Tropentag 2006
University of Bonn, October 11-13, 2006
Conference on International Agricultural Research for Development

Seven Years after the SFB 308 – Adoption Patterns of Agroforestry Systems in Benin

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Abstract

1986 to 1999 German and Beninese scientists have been working in Benin on the development of agroforestry systems in the context of the SFB 308 project "Adapted Farming in West Africa". This contribution cannot pretend to present the very large amount of disciplinary research work that has been conducted during this program. We will focus on technologies which researchers intended to design in response to an increasing land pressure and soil impoverishment, to degrading fallow-based cropping systems. Evolving from alley cropping systems, a large range of designs were experimented on-farm in order to cope with specific labour, cash and competition constraints, including alley farming with *Gliricidia sepium*, live fences with *Senna siamea*, *Cajanus cajan* as a short fallow, *Mucuna utilis* as a cover crop and a planted perennial fallow with *Acacia auriculiformis*. 1992-99, these technologies were tested under different edaphic and socioeconomic conditions.
Most of the on farm research was conducted along a south-north gradient over 250 km. On six sites, between 1994 and 1999, 600 farmers chose one design or more, set up 800 trial plots, and compared them with their initial farming practices. Researchers monitored agronomic and socioeconomic performances and farmers were invited to adjust designs and management practices in order to make them as feasible and profitable as possible.

At the end of the program, national farming systems research teams took over some of the research sites and technologies and went on working on them and cooperating with experimenting farmers. The public extension system was getting very weak but some NGOs were invited to promote research results in non experimenting villages.

In 2005, adoption of these systems was surveyed in two southern research sites as well as in and around R&D central sites. In the South, farmers who had been testing at least one of the technologies between 1994 and 1999 were visited. 65% of these farmers have been adopting the Acacia planted fallow. The other techniques have been tested but rejected. Adoption mainly depends on the profitability after marketing fallow products and on a low input set up of the fallow. In the central part of Benin, 28% of yam farmers adopted a cover crop and 8% the alley cropping system. The yam-based alley cropping was adjusted by farmers who reduced shrub density and labour demand of the technology and by researchers who included a cover crop in the rotation in order to improve soil fertility and effects on yam yields. Adoption rate is lower but has not yet reached the plateau of the S-curve.

Even if the SFB 308 has been conducting research over more than a decade, research cannot be considered as being completed until farmers, researchers and extensionists have been monitoring new constraints appearing in the course of adoption. This adoption process is still in the making, new constraints require policy changes as well as information and lobby by traders, banks, input suppliers etc., and new research topics appear that have to be worked out.

On the other hand, during the SFB 308, major changes in the way of conducting research in collaboration with farmers were then tested, have been adopted as the normal practice within the national research system, yielded some successes and still do.

1. Context

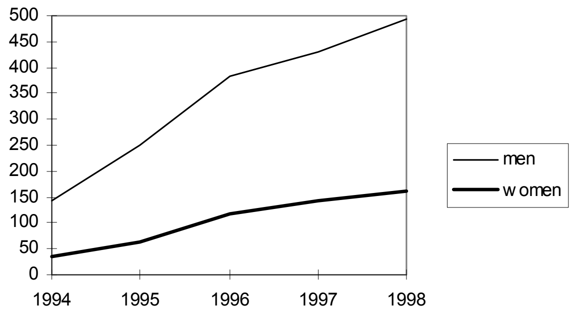
1986 to 1999, German and Beninese scientists have been working in Benin on the development of agroforestry systems in the context of the SFB 308 project "Adapted Farming in West Africa". This contribution cannot pretend to present the very large amount of disciplinary research work that has been conducted during this program. We will focus on technologies researchers intended to design in response to an increasing land pressure and soil impoverishment, to degrading fallow-based cropping systems. Evolving from alley cropping systems, a large range of designs were experimented on-farm in order to cope with specific labour, cash and competition constraints, including alley farming with *Gliricidia sepium*, live fences with *Senna siamea*, *Cajanus cajan* as a short fallow, *Mucuna utilis* as a cover crop and a planted perennial fallow with *Acacia auriculiformis* (table 1). 1992-99, these technologies were tested under different edaphic and socioeconomic conditions.

