

Agricultural change, rural labor markets, and forest clearing:
an illustrative case from the Philippines

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ABSTRACT. This paper studies the links between agricultural employment and upland activities at a tropical forest margin. A model of lowland agricultural production is combined with a model of labor allocation on a representative upland farm to show how labor productivity, agricultural wages, and the returns from upland activities determine rates of forest clearing. Farm level data from the Philippines demonstrate how agricultural intensification—in the form of lowland irrigation development—led to an increase in labor demand, an increase in employment of upland inhabitants, and small but statistically significant reductions in rates of forest clearing.

Keywords: Philippines, irrigation, technical change, labor markets, deforestation

I. INTRODUCTION

Inadequate labor absorption is an important economic and environmental policy problem in many developing countries. In the Philippines, approximately 4.4 million jobs must be generated each year to employ additions to the labor force, two-thirds of which come from rural areas. An important outcome of rapid population growth in many frontier areas of the Philippines has been the expansion of agriculture into marginal and environmentally sensitive upland areas (Cruz, et al. 1992; Western 1988). Historically, deforestation rates in the Philippines have been high.¹ High rates of forest clearing in the uplands are driven, in part, by the efforts of low-income farmers to secure subsistence.² Finding ways to increase agricultural capacity and rural incomes without jeopardizing remaining forest resources has emerged as an important policy goal throughout the Philippines, and especially in Palawan (Sandalo 1996).

Agricultural intensification in lowland areas—for example, through innovations such as irrigation development—is one path by which agricultural capacity and rural incomes can be enhanced. But from an environmental perspective, attempts to raise rural incomes through agricultural improvement can work at cross-purposes. Technologies that increase the returns to agriculture can reduce the need for subsistence-driven land clearing, but by raising incomes and the returns to agricultural activities they can also provide incentives to convert forest to farmland or other uses (Kaimowitz and Angelsen 1998).

Forest clearing is driven by numerous factors beyond timber trade. In many areas of Central America and the Amazon, farmers seeking expansion of their livestock holdings are an important part of the process of forest clearing (Faris 1999; Mattos and Uhl 1994; Yanggen, Reardon, and Bandy 1999). Rising prices of shrimp for export combined with favorable economic conditions for their production have provided the catalyst for mangrove destruction in

many areas (Nickerson 1999; Parks and Bonifaz 1995). And policy-induced expansion of plantation and cash crops has been implicated in forest destruction throughout Africa, Asia, and Latin America (e.g. Angelsen 1995; Thiele and Wiebelt 1993; Barbier and Burgess 1996).

In most settings, incentives for clearing forest are determined, in part, by the relative returns to labor directed at cutting trees. In a recent review of the literature on tropical deforestation, Kaimowitz and Angelsen (1998) conclude that an inverse relationship exists between rural wages and deforestation rates. This is because in many areas the forest constitutes an important potential source of new land and livelihood for those who are not otherwise gainfully employed. Although not an “employer” in the literal sense, the forest is the first destination of many settlers and the final destination of others, and incentives to clear forest are strongly influenced by costs of access and returns to alternative activities. Where rural labor markets exist, employment opportunities influence choice of activity and time allocation. As a result, the rural labor market provides a useful lens through which to examine the link between economic development in the lowland economy and incentives for forest clearing in upland areas. Although rural employment obviously includes employment both inside and outside of agriculture, the focus in this paper is on the agricultural labor market and the employment effects of agricultural intensification. The argument explored in the paper is the following: economic policies that intensify lowland agriculture have the potential to encourage labor absorption and help slow local rates of forest clearing. But such policies do not guarantee that employment gains will be sustained or that forest clearing will stop.

Part of the reason behind this cautionary view is that, from a theoretical perspective, the overall impact of agricultural intensification on rural agricultural employment is ambiguous. Some forms of intensification, such as irrigation development, can increase labor demand by

facilitating multiple cropping and thereby increasing the annual effective area under cultivation. But in the case of irrigation it is equally clear that technical progress can reduce overall labor demand if it is biased against labor. A number of researchers have observed that, while irrigation may not have a “built-in” bias against labor, farmers who have access to irrigation also tend to adopt labor-saving methods such as mechanized production or chemical-based weed control (e.g. Lingard 1994; Castillo, Gascon, and Jayasuriya 1983; Kikuchi and Hayami 1983). As an example, Coxhead and Jayasuriya (1986) describe a case from the Philippines where employment in irrigated farming declined, even though real wages were falling.

The goal in this paper is both conceptual and empirical. The investigation focuses on understanding how a change in the technology of lowland agricultural production alters incentives for activities at the forest margin. Two theoretical models are presented to link representative lowland and upland households. The subsequent empirical analysis tests the hypothesis that irrigation development in lowland agriculture reduces rates of forest clearing in adjacent upland areas. Data from a frontier farming area of the Philippines are used to trace the impact of lowland irrigation development to changes in the range and intensity of activities undertaken by upland households. The patterns of activity observed at these sites underscore the importance of the rural labor market as a mechanism influencing environmental outcomes in remote and environmentally sensitive areas.

Results show irrigation development led to an overall increase in labor use on lowland farms vis-à-vis rainfed conditions. Although labor demand per hectare was lower on irrigated lowland farms than on neighboring rainfed farms, and was also lower on irrigated lowland farms than it had been when the same parcels were not irrigated, increases in cropping intensity were sufficient to compensate for labor shedding. Annual agricultural employment under irrigated

conditions was higher in absolute terms than under rainfed conditions. In addition, the number of *upland* workers hired to work on lowland farms increased following irrigation. Upland residents who gained employment on lowland farms reduced their rates of forest clearing by small but statistically significant amounts.

Whether the observed gains in employment and the associated reductions in rates of forest clearing can be sustained remains unclear. In addition to endogenous forces at work in the local economy, external factors—such as continued population growth, rural to rural migration, recovery from the Asian economic crisis and El Niño events, and shifts in economic policy all may influence incentives for agricultural expansion and forest degradation over time. Furthermore, results from simulations based on data collected on irrigated farms also suggest that, *ceteris paribus*, if lowland farmers adopted a more efficient strategy for production on irrigated farms, the result would be a net *loss* of jobs and possibly greater forest pressure in the uplands. The simulation results therefore cast a somewhat cautionary shadow over the otherwise upbeat conclusions of the paper and underscore the fact that, in general, technical change in lowland agricultural production has ambiguous implications for changes in forest cover.

II. A MODEL OF LOWLAND TECHNICAL PROGRESS AND UPLAND ACTIVITY

The theoretical model that underlies the empirical section of the paper seeks to integrate in the most simple way possible lowland and upland farm households. The structure of the model is guided both by a desire for parsimony and by a set of stylized empirical facts drawn from the sample of farms studied below. Lowland households are viewed as agricultural in their orientation. Upland households, because of their limited agricultural capacity, are recognized as engaging in a range of income-generating activities. These include low-input and shifting

agriculture in the uplands, forest clearing, exploitation of upland forest resources, and sales of labor in the lowlands when opportunities arise.

