level of agricultural productivity have been demonstrated by several authors (Versteeg and Koudokpon 1991; van der Pol, Gogan, and Dagbenonbakin 1993; Quenum 1995; Houndékon and Gogan 1996).

CURRENT CROPPING SYSTEMS

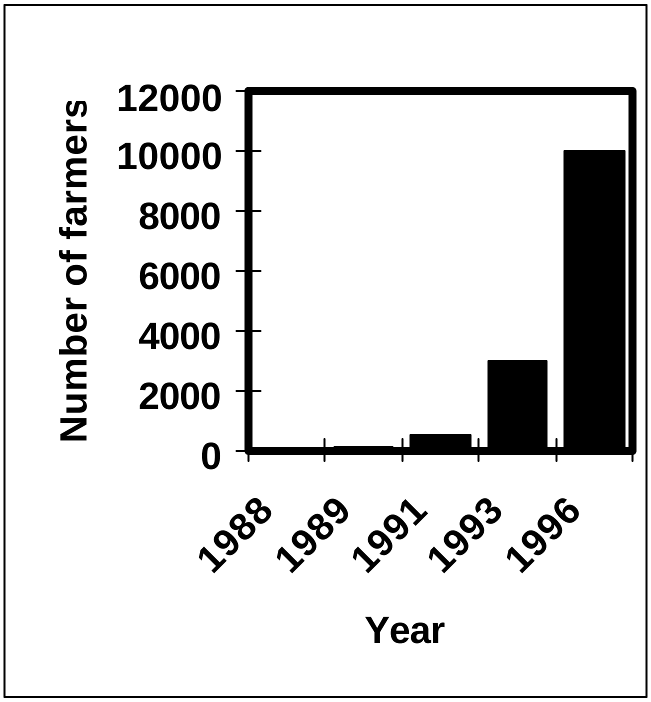
There are two cropping seasons during the rainy period: the main season runs from April to July and the second season from September to October. Due to climate changes, yields from the second season crops have become erratic (Mutsaers 1991). Farmers produce multiple crops in multiple associations. Crop enterprises include maize + cassava + groundnut, maize + cassava + cowpea, maize + cassava; cotton is a minor crop in the savanna ecology, grown as a sole crop. In every field and in all crop combinations, oil palm trees are sparsely intercropped with food crops. Oil palm plays a major social and economic role in the study area (Meikle, Gutierrez, and Herren 1996). If the farmer is a tenant and had planted palm trees during the tenure period, arrangements are made with the landlord to share the palm products. Major constraints to agricultural production are low soil fertility, weed infestation, pressure from insects and diseases, high population density, and poor infrastructure (RAMR 1987).

INTRODUCTION OF THE *MUCUNA* PLANTED FALLOWS

To improve the status of soil fertility and reclaim degraded and weed-infested land, land improvement technologies were introduced to farmers beginning in 1987 by the Institut National de Recherche Agricole du Bénin (INRAB) *Project Recherche Appliquée en Milieu Réel* (RAMR) in collaboration with the International Institute of Tropical Agriculture (IITA) and the Institut Royal des Tropiques □ the Netherlands (RAMR 1987). These technologies included alley cropping (with many agroforestry species such as *Leucaena leucocephala*, *Leucaena diversifolia*, *Albizia lebbeck*, *Calliandra calothyrus*, *Acacia auriculiformis*, *Acacia magnum*, and *Gliricidia sepium*), intercropped maize/*Cajanus cajan*, and *Mucuna* (*Mucuna pruriens* var. *utilis*) planted fallows (Versteeg and Koudokpon 1991). On-station and on-farm trials have demonstrated the technical superiority and the economic profitability of alley farming over conventional bush fallow systems for both crop production and animal production. However, adoption by farmers has been low, lagging behind expectations (Atta-Krah and Francis 1986; Kass et al. 1995; Tuah 1995). The benefits from the use of a green manure cover crop system, such as *Mucuna* for West Africa are well summarized by Vissoh et al. (1998).

The adoption of *Mucuna* planted fallow has proven successful, and farmers increasingly use the technology (Figure 1).

Figure 1 Approximate number of farmers utilizing *Mucuna* in Benin Republic



The technology consists of planting *Mucuna* in a relay cropping with food crops. *Mucuna* seeds are sown 30 days after planting food crops (mainly maize) in the first cropping season. *Mucuna* remains in the field after maize is harvested until the end of the second cropping season, thereby precluding the planting of a second crop. This allows groundcover to fully develop for biomass accumulation and nitrogen fixation while weeds such as *Imperata* are smothered. During the following dry season that lasts from November to March, *Mucuna* dies off and the farmer can farm the field again at the next main cropping season with minimum investment in labor to open the rows through the *Mucuna* mulch. Off-farm trials of improved Mucuna fallow conducted over 8 years from 1987 to 1994 reported three- to five-fold increases in maize yield over the farmer's traditional system (Quenum 1995) due to soil fertility improvements and weed control. Sanginga et al. (1996) mentioned an accumulation of about

167 kg Nitrogen/ha per 12 weeks in *Mucuna* fields, while Dovonou (1994) noticed a reduction of *Imperata* shoots from 270 to 32 plants/m[1] when *Mucuna* is planted in *Imperata*-infested fields. Akobundu (1987) described *Imperata* as the most noxious weed in the derived savanna of West Africa. Overall, Osei-Bonsu and Buckles (1993) mentioned the small investment (capital, labor and managerial skills) that is required in the *Mucuna*-based systems as one of the factors favoring a quick spread of the technology in West Africa as compared to other soil fertility improving technologies, such as alley farming or inorganic fertilizer.

