SUSTAINABLE FARM MANAGEMENT IN THE AMAZON PIEDMONT

by

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This paper develops a model of wealth accumulation of small producers and presents the results of a statistical analysis using survey based data at the farming household level. The general goal of the paper is to consider the sustainability of farming systems in tropical forested areas, in the interest of rural development and tropical forest conservation. We show that in this risky frontier farmers respond to production factor enhancements, that mobility impulses attributable to productivity declines are low, and that agrofoestry systems do not offer strong advantages over annual-based systems.

Este artigo dá um modelo de acumulação econômica por produtores pequenos e também dá os resultados de análise dos dados de um levantamento de produtores pequenos na Amazônia. O propósito do artigo é considerar a sustentabilidade da agricultura tropical, o desenvolvimento rural, and a conservação das florestas tropicais. Mostramos que a acumulação tem uma relação com fatores da produção econômica, que a mobilidade de produtores esta baixa, e que sistemas agroflorestais não tem vantagens forte com respeito a sistemas subsistência.

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I. INTRODUCTION

Real per-capita incomes as well as food production have declined in a number of tropical countries during recent decades. (See Bilsborrow and Geores 1990.) While many factors have probably played a role in this process, environmental degradation resulting from unsustainable farm practices could be implicated. Many assessments of small-scale agriculture in tropical frontiers explicitly address the environmental impacts of farming practices and their destructive consequences for long-run agricultural productivity (e.g., Moran 1983a; Collins 1986; Blaikie and Brookfield 1987).

Subsistence agriculture and shifting cultivation in particular involve approximately 500 million people worldwide, whose activities affect 2.4 million Km2 of closed forest (Goldammer 1988; FAO/UNEP 1982a), or about 20 percent of the tropical resource base (FAO/UNEP 1982b, 1982c, 1982d). Given the magnitude of this population, unsustainable small-scale farming practices represent an ecological threat of the first magnitude for tropical forests, and also undermine social welfare in rural frontiers.

Attempts to explain deforestation frequently point to the link between environmental degradation and productivity impacts. In the oft-cited (but unproven) scenario (Leslie 1980; Myers 1980; Office of Technology Assessment 1984; Walker 1987; Repetto 1988; Repetto and Gillis 1988; Walker and Smith 1993), subsistence farmers follow roads into forested areas and begin farming. After a few years, soil fertility apparently declines, and the farmers move on to another patch of forest, in a continuing cycle of land clearance.

This paper develops a theoretical model of wealth accumulation for small-scale farmers with incomplete market attachments, and implements econometric estimations to assess opportunities for the sustainability of farms in the Brazilian Piedmont, near Santarem, Brazil (State of Para). The main intent is to illuminate factors influencing *economic* sustainability, within the context of known ecological contraints. In particular, the statistical assessment and interpretation is presented in light of the what we refer to as the *agroforestry* paradigm for sustainability in tropical forested areas.

The paper is organized as follows. The next section (II) discusses agroforestry, sustainability, and economic development. Section III presents a theoretical model of wealth accumulation under subsistence conditions. This model provides a conceptual basis for statistical analysis of a sample of farms from the Santarem area, which is described along with the results in section IV. Section V is a discussion, and Section VI concludes the paper by considering the relationship between farm structure and sustainability; aspects of rural development policy are also addressed.

II. AGROFORESTRY AND SUSTAINABILITY

Agroforestry theoretically ensures agricultural sustainability by providing a steady yield of market goods; in so doing, it mitigates invasive forest mobility leading to excessive deforestation. In particular, woody vegetation is more conserving of soil resources and tempers productivity reduction commonly assumed to act as a push factor in farm out-migration. While soil fertility may eventually decline to problematic levels under perennial cropping, it will do so more slowly than with annual crops, thereby reducing migration frequencies.

In addition to mitigated fertility decline, tree crops also provide positive production externalities for associated annual crops through the maintenance of microclimates conducive of plant growth and through erosion control (Etherington and Matthews 1983; Mercer 1991). Such interactive effects can lead to positively sloped segments of production possibility frontiers and, consequently, greater annual crop production than would occur in the absence of woody vegetation. Management interventions in forest fallows can further enhance these production externalities (Unruh 1988, 1990).

