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Farmer Education and Adoption of Slash and Burn Agriculture

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Abstract

Education can play a critical role in moving farmers in developing countries away from environmentally harmful slash and burn agriculture. The present research examines the extent to which extension education can promote adoption of cropping systems other than slash and burn. Choice of cropping system by farmers in Cameroon, whether slash and burn, multiple crops, or mono-cropping, is modeled as a function of farm size, farmer educational level, and visits by extension personnel. Results indicate that higher visitation rates by extension personnel reduce not only the likelihood of farmers choosing slash and burn agriculture, but also promotes movement into mono-cropping. Since mono-cropping represents a move toward export-oriented agriculture in Cameroon, this movement may assist in promoting greater economic development across western Africa. Continued efforts in extension education are, therefore, critical in both reducing the environmental damage from slash and burn agriculture and promoting adoption of more profitable cropping systems.

Key Words: conservation, slash and burn, production technology, economic development

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Introduction

Slash and burn is an endemic agricultural cropping practice in the tropical rain forest regions of western Africa, South America, and southeast Asia (Kotto-Same et al. 2000). The practice consists of cutting down trees on part of the forest to clear space for an agricultural plot. After allowing the cleared foliage to dry, the farmer then burns the downed trees and immediately crops the land. Two to four years later, the farmer moves to new areas as agricultural yields on the cleared plot fall as a result of weeds, insect pests, plant diseases, and declining soil fertility.

The Food and Agricultural Organization of the United Nations (FAO) estimated that between 1981 and 1990, the average global deforestation rate in the humid tropics was 0.1 to 0.14 million-km² per year, resulting in millions of hectares of degraded land, increased production of greenhouse gases and major loss of biodiversity (FAO, 1985). In Cameroon, about 100,000 hectares of closed canopy forest is lost annually, taking the estimated rate of deforestation to 0.6% (FAO, 1997). Kotto-Same et al. (2000) also attributed some of the problems of low productivity and food security to slash and burn cropping systems. FAO (1985) pointed out that under conditions of rapid population growth, slash and burn as a cropping system has relatively weak potential to provide rural populations either with adequate food supplies or sufficient income to support healthy and prosperous lives. On the whole, slash and burn agriculture leads to environmental degradation, low food production, and overall food insecurity in tropical rain forests.

Attempts have been made to move farmers in tropical regions away from slash and burn agriculture toward more efficient and sustainable cropping methods [Alternative to Slash and Burn Program (ASB), 2001; Kotto-Same et al., 2000; ASB, 1997; Cleaver, 1993]. These typically rely on greater use of inputs, such as mineral or organic fertilizers, pesticides, and agroforestry or tree-based food cropping systems that include fallowing with improved legumes. Although such practices reduce population pressures on forest and soil resources and also display higher land productivity and less spatial expansion (Kotto-Same et al., 2000), the challenge is that land is seldom considered a scarce resource by the farmers. The land tenure system in Cameroon is based on “first use and continuous occupancy” policy. The first person who cultivates a parcel in the forest and who shows continuous use of that parcel is the owner of the parcel.

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As a policy issue, the central question is how to encourage farmers in tropical regions to move from slash and burn cropping to more sustainable methods. Feder and Slade (1984) suggest providing slash and burn farmers information about alternative cropping practices and the long-run impacts of slash and burn. Information on the use of sustainable farming technologies can be delivered to farmers through two channels: the agricultural extension network (public and private) and the informal and formal communication services within local organizations. The present analysis focuses on the first of these two information paths; specifically, the effectiveness of increased extension education visits in promoting movement away from slash and burn agriculture. This is done within the context of the west African nation of Cameroon using farm-level data on cropping methods used by farmers in the tropical Fako region.

Background

Significant effort has been extended in analyzing the causes of deforestation due to slash and burn agriculture. Multiple reasons, ranging from increased population pressure (Jones and O'Neill, 1992), land tenure (Larson and Bromley, 1990), government policies (Deacon, 1995), and price risk (Barrett, 1999) have been put forth as potential explanations for why farmers in developing nations choose to employ slash and burn agriculture. While identifying the reasons farmers in developing nations opt for slash and burn agriculture is a necessary first step to remedying deforestation, it does not assess the effectiveness of alternative remediation policies. Additionally, it does not address the ability of individual farmers to receive the information necessary to reduce or eliminate slash and burn agriculture.