Although the model of lowland-upland interaction does not constitute a formal general equilibrium analysis, the spirit of the undertaking is consistent with the view that rates of forest clearing—and reductions in those rates—can be traced to incentives generated in the larger economy within which frontier farming takes place (Coxhead and Jayasuriya 1994). As noted above, increases in rural employment may originate outside agriculture. But in the context of the empirical example presented below, no upland residents were found to be working outside the agricultural sector. So the primary phenomena of interest here are the impacts of irrigation development in lowland agriculture on labor demand, and the willingness of upland farmers to shift their labor from upland activities (where returns to farming and clearing forest are relatively low) to lowland farms (where increases in agricultural productivity and income generate demand for labor). The analysis begins with lowland farms and then traces policy and technology changes from lowland farms to the forest margin, via direct and indirect influences on upland households.

Technical change and lowland agricultural production

In the case of lowland farms the conceptual goal is to study the impact of irrigation development on resource allocation and commodity demand. The analysis builds on a standard model of household production, which integrates producer, consumer, and worker decisions (e.g. Singh, Squire, and Strauss 1986). For convenience, production and consumption decisions are assumed to be separable. This implies a recursive solution to the household's problem. For the current study this approach is justified by empirical facts: the lowland households studied below face

exogenously determined prices; they utilize credit and have access to markets for all inputs and products; and they are, at least in years without aberrant rainfall patterns, net sellers of food.

To proceed, let us assume the lowland household maximizes utility, which is defined as consumption of an agricultural good (c_a), a composite “forest product” consisting of charcoal, fuelwood, building materials, etc. (c_f), and leisure (c_l). Prices of these goods are p_a , p_f , and w , where the latter reflects the opportunity cost of leisure time. Let \mathbf{x} define a $k \times 1$ vector of agricultural inputs and let \mathbf{p}_x define the corresponding vector of factor prices. Then the household’s problem is to maximize utility subject to a full income constraint and a time constraint. The problem is defined as:

$$\underset{c_a, c_f, c_l}{\text{Max}} u(c_a, c_f, c_l) \quad [1]$$

subject to:

$$\pi^* + w\bar{l} = p_f c_f + w c_l + \mathbf{p}_x \mathbf{x} \quad [2]$$

$$c_l + l^s = \bar{l} \quad [3]$$

where π^* denotes maximum agricultural profit, l^s represents the lowland household’s supply of labor to agricultural production and \bar{l} represents the household’s labor endowment. The household first solves the production problem, namely maximization of profit:

$$\mathbf{p} = p_a q_a - \mathbf{p}_x \mathbf{x} - w l \quad [4]$$

subject to the technology of production:

$$g(q_a, \mathbf{x}, l; \boldsymbol{\theta}) = 0 \quad [5]$$

where q_a represents agricultural output, l represents total labor use (which includes household and hired labor, if any), and $\boldsymbol{\theta}$ represents the technology of production.

Via standard analytical techniques one can assess household response to price and technology changes. Defining full income as:

$$y = p_a q_a - \mathbf{p}_x \mathbf{x} - wl + w\bar{l} \quad [6]$$

the reduced form of the household problem includes one equation for agricultural supply:

$$q_a = q_a(p_a, \mathbf{p}_x, w; \mathbf{q}) \quad [7]$$

$k + 1$ equations for factor demands:

$$x_i = x_i(p_a, \mathbf{p}_x, w; \mathbf{q}), \quad i = 1 \text{ to } k \quad [8]$$

$$l = l(p_a, \mathbf{p}_x, w; \mathbf{q}) \quad [9]$$

and three equations for commodity demands:

$$c_j = c_j(p_a, p_f, w, y), \quad j = a, f, l. \quad [10]$$

Several points regarding this system of equations are worth highlighting. First, consider the impact of changes in technology on household income and commodity demand. By equation [6] we can write this impact as:

$$\frac{\partial y}{\partial \mathbf{q}} = p_a \frac{\partial q_a}{\partial \mathbf{q}} - \sum_i p_{x_i} \frac{\partial x_i}{\partial \mathbf{q}} - w \frac{\partial l}{\partial \mathbf{q}}. \quad [11]$$

The expression in equation [11] will be positive so long as technical change is factor augmenting and all inputs are normal. Note further that if \mathbf{x} excludes the fixed-factor land, and if the impact of technical progress is such that it raises revenues by a sufficiently large amount, then the impact of technical progress on the incomes of land-owning households will be “strong” in the sense that $\partial y / \partial \theta$ will be large. This income gain, the magnitude of which is primarily an empirical matter, figures prominently in the household’s labor response to technical change because it influences consumption of leisure. This issue is addressed below. As always, relative

shifts in factor shares as a result of the technical change will depend on relative factor prices and the extent to which the technology exhibits factor bias. These too are empirical issues.

Regarding commodity demands, the impact of technical change on agricultural goods and forest products can be described by:

$$\frac{\partial c_i}{\partial \mathbf{q}} = \frac{\partial c_i}{\partial y} \frac{\partial y}{\partial \mathbf{q}}, \quad i = a, f. \quad [12]$$

The impact of an income-increasing shift in technology will be positive for normal goods and negative for inferior goods. This result provides the first of two important insights regarding the impact of lowland technical change on activities at the forest margin, namely that by raising lowland farm incomes, technical progress in the lowland sector unambiguously increases demand for forest products with positive income elasticities and decreases demand for forest products with negative income elasticities.

Whether an increase in demand for forest products results in deforestation depends on many factors. Some forms of forest use (such as extraction of minor forest products) are benign and sustainable and therefore do not necessarily place pressure on the forest. Other types of forest use, including timber extraction and permanent conversion of forest to agricultural land may directly lead to deforestation. Further complicating the analysis of demand-driven impacts on the forest is that the incentive for upland households to provide forest products rests upon the relative returns to factors used in their production. Many forest products generate extremely low returns, and thus the extent to which an increase in the price of forest products increases their supply depends on the opportunity cost of labor among upland residents.

A second—and from the perspective of this paper—more important insight into how lowland technical change might affect activities at the forest margin comes from examining the impact of technical progress on the agricultural wage and on patterns of lowland labor demand.