The biggest benefit from using the technology in the shortrun is on weed control. To a lesser extent a short term impact on soil fertility occurs as well since the thick mulch left on the soil surface by *Mucuna* already has some positive effects on soil moisture and run off, which contribute to the increase in yield. *Mucuna* leaves decompose quickly and

[1] NO_MARKET and CASH_INC are not significantly correlated so that one of them can be excluded from the analysis. CASH_INC indicates the amount of cash earned from selling Mucuna seed while NO_MARKET reports on whether farmers perceived or did not perceive the lack of market for Mucuna seed a major constraint to adoption. For non-adopters the observed lack of market for Mucuna seed could be a reason for the rejection of the technology.

the effects on soil fertility improvement are typically perceived in the second year following its introduction. The level of field degradation (weed infestation, low yield) and the availability of land are among the factors that determine the frequency with which *Mucuna* is used.

TENURIAL ARRANGEMENTS

African customary land tenurial systems are often characterized by the inalienability of land. Fields are to a varying degree controlled by the extended family and influenced by community-level decisions. In many parts of West Africa, individuals have private user rights on the product from cultivation but do not have private ownership of land in terms of the ability to sell land. However, slow changes of land tenure systems have been observed in the study area, as the present case study will highlight. Among forces driving the land tenurial arrangements, Biaou (1993) indicated changes in social organization, population pressure, and economic factors. It is also possible that changes in land tenurial systems induce changes in social organization and economy.

Our survey identified four types of tenure status: divided inheritance, gift, purchasing, and sharecropping/renting. Fields are managed by both men (64.3 percent of the fields) and women (35.7 percent). Biaou (1993) also found the proportion of fields managed by men was higher than that of women in the same study area. The farmers (either male or female) have private user rights on their production. However, the mode of acquisition of the cultivated fields shows gender differences (Table 1). Divided inheritance is the dominant tenurial arrangement for the access to land (about 52 percent for all the fields). Only male children can inherit land in the study area. After the death of the head of the family, his fields are divided and reallocated among his sons. This is the major way of transferring the rights over land from one generation to the next. During his lifetime, the head of the family, extended or nuclear, can also allocate a portion of land to a newly married son who will have full control over his own parcel of land. Land "*belongs*" to the heirs as long as it is cultivated or under short fallow. If abandoned, land can be reallocated by the extended family to another son. Daughters do not inherit land under customary rules. However, woman farmers commonly cultivate land they receive from their husbands (52.2 percent of the women fields in Table 1). In the case of divorce, land returns to the husband's family. If the husband dies, the widow can exert usufruct rights on land on behalf of her small sons until they take over at their majority. Biaou (1996) observed the same mechanisms on land transfers for the inland valleys in the southern Guinea savannas of the Benin Republic.

Table 1 Distribution of cultivated fields according to tenure status and gender in southern Benin Republic

Tenure status	Male (n = 287)	Female (n = 159)	All (n = 446)
	(Percent)		
Divided inheritance	80.8	0.0	52.0
Purchasing	6.6	2.5	5.2
Sharecropping/renting	12.6	45.3	24.2
Gift	0.0	52.2	18.6
Total	100.0	100.0	100.0

Notes: Consider only columns percentage.
n = number of fields.
Source: Field surveys.

The second dominant mode of access to land is through sharecropping/renting (24.2 percent of the fields). Although it is the second most common means of access to land for both men and women, its relative importance for women is very high. Renting involves a cash payment for a fixed period. The rent to be paid depends on the duration of the contract. Biaou

(1993) indicates that for long-term contracts of around 20 years, rent is on average 2.5 times the yearly per hectare price of short (3- 4-year) contracts.

Sharecropping is similar to renting, except that payment is made in kind based on crop production. Two types of sharecropping are common: type 1:2 involves giving one third of the products from food crops and all oil palm products to the owner; type 1:1 involves equally sharing all the agricultural products (food crops and oil palm).

The gift mode is the third major mode of access to land (about 19 percent of the fields). It does not involve any payment nor any share of agricultural products. This category represents the means by which married women who farm receive land from their husbands. This mode of access to land also provides long-term security over land for women as long as they remain in the husband's family.

Purchasing was found to be the least frequent mode of access to land overall. It is indeed the third mode for both sexes since women do not inherit land and men do not acquire land through the gift mode. Despite the norm that land is inalienable, held by the extended family, in practice a land market has existed for many years in the study area (Biaou 1993). At the time of the survey (1993), the price ranged from FCFA[2] 120,000/ha to FCFA 260,000/ha (1 USD = 252 FCFA). In recent years, the price of land has increased (Figure 2). Scarcity of land might have resulted in the increase in the nominal price for the last 30 years due to population pressure.[3] The total payment may be made at once, but in many cases, it is made in installments. At the end of the last payment, an agreement is signed between the parties and in