<u>Table 1</u>: Main features of the designs proposed during the SFB 308

Technology	Design	Species	Density of the fertility improving specie(s)	Duration of the rotation	Specific features
Simultaneous planted fallow	Blocks in the field or borders around it	<u>Senna siamea</u> and <u>Gliricidia sepium</u>	Up to 4.800	Set up : 2 years, and then obsolescence had not been reached after 6-8 years	Pruned at 50-100 cm at least once per season
Natural simultaneous fallow	Stocks coppicing in non degraded bush fallow	All perennial species assessed as improving fertility and not disturbing the associated crop	Up to 10.000	Immediate effects of mulch	Pruned at 50-100 cm at least once per season
Alley cropping	4 meters wide alleys	<u>Gliricidia sepium</u>	2.500-5.000	Set up : 2 years Obsolescence not reached within project duration	All stems but one pruned, living and cut stems used as yam stakes
Acacia planted fallow	2 * 2 meter planting	<u>Acacia auriculiformis</u>	2.500	4 years growth of the trees – 4 years cropping	Trees pruned during the growth and when fallen down; mulch spread
Cover crop	In relay cropping with maize or alone on the plot	<u>Mucuna utilis</u>	15.000	One year growth, one-two years mulch effects on the crops	Dies before the onset of the rains
Annual fallow	In blocks in the field	Cajanus cajan	4800	One-two years growth, blocks being moved	Pruned

Most of the on farm research was conducted along a south-north gradient up to 250 km from Cotonou. On six sites, between 1994 and 1999, 600 farmers chose one design or more, set up 800 trial plots, and compared them with their initial farming practices (Fig.1). Researchers monitored agronomic and socioeconomic performances and farmers were invited to adjust designs and management practices in order to make them as feasible and profitable as possible. Regular joint field visits by farmers and researchers on each sites and exchanges among farmers allowed for collective assessment and adaptation of each technology. 1999, 30% of the testing farmers had extended their experiments beyond the test plots, which was considered as a first step in the adoption process.

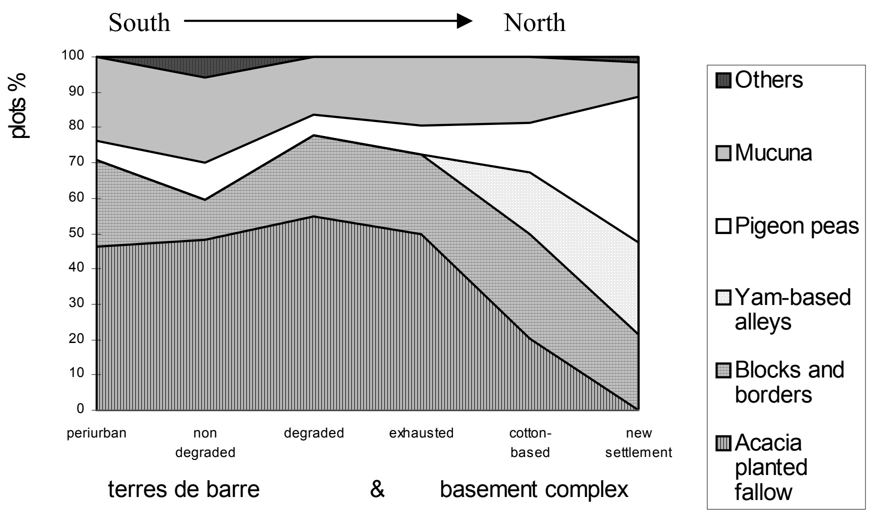
Figure 1 : Men and women participating in the evaluation of technologies during the SFB 308



Source: Doppler et Floquet, 2000. SFB 308 End report

Farmers' constraints strongly differ from site to site and within sites according to their land rights, and therefore gender and age. In the southern part of Benin, population density is higher, land is scarcer than in the central part; in both regions soil impoverishment differs according to the settlement oldness. As expected, farmers' preferences in the test phase varied according to the site. Southern farmers displayed a preference for <u>*Acacia auriculiformis*</u> perennial planted fallow and to a lesser extent for <u>*Mucuna utilis*</u> annual cover crop. Farmers operating on the basement complex preferred the pigeon pea annual fallow and the yam-based alley farming with <u>*Gliricidia sepium*</u> (Fig. 2).