To study this, it is necessary to consider two interacting forces: (i) the extent to which technical change increases or decreases demand for labor on lowland farms, i.e. $\partial l/\partial\theta$, and (ii) the extent to which technical change increases demand for consumption of leisure by lowland household members, i.e. $\partial c_l/\partial\theta$. In general, a rising wage tends to reduce incomes on farms that purchase labor, and therefore discourages consumption of leisure. However, if technical progress increases the returns to land owned by a household, this increase in income may outweigh the reduction in income associated with a higher wage bill and lead to greater consumption of leisure. To see this, one can differentiate the leisure demand equation with respect to the technology parameter. The impact of technical progress on the demand for leisure is:

$$\frac{\partial c_l}{\partial \mathbf{q}} = \frac{\partial c_l}{\partial y} \frac{\partial y}{\partial \mathbf{q}} + \frac{\partial c_l}{\partial w} \frac{\partial w}{\partial \mathbf{q}} \quad [13]$$

where the first term on the right hand side of equation [13] is an income effect (leisure increasing) and the second term is a price effect (leisure reducing). To gain some insight into the net effect of these opposing forces, first differentiate the demand for leisure with respect to the wage and decompose the result via the Slutsky equation. This yields:

$$\frac{\partial c_l}{\partial w} = \frac{\partial c_l}{\partial w} \Big|_{u=\bar{u}} - (l - l^s) \frac{\partial c_l}{\partial y} \quad [14]$$

where the term $(l - l^s)$ is positive for households that are “net buyers” of labor and is negative for households that are “net sellers” of labor (Sadoulet and de Janvry 1995). To the former, wages are a cost of production; to the latter, wages represent income.

Now use [14] and the result for $\partial y/\partial\theta$ from [11], to rewrite [13] as:

$$\frac{\partial c_l}{\partial \mathbf{q}} = \frac{\partial c_l}{\partial y} \left(P_q \frac{\partial q}{\partial \mathbf{q}} - \sum_i P_{x_i} \frac{\partial x_i}{\partial \mathbf{q}} - w \frac{\partial l}{\partial \mathbf{q}} \right) + \frac{\partial w}{\partial \mathbf{q}} \left(\frac{\partial c_l}{\partial w} \Big|_{u=\bar{u}} - (l - l^s) \frac{\partial c_l}{\partial y} \right). \quad [15]$$

The first term on the right hand side of equation [15] is the change in consumption of leisure that results from a change in agricultural income. This is positive. Its magnitude will depend on factor payments and the amount by which output and revenue increase as a result of technical progress. If agricultural returns, net of variable input costs, accrue to land, then land-owning households might enjoy a relatively large increase in income as a result of technical progress. Indeed, this is a major motivating force behind public investments in agriculture and land-titling and agrarian reform programs.³

The second term on the right hand side of [15] is the change in consumption of leisure associated with an increase in the agricultural wage. This is unambiguously negative for farms that hire labor: income and substitution effects both discourage consumption of leisure.⁴ Thus whether lowland technical progress increases rural employment depends largely on three forces: (i) the factor requirements of the technology; (ii) the change in income on lowland farms; and (iii) the propensity of lowland farm households to consume leisure. When a technology uses labor intensively, increases income, and promotes consumption of leisure, then technical change will increase local demand for labor. In all other instances, the net impact of technical progress on labor demand depends on the empirical signs and magnitudes of these effects.

To summarize the gist of the argument thus far, consider an initial equilibrium that is characterized by an existing technology used by a representative lowland farm. Keeping with the empirical example presented below, this existing technology is taken to be rainfed rice production. The lowland farm may rely solely on family labor, or—as is more likely—it may use a combination of family, shared, and hired labor. This lowland farm uses hired labor up to the point where the value of the marginal product of hired labor equals the wage.⁵ Starting from this initial equilibrium, suppose an innovation takes place in the lowland agricultural sector, for

example development of an irrigation system to provide water storage and delivery. If this innovation raises the value of labor in production, it will tend to boost labor use. Furthermore, if irrigation facilitates multiple cropping during a calendar year, annual labor demand may rise. This may occur because more labor is used during a single cropping season, because labor is used during times of the year that it was formerly not used, or both. In other words, the technical change may increase *effective labor demand*, i.e. the total amount of labor used on a hectare of land in a calendar year. As empirical results reported below illustrate, this distinction is important. It is clearly possible for irrigation to be labor saving, and to thereby reduce per-hectare amounts of labor used in a particular cropping season, but to nevertheless increase the amount of labor used in a calendar year by increasing cropping intensity.

Note further that, even if technical change reduces effective labor demand, it could increase the consumption of leisure in a lowland household if it increases income by a sufficient amount. Higher consumption of leisure will lead the lowland household to substitute hired labor for family labor. Greater demand for labor will in turn raise the wage rate because a higher wage is required to draw new workers away from alternative activities. This logic leads to the second main implication of the model. By raising demand for leisure and reducing the supply of household labor used in agricultural production, technical progress in the lowland sector may raise demand for labor and thereby put upward pressure on the agricultural wage. If lowland technical progress increases lowland incomes by a large amount, workers will be hired to replace family labor. To the extent newly hired workers would otherwise engage in activities at the forest margin, the local labor market provides a conduit through which improvements in lowland agriculture may influence rates of forest clearing.

Upland farms and labor allocation decisions

The analysis now shifts to the uplands. To fully understand how lowland technical progress influences rates of forest degradation it is necessary to build a conceptual link between the lowland and upland sectors. In this section, arguments regarding labor allocation are again developed somewhat formally in order to highlight the mechanism that leads upland households to reallocate labor.

Consider the labor allocation decision of a representative upland household. For sake of simplicity, and in keeping with the relatively rudimentary and low-input nature of the upland economy, it is assumed that (i) labor is the only variable input allocated by upland household, (ii) the pool of labor available in the household is homogenous, and (iii) labor is allocated to maximize economic returns. The upland household can engage in three income-generating activities: upland agriculture, forest exploitation (including land clearing for agriculture), and off-farm work. For convenience, the upland agricultural product may be thought of as essentially identical to the product of lowland production (though it need not be). In terms of notation, upper case letters are used for the upland household; otherwise definitions remain as above. Agriculture is identified by the subscript a , forest use is identified by subscript f , and off farm work is identified by subscript o . Returns to upland activities are determined by the price of output associated with the activity and the level of labor effort devoted to the activity. No other inputs are used. The upland production functions, $G(L_a)$ for agriculture and $F(L_f)$ for forestry are assumed to be concave. Labor is a necessary input, and the production functions exhibit diminishing returns to use of labor. When working on a lowland farm, an upland worker receives the wage w . This wage is set competitively, in the local labor market, and depends, via

the implicit function defined by equation [9], on the technology of lowland production.⁶ The lowland technology is again represented by θ .

Defined in this way, the upland household's income-generation problem is to maximize:

$$\mathbf{p} = p_a G(L_a) + p_F F(L_f) + w(\mathbf{q})L_o \quad [16]$$

subject to:

$$L_a + L_f + L_o = \bar{L}. \quad [17]$$

As stated, the upland household's problem assumes production and consumption decisions are separable. This assumption, of course, is somewhat problematic in the case of upland households, many of which cannot readily participate in markets. Nevertheless, because upland households participate in the local labor market it is logical to assume that labor allocation decisions are guided by the opportunity cost of labor, as governed by the lowland agricultural wage. It is important to recognize, however, that supply responsiveness in upland households may not be frictionless due to failures in closely related product or factor markets.