By stemming fertility decline and improving annual crop production, *ceteris paribus*, agroforestry slows and perhaps reverses the process of resource degradation that impoverishes producers, and "pushes" them to their next farm site, presumably a forested area. At the same time, markets are likely to exist for perennial crops, allowing for an accumulation of real income and participation in consumer markets. Such consumption can reduce the appeal of urban locations, thereby mitigating the pull factors influencing mobility decisions. In addition, agroforestry reduces off-farm forest degradations to the extent that useful products are incorporated in the woody vegetation component of the cropping system.

The economic advantages of agroforestry have been illustrated in static terms primarily by reference to positive externalities in production frontiers (Etherington and Matthews 1983; Mercer 1991). We turn now to a variant of this model which allows for wealth accumulation and includes subsistence food production and market exchange for consumer goods. The purpose of the model is to provide a description of farm success, in terms of increasing levels of durable goods ownership.

We have focused on durable goods, since collecting consistent monetary income and wealth data in rural areas of tropical countries is problematic due to inflation, imperfectly developed financial institutions, respondent biases, and incomplete records. Durable goods accumulation, then, serves as our indicator of increased income and improved standards of living, essential to the economic sustainability of farming systems, and a likely goal of rural development projects (Moran 1983b). The model serves as the theoretical basis for the statistical treatment of farm production dynamics that follows.

III. WEALTH AND SUBSISTENCE

Consider production of a food crop and perennials, and market exchange between perennials and consumer durables. More generally, the perennial crop may be taken as a market crop that could be produced on an annual basis. The food crop is not marketed, but it must be consumed according to a dietary minimum. Additional consumption is assumed to provide no additional utility. The farming household derives no utility from perennial production, which is a pure production activity.

The production possibilies are described by a function concave to the origin in perennials/food crops space. (See Figure 1a.) Level sets of the utility function in consumer goods/perennials space are slightly curved lines intersecting the consumer goods axis, indicating the indifference of the households for consumption of perennials (P). (See Figure 1b.) Subsistence requirements in the utility function ensure that wealth (W) maximization in production always occurs where the vertical line associated with subsistence intersects the production possibilities frontier.

Under such a representation, utility maximization takes place at point C^* in consumer goods/perennials space, for the wealth maximization outcome at point P^*. Consumer goods accumulation occurs in figure 1b with shifts from the origin in the budget constraint. These arise as production possibilities expand away from the origin, with the deployment of additional factors, leading to wealth increments as the overall value of perennial output rises. Decumulation of consumer goods occurs with factor depreciation and loss, and a consequent contraction of production possibilities. Relative price changes also affect the consumption outcomes.

With constant prices, a change in consumer goods consumption is proportional to perennial output, which is proportional to wealth accumulation, given by vertical shifts in the wealth line in Figure 1a. On the basis of these relationships, wealth accumulation may be estimated using consumer goods as a dependent variable.

IV. ANALYSIS OF SUSTAINABILITY OUTCOMES

Accumulation dynamics were statistically assessed for a sample of mostly small producers. In essence, changes in consumer durables were regressed against alternative combinations of factor and factor growth variables, as suggested by the model. The intent of the analysis is not to characterize production technology or the functional form of production possibilities, but to give some assessment of the sensitivity of output to production factors, in the interest of forecasting development impulses of potential policy initiatives, such as provision of cheap fertilizers, credit subsidies for technological improvements, and so on.

While the explicit statistical framework addresses *economic* phenomena, in an effort to identify conditions associated with economic sustainability, the data contain ecologically-relevant information. In particular, it is possible to distinguish between farming systems with perennials, and subsistence-oriented farms that have no trees or other woody vegetation. This allows for an assessment of the agroforestry paradigm in terms of economic sustainability. We assume *a priori* that tree cover is consistent with ecological sustainability.

The analysis uses data collected from 68 fazendas during the month of November, 1992, in the vicinity of Tapajos National Forest near Santarem. Santarem is the third largest population center in the Brazilian Amazon region. While much attention has focused on alluvial areas of the basin, our sample comes from upland areas; over 85 percent of the Amazon basin is piedmont. Rainfall in the region averages 2-3000mm per year and is seasonal, with a pronounced dry spell from June to December.

Of the sample of 68 fazendas, 14 represent annual (and largely subsistence) systems, with no trees except perhaps an occassional fruit tree for household consumption; the remaining systems all contain woody vegetation but one, which is strictly a ranching operation. The subsistence systems are in fact likely to grow some crops for market (such as manioc), although market attachment is sporadic and local in nature. The agroforestry systems, in turn, often possess home gardens for domestic consumption, in addition to purely market-oriented crops such as pepper and cacao.