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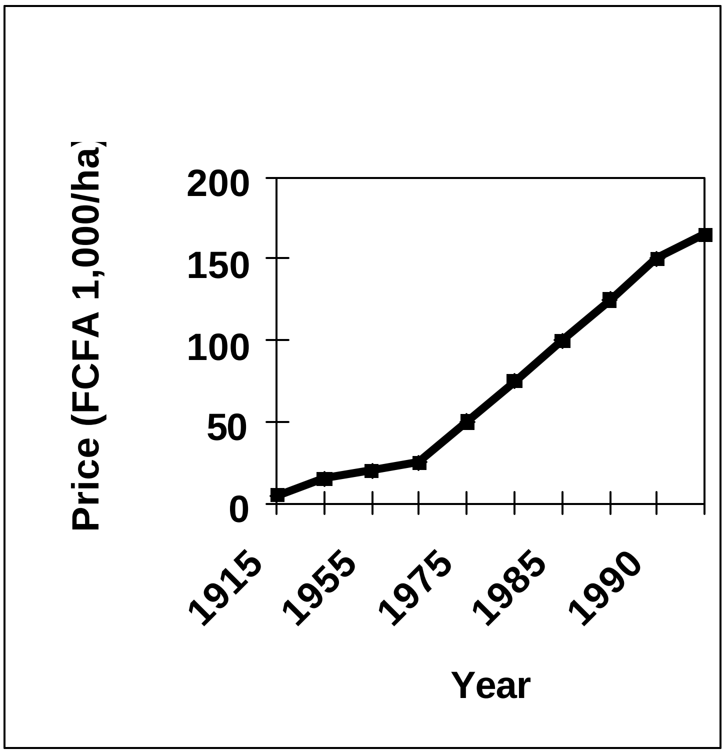
[2] FCFA is the currency of Benin Republic.

[3] Local currency had never been devaluated since its creation. The authors used the nominal price to show the increase in the land price, since the nominal price corresponds to the price paid locally to purchase land.

the presence of witnesses. Biaou (1993) related many conflicts resulting from arrangements to pay in installments.

Figure 2 Changes in the land nominal price over time at Zouzouvou village in Benin Republic (FCFA 1,000/ha)



For men as well as for women tenures derived from divided inheritance, purchasing, and gifts provide the long-term security over land that is hypothesized to be related to the adoption of a soil-improving technology. All together, these tenure systems represent 75.8 percent of the survey fields.

3. METHODOLOGY

SAMPLING PROCEDURE

Data were collected in 1993 in four villages where the technology had been introduced to the farmers between 1987 and 1991. In the four villages farmers were stratified into 2 groups: those who had used *Mucuna* at least once and those who had never used it. A proportionately random sampling in the two groups led to 143 users (35%: women; 65%: men) and 134 non-users (38%: women; 62%: men) of the technology. The former group represented 52 percent of the sample and the latter, 48 percent. Data were collected on 446 fields, 47 percent of which had received *Mucuna* at least once and 53 percent had not. Data contained information on the field characteristics, farm resources, socioeconomic characteristics of the respondents, and farmers' perception of the technology-specific features.

Descriptive statistics such as means, frequency of events were used to describe the tenure arrangements while probit models were applied to conduct the econometric analysis.

EMPIRICAL MODEL FOR THE ECONOMETRIC ANALYSIS

Probit models were used in the present study to analyze the process involved in the adoption of the *Mucuna* planted fallow with particular reference to the effects of land tenure systems on the spread of the new technology. The ability to handle a binary dependent variable and multiple continuous and categorical variables makes probit a suitable choice for this empirical analysis (Ameniya 1981; Maddala 1983; Griffiths, Hill, and Judge 1993; Liao 1994).

Dependent Variable

The dependent variable Y was defined in the present study as an index of two variables that are involved in the decision whether to adopt the technology. The first variable is on the history of the survey fields being investigated: has the field been planted in *Mucuna* either for the control of *Imperata* or for the improvement of soil fertility? (Yes or No.) The second variable is on the farmer's decision to adopt the technology on a continuing basis: is the farmer satisfied with using the technology in the survey field and willing to continue using it, either in the same field or any other field of the farm that could require the same intervention? (Yes or No.)

We defined $Y = 1$ if yes to both questions

$Y = 0$ if otherwise

Of the 446 survey fields, 21.3 percent belonged to the category $Y = 1$, i.e.; farmers had tried *Mucuna* and are willing to continue using it. This approach departs from many other adoption studies (Shakya and Flinn 1985; Akinola 1987; Hailu 1990; Polson and Spencer 1991; Adesina and Zinnah 1993; Green and Ngo'ng'ola 1993), which consider only whether the farmer has ever used a particular technology or its current use. Application of this approach would have resulted in a rate of adoption as high as 52 percent, indicating widespread adoption at the household level. However, the plot level approach applied here shows that 47 percent of fields had been planted with *Mucuna* at some time while on 21.3 percent it was likely that the use would continue. Although the rate for sustainable adoption (21.3% of fields) is low, field level analysis recognizes that degradation of a resource base is site specific, and therefore this criterion is a better method to assess the adoption of a resource management technology.

In the case of a land-improving technology, the heterogeneity of fields within a farm makes it possible for a farmer to be both an adopter of the technology for one or more fields that experience degradation and a nonadopter for any other field that does not require such an intervention. The distribution of the fields by tenurial system for adoption versus non-adoption categories appears in Table 2. Percentages of fields in the categories of secure tenure (inheritance, gift, purchase) were higher among those fields where *Mucuna* was adopted compared to the percentages of fields in those categories where no adoption occurred. Among those fields where no adoption occurred, relatively higher percentages were in the sharecropped and rented category.