The focus at this stage is on the relationship between technical progress in lowland agriculture and the amount of labor devoted to the forest-degrading activity; that is, the sign and magnitude of $\partial L_f / \partial \theta$. If an upland household engages in all activities, then a household maximum occurs where the value of the marginal product of labor is equal for each activity:⁷

$$p_a \frac{\partial G(L_a)}{\partial L_a} = p_F \frac{\partial F(L_f)}{\partial L_f} = w(\mathbf{q}). \quad [18]$$

Despite the limitations acknowledged above, the logic behind equation [18] provides a useful framework for investigation. For example, provided work is available, a household that reports no off-farm employment (i.e. $L_o = 0$) but some amount of upland agricultural production (i.e. $L_a > 0$) reveals that the available wage is less than the expected return to labor allocated on

the farm (i.e. $w < \partial G/\partial L_a$). Similarly, a household that clears forest to establish new agricultural areas ($L_f > 0$) may be responding to a low rate of return to farming an existing parcel of land.

To proceed, consider an initial equilibrium characterized by an existing technology in the lowlands and a representative upland household engaging in each upland activity. Suppose innovation takes place in the lowlands. This can be represented by a shift in the lowland technology parameter from θ to θ' . Let us assume that the change raises lowland labor demand and increases the agricultural wage. This higher wage produces a temporary disequilibrium in the upland household's optimal labor allocation pattern since

$$p_a \frac{\partial G(L_a)}{\partial L_a} = p_f \frac{\partial F(L_f)}{\partial L_f} < w(\mathbf{q}'). \quad [19]$$

An increase in the agricultural wage encourages the household to re-equate marginal returns to labor. If the production functions $G(L_a)$ and $F(L_f)$ are concave, a new equilibrium can be obtained by reducing levels of L_a and L_f (so that $\partial G/\partial L_a$ and $\partial F/\partial L_f$ rise). In theory, the amount of labor allocated to all alternative activities will fall in response to an increase in the wage. The amount by which these allocations fall depends on the curvature of the respective production functions. In general, whether upland forest-degrading activities decline in response to a technology shift in the lowlands depends on two factors: first, the extent to which the technological change precipitates an increase in the wage (i.e. $\partial w/\partial \theta$); and second, the degree to which a change in the opportunity cost of upland labor—as reflected in the wage rate—precipitates a reallocation of effort away from the forest margin (i.e. $\partial L_f/\partial w$). The impact of lowland technical progress on rates of upland forest clearing will therefore depend on how technical progress affects factor intensities and factor payments, as well as the magnitudes of income elasticities of demand for products provided by the upland sector.

From a trade-theoretic perspective, the upland sector may be thought of as a small Hecksher-Ohlin economy. The impact of lowland technical progress on upland activity depends on both the direct impacts arising in the labor market and the indirect impacts arising in commodity markets. Growth in lowland production (as a result of irrigation) tends to pull labor out of upland production.⁸ This is simply a Rybczynski cost effect. But to the extent the growth in lowland agricultural production increases incomes throughout the lowland economy, technical progress will increase demand for upland products (and simultaneously reduce incentives for upland households to abandon forest-degrading activities). The bundle of upland products may include products with high income elasticities (such as temperate-zone vegetables) and products with low income elasticities (such as charcoal, fuelwood, or rough building materials). As Jayasuriya (1999) argues, as long as the complete bundle of forest products coming out of the upland sector is not highly income elastic, the labor-pull effect of lowland technical progress is likely to dominate the commodity demand effect. In other words, faster growth in the lowland economy, fueled by technical progress, will tend to reduce forest clearing by pulling labor resources out of the uplands. The remainder of the paper investigates this conjecture empirically, using data from lowland and upland farms to measure the impact of irrigation on lowland labor demand, and the impact of labor market opportunities on the labor allocation decisions of households living along the forest margin.

III. DATA

The data for this study come from farms in two lowland communities and two upland communities in southern Palawan, in the Philippines. The data were collected in 1996 and 1997 and cover agricultural production during the periods June 1995 to May 1996 and June 1996 to

May 1997, respectively. The lowland dataset includes information from 108 farms. Prior to irrigation, all of the lowland farms were rain fed. At the time of the second survey, the process of irrigating lowland farms was not yet complete; 53 farms were irrigated and 45 farms remained rain fed. Together, the set of lowland respondents constitutes a 35% sample of the two lowland communities. The upland dataset consists of information from 104 upland farms adjacent to the lowland study sites. The upland dataset constitutes a 30% sample of the two upland communities. All upland households lived on or near the forest margin. Previous research from the upland sites reveals strong positive correlation between levels of household poverty and the probability of forest use (Shively 1997). Although in many frontier areas of the tropics, especially in Latin America, forest clearing for livestock grazing is important (e.g. Faris 1999), livestock do not play an important role in upland production strategies at this site. Garcia et al. (1995) and Martinez and Shively (1998) provide additional details regarding the site.

Columns 1 and 2 of Table 1 illustrate some of the differences observed between irrigated and rainfed lowland farms. Although lowland farms were broadly similar in terms of demographic features, average farm size differed significantly by irrigation status. The average irrigated farm occupied 2.6 hectares and the average rainfed farm occupied 5.1 ha. This indicates that some rainfed farms were reduced in size following irrigation. With the exception of hired labor, all means for irrigated farms reported in Table 1 were significantly different from means for rainfed farms (at a 90% confidence level). As expected, average yield among irrigated farms (3,639 kgs/ha) was higher than among rainfed farms (3,200 kgs/ha). Furthermore, due to unreliable water supplies during the dry season prior to irrigation, rainfed farms tended to produce only one crop per year whilst irrigated farms produced two crops per year, on average. As a result, income per hectare was significantly higher on irrigated farms (41,651

Pesos/hectare/year compared with 25,921 P/ha/yr on rainfed farms). Irrigated farms spent 80% more on pesticides than rainfed farms (1,656 P/ha/yr vs. 917 P/ha/yr). However, they used less labor per hectare overall, and less family labor per hectare than rainfed farms (37 and 13 man-days per hectare compared with 43 and 20 man-days, respectively). The latter pattern indicates irrigation induced a reduction in overall labor use per hectare and a release of family labor.