The attributes of both a farmer and his farm will limit his ability to adopt alternative methods of production. Simply put, some farms and farmers are not compatible with certain types of production methods. This problem, known as asset heterogeneity, is one explanation for why farms do not adopt alternative production methods even when those methods are generally perceived as more profitable (Bellon and Taylor, 1993; Perrin and Winkelmann, 1976). Farm attributes include factors such as farm size, crop type, and soil fertility characteristics. Farmer characteristics include age, gender, household size, farming experience, income level, existence of additional sources of income, level of educational attainment, access to financial capital, and attitudes towards risk. Institutionally, variables such as land tenure and property rights, access to financial capital through loans, the existence of physical and soft marketing infrastructures, the availability of agricultural extension services, the effectiveness of information dissemination about alternative technologies, and the support from social networks or membership/participation in local organizations; and agricultural policies all influence technology adoption (Caviglia and Kahn, 2001; Kwasi, Snijders, and Folmer, 1999; Adesina and Chianu, 2000; Casey and Caviglia, 2000; Feder and Slade, 1984). Adesina and Zinnah (1993) and Adesina and Baidu-Forson (1995) have included farmers' subjective assessment of technology attributes as explanatory variables in the decision-making of choice of agricultural technology. Research findings from Negatu and Parikh (1999) and Batz et al. (1999) confirm this influence of farmers' perceptions of technology characteristics on the adoption process.

This research examines how asset heterogeneity, specifically the personal traits of individual farmers and farms in Cameroon, limits the ability of farmers to move beyond slash

and burn agriculture and whether or not improving education through visits by extension personnel can reduce slash and burn agriculture.

As mentioned, this research examines how farmers in the west African nation of Cameroon select the methods used to produce agricultural products. Kotto-Same et al. (2000) reported that farmers in the humid forest of south Cameroon practice two dominant slash and burn cropping systems. The different forms of slash and burn generally depend on the length of time the land is abandoned or left for fallow and whether clearing the land is required. In some areas and during dry periods, clearing the land before burning is not necessary.

For the present analysis, farmers can choose among three alternative methods to produce crops: slash and burn, multi-cropping, and mono-cropping. Using data on individual farmers, including information on land tenure, value of crops grown, and on-farm capital, the choice of production methods is modeled in part as a function of education and visits by extension personnel to determine how effective extension education is in moving farmers in Cameroon away from slash and burn as a production method. The reliance on farmer-level data and an emphasis on evaluating the effectiveness of extension education in reducing slash and burn agriculture distinguish this effort from previous research on this issue.

Empirical Model

Each farmer will select the production method that he perceives as the most profitable. Choosing a particular method of production reveals that a farmer perceives that system as being relatively more profitable than the alternatives. Profits for the j -th farmer from producing crops using the i -th production system are π_{ij} . These profits are a function of farm attributes, X , including the number of visits by extension personnel to the farm. Therefore, the expected utility of perceived profits, $U(\pi_{ij}(X))$, are a function of farm attributes. For a grower to shift from one method of production to another, the expected utility from perceived profits under the i th production method must be at least as large as those under the base method that the farmer is already employing:

$$(1) \quad \Delta U(\pi) = U(\pi_{ij}) - U(\pi_{0j}) > 0$$

where $i = 0$ denotes the base slash and burn production method.

One of the principal problems when dealing with slash and burn agriculture is that the majority of the costs are social. Farmers either may not realize or appreciate the ecological costs of their actions so their perception of profits may be incomplete. As a result, farmers may adopt slash and burn simply because they do not fully account for the social costs of their actions. Education is essential in making farmers aware of both the true costs of slash and burn agriculture and of the alternatives to slash and burn as a production system. In the present context, the goal is to assess whether or not improving farmer education through visits by extension personnel makes farmers more aware of the costs of slash and burn agriculture and promotes movement toward other methods of production. To accomplish this, changes in visits by extension personnel must increase the difference in expected utility from perceived profits between slash and burn agriculture and the alternative methods of production. Essentially,

extension visits must either make farmers more aware of the full ecological costs of slash and burn agriculture and/or the profit potential in using cropping methods other than slash and burn. However, since individual farmers respond to education differently and because land tenure issues may limit the ability to absorb education, there is no a priori theoretical indication extension visits will promote movement away from slash and burn agriculture. Consequently, this issue must be addressed empirically.