Explanatory Variables

The results from Table 1 indicate that tenure status is linked to the gender of the plot manager. Therefore, in selecting the explanatory tenure variables, the interaction between gender and tenure types resulted in the creation of a set of six distinct tenure

Table 2 Distribution of cultivated fields according to tenure status and adoption categories in southern Benin

Tenure status	Field of adoption (n = 95)	Field of no adoption (n = 351)	All (n = 446)
	(Percent)		
Divided inheritance	58.9	50.1	52.0
Purchasing	7.4	4.6	5.2
Sharecropping/renting	2.1	30.2	24.2
Gift	31.6	15.1	18.6
Total	100.0	100.0	100.0

Notes: Consider only columns percentage.
n = number of fields.
Source: Field surveys.

arrangements: purchasing by women, purchasing by men, gift to women, inheritance by men, sharecropping/renting by women, and sharecropping/renting by women. The first four tenure arrangements correspond to long-term security over land and the remaining two correspond to insecurity over land. From these two categories of variables on security, three variants of the probit model are considered. The first includes independent variables on secure tenure arrangements; the second has variables on insecure tenure arrangements; and the third combines both. The rationale for running separate regressions is to compare the discriminating power of the tenure variables when the analysis for each group is run separately and their synergistic effect when they are combined in the regression.

In addition to gender-related variables on tenure arrangements, a vector of 20 explanatory variables was considered on the basis of their hypothesized relationship with the dependent variable. All of the explanatory variables were grouped into three for each

Table 3 Explanatory variables in the empirical probit model for the 3 variants

Variable	Type	Variable description	Expected sign	Model variant 1	2	3
	Group 1: Field characteristics					
WEEDING	C	Number of weeding	+	A	A	A
SOILTYPE	B	Type of soil (Clay = 1, otherwise = 0)	-	A	A	A
FIELDSIZE	C	Field size in *kantis*[a]	-	A	A	A
PALMAGE	C	Age of oil palm in years	+	A	A	A
PUR_WOMEN	B	Plot purchased by women (Yes = 1, No = 0)	+	A	NA	NA
PUR_MEN	B	Plot purchased by men (Yes = 1, No = 0)	+	A	NA	NA
GIVE_WOMEN	B	Plot given to women (Yes = 1, No = 0)	+	A	NA	NA
INHERIT_MEN	B	Plot inherited by men (Yes = 1, No = 0)	+	A	NA	NA
RENT_MEN	B	Plot rented/ sharecropped by men (Yes = 1, No = 0)	-	A	A	NA
RENT_WOMEN	B	Plot rented/ sharecropped by women (Yes = 1, No = 0)	-	NA	A	NA
LANDSECURE	B	Land security (Yes = 1, No = 0)	+	NA	NA	A
	Group 2: Farm and farmer's specific variables					
AGE	C	Farmer's age in years	+	A	A	A
SCHOOL	B	Farmer's primary school (Yes = 1, No = 0)	+	A	A	A
SEX	B	Farmer's sex (Male = 1, Female = 0)	+	NA	NA	A
CL_RATIO	C	Consumer: Labor ratio	-	A	A	A

Table 3 Explanatory variables in the empirical probit model for the 3 variants (continued)

Variable	Type	Variable description	Expected sign	Model variant 1	2	3
MEMBER	B	Membership of local organization (Yes = 1, No = 0)	+	A	A	A
FALLOW	C	Fallow land in *kantis*	-	A	A	A
POP_DENS	B	Population density of the village (High = 1, Low = 0)	+	A	A	A
EXTENSION	B	Source of information on technology (Formal = 1, Informal = 0)	+	A	A	A
	Group 3: Farmer's perception of technology-specific attributes					
EDIBLE	B	Grain not edible (Limit adoption = 1, Otherwise = 0)	-	A	A	A
LOSSCROP2	B	Loss of second crop (Limit adoption = 1, Otherwise = 0)	-	A	A	A
SNAKES	B	Source of snakes (Limit adoption = 1, Otherwise = 0)	-	A	A	A
ITCH	B	*Mucuna* hair itch (Limit adoption = 1, Otherwise = 0)	-	A	A	A
PALATABLE	B	Palatability by livestock (Limit adoption = 1, Otherwise = 0)	-	A	A	A
CASH_INC	C	Cash income in FCFA	+	A	A	A
SHORT_SEED	B	Availability of seed (Not available = 1, Otherwise = 0)	-	A	A	A
NO MARKET	B	Lack of market (Yes = 1, Otherwise = 0)	-	A	A	A

Notes: B= Binary C = Continuous A = Applicable NA = Not applicable.
[a]*Kantis* is a local unit of area (± 0.25ha).
Source: Field surveys.

of the model variants (Table 3). The first group of variables is on the field characteristics. Farmers are expected to target the technology to a field they consider to be of poor quality, so soil fertility (SOILFERT) is expected to have a negative effect on adoption. The number of times the farmer weeds a maize plot during a cropping season increases with the level of *Imperata* infestation (Houndékon and Gogan 1996). Therefore a positive relationship is expected between the number of weeding variable (WEEDING) and the adoption of the technology. Two major soil types (SOILTYPE) exist in the study area: vertisols in the valley bottoms and alfisols in upland fields. Vertisols have heavy clay content that often causes flooding during the rainy season (RAMR 1987). Velvet bean does not accommodate inundation. Therefore, the adoption of the technology is expected to be low in a soil with a heavy clay content and high, if otherwise. Planting *Mucuna* in fields of young palm trees will smother the trees. The age of the palm trees variable (PALMAGE) in the field is expected to have a positive relationship with the adoption.