The final columns of Table 1 contain data from the sample of upland farms. For upland households, data in Table 1 do not distinguish between pre-irrigation and post-irrigation periods but rather between a household's employment status following irrigation. It is important to point out that, both before and after irrigation, all employment reported by upland residents originated on lowland farms located in the study area. As data in Table indicate, following irrigation 83 households (80% of the upland sample) reported earnings from work on lowland farms. The average wage share of total income in the upland sample (including the imputed value of output consumed at home) was 0.10 prior to irrigation and 0.35 following irrigation. Households engaging in work on lowland farms had slightly smaller farms, on average, than those that did not (2.0 ha vs. 2.5 ha). They also had lower per capita incomes (3,244 P/yr vs. 4,586 P/yr). Employment on lowland farms certainly helped to augment income for households with limited agricultural capacity, but as Shively and Martinez (2000) point out, wage earnings were not sufficient to close the income gap between upland household with and without employment. As a result of low agricultural capacity, upland households with wage income were still more likely to report activities with relatively low rates of return. As the final rows of Table 1 indicate, this included a slightly greater likelihood of forest clearing (16% vs. 15%) and a higher probability of charcoal and fuelwood sales (27% vs. 23%). Upland households with off-farm employment also reported clearing larger areas of forest than those without off-farm work (0.18 hectare per year

vs. 0.10 hectare per year).⁹ With the exception of some limited forays into cashew and mango production, none of the upland households reported engaging in production of crops that could be construed as destined for export markets. Nevertheless, the decisions by upland households to plant these and other cash crops (such as corn) have historically responded to changes in relative prices (Shively 1998). It therefore seems very likely that some of the observed rates of forest clearing are driven by factors determined outside the local economy.

IV. RESULTS

Patterns of labor use on lowland farms

Overall patterns of labor use under irrigated and rainfed conditions display some parallels. For example, owners tended to hire labor at a greater rate than renters, regardless of irrigation status or farm size. Similarly, per-hectare labor use (especially of family and shared labor) was greatest on small farms, and decreased with farm size, regardless of irrigation status. The latter reflects higher rates of hand-tractor and chemical use on large farms. When employment is decomposed by source and farm size, patterns of labor use differ between irrigated and rainfed groups. For all farm sizes, levels and proportions of family and shared labor were lower under irrigated conditions than under rainfed conditions. In contrast, the use of hired upland labor was higher under irrigated conditions, regardless of farm size. The data thus very clearly show that during the shift from rainfed to irrigated operations, family labor was released from rice production and *upland* workers were hired as substitutes. Although many lowland workers continued to be hired to work on lowland farms following irrigation, the bulk of post-irrigation employment gains accrued to upland residents. Martinez and Shively (1998) report that, in the study area, upland workers constituted 4% of total lowland labor prior to irrigation and 12% of

total lowland labor after irrigation. The data on employment reveal no strong seasonal patterns, although there was a slight tendency for hiring to expand in the dry season. This may indicate a greater willingness by upland farmers to forgo corn production (a dry season cash crop) than rice production (a wet season food crop).

Summary data regarding labor use and cropping intensity on lowland farms are presented in Table 2. Several important patterns are displayed in these data. As stated above, the amount of labor used under irrigated conditions in a given season was lower than that used under rainfed conditions (37 vs. 43 man-days per hectare, per cropping). That is, a decrease in labor demand per hectare accompanied the shift from rainfed to irrigated production. However, after one accounts for the higher cropping intensity on irrigated farms (1.9 crops per year vs. 1.3 under rainfed conditions), total annual labor use was approximately 36% higher with irrigation. These figures translate into total annual labor use of 70 days/ha on irrigated farms and 55 days/ha on rainfed farms. In other words, the shift from rainfed to irrigated production resulted in a 27% increase in total labor use per hectare. Data in Table 2 further show that family labor used in production fell following irrigation. As noted previously, the main beneficiaries of this shift were upland households: the annual number of days of upland labor hired per hectare rose 268% (albeit from a small base) during the transition to irrigated production.

Implications for patterns of activity on upland farms

The data in Table 3 highlight reported activities and outcomes on upland farms before and after irrigation. Rates of forest clearing, average area cleared, and wage income all differ in the pre- and post-irrigation samples by statistically significant amounts. Data point toward a small but significant reduction in the proportion of households reporting forest clearing before and after

irrigation. The proportion of households reporting that they cleared forest during the previous year fell from 18% before irrigation to 12% after irrigation. Also significant is the change in reported area cleared. In the pre-irrigation sample the average area reported cleared (by those reporting land clearing) was 2.5 ha. In the post-irrigation sample the corresponding figure was 1.9 ha. Taken together, these statistics indicate that the annual rate of forest clearing declined 48% between the pre-irrigation and post-irrigation periods.¹⁰

Modest changes in upland agricultural practices were also observed following irrigation. Although the reported area planted to rice (the staple upland crop) did not change, the average area planted to corn (a cash crop), fell slightly, from 1.2 ha to 1.1 ha. Wages from employment on lowland farms more likely served as a substitute for cash income from corn production, than as a substitute for the staple crop.¹¹ The sharp spike in wages that followed irrigation suggests upland labor supply may be constrained by the marginal value product of labor on upland fields. Although upland households exhibit some willingness to abandon their main cash crop (corn) in favor of wage labor, it seems likely that a much larger wage increase would be necessary to precipitate upland abandonment of the main upland staple crop (rice). Moreover, in the long run, a key determinant of forest pressure in the area will be the way in which new income (both on lowland and upland farms) gets used (e.g. whether for chain saws, livestock, or fertilizer). Moreover, as Carter and Wiebe's (1990) analysis from Kenya demonstrates, the distribution of such gains may have important implications for not only forest pressure, but also for the trajectory of agricultural productivity and agrarian structure in the area.

Overall welfare changes for upland households cannot be completely assessed with these data. However, data on days of employment and average wage income support the hypothesis that lowland irrigation development improved welfare for upland households. The number of

upland households with wage employment rose following irrigation; the average number of days of employment on irrigated farms rose considerably; and the average reported daily wage was two-thirds higher after irrigation. These patterns corroborate local reports that the labor market experienced a “boom” following irrigation. Aggregating across all households, data show that the aggregate amount of wage income reported by the sample of upland respondents increased nearly 3-fold following irrigation.

V. OPTIMAL LABOR USE AND FORECASTS OF POTENTIAL LABOR SHEDDING

Although these empirical findings are encouraging, one needs to exercise caution in concluding that lowland irrigation will unambiguously reduce forest clearing, even where scope remains for expanding the lowland area under irrigation. In particular, data presented above reveal only the initial, short-run impact of irrigation on patterns of labor demand on lowland farms. To investigate whether these employment gains might be sustained over time, the analysis now moves beyond discussion of observed patterns to ascertain whether the logic of profit maximization might eventually lead lowland farmers to use less labor-intensive combinations of inputs. The goal of this analysis is to predict whether logical changes in lowland farmer practices might reverse the beneficial impacts of irrigation highlighted above. To get at these issues, simulation results based on the empirical data are used. The analysis follows a standard approach to measuring and forecasting factor demands. To begin, production functions were formulated and estimated econometrically. Regression results were then used to derive profit-maximizing input levels conditional on observed input and output prices. By estimating optimal labor use under irrigated conditions, and by comparing these results to input levels observed on rainfed

and irrigated farms, it is possible to draw inferences regarding changes in labor demand and rates of forest clearing that could arise over time in response to irrigation.