Figure 2: Relative weight of the technologies chosen according to the sites and a south-north gradient in 1998



Source: Doppler et Floquet, 2000. SFB 308 End report

2. Methods

As this SFB 308 project was concerned with farmers' evaluation and adaptation of technologies, a range of hypothesis on diffusion and adoption had been formulated and partly tested during the 5 years of researchers' intervention. Part of these hypothesis are revisited 7 years after the SFB 308 completion (table 2).

Table 2: Some of the hypothesis on diffusion and adoption of soil improving technologies developed during SFB 308

H1. *Innovations*: There are soil fertility improving technologies (SFIT) which improve economic returns to land and labour H3. *A range of options* with different requirements: SFIT improve farmers' income in the short to medium run and allow him or her to better reach his/her specific goals. Because farmers have different resource endowments and preferences, they need different mixes of some of these SFIT. H4. *Equity issues*: All farmers may find feasible solutions but elder male land-owning farmers will profit the most from adoption. Impact on women may be not as positive as intended. H6 *Local manufacture of knowledge*: If SFIT are processed into know-how and farming practices by farmers, their feasibility is improved and they have better chance of being adopted. H7. *Farmer to farmer diffusion*: If some SFIT are evaluated as successful by some farmers testing and developing them, they will be further diffused among the neighbouring farmer's community

Source: Doppler et Floquet, 2000. SFB 308 Endreport

In 2005, two post graduate students conducted studies on adoption in at least partly the same sites or surrounding region.

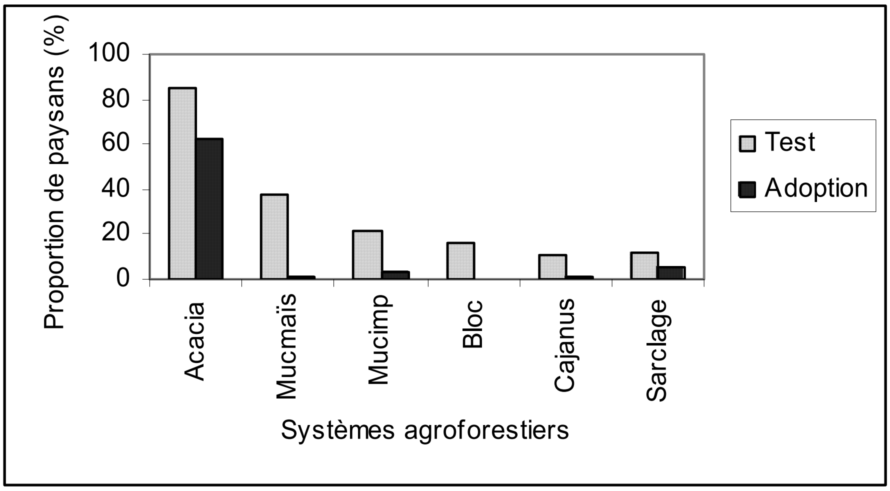
In the southern part, the research focussed on 2 of the 3 villages where SFB had been working (Hevié in the periurban area and Hayakpa, located in a more rural area about 30 Km away from Cotonou). Technologies promoted within the frame of SFB 308 have not been further researched on after the end of the project but some other soil improving technologies have been tested (combining organic manure and fertilizers) on these sites. Other projects promoting Acacia as a firewood product might also have had spill over effects on these villages, especially Hevié, where many new landowners from the city are planting Acacia in order to secure their property. Farmers who had been taking part in the tests were interviewed on their actual adoption and perceptions of the technologies. Effects of the adoption on their income and some soil indicators (organic matter and mycorrhiza) were assessed. 91 households heads were surveyed..

In the central part of Benin, research has been conducted by a farming system specialist operating for the national agronomic research INRAB. He has been contributing to the further development of soil fertility improving technologies for the last 6 years. In order to include yam crops into a rotation and to protect forest from clearing, alternative technologies with woody and herbaceous leguminous were further promoted (R-D). Researchers built on SFB 308 results on yam based alley cropping system but included farmers criticisms and adaptations in order to develop a new range of technologies. The density of Gliricidia shrubs was reduced in order to reduce the labour required for repeated coppicing and herbaceous cover crops (<u>Mucuna pruriens var utilis</u>, <u>Aeschynomene histrix</u> et <u>Stylosanthes guianensis</u>) were included in the cropping systems in order to maintain soil fertility. While public extension was more or less dismantled, NGOs relayed RD research in diffusing main results to farmers in the regions surrounding the sites where RD teams conduct on farm research together with farmers. The adoption study was then conducted on RD sites and on diffusion sites in two areas characterised by a high density (Dassa & Glazoué – about 50 inhabitants/km²) resp. a lower population density (Savalou, Bantè, Savè, Ouessé– about 25 inhabitants/km²). It concerns yam producers in 27 villages (48% of producers cultivate yam). 306 households were surveyed, out of which 103 are adopters. Adopters' profiles could be depicted using a polynomial logit model.