Variables on secure tenure for variant 1 of the probit model are expected to have a positive relationship with adoption, compared to insecure tenure, which is the default in this model. Those variables are purchasing of a plot by women (PUR_WOMEN), purchasing of a plot by men (PUR_MEN), gift mode of access to a plot by women (GIVE_WOMEN), and inheritance of a plot by men (INHERIT_MEN). Variables on sharecropping/renting of a plot by men (RENT_MEN) and by women (RENT_WOMEN) for variant 2 of the probit model are hypothesized to have a negative relationship with adoption, compared to the default of secure tenure of model 2. A binary variable on security over land (LANDSECURE) was created from the above two tenurial types and separated from gender for variant 3 of the probit model. Any type of secure tenure takes the value 1 on LANDSECURE, and 0, if insecure tenure. The hypothesized relationship is positive between LANDSECURE and adoption. We hypothesize a negative relation between the variable on the field size (FIELDSIZE) and adoption. This is because the seeds were relatively evenly distributed among the farmers, and hence it was difficult for a farmer to get enough seed to plant a large field. So, whereas there may be considerable household level adoption, adoption on large fields is expected to be low.

The second group of explanatory variables is related to the farmers' characteristics. Although hypotheses concerning the relation between farmers' age and adoption are mixed, with some arguing that younger farmers are more open to innovation that older farmers (Akinola 1987; Polson and Spencer 1991), this study hypothesizes that older farmers would have accumulated enough land and financial resources to take the risk of losing a second-season crop in anticipation of relatively larger future gains from adoption. Therefore, the expected relationship is positive. The level of farmers' education (SCHOOL) is expected to have a positive effect on adoption. This is supported by findings of Tautho (1985) who showed that 92% of adoption studies conducted between 1953 and 1964 concluded there was a positive relationship between the level of education and the adoption of innovations.

Gender implications from the adoption of the new technology are addressed through the interaction of gender and tenure status in variant 1 and 2 of the probit model. A variable on sex (SEX) was added in variant 3 of the probit model because the variable LANDSECURE does not differentiate by gender. Women are involved in agriculture on their husband's fields but do not have easy access to the other resources such as technology, information, and extension. We hypothesize a high adoption rate for men, and a low adoption rate for women, regardless of the type of tenure arrangement. In a low capital-intensive agriculture, land and labor are the major factors of agricultural production. A consumer-labor ratio (CL_RATIO) was calculated to reflect family labor availability and demand for land to satisfy the food requirements for the household. Chayanov (1990) found that low values of the ratio correspond to abundant family labor that could allow for the adoption of a land-extensive technology such as *Mucuna*. One could therefore expect a positive relation with technology adoption. In the present study, we consider that high values of the ratio would correspond to relatively less family labor and therefore generate a negative relation with adoption. The surveyed farmers come from four villages with a contrasting rural population density (POP_DENS), ranging from 22 to 250 inhabitants per square kilometer. Because the pressure on land and the resulting weed infestation and soil degradation are high in populated areas, the need to adopt *Mucuna* would be high. Therefore, the expected relationship with the adoption is positive. The size of fallow (FALLOW) was hypothesized to have a negative relationship with the adoption of the *Mucuna* planted fallow. For the owner of abundant land in fallow, it is cheaper to restore soil fertility or control weeds by leaving land to lie fallow than by disbursing scarce family resources to plant and manage the *Mucuna* technology. A farmer's membership in a local agricultural organization (MEMBER) was hypothesized to have a positive relation with adoption. In the study area, extension messages are usually channeled through such institutions. Frequent contacts with extension services (EXTENSION) are also expected to have a positive relation with adoption Tautho (1985).

The third group of explanatory factors is derived from questions that all farmers were asked on how they perceive the technology. Perceptions differed from one farmer to another. The inclusion of perceptions helps clarify what attributes of the technology seem to be important for farmers when making their adoption decisions and what types of technical messages have been poorly transmitted (Adesina and Zinnah 1993; Manyong et al. 1996). Eight perception variables were considered. *Mucuna* seeds are not edible because they contain anti-nutritional factors (Versteeg et al. 1996). That characteristic (EDIBLE) is hypothesized to diminish their attractiveness to farmers and hence reduce the rate of adoption. Farmers' awareness that *Mucuna* seed have no market (NO MARKET) was expected to limit the expansion of the technology. We hypothesize that the more income (CASH_INC) the *Mucuna* technology generates through the sale of seed or fodder the higher will the adoption rate be. It was shown that the *Mucuna* planted fallow eliminates the possibility of growing food crops during the second cropping season (Versteeg and Koudokpon 1991). The loss of a second-season crop (LOSSCROP2) was hypothesized to constrain the adoption of *Mucuna*. Those farmers with highly infested fields may not consider the loss of a second season crop because fields are already abandoned. The *Mucuna* canopy creates a microenvironment that attracts arthropods. The farmers' fear that *Mucuna* attracts snakes (SNAKES) was hypothesized also to slow down adoption. In the study area there are wild *Mucuna* species that made the skin itch. Farmers are thought to wrongly associate the improved and newly promoted nonirritant *Mucuna* varieties with the wild species. The itching feature (ITCH) was hypothesized to reduce adoption. Roaming livestock eat *Mucuna* leaves, so perceptions that the fallow crop may be destroyed by livestock (PALATABLE) would be a constraint for the expansion of the technology. Therefore, the expected relationship is negative. The early period of the diffusion of *Mucuna* was characterized by a shortage of seed (RAMR 1987). Informal surveys conducted with farmers listed lack of seed among the constraints to the expansion of *Mucuna* (Vissoh et al. 1997). Perceived shortage of seed (SHORT_SEED) was therefore hypothesized to limit the adoption of the technology.