Table 4 contains regression results from ordinary least squares (OLS) and stochastic frontier (SF) production functions. In both regressions the logarithm of per hectare output serves as the dependent variable and the functional form used is Cobb-Douglas. Both regressions contain identical sets of independent variables, with the exception of two error parameters that appear in the SF model. The SF model was estimated under the assumption of an exponential error structure. The logic behind using these specifications is that observed labor use may not reflect the most profitable or efficient use of labor and that, over time, lowland farmers may adopt factor shares that more closely resemble the most profitable production strategies. Clearly, other—and more flexible—formulations of the production function are possible. The goal here is merely to explore alternative views of labor demand that are supported by the data.

As the results in Table 4 indicate, all parameter estimates in the regressions have the expected signs and most are statistically significant at the 90% confidence level or above. Labor, fertilizer and pesticide all contribute positively to yields. The wet season is associated with higher yields. The negative sign on farm size suggests smaller irrigated farms in the sample were either more efficient in their production or occupied more productive land. Owner-occupied farms reported significantly higher yields than rented farms. The source of the difference, however, remains unobserved. The regressions exhibit strongly diminishing returns to input use. An important difference between the OLS and SF results arises with respect to the relative importance of labor and fertilizer: the marginal impact of labor is substantially lower in the frontier specification, while the marginal impact of fertilizer is somewhat higher. Based on a

likelihood test suggested by Pollak and Wales (1991), the SF model is preferred to the OLS model on purely statistical grounds.¹²

Regression results reported in Table 4 were used to derive profit-maximizing input levels, conditional on input and output prices, to determine input levels that would constitute profit-maximizing optima for a representative irrigated farm. Derived input levels are reported in Table 5, along with levels observed on rainfed and irrigated farms. In interpreting results in Table 5, it is important to recall data from Table 2 showing that, for this sample of lowland farms, the shift from rainfed to irrigated production led to a 13% reduction in labor demand per hectare, but that an increase in cropping intensity boosted effective (annual) labor demand per hectare by 27%.

In contrast, results in Table 5 suggest that, on irrigated farms, observed levels of labor use exceeded levels derived from the OLS and SF models. In other words, irrigated farms appear to have been operating below profit maximizing levels, and the shift from observed to “optimal” factor proportions could be expected to generate additional labor shedding.¹³ How great might the reduction in labor use be? In the case of the OLS parameter estimates, effective labor demand falls to 62.4 days/ha/yr. This still represents a 13% increase over the rainfed baseline. But in the case of the SF parameter estimates, effective labor demand is predicted to fall to 43.5 days/ha/year—a 21% reduction in overall labor demand from the rainfed baseline. In other words, econometric evidence shows that if lowland farmers adopted a more efficient strategy for production on irrigated farms than was observed, the result would be a net *loss* of jobs. As the final row of Table 5 indicates, full utilization of irrigation in the dry season tends to offset these per hectare declines, though not entirely.

VI. CONCLUSIONS

This study examined whether technical progress in lowland agriculture led to increases in agricultural productivity and wages, and whether these changes, in turn, led to greater employment opportunities for low-income households living near the forest margin. The analysis showed that, compared with outcomes for rainfed conditions, irrigation development in lowland agriculture increased the probability of employment for upland residents, more than doubled the number of days of employment for those working on lowland irrigated farms, and increased the wage income of farms in the upland sample by a factor of three. Importantly, these short run changes coincided with reallocations of time away from forest clearing and hillside farming—especially of annual cash crops—in the uplands. This finding is important because it confirms that under the right agronomic and demographic conditions, lowland agricultural intensification—whether brought about through irrigation development or other means—can reduce pressure on forests and improve environmental outcomes in marginal upland areas.

Despite these fairly encouraging findings, the final section of the paper suggests caution in their interpretation. While irrigated farms exhibited fairly intensive use of fertilizers and pesticides, additional reductions in labor use could occur. Simulations based on econometric results indicate labor use would likely fall under profit maximization, perhaps by as much as 21% compared with rainfed production. This would be the case, for example, if lowland farmers adopted factor proportions consistent with profit maximization at the production frontier. It is also worth bearing in mind that the upland area studied in this paper is physically adjacent to the lowland area. As a result, generalizing these findings to locations where larger distances separate lowland and upland areas might be problematic: the opportunity cost of travel for upland households could discourage reallocation of labor from upland to lowland activities. Finally, it is

important to point out that, because factor substitution is driven in part by factor costs, government policies that reduce costs for pesticides or machinery without taking account of the favorable environmental impacts of more labor-intensive production could seriously undermine the beneficial impacts of rural employment reported here. In contrast, policies that encourage the use of rural labor—either explicitly, or implicitly through improvements in labor productivity—could prove to be powerful tools to reduce rates of forest clearing. Given the beneficial economic, environmental, and distributional impacts associated with drawing labor away from the forest margin, such policies could likely be justified on grounds of efficiency, environmental protection, and equity—a win-win-win situation. Space limitations preclude further investigation of the potential impacts of price and policy changes on observed patterns of employment and forest clearing, but based on empirical evidence from other frontier areas, these are likely to be extremely important conditioning factors over time, and warrant continued attention by researchers and policy makers.

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Notes

¹ The terms deforestation and forest clearing are not synonymous and their use is problematic.

When pressure on forests is low, forest clearing, which may take the form of cyclic clearing of trees followed by forest regeneration after fallowing, need not lead to deforestation.

Deforestation generally implies permanent loss of forest cover, which may or may not occur in response to short-cycle forest clearing by smallholders. In this paper, the term forest clearing is preferred, and is used to describe a set of activities undertaken by upland households that includes expansion of agricultural land and extraction of forest products such charcoal, fuelwood, or building materials that may temporarily or permanently alter the character of a forest.

² During the past three decades, Philippine economic policies also have played an important role in promoting the expansion of agriculture at forest margins. These policies have consisted mainly of market interventions directed at supporting and stabilizing farm prices and trade interventions directed at reducing dependence on imports and defending the livelihood of upland farmers.

Corn producers in particular—mainly upland farmers—have received considerable encouragement in the form of import restrictions and domestic price supports (Coxhead 1997).

³ Consistent with this view, the econometric results presented below show that production and agricultural revenue were higher on owner-occupied parcels of land than on rented parcels.

Evidence also suggests owners were more likely to hire workers than were renters.