The model follows Caviglia and Kahn (2001) and Adesina and Chianu (2000) in assuming a random utility framework for the farmer's utility maximization problem. Given this, each farmer maximizes expected utility by opting for the production method with the highest perceived profits, given by:

$$(2) \quad U(\pi_{ij}(X)) = f_{ij}(X) + \varepsilon_{ij}.$$

Here $f_{ij}(X)$ is a deterministic function of farm attributes and ε_{ij} is a random variable representing unobserved attributes. It is not necessary to estimate each farmer's utility or profit function. The probability of adopting a particular production method as a function of farm and farmer attributes can instead be estimated using a discrete choice model. This can be accomplished by assuming $f_{ij}(X)$ takes the form $\beta' X_j$, where β_i is a vector of parameters associated with the production method and X_j is a vector of observed farm and farmer attributes.

Translating the difference in expected utility into a workable limited discrete choice model requires assuming a distribution for the difference between the ε_{ij} s. Assuming the ε_{ij} s are random independent variables following a Weibull distribution, the distribution of the difference between the ε_{ij} s is logistic (Domencich and McFadden, 1975). Since farmers are assumed to choose between three alternative methods of production, the model outlined in Equation 1 reduces to a multinomial logit where the probability of employing a particular production method is a function of both farm and farmer attributes, including visits by extension personnel and measures of land tenure.

As noted previously, farmers in Cameroon can choose between three alternative methods of production: slash and burn, where a field is razed and crops grown until the soil is depleted, typically producing cassava, cocoyam, taro, and corn; multi-cropping, where permanently-cropped fields produce cassava, cocoyam, taro, corn, sweet potato, yam, and plantains, both for subsistence and for sale; and mono-cropping, where farmers grow a single cash crop, typically yam, cacao, or coffee. In general, slash and burn agriculture is the least profitable of the three choices, while mono-cropping is the most profitable. However, this does not always hold true. Variations in management, access to labor and capital, and ownership of land can overcome or undermine these inherent differences in profits such that a farm can be more profitable under a less profitable system than would be initially assumed. Additionally, since profit drives the choice of production method, some farmers may opt for a lower cost but otherwise generally less profitable system if that system is appropriate for the farmer's attributes. Both of these outcomes point toward the effects of asset heterogeneity.

It is assumed that higher numbers of visits by extension personnel will make farmers more aware of the ecological costs of slash and burn agriculture.¹ Consequently, as the number of visits rises, farmers should switch from slash and burn agriculture to the other, more environmentally sustainable, methods of production. Unfortunately, land tenure issues may counteract the effects of education. If farmers do not own the land they till, they may be less likely to employ sustainable production methods on the land they farm regardless of how much they know about the environmental costs of their actions. To address this issue, it is necessary to measure not only how education influences adoption of more sustainable methods of production, but also how land tenure issues affect adoption of alternatives to slash and burn agriculture.

For this analysis, slash and burn production represents the base production method. The base method represents a choice made outside the framework of the present model. As such, the probability of selecting the base technology is indeterminate. Following Amemiya and Nold (1975), this problem can be overcome by normalizing the β_0 (the coefficients for slash and burn agriculture) to zero. Once this is done, the probability that the i -th production method is adopted by the j th farmer is:

$$(3) \quad \text{Pr}_{ij} = \frac{e^{X_j \beta_i}}{\sum_i e^{X_j \beta_i}}$$

Data to assess the influence of education and land tenure on the choice of production method for farmers in Cameroon came from surveys conducted by the United States Agency for International Development (US AID) in Cameroon. The Roots and Tubers Research Project (ROTREP) of US AID collected agro-economic data at the farm level in the Fako region of southern Cameroon during the first cropping season in 1992.² The survey covered 396 farmers with approximately 614 farms, representing approximately 23% of all farmers in this region. The survey covered production methods, total hectares available for cultivation, farmer age, number of annual visits by extension personnel, years of formal education completed by the farmer, number of farms owned by the farmer, hectares actually owned by the farmer, total cash value of the farmer's production (in Cameroonian Francs), total quantity of labor available to the farmer (in 8-hour days), and total capital available to the farmer (in Cameroonian Francs).

A single equation multi-nomial logit model is used to measure the effects of education and land tenure on the choice of production method by farmers in Cameroon. The analysis uses 10 continuous variables. The continuous variables, described previously, are: owned hectares, farmer age, number of extension visits, farmer education, number of farms owned by the farmer, cultivated hectares, output value, labor quantity, and capital quantity. Additionally, the ratio of owned to cultivated hectares (a measure of land tenure) is also included. As mentioned previously, slash and burn agriculture is the benchmark production method, with multi-cropping being the next choice, followed by mono-cropping. The probability of adoption for each

¹ All farmers have an equal chance of being visited by extension workers. The selection of which farms to visit is done randomly using stratified random sampling techniques and other random statistical techniques.