4. RESULTS FROM THE ECONOMETRIC ANALYSIS

Prior to econometric studies, a correlation analysis was computed. No strong correlation was found among the explanatory variables. The results from the three variants of the probit model are presented separately for Model 1 on secure tenure variables (Table 4), Model 2 on insecure tenure variables (Table 5), and Model 3 on both secure and insecure tenure variables (Table 6).

VARIABLES ON LAND TENURE

The results from Model 1 (Table 4) showed that the coefficients for the variables on security over land are all significant at either 0.01 (INHERIT_MEN, PUR_MEN and GIVE_WOMEN) or 0.05 level (PUR_WOMEN). The sign for each coefficient is consistent with the expectation; that is, the probability of adopting the technology increases if the plot is acquired through the inheritance mode for men, gift mode for women, and by purchasing for both sexes. The coefficients under the last column in Tables 4-6 are the marginal effect a particular independent variable has on the average probability of adoption for the studied sample. The traditional modes of access to land had the highest marginal effects (0.54 for inheritance and 0.24 for gift) while the new modes had the lowest marginal effects (0.07 for purchasing by men and 0.02 for purchasing by women).

Table 4 Probit results on significant variables from Model 1 (secure tenure by gender)

Variable name	Expected sign	Estimated coefficient	T-ratio	Weighted aggregate elasticity
INHERIT_MEN	+	1.3892***	2.9088	0.5409
PUR_MEN	+	2.0694***	3.0857	0.0687
PUR_WOMEN	+	2.2491**	2.4702	0.0208
GIVE_WOMEN	+	1.3170***	2.6391	0.2373

SOILFERT	-	0.5856**	2.5205	0.1942
SOILTYPE	+	1.0753**	2.1541	0.6215
WEEDING	+	0.6337***	8.3570	1.3604
PALMAGE	+	0.1593**	2.5152	0.1188
AGE	+	0.0231***	2.7324	0.6136
FALLOW	-	-0.0180**	-2.2174	-0.0999
EXTENSION	+	1.1542***	3.3298	0.5893
LOSSCROP2	-	-0.4901**	-2.2300	-0.1373
CASH_INC	+	0.0001***	2.5894	0.1095
INTERCEPT		-7.5328***	-7.4242	-4.8045

Likelihood ratio test = 249.5***.
McFadden R-square = 0.54010.
Percentage of right predictions = 89.23%.
* .01 level.
** .05 level.
Source: Analysis of data from field surveys.

The results on insecure tenure types from Model 2 (Table 5) showed a consistent trend, in keeping with the original hypothesis. The variable on sharecropping/renting of land by women (RENT_WOMEN) had the expected negative sign and a significant coefficient at the 0.05 level. The coefficeint on the same variable for men (RENT_MEN) was not significant though it had the expected sign. The negative sign on the coefficients for women implies that insecure tenure is somewhat of a constraint to the adoption of *Mucuna*.

Table 5 Probit results on significant variables from Model 2 (insecure tenure by gender)

Variable name	Expected sign	Estimated coefficient	T-ratio	Weighted aggregate elasticity
RENT_WOMEN	-	-1.7367**	-2.4778	-0.0188
RENT_MEN	-	-1.0332ns	-1.6371	-0.0158
SOILFERT	+	0.5971***	2.6474	0.2002
SOILTYPE	-	0.9283*	1.8197	0.5420

WEEDING	+	0.6253***	8.3726	1.3572
PALMAGE	+	0.1473**	2.3771	0.1116
AGE	+	0.0211**	2.5367	0.5672
FALLOW	-	-0.0158**	-1.9655	-0.0915
EXTENSION	+	1.1056***	3.3121	0.5739
LOSSCROP2	-	-0.4568**	-2.1284	-0.1278
ITCH	-	0.3967*	1.6999	0.1501
CASH_INC	+	0.0001**	2.5219	0.1063
INTERCEPT		-5.8105***	-6.6130	-3.7545

Likelihood ratio test = 246.8***; McFadden R-square = 0.5343
Percentage of right predictions = 89.68%; *** = .01 level, ** = .05 level; * = .10 level
ns= not significant at .10 level
Source: Analysis of data from field surveys

The results from Model 3 are in line with expectations. The variable on land security (LANDSECURE) has a positive sign. The estimated coefficient is significant at the 0.01 level, meaning that farmers are more likely to adopt the technology if the tenure status provides long-term security over land. *Mucuna* is an annual crop. It was introduced primarily to serve the purpose of resource-poor farmers who could not widely adopt perennial land-improving agroforestry technologies such as alley farming because of land insecurity (RAMR 1987). However, the above results suggest that tenure arrangements need to be considered for adoption of resource management technologies applied to annual crops whenever such improvements generate long-term benefits. The implication in the case of *Mucuna* is that farmers appear to value its long-term soil fertility benefits and that this factors into their adoption decision.

The marginal effect of LANDSECURE is 0.84 percent. That percentage is about the sum of the marginal effect on the various tenure types from Model 1 and 2. It seems there is an additive effect of the marginal effects from combining the two single models (Model 1 and 2) into one (Model 3). The estimated coefficient for sex is not significant even at the 0.20 level. This result implies that the decision to adopt or reject the technology is gender-neutral, once differences in tenure are accounted for. The statistical significance of the coefficients for the variables on land tenurial type by gender found in Model 1 (Table 4) and 2 (Table 5) is probably explained by only the land tenure component. The differences between the coefficients for males and females with the same tenure category are not significant. Those findings suggest that Model 3 is a good substitute for Model 1 and 2. Therefore the breakdown of land tenure by gender does not bring any additional benefits to the analysis.