⁴ For a farm household that sells labor, the pure income effect of a higher wage (the second term on the right hand side of equation [14] can in some instances dominate the substitution effect

resulting from a higher price of leisure. This is because when the level of consumption of leisure

is low, the marginal utility associated with consuming an additional unit of leisure is sufficiently high that it outweighs utility gains from consumption of other goods. In the sample studied in this paper all of the lowland households were either self-sufficient or net purchasers of labor.

⁵ In many cases hired labor may be an imperfect substitute for family labor, especially if supervision is difficult or costly. This can dampen incentives to replace family labor with hired labor. For an example from a different location in the Philippines, see Coxhead, Shively, and Shuai (1999).

⁶ Wages at the field site depart from those prevailing elsewhere in the Philippines. Wages are determined locally due to remoteness of the area and relatively low population density in surrounding areas. Agricultural wages depend on the nature of tasks performed, the perception of worker productivity (upland workers tend to be paid slightly less for the same task than lowland workers), and the season in which they are performed. Planting and harvest periods in the lowlands tend to coincide with those in the uplands. As a result, the wage adjusts throughout the year in response to the opportunity cost of labor. To the extent irrigation facilitates cropping during the dry season, some of the gains in employment documented for upland workers arise from reductions in the planting of the dry season crop (corn), rather than the wet season crop (rice).

⁷ Not all households engage in all activities, of course. If a household specializes (either by choice or due to resource constraints), an appropriate modification of equation [18] may be required to account for inequalities. The deviation of shadow prices from market prices will depend, in general, on transaction costs, risk aversion, and the covariance of risks across activities (for a discussion, see Sadoulet and de Janvry 1995). A household's apparent failure to

equate marginal returns may actually reflect attempts to equate shadow values. This will especially be the case if production and consumption decisions are made jointly.

⁸ Rising wages also will tend to draw labor from neighboring lowland communities, or even induce migration from a distance, but only to the extent information about the wage premium is known, and only if the premium is sufficient to compensate for transport and dislocation costs.

⁹ Based on rates of forest clearing reported by respondents and the estimated 30% sample frame, newly cleared area represented about 7% of all cropped area in the uplands. However, not all area cleared constitutes destruction of primary forest. Data from the site suggests that about 30% of newly planted area in 1996 had been virgin forest in the preceding year, 46% had been degraded forest and shrubland, and 24% had been grassland.

¹⁰ It is difficult to find a compelling competing explanation for the reduction in cleared area. No major expansion of cash crops took place immediately prior to irrigation and no fundamental change in economic policy occurred that strongly influenced crop prices over the period. Although the Philippines was hit by the Asian crisis and spontaneous currency devaluation beginning in mid-1997, it seems unlikely that this could have led to the reduction in forest clearing observed in the 1997 data. If anything, depreciation of the peso would have made export crops more lucrative, but the data show a reduction in forest clearing post-depreciation, not an increase. The only remaining possibility is that the reduction in rainfall associated with El Niño weather patterns might have discouraged agricultural activities during late 1996 and early 1997, and thereby reduced demand for new parcels of land. Follow-up data from the area will be needed to gauge the importance of these external effects, however.

¹¹ Data reported by Shively (1998) show an inverse relationship between agricultural capacity and rates of perennial crop adoption in the area. These results suggest poverty alleviation might not only reduce rates of forest clearing in an upland community, but also encourage a transition to more sustainable perennial-based cropping patterns on upland farms.

¹² The asymptotic criterion for model selection is a choice between nonnested hypotheses. Let H_1 represent the hypothesis that the OLS model is correct and let H_2 represent the hypothesis that the SF model is correct. Let n_1 = the number of parameters in the OLS model and let n_2 = the number of parameters in the SF model. Finally, let L_1 = the log-likelihood value of the OLS model and let L_2 = the log-likelihood value in the SF model. The test proposed by Pollak and Wales (1991) is based on a likelihood dominance criterion (LDC) and advises the following grounds for model selection:

LDC prefers H_1 if $L_2 - L_1 < [C(n_2 + 1) - C(n_1 + 1)] / 2$

LDC prefers H_2 if $L_2 - L_1 > [C(n_2 - n_1 + 1) - C(1)] / 2$

where $C(v)$ is the critical value of the chi-square distribution with v degrees of freedom at some fixed significance level. In the case of the models reported in Table 4, relevant data are $n_1 = 7$, $n_2 = 9$, $L_1 = -5.76$, $L_2 = -3.38$. Since $L_2 - L_1 = 2.38$ exceeds the 95% critical bound $[C(n_2 - n_1 + 1) - C(1)] / 2 = 1.99$, the test indicates a statistical preference for the SF model.

¹³ As noted in the text, the regression results from Table 4 were used to parameterize a profit function for irrigated operations. One might question whether profit maximization accurately represents the goals of farmers. Martinez and Shively (1998) argue the observed increase in labor use accompanying irrigation could reflect other considerations by farmers, including risk aversion.

Table 1 Characteristics farms in the sample

	Lowland		Upland ^a	
	Rainfed	Irrigated	With off-farm work	Without off- farm work
Farm size (hectares)	4.2	2.5	2.0	2.5
Household size (members)	4.8	5.8	4.9	4.8
Income per capita ^b (pesos/person, 1996)	25,364	22,604	3,224	4,586
Income per hectare ^b (pesos, 1996)	25,921	41,651	6,783	7,302
Tenure security (% w/title)	78%	48%	42%	43%
Rice yield (kgs/ha)	3,200	3,639	1,733	1,833
Effective cropping (crops/yr)	1.2	1.9	1.0	1.0
Fertilizer use (kgs/ha or %)	180	157	29%	33%

— table 1 is continued on next page —

Table 1, concluded

Pesticide use	917	1,656	14%	10%
(pesos/ha or %)				
Total labor use	43	37	--	--
(days/ha)				
Family & shared labor	20	13	--	--
(days/ha)				
Hired labor	23	25	--	--
(days/ha)				
Forest clearing	--	--	16%	15%
(% of households)				
Charcoal and fuelwood	--	--	18%	23%
sales (% of households)				
Area of forest cleared	--	--	0.18	0.10
(ha/yr, average)				
Number of farms	45	53	83	21

Notes:

^a For upland households, data in this table are pooled across years and do not distinguish between pre-irrigation and post-irrigation periods.

^b At the time of the survey \$1 US = 25 pesos.

Table 2 Labor use, cropping intensity, and changes in labor use

	Rainfed (observed)	Irrigated (observed)	Change from rainfed case ^a
Family labor (days/ha)	18.2	12.7	-30%
Upland labor (days/ha)	1.6	4.3	+269%
Total labor (days/ha)	42.7	37.1	-13%
Cropping intensity (crops/yr)	1.3	1.9	+47%
Effective demand (days/ha/yr)	55.1	70.1	+27

Notes:

^a Data refer to observed means for the sample of farms without irrigation and the sample of farms with irrigation, irrespective of the period of observation.