3. Results

In the southern part of Benin, 65% of the farmers who had taken part in the test process during the SFB 308 have been adopting the Acacia fallow system. All other technologies were tested over several years and abandoned (fig. 3). The main reason put forward by farmers is the income that can be drawn from the sale of firewood, poles and "acadjas[1]". Soil fertility improvement after the acacia fallow only comes next. Non adopters explain their behaviour by their lack of secure land rights, land sales and difficulties in coping with the labour requirements of the technologies. Accordingly, adoption is lower in the periurban area where land rights are much more insecure, in spite of a higher demand, a higher price for woody products and a higher profitability of the technology. Only very women –mostly elder widows- could go on expanding their Acacia plot, and even then, their rights over the plot remain insecure.

Figure 3: Number of farmers having tested in 1999 and adopted in 2005 technologies in both villages



Source: Cakpo Y., 2005

Farmers adopting the Acacia technology devote more than 20% of their farm area to the planted Acacia fallow while their hardly reduce their natural fallow. While non adopters crop 64-77% of their farm area, adopters cultivate 38-61% of it (table 3).

Table 3: Land use patterns by adopters in Hevié and Hayakpa

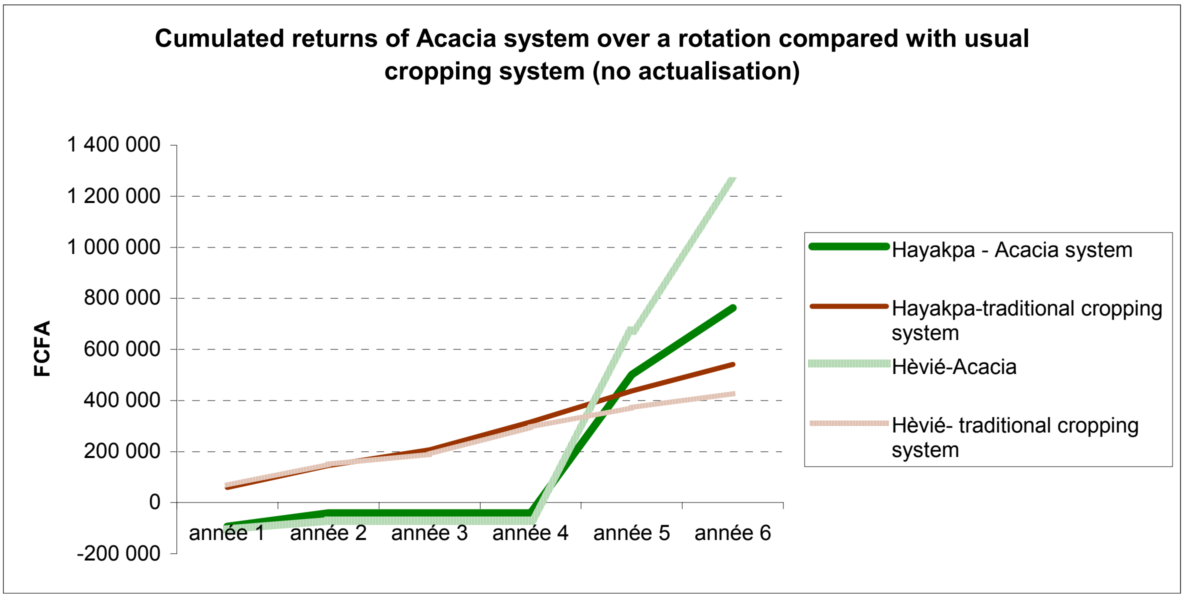
	Adopters		Non adopters	
	Hevié	Hayakpa	Hevié	Hayakpa
Farmers having taken part in the test (%)	53%	78%	47%	22%
Farm area (ha)	1,77	3,64	1,31	3,09
Natural fallow area (%)	11,6	24,8	18,1	28,9
Acacia fallow area (%)	25,1	22,7	0	0
"Cassava fallow" (%)	2,6	14,8	4,7	7,4
Cultivated area (%)	60,8	37,6	77,2	63,7

Source: Data collected by Y. Cakpo, 2005

[1] Acadjas are shrubs that are used on the coastal lagoons by fishers in order to create shelters for fish and take control over a part of the lagoon area.