OTHER VARIABLES

The results from the econometric analysis on the other variables are almost similar for the three variants. Four variables (SOILFERT, SOILTYPE, WEEDING, PALMAGE) out of five are significant for the field characteristics. Three variables (AGE, FALLOW, EXTENSION) out of seven are significant for the farmers' characteristics. Two to four variables (LOSSCROP2, CASH_INC, ITCH, PALATABLE) out of eight are significant for the technology-specific attributes. Field characteristics were very important in the decision to adopt *Mucuna*. Omission of field characteristics in any adoption model for a resource management technology would create a bias in the understanding of the adoption process (see also Manyong et al. 1996).

Results indicate that the number of weedings is the primary driving force behind adoption. Indeed, farmers who adopted the *Mucuna* technology seem to have done so primarily to control weeds (77 percent of *Mucuna* users); soil fertility was of secondary importance (23 percent of *Mucuna* users). Whereas weed control was the entry point for adoption, it appears that the short-term benefit of weed control is subsequently overcome by appreciation for the long-term benefit on soil improvement, as evidenced by the effect of tenure on the adoption.

The expected sign for all the significant variables was validated except for the soil type factor (SOILTYPE) in Model 1, 2, and 3; the itching factor (ITCH) in Model 2 and 3; and the palatability to animals factor (PALATABLE) in Model 3. A change in the sign for the SOILTYPE variable means that adoption is higher on clay soils, probably to replace the excavation of *Imperata* rhizomes by hoe weeding that is labor demanding. A possible explanation for the opposite sign for the itching factor is that farmers do not associate the varieties cultivated with the wild species of *Mucuna* that itch, as it was hypothesized. For the

PALATABLE factor, farmers appear to value the fodder from *Mucuna* as a plus rather than a constraint in the decision to adopt the new technology.

SENSITIVITY ANALYSIS ON THE LAND SECURITY FACTOR

It appears from the previous analysis that Model 3 could be a substitute for Model 1 and 2. Therefore the sensitivity analysis was conducted only on the overall land security factor in Model 3. The prevailing conditions at the period of the survey indicated that 75.8 percent of survey fields were held under tenures offering long-term land security and 24.2 percent under those with relative insecurity. The resulting rate of adoption was 21.3 percent. A sensitivity analysis on land policy indicates that security over land for all the fields would increase the rate of adoption from 21.3 percent to 22.4 percent, or only a little change of +5.2 percent. However, insecurity over land for all the fields would decrease the adoption rate from 21.3 percent to 5.6 percent, or a steep drop of -73.7 percent (Figure 3). Increasing numbers of farmers utilizing *Mucuna* in southern Benin (Figure 1) is probably facilitated by the existing traditional modes of access to land that allow security over land for most of the fields.

Results from Table 6 show that the number of weedings was a major determinant for the adoption of the technology. Predicted probabilities were computed in order to assess the changes in the probability of adoption when the frequency of weeding is increasing for both cases of land security and land insecurity. Results are presented in Figure 4. The probabilities of adoption increase with the number of weeding during a

Table 6 Probit results on significant variables from Model 3 (both secure and insecure tenure)

Variable name	Expected sign	Estimated coefficient	T - ratio	Weighted aggregate elasticity
LANDSECURE	+	1.3543***	2.9264	0.8392

SOILFERT	+	0.5732**	2.5599	0.1928
SOILTYPE	-	0.9915**	2.0198	0.5788
WEEDING	-	0.6303***	8.3617	1.3673
PALMAGE	+	0.1413**	2.2693	0.1060
AGE	+	0.0218***	2.6206	0.5860
FALLOW	-	-0.0177**	-2.2304	-0.1017
EXTENSION	+	1.1322***	3.3597	0.5883
LOSSCROP2	-	-0.4439**	-2.0564	-0.1246
ITCH	-	0.4410*	1.8486	0.1668
CASH_INC	+	0.0001**	2.4743	0.1038
PALATABLE	-	0.4765*	1.6655	0.0682
INTERCEPT		-7.3682***	-7.4093	-4.7592

Likelihood ratio test = 246.8***; McFadden R-square = 0.5343.
Percentage of right predictions = 89.46%; ***= .01 level; **= .05 level; *= .10 level.
Source: Analysis of data from field surveys.