² The surveys were actually conducted in 1993-1994, after the 1992 crops had been produced.

production system and the marginal effects of each variable are also calculated. Estimation is carried out using the LIMDEP econometrics software package.

Estimation Results

The results for the multinomial logit model are reported in Table 1. The majority of coefficients are significant at least at the $\alpha=0.1$ probability level. Measuring the performance of a qualitative choice model is different from a conventional Least Squares model in that qualitative choice models do not have a single reliable measure of model fit (Maddala, 1987). To assess the fit of the model, a variety of goodness-of-fit measures are reported. These include the McFadden R^2 (0.46), the log-likelihood ratio test (282.428 with 20 degrees of freedom), and the percentage of correct predictions (86.38%). The McFadden R^2 is calculated as $R^2 = 1 - L_{\Omega}/L_{\omega}$, where L_{Ω} is the unrestricted maximum log-likelihood and L_{ω} is the restricted maximum log likelihood with all slope coefficients set equal to zero (Amemiya, 1981). The log-likelihood ratio test is given by $2(L_{\Omega} - L_{\omega})$ and is asymptotically distributed as a chi-squared random variable. The percentage of correct predictions is calculated as the total number of correct predictions as a percent of the number of observations. All three measures indicate a good fit for the model and relatively high explanatory power for the model.

The parameters shown in Table 1 give some indication of how important education, and particularly continuing education in the form of extension visits, is in determining what methods a farmer uses to produce crops. For both multi-cropping and mono-cropping, years of completed education and visits by extension personnel are significant and positive, particularly for the relatively more profitable mono-cropping. This suggests that as visits by extension personnel rise, farmers are more likely to move away from environmentally costly slash and burn agriculture toward the two alternative methods of production.

Figure 1 further confirms this point by showing the likelihood of adopting the three methods of production as a function of visits by extension personnel.³ As the figure shows, higher levels of extension visits reduce the likelihood of employing slash and burn as a production system. Additionally, the figure shows that at higher levels of extension visits to farmers the likelihood of using multi-cropping as a production method also falls. This is in keeping with multi-cropping's status as an intermediate production method. In response to education, some farmers may move from slash and burn to multi-cropping, but those using multi-cropping may elect to adopt mono-cropping. As a result, multi-cropping sees both entry and exit by farmers, and at higher levels of education the overall impact of these two competing effects is negative. On the whole, improving farmers' education through visits by extension personnel appears to greatly improve the likelihood of farmers moving toward more profitable cropping systems and away from slash and burn methods.

³ All other parameters are held at their means.

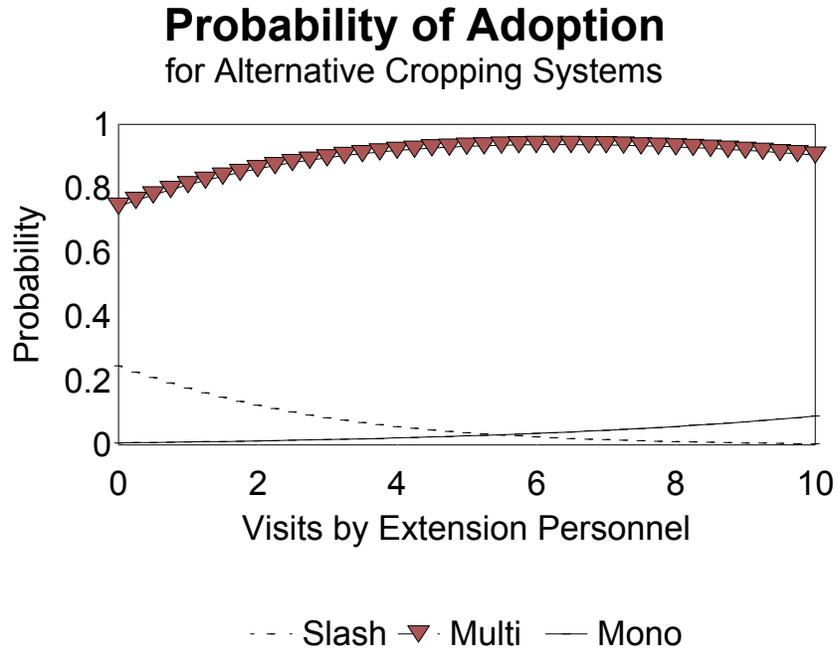
Table 1: Multinomial Logit for Cropping System Adoption Model