Table 1 presents results for the regression analyses. A variety of specifications were tested. In particular, models 1 and 2 (in tables 1a and 1b) exclude initial factor endowments, while models 3 and 4 include them. The specification difference within model pairs 1-2 and 3-4 relates to the dependent variable. Wealth gain (or gain in consumer durables) is given in absolute terms in models 1 and 3, and in relative terms in models 2 and 4.

For the wealth gain information, the questionnaire elicited data on ownership of consumer durables upon arrival at the fazenda, as well as at the present time, allowing for the construction of an accumulation index based on net acquisitions (or losses); price information was not observed. We obtained ownership information on radios, refrigerators, televisions, electricity, and cars. The questionnaire contained an *other* category; common additional goods were bicycles and stoves.

Wealth was defined as an index summed over all classes of consumer durables, given the absence of price data; we did not weight by relative value. Wealth change was given as the sum of changes between original ownership and current ownership of individual goods. For example, if a person owns bicycles at the present time, but not upon arrival, we recorded a plus one. In our analysis, wealth change is given as the sum of all such calculations across all classes of goods.

The independent variables used in the analysis were initial levels of agricultural inputs (fertilizers, pesticides, irrigation) and changes in use over time, initial technological level (tractors, chainsaw, carts, generators, etc.) and their changes over time, human capital (age of head of household and education level) and on-farm acquisitions (length of residence). The questionnaires did not yield information on initial workforce level. Thus, current workforce was taken as the independent variable for initial labor inputs, under the assumption that correlation exists between current workforce and initial workforce. In a similar vein, the proxy for change in labor force is outmigration intensity, the ratio of the number of familial outmigrants from the farm and family size. Finally, a variable for off-farm income is included, since 49 percent of the farms received some support of this kind.

It is assumed that farmers are well-informed about their market opportunities, and develop their farming practices accordingly. In the context of the theoretical model, the value yielding crop could be a perennial or annual crop, depending on the market situation. The model explains accumulation in terms of factors and not explicitly in terms of crop choices.

Farming system structure is addressed in two ways: (1) through model specification using a dummy variable for agroforestry, under the strong definition that agroforestry is any system incorporating any woody vegetation; and (2) by analysis of the residuals, on the basis of gross characterizations of the cropping patterns. Table 1a presents specifications not sensitive to farming systems; in Table 1b, the tested models include a dummy variable set to 1 if the farming system possesses any woody vegetation.

In general, the various regression models explain from 40 to 50 percent of variation in the accumulation variables. Of special note is the robustness of the increased inputs variable, and its evident importance to economic performance. In every specification, this variable is highly significant, and its coefficient is of the expected sign. Results for initial input levels are also suggestive; in specification 4, the estimated coefficient is significant at the 5 percent level for a one-sided test.

Results for 'increased technology levels are generally robust across the specifications not using an agroforestry dummy variable. Technological improvements seem to lead to accumulation outcomes, although not with the significance observed for increases in input applications. Nevertheless, inclusion of an agroforestry dummy variable impairs to a certain degree the performance of the technological change measure, presumably indicating correlation between agroforestry and technological adoption.

Of special note is the performance of the agroforestry dummy in Table 2a. While its coefficient is positive as anticipated by the agroforestry development paradigm, its significance is suggestive in only one specification (number 1). Other variables also show low significance levels. Human capital acquisitions (education, experience, and age) do not affect accumulation in this model, nor do transfers of off-farm income or the households labor force dynamics.

It is important to interpret results on these other variables in a cautionary light, however. In particular, farm labor force is difficult to define, and correlation between current workforce and initial workforce cannot be expected to be sufficiently high to provide a good estimate for the labor endowment effect. Similarly, weak correlation between outmigration intensity and labor force change might be compromising the performance of the labor-force change proxy.

In the various regressions, subsistence and agroforestry systems show distinctly different residual patterns. Of the subsistence systems all are relatively well-predicted in the various specifications, with little residual variation from predicted values of accumulation. In specification 1, residuals of three of seven farms possess t-statistic values in the neighborhood of ¦.5¦, while the others are all less. This same pattern holds for specification 2. In specifications 3 and 4, variation in the neighborhood of ¦.5¦ is observed for one and two observations, respectively.

For agroforestry observations, deviations of ¦.5¦ and greater are observed for one half to two thirds of all observations in the four specifications. Moreover, the greatest positive and negative deviation values (normalized as t-statistics) are observed among the agroforestry systems.