Figure 3 Effects of land security on the adoption of *Mucuna* in Benin Republic

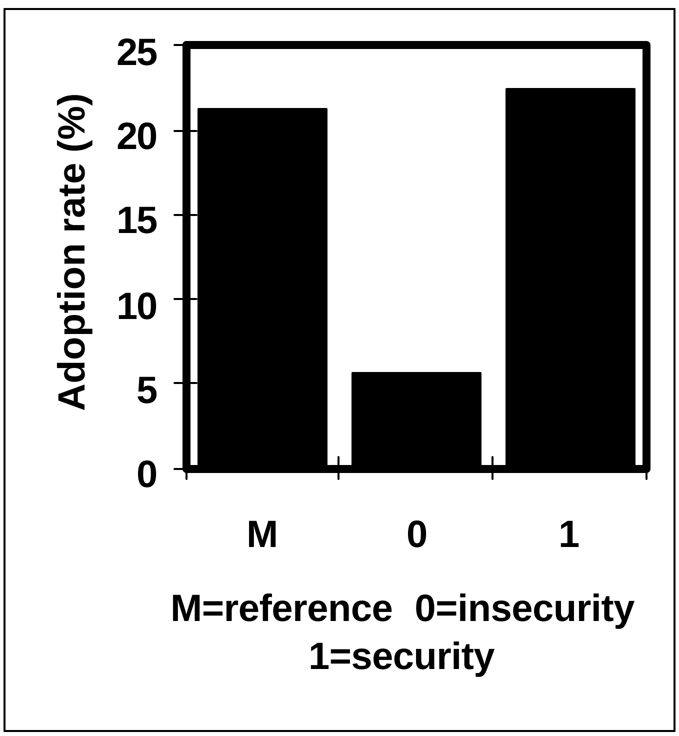
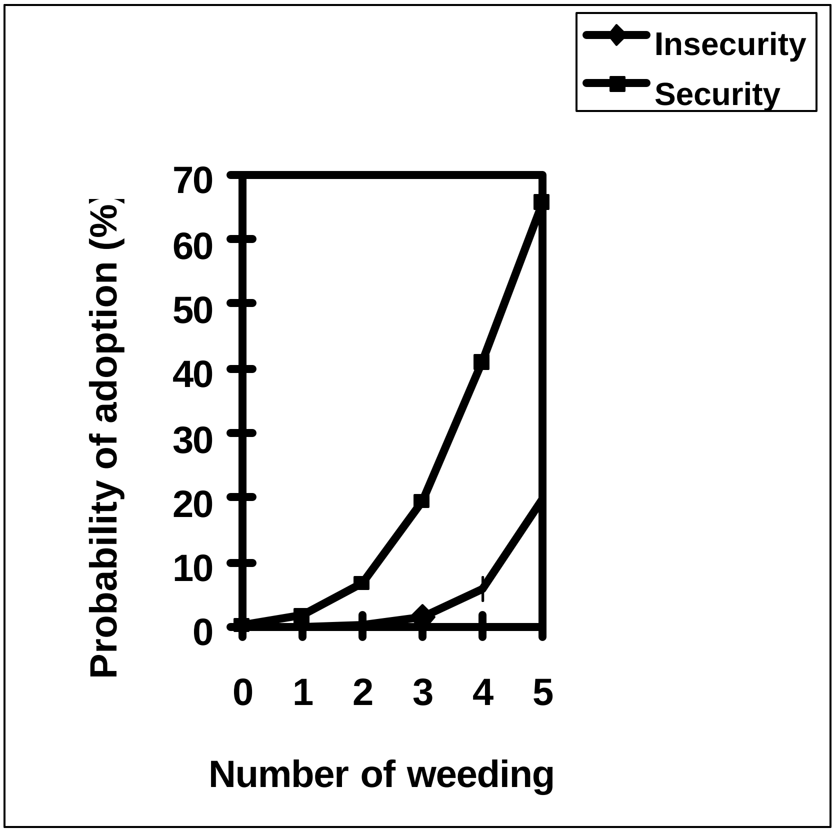


Figure 4 Effects of the number of weeding on the probability of adoption of *Mucuna* under land security and land insecurity in Benin Republic



cropping season. However, the difference in the magnitude of probabilities between secure tenures and insecure tenures increases as the number of weeding increases. The probability of adoption is 0.66 at 5 weedings in the case of secure tenures, but only 0.17 in the case of insecure tenures. Other evidence demonstrates that several factors contribute to adoption of *Mucuna*. Houndékon and Gogan (1996) show that a combination of four factors would increase the rate of adoption up to 85 percent. Those factors are land security for all fields (LANDSECURE variable), extension messages for all farmers (EXTENSION), four weeding for a crop during a cropping season (WEEDING), and an income of FCFA 10,000 from the selling of *Mucuna* grain (CASH_INC). Such a high rate of adoption could not be reached by each of those four factors if considered separately.

5. SUMMARY AND IMPLICATIONS FOR POLICY

Many options for land-improving technologies were introduced to farmers in a populated area of the derived savanna zone of Benin. Of the introduced technological options, the *Mucuna* planted fallow proved successful in its adoption by farmers and the technology has experienced an increasing number of users since its introduction in 1987. As an annual crop, the technology was believed to serve the purpose of small-scale and resource-poor farmers who could not afford to widely adopt perennial agroforestry land-improving technologies.

The results from the adoption study indicate that farmers value the *Mucuna* planted fallow for both its short-term and long-term benefits. The effect of smothering the aboveground parts of the noxious weed is observed in the short-term and serves as an entry point for adoption. Yet, control of the belowground parts of the weed and improvement in soil fertility constitute long-term benefits. Because of the presence of long-term gains, security over land becomes a determinant factor for adoption.

The breakdown of land tenure by gender into two separate models for secure and insecure tenure yields recommendations that are not significantly different from those on a combined model with one variable for long-term security over land. This suggests that adoption of *Mucuna* is gender-neutral. Lack of private ownership of land for women apparently does not prevent them from adopting *Mucuna* since they appear to have security on land they receive from their husbands.

Whereas ensuring the maintenance of existing high levels of tenure security is important for sustainable adoption of *Mucuna* technology, it does not imply that measures should be undertaken to convert sharecropping/renting arrangements to more secure forms of tenure. These less secure modes of access are important to women by enabling them to get access to additional land. In addition to enhancing tenure security over land, increasing the rate of adoption of *Mucuna* would require the combination of many other factors, such as a market for *Mucuna* seed and efficient extension services.

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