Cropping System	<i>Multiple-Cropping</i>	<i>Mono-Cropping</i>
Parameter:		
Constant	2.2351	1.0077
s.e.	1.2159	1.7182
Total Acres	-0.8931	-0.0459
s.e.	0.3145	0.5171
Age	0.0297	0.0343
s.e.	0.0189	0.0251
Extension Visits	0.4142	0.6485
s.e.	0.2130	0.2424
Education	0.1583	0.2059
s.e.	0.0732	0.0906
Farms Managed	-0.0963	0.2395
s.e.	0.1307	0.1793
Cultivated Acres	3.2286	2.6048
s.e.	1.1727	1.3619
Output Value	0.0000	0.0000
s.e.	0.0000	0.0000
Total Labor	-0.0051	-0.0077
s.e.	0.0028	0.0035
Total Capital	-0.0000	-0.0000
s.e.	0.0000	0.0000
Land Ratio	-0.7191	-2.4546
s.e.	0.2342	0.7727

Goodness of Fit Measures:

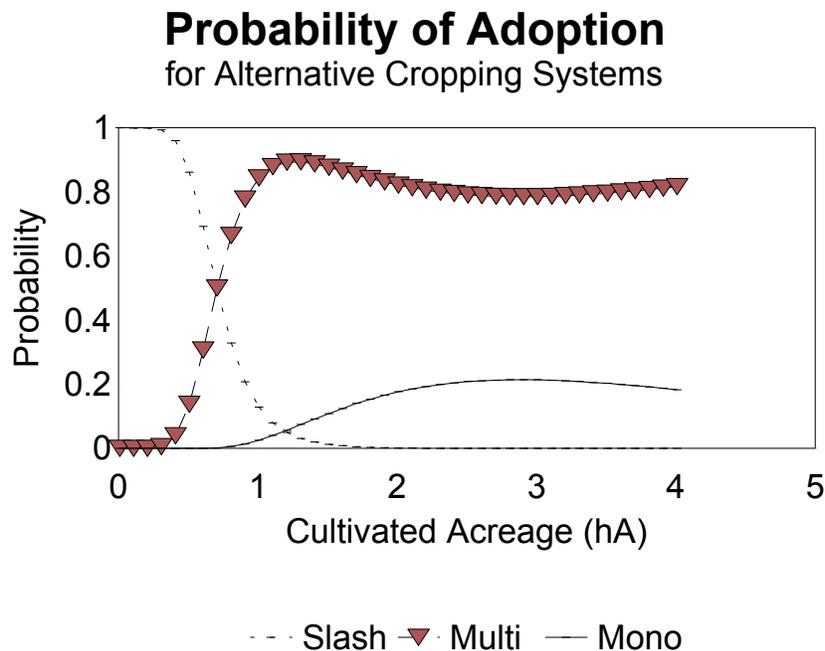
McFadden's R ²	0.464
χ^2 Test	284.42
d. of f.	20
Percentage Correct Predictions	86.38%

Figure 1: Probability of Adopting Alternative Cropping Systems as Function of Extension Visits