Organic content, phosphorus (P_{ass}) and biological activity measured by mycorrhiza density are significantly higher after an Acacia fallow compared to a cultivated field. Maize yields are about 600 kg in both villages in the usual cropping systems and 1200-1400kg in the first year after Acacia harvest. Effects of the mulch do not last over two or three seasons. Natural growth of young Acacia seedlings might then compete with the crops and many farmers burn the Acacia mulch, which they perceive as too bulky, instead of spreading it over a larger area as recommended by researchers.

Figure 4: Cumulated returns of the Acacia system during a 6 years rotation compared with the usual local cropping system

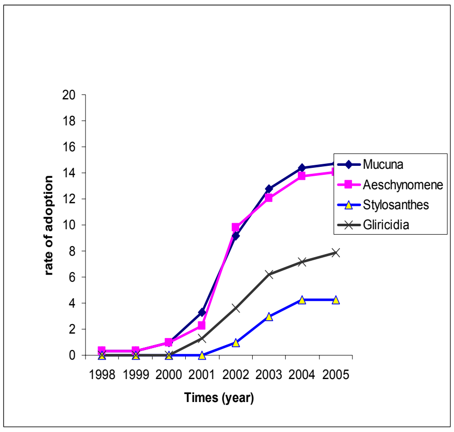


Source: Data collected by Y. Cakpo, 2005

Profitability of the acacia system estimated by its cumulated income is about twice higher than the maize cropping system in the periurban village where marketing of woody products is easier and brings out a higher price (fig. 4). If future income is depreciated on the basis of the credit rate (18%), Acacia outdoes not anymore the conventional cropping system in Hayakpa but still does in Hevié (571.560 against 290 074 FCFA NPV). The profitability of the acacia system surveyed in 2005 in Hèvié is very similar to estimations done in 1999 but the situation in Hayakpa did not meet expectation because of marketing and transport problems.

In the central part of Benin, yam is a very profitable crop and innovations improving its performances had already been assessed as highly profitable during the SFB 308 for farmers who can cope with labour constraints. Observations in 2005 confirm these former conclusions.

Maliki's recent investigation on soil fertility technologies in yam based cropping systems reveals similar patterns of adoption on both RD-sites and non RD sites, but speed of adoption is significantly higher on RD site where a probable maximal rate of adoption in the S curve is being reached after 8 years tests (1998-2005). The patterns (fig.5) reveal a higher potential adoption rate for annual cover crops (14% of farmers on RD sites for both *Mucuna utilis* and *Aeschynomene histrix*) than for the alley cropping system (8% farmers).



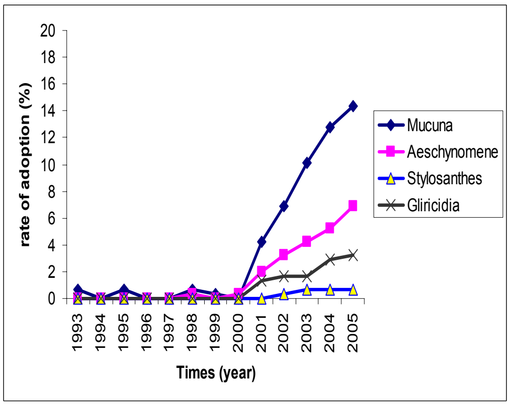


Figure 5: Adoption rate of *Mucuna pruriens, Aeschynomene histrix, Stylosanthes guianensis and Gliricidia sepium* on R-D sites

Figure 6 : Adoption rate of *Mucuna pruriens, Aeschynomene histrix, Stylosanthes guianensis and Gliricidia sepium* out of R-D sites

Adopters' profile in 2005 from a logit analysis reveals the following attributes: being a landowner, with large farm and family (attributes for being also a large yam grower), being educated and with contacts to extension, being rather young, having access to credit, the latter being correlated with the former criteria. Adoption is also significantly higher in the area with a higher land pressure. Women who have more insecure land rights are more prone to adopt annual cover crops than men. These trends are similar to those observed during the SFB 308, *Cajanus cajan* annual fallow being here replaced by cover crops. Difficulties in coping with shrub and herbaceous residues is a frequent reason given for non adoption.