V. DISCUSSION

The regression analysis has allowed for the identification of economic growth factors leading to stable or increasing standards of living, as represented by the accumulation of valuable consumer durables. Despite an inherently variable environment, it was possible to show with relatively few observations that accumulation is linked to increasing levels of farming inputs; moreover, the result for technological improvements is highly suggestive. (See Moran 1983a; Smith 1990.) It would be premature to rule out the importance of the labor factor given difficulties in variable definition; nevertheless, the results are consistent with satisficing behavior at subsistence level. Increased labor quantities may allow for increased consumption of leisure.

Generally, agroforestry systems have been able to accumulate more consumer durables than the annual crop systems. Twenty three of the fifty two farming systems with woody vegetation have shown net addition to their store of durable goods, as compared to three out of fourteen for the non-agroforestry systems. Nevertheless, results suggest that the agroforestry adoption in-an-of itself is not the driving force behind the accumulation process; agricultural inputs are evidently much more important overall.

Moreover, analysis of the residuals suggests that while the agroforestry option holds out an opportunity for gain, it does not eliminate the possibility of failure. A farming approach in tropical areas based on subsistence annuals appears more secure. Agroforestry systems are likely to allow for increased market participation on part of small-scale farmers, but the results indicate that a fair degree of risk is involved.

Much agroforestry research has acknowledged the extreme conditions of spatial variation involved in environmental factors influencing the adoption of related systems and their likelihood for success. While the theoretical writing on agroforestry (e.g. Etherington and Mathews 1983; Mercer 1992) recognizes the adoption of woody vegetation into a farming system is an investment decision, the elements of risk and uncertainty that affect investment behavior have remained largely unaddressed.

In an unpredictable and resource scarce environment, a subsistence approach to farming that relies on a dependable set of annual crops may be reflective of risk averse behavior. Risk takers, in turn, may be predisposed to woody vegetation. In this context, it is appropriate to view agroforesters as innovators, in which case the adoption of woody vegetation is largely influenced by attitudes toward risk, *ceteris paribus*. Simple extension of techniques and the distribution of market information may not be sufficient to convince all farmers to shift factors into the production of perennial crops.

Agroforestry has been ventured as a key component to policies for sustainable rural development in tropical areas. While the literature holds that agroforestry systems realize reduced ecological impacts, optimal production decisions in risky environments may yield cropping systems with few trees. This is likely to be the case for farmers who are risk averse, and with few economic resources to begin with. In our sample, the systems including woody vegetation had on average two times more farm implements in aggregate terms, at the start of operations. Given the high variation in economic outcomes for perennial systems, low wealth levels in the initial farming stage allow little leeway for failure.

Governments have no control over the intrinsic potential for certain types of behavior (such as risk avoidance), but they can affect the likelihood of catastrophic events the make such behavior manifest, as for example in choice of cropping systems. Price variation in crops can be reduced through market interventions, and output variation can be mitigated through appropriate technology transfers. The most effective approach for the part of the Brazilian Amazon we have studied remains an empirical question.

Agroforestry may provide for market participation, but this is no guarantee that adopting farmers will be successful and experience increasing standards of living; the regression results show little accumulation effect for the woody vegetation systems independently of the increased inputs and technology levels that they involve. Agroforestry does not, in-and-of itself, appear to meet the criterion of agricultural sustainability any more successfully than the pure annual systems in our sample.

Concerns about invasive forest mobility have motivated the search for alternatives to shifting cultivation based on annual crops, and have contributed significantly to the interest in sustainable rural development. This issue is relevant to our sample, given the close proximity of Tapajos National Forest and Brazilian concerns for sustainable resource management (Weaver 1983).

Temperate forest management derives from the concepts of Faustmann (Hirshleifer 1970) and relies on well-defined property institutions. When property rights are clearly articulated, Faustmann rotations provide an optimizing management scheme based on the capture of resource rents, which induces sustainability incentives on part of the forest owner. When property is not well-defined due to institutional constraints or enforcement difficulties, as is often the case in tropical countries with large forests, the sustainability incentives may dissipate with rent loss due to uncontrollable forest conversion. Evidently, forest management in tropical countries requires a social policy dimension addressing small-producer behavior (Nair 1991). Fixing these farmers to a single plot of land is the hope of agroforestry.