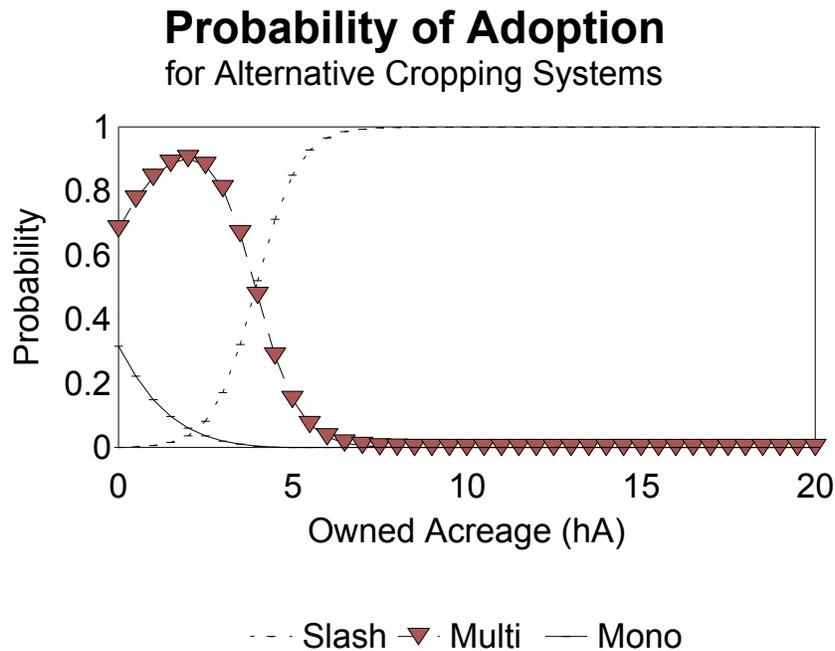
Higher levels of land cultivation may prompt farmers to adopt slash and burn agriculture as a means of bringing more acreage into production faster. Consequently, the overall impacts of higher levels of cultivation on the adoption of alternative methods of crop production is another important issue in designing policies to reduce slash and burn agriculture. Figure 2 expresses the probability of adopting the three alternative methods of production as a function of cultivated acres. In general, higher levels of cultivated acres reduces the probability of farmers employing slash and burn as a production method. Additionally, at lower levels of production most of these transfers are into the higher profit mono-cropping. However, at higher levels of cultivated acreage, multi-cropping begins to rise. This is most likely due to the relatively high labor requirements of cultivating yams, the primary crop grown by farmers practicing mono-cropping. At higher levels of cultivation, it may simply be infeasible to find the labor to cultivate the additional acres in yams and cocoa or coffee if the farmers choose multi-cropping instead. On the whole, these results suggest that there may be scale issues that limit farms' abilities to move from one method of crop production to another, an important consideration in designing public policy and an example of how asset heterogeneity limits the adoption of alternative production methods.

Figure 2: Probability of Adopting Alternative Cropping Systems as Function of Cultivated Hectares



The compliment to land cultivation is land ownership. Land tenure is also a critical issue in addressing why farmers choose to use slash and burn as a production system. The present analysis distinguishes between total acreage cultivated by a farmer and the acreage the farmer actually owns. As a result, it is possible to compare how land ownership affects the decision to employ slash and burn agriculture. These results are summarized in Figure 3. Increasing levels of land ownership by farmers in Cameroon promotes adoption of mono-cropping, with most of the adoption occurring as farmers move from multi-cropping to mono-cropping. However, higher levels of land ownership also promotes higher adoption rates for slash and burn agriculture. In general, it appears that higher levels of land ownership pushes some farmers from multi-cropping toward more profitable mono-cropping but also makes a small minority of farmers more likely to clear land using slash and burn methods. Recalling that these probabilities hold cultivation levels constant, the results suggest that increasing land ownership without corresponding increases in cultivated acres may not be an effective tool in promoting movement away from slash and burn agriculture. From a policy perspective, this implies that any attempts to increase land ownership must be tied to efforts to increase production levels through higher levels of cultivated acres.

Figure 3: Probability of Adopting Alternative Cropping Systems as Function of Owned Hectares



Conclusions

Slash and burn agriculture in tropical rainforests not only poses a significant threat to regional ecology, but also contributes to food supply instability. Moving farmers in tropical regions away from slash and burn agriculture toward more sustainable methods of production is a critical goal both environmentally and developmentally. Using data on crop production methods by farmers in the west African nation of Cameroon, this research indicates extension education is a valuable tool in encouraging farmers to switch from slash and burn agriculture toward more sustainable methods. However, the general effect of this education is to push farmers toward mono-cropping for export, often at the expense of more diversified crop selections.

The policy implications of this outcome are significant. If the effects of increasing farmer education through extension visits is to reduce diversity in the agricultural base of a developing nation, long-run agricultural sustainability may be put at risk. Basically, the problem of slash and burn may be solved at the expense of food security. While increasing extension visits appears to reduce slash and burn agriculture, care needs to be taken that the education does not push farmers into other methods that are equally unsustainable.

Additionally, analyzing how scale and land tenure issues influence the choice of production methods suggests that the choice of production method is very sensitive both to the number of acres a farmer is cultivating and to how many of those acres actually belong to the farmer. In particular, changing land ownership levels without corresponding increases in production levels, or vice versa, does not promote movement out of slash and burn production methods.

Consequently, extension education is a useful tool in moving farmers away from slash and burn agriculture, but issues related to production levels and land tenure cannot be overlooked. Designing policy for developing nations should, therefore, recognize that heterogeneity of assets is critical in studying technology adoption (Bellon and Taylor, 1993; Perrin and Winkelmann, 1976). Models must reflect that differences in production scale and land ownership are equally important as education in determining how a farmer produces his/her crops.

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