4. Conclusions

In each ecological region, one major technology was selected because of the demand and profitability of the associated crop or of the fallow itself and evolved through adaptations by both farmers and researchers. Adopters' profiles changed over time. At the beginning of the SFB, experimenting farmers were elder landowners with larger farms and farming as a main activity, who could take the risk of trying out something new. At the end of the SFB, experimenting farmers also included younger farmers and women, but adoption was still correlated with larger farm in the South and land ownership in both areas. These factors remained valid in 2005 but farm size lost importance.

Technologies and main hypothesis developed during the SFB 308 would deserve reassessment with a more systematic and multidisciplinary frame than what is resulting from compiling results of the separate investigations presented here. Nevertheless, it seems that most of the hypothesis presented above cannot be rejected, except the hypothesis on farmer to farmer diffusion. Diffusion seems to require the intervention of change agents. New constraints do appear at the beginning of the diffusion process that would now require changes in wood marketing, in access to credit encouraging adoption and in land use rights that can cope with soil improving agroforestry perennials by tenants. In order to solve these problems, farmers' organisation, researchers and NGO should organize a good lobby by policy makers, finance institutions and firewood traders.

Over the last decades, innovations concerned the way of doing research. Instead of a sequential research process where farmers enter at the end for evaluating technologies, research is conducted together with farmers at each step, on farm and off site work being intertwined. The national research system underwent major reforms in order to respond to the demand of its clients, every researcher reporting his results first in front of his peers, then in front of clients and researchers during workshops where thematic to be addressed are also collectively discussed. The whole brought most of the scientists back into the fields together with the RD teams. Nowadays, the set up begins to show weaknesses in term of encouraging short term research to the detriment of longer term issues and programs. Moreover, not all categories of farmers are able to articulate their needs in order to have research agendas being drawn out of them.

5. References

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Annex

Results of the polynomial logit model estimated in the central part of Benin

The models presented rather good predictive and estimated properties. Indeed, log-probabilities (-143.08; -144.01; -57.92) and values of the test of χ^2 (104.74; 44.01; 15.46) were significant at 1 % level respectively for Mucuna and Aeschynomene and of 5 % for Stylosanthes. Except Gliricidia, which presented a weak estimated value of χ^2 for the model. The percentages of correct prediction were high in the entire model (77 %; 80.%; 94 % and 89 %) respectively for Mucuna, Aeschynomene, Stylosanthes and Gliricidia.

Table a: Econometric model of the factors affecting adoption of *Mucuna pruriens var utilis* for yam production in the region of Collines

Acronym of variables	β estimated	T test
ZONE	0,244	4,792***
SUPDISP	0,009	2,836**
SEXE	-0,179	-3,294***
NBOUCH	0,011	2,284**
FTRAV	-0,012	-1,146
ORIGIN	-0,032	-0,550
CONTACT	0,382	7,868***
CREDIT	0,353	3,544***
NIVELEV	0,003	1,948**
Number of adopters	103	
Household size	306	
Log-probabilities	-143,.08	
X²	104,74***	
% of prediction	77	

Source: Maliki, 2005

** and *** represent significant level to 5% and 1% respectively
β = estimated coefficient for each independent variable
T test = β/Standard error

Table b: Econometric model of the factors affecting adoption of *Gliricidia sepium* for yam production in the region of Collines

Acronyme des variables	β estimated	T test
ZONE	0,064	1,660*
SUPDISP	0,353E-03	-0,137
SEXE	0,022	0,541
NBOUCH	0,005	1,393
FTRAV	0,008	1,068
ORIGIN	-0,063	-1,415
CONTACT	0,089	2,428**
CREDIT	0,191	2,540**
NIVELEV	-0,001	-1,067
Number of adopters	33	
Household size	306	
Log-probabilities	-109,72	
X²	-	
% of prediction	89	

Source: Maliki, 2005

** and ** represent significant level to 10% and 5% respectively
β = estimated coefficient for each independent variable
T test = β/Standard error