In this regard, it is of interest to note that mobility, generally speaking, tends to be low in our sample. Moreover, there are no appreciable differences between the pure annual systems and those involving woody vegetation. Household heads of annual cropping systems have lived on 2.14 farms in the past twenty years, compared to 2.13 for agroforestry operations. In addition, the agroforestry farms generate 1.9 familial outmigrants, while the more subsistence-oriented farms generate 1.5.

Although residential mobility is low in the sample, and inconsistent with the popular notion of invasive forest mobility, farms do rotate crops regularly in slash and burn activities, with an average return cycle of four years. This is so for both the pure annual systems and those with woody vegetation, which normally contain large annual crop components. The agroforestry systems burn more land each year than those without trees.

Given the crop rotation cycles within the individual farms, and the low rates of life-time mobility of household heads, it appears that the agricultural systems in place in our sample do not fit the mobility model linking soil resource degradation due to repeated rotations to forest invasion. This is not to say that forest attrition does not occur both inside and outside Tapajos National Forest.

Farmers in our sample have cleared old forest (*mata*) an average of five times during their current land tenure, or an average of about once every three years. Moreoever, parts of the national forest itself may be at risk to farming practices of resident squatters. Nevertheless, for the farmers in our sample, the initial land allocation appears adequate to constrain forest clearance to within property boundaries, and for the life-cycles involved. Loss of family labor, especially adult children, can severely constrain agricultural activities including land clearance as the household unit ages (Lisansky 1990).

VI. CONCLUSION

Our study suggests that agroforestry provides no intrinsic economic advantage over annual systems independently of associated inputs and technological adoptions. Also, risk aversion may be strongly operative in small-scale producer decisions, which has implications for policy meant to encourage agroforestry adoption.

It is important to keep in mind, however, that we base our conclusion on a gross distinction between agroforestry and annual-based systems. Many people in our study region (and throughout the tropics) use woody vegetation in their farming systems as a matter of course, indicating an obvious set of production preferences. There appears to be little need to promote agroforestry *per se*, at least with respect to a strong definition of what constitutes an agroforestry system. One potential direction of research would seem to be the characterization of the optimal system involving woody vegetation. In this regard, Smith (1978) has argued, in the context of agricultural development along the Transamazon highway, that a diverse cropping pattern based on manioc, presumably with some perennial and woody vegetation, mitigates pest and disease damage and also buffers farmers from price variation.

Our findings show that residential mobility is not highly variable across agricultural systems, which implies agroforestry does not necessarily stem forest invasion; more generally, our results on mobility are inconsistent with the standard notion that peasants are pushed into forests because of declining productivity. Finally, net aggregate accumulation is occurring, a finding consistent with the observation that many colonists to the region of the Transamazon highway in the 1970s managed to attain "respectable levels" of income and productivity (Moran 1981).

Evidently, the farming systems in the vicinity are to a certain degree sustainable, in both economic and ecological terms, although they clearly are not generating rapidly rising incomes or impressive development spillovers. It is likely that forest invasion continues to occur in the region, but this is most likely attributable to first-time in-migrants. Some outmigrants from our sample go to rural areas (45%), but the majority go to cities (55%). Given an aging farm population and farm abandonment due to family fragmentation and the mortality of household heads, it is an empirical question whether net forest clearance in the aggregate would continue in the absence of interregional migrations.

The conditions of life in this rural area of the Brazilian Amazon are difficult. While some accumulation seems to be occurring at farm level, it is slow, and possibly non-existent in per-capita terms. Our results suggest that farmers in the region will respond to policies improving their factor endowments by developing capabilities to participate in consumer markets. The existing *sustainability* of these farming systems could be considerably enhanced in economic terms, and not at the expense of natural resources in the region.