Table 3 Forest conversion indicators before and after irrigation^a

	Pre-irrigation	Post-irrigation
Households reporting forest clearing (%)	18%	12% ^b
Average forest area cleared (hectares/year)	2.5	1.9 ^b
Area in rice (hectares)	0.95	0.94
Area in corn (hectares)	1.20	1.05
Lowland employment (days/household/year)	18	44 ^b
Average lowland agricultural wage (pesos/man-day)	45	75 ^b
Agricultural wage income ^c (pesos/household/year)	1,150	3,226 ^b

Notes:

^a “Pre-irrigation” refers to the period prior to irrigation: all lowland farms were rain fed. “Post-irrigation” refers to the period after which lowland irrigation development had taken place. At the time of the survey some lowland farms remained rain fed.

^b Indicates means are significantly different at a 95% confidence level.

^c Refers only to households who had employment on lowland farms.

Table 4 Production Function Results

<i>Independent variables</i>	OLS	Stochastic Frontier
Constant	6.7513	7.1929
	(0.3997)	(0.3408)
Log of labor	0.0988	0.0577
(man-day per hectare)	(0.0621)	(0.0513)
Log of Fertilizer	0.1309	0.1395
(kgs per hectare)	(0.0648)	(0.0629)
Log of Pesticide	0.0386	0.0324
(Pesos per hectare)	(0.0215)	(0.0198)
Season	0.2629	0.2204
{0,1}	(0.0534)	(0.0468)
Farm size	-0.0259	-0.0209
(hectares)	(0.0111)	(0.0096)
Tenure	0.1519	0.0783
(0=rented, 1=owned)	(0.0574)	(0.0526)

— table 4 is continued on next page —

Table 4, concluded

<i>Error parameters</i>		
θ	—	4.0158 (0.8817)
σ^2	—	0.1313 (0.0328)
R^2	0.36	—
Log-likelihood	-5.76	-3.38
Number of observations	105	105

Table 5 Predicted changes in labor demand^a

	Effective demand (days/ha/yr)	Change from rainfed (%)
Rainfed (observed)	55.1	--
Irrigated (observed)	70.1	+27%
Predicted (OLS)	62.4	+13%
Predicted (frontier)	43.5	-21%
Predicted (frontier, full utilization)	46.0	-16%

Notes:

^a Results are based on a representative three-hectare, owner-occupied farm.

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⁶ Wages at the field site depart from those prevailing elsewhere in the Philippines. Wages are determined locally due to remoteness of the area and relatively low population density in surrounding areas. Agricultural wages depend on the nature of tasks performed, the perception of worker productivity (upland workers tend to be paid slightly less for the same task than lowland workers), and the season in which they are performed. Planting and harvest periods in the lowlands tend to coincide with those in the uplands. As a result, the wage adjusts throughout the year in response to the opportunity cost of labor. To the extent irrigation facilitates cropping during the dry season, some of the gains in employment documented for upland workers arise from reductions in the planting of the dry season crop (corn), rather than the wet season crop (rice).

⁷ Not all households engage in all activities, of course. If a household specializes (either by choice or due to resource constraints), an appropriate modification of equation [18] may be required to account for inequalities. The deviation of shadow prices from market prices will depend, in general, on transaction costs, risk aversion, and the covariance of risks across

activities (for a discussion, see Sadoulet and de Janvry 1995). A household's apparent failure to equate marginal returns may actually reflect attempts to equate shadow values. This will especially be the case if production and consumption decisions are made jointly.

⁸ Rising wages also will tend to draw labor from neighboring lowland communities, or even induce migration from a distance, but only to the extent information about the wage premium is known, and only if the premium is sufficient to compensate for transport and dislocation costs.

⁹ Based on rates of forest clearing reported by respondents and the estimated 30% sample frame, newly cleared area represented about 7% of all cropped area in the uplands. However, not all area cleared constitutes destruction of primary forest. Data from the site suggests that about 30% of newly planted area in 1996 had been virgin forest in the preceding year, 46% had been degraded forest and shrubland, and 24% had been grassland.

¹⁰ It is difficult to find a compelling competing explanation for the reduction in cleared area. No major expansion of cash crops took place immediately prior to irrigation and no fundamental change in economic policy occurred that strongly influenced crop prices over the period. Although the Philippines was hit by the Asian crisis and spontaneous currency devaluation beginning in mid-1997, it seems unlikely that this could have led to the reduction in forest clearing observed in the 1997 data. If anything, depreciation of the peso would have made export crops more lucrative, but the data show a reduction in forest clearing post-depreciation, not an increase. The only remaining possibility is that the reduction in rainfall associated with El Niño weather patterns might have discouraged agricultural activities during late 1996 and early

1997, and thereby reduced demand for new parcels of land. Follow-up data from the area will be needed to gauge the importance of these external effects, however.

¹¹ Data reported by Shively (1998) show an inverse relationship between agricultural capacity and rates of perennial crop adoption in the area. These results suggest poverty alleviation might not only reduce rates of forest clearing in an upland community, but also encourage a transition to more sustainable perennial-based cropping patterns on upland farms.

¹² The asymptotic criterion for model selection is a choice between nonnested hypotheses. Let H_1 represent the hypothesis that the OLS model is correct and let H_2 represent the hypothesis that the SF model is correct. Let n_1 = the number of parameters in the OLS model and let n_2 = the number of parameters in the SF model. Finally, let L_1 = the log-likelihood value of the OLS model and let L_2 = the log-likelihood value in the SF model. The test proposed by Pollak and Wales (1991) is based on a likelihood dominance criterion (LDC) and advises the following grounds for model selection:

LDC prefers H_1 if $L_2 - L_1 < [C(n_2 + 1) - C(n_1 + 1)] / 2$

LDC prefers H_2 if $L_2 - L_1 > [C(n_2 - n_1 + 1) - C(1)] / 2$

where $C(v)$ is the critical value of the chi-square distribution with v degrees of freedom at some fixed significance level. In the case of the models reported in Table 4, relevant data are $n_1 = 7$, $n_2 = 9$, $L_1 = -5.76$, $L_2 = -3.38$. Since $L_2 - L_1 = 2.38$ exceeds the 95% critical bound $[C(n_2 - n_1 + 1) - C(1)] / 2 = 1.99$, the test indicates a statistical preference for the SF model.

¹³ As noted in the text, the regression results from Table 4 were used to parameterize a profit function for irrigated operations. One might question whether profit maximization accurately

represents the goals of farmers. Martinez and Shively (1998) argue the observed increase in labor use accompanying irrigation could reflect other considerations by farmers, including risk aversion.