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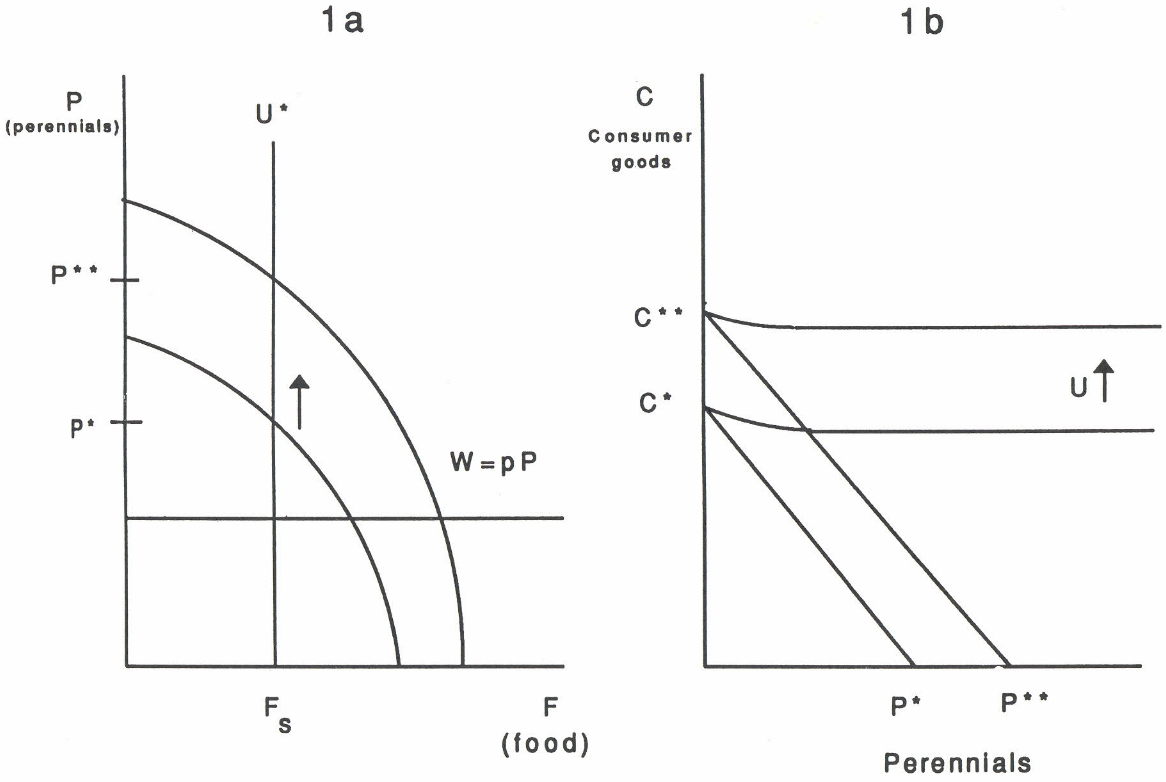

Figure 1 Production and consumption space

TABLE 1a

Regression Results

	1	2	3	4
	.43[1]	.31	.44	.52
	3.97[2]	2.378	1.681	2.261
	(.0026)[3]*	(.0417)**	(.1415)	(.0478)**
Land				
L			.000373	-.002250
			(.9499)	(.5873)
ΔL	-.002236	-.000722	-.001864	-.000532
	(.3447)[4]	(.6937)	(.5340)	(.7982)
Labor				
N			-.024759	-.047607
			(.8660)	(.6419)
ΔN	-.307922	-.2171	.007380	-.171410
	(.7033)	(.7301)	(.9946)	(.8210)
Technology				
K			.199294	.178026
			(.5981)	(.4997)
ΔK	.298805	.153690	.568805	.450744
	(.0573)	(.2025)	(.0981)**	(.0620)**
Inputs				
I			.707069	.625331
			(.1772)	(.0903)**
ΔI	.956198	.640290	1.453445	1.21742
	(.0052)	(.0149)*	(.0053)*	(.0012)*
Age	-.002608	-.003986	-.010360	-.014374
	(.8968)	(.7991)	(.7119)	(.4638)
Experience	-.026201	-.007829	-.029053	-.0126235
	(.3039)	(.6912)	(.4045)	(.6009)
Off-farm Income	.330885	.130653	.071983	-.081920
	(.4863)	(.7233)	(.9141)	(.8601)

(1) factor growth specification with absolute wealth gain
(2) factor growth specification with relative wealth gain
(3) initial stock specification with absolute wealth gain
(4) initial stock specification with relative wealth gain

[1] R-Square

[2] F-Statistic of regression

[3] Significant-level of F-Statistic

[4] Two-tailed Significance levels of the appropriate t-statistics are in parentheses.

* significant at $\alpha = .01$, one-sided test.

** significant at $\alpha = .05$, one-sided test.

TABLE 1b
Regression Results

	1 .41 3.67 (.0024)*	2 .35 2.305 (.0423)**	3 .49 1.95 (.0795)**	4 .52 2.02 (.0733)**
Agroforestry	1.163357 (.1590)	.663882 (.2229)	.763063 (.4436)	.29629 (.6344)
Technolog				
ΔK	.162819 (.3685)	.128813 (.2873)	.54362 (.1557)	.433598 (.0801)**