Assessing Local and National Policy Options to Promote Sustainable Upland Farming in Southeast Asia: Insights from an Economy-Environment Model of the Manupali Watershed in the Philippines

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Abstract. Do the most promising policies to promote sustainable upland farming originate at the local or national level? Will coordination of local and national efforts produce better outcomes? Using a optimization-simulation model of the Manupali watershed in the Philippines we address these issues by comparing the economic and environmental effects of four sets of stylized policy changes: (1) local policies that restrict some forms of land use; (2) local attempts to subsidize environment-friendly technologies; (3) a crop-specific tax levied on vegetable producers; and (4) a hybrid approach that seeks to coordinate local technology initiatives with broader-based incentives rooted in pricing policy. We study the economic and environmental impacts of these stylized policy changes over a 10-year time horizon.

I Introduction

The protection and management of watersheds is both a local and national policy imperative throughout the developing world, especially in densely populated regions of South and Southeast Asia (Doolette and Magrath 1990; APO 1995). Biophysical links between upland farms and downstream water users are by now well known (e.g. Dixon and Easter 1986).[1] Unfortunately, policies to promote sustainable upland farming remain elusive.

In most tropical watersheds rates of land degradation depend upon decisions made by upland farmers. These decisions, in turn, are influenced by the interplay of wages, prices, and economic opportunities in the general economy (Coxhead 1997; Shively 1998; Coxhead, Shively, and Shuai 2002). To varying degrees circumscribed by resource constraints, personal goals, and societal norms, decision makers respond in predictable ways to policy changes instituted at local and national levels. But the ongoing process of economic decentralization and political devolution places pressure on local and national decision makers to define and articulate their spheres of influence and responsibility. This evolution in policy making raises questions about the appropriate point of entry for policy makers.

In this paper we use results from a simulation model of economy-environment linkages to study and compare some stylized policy options available to local and national policy makers for whom watershed protection is a goal. Our empirical focus is the Manupali watershed, in the Philippines.[2] Our results are based on a modeling strategy that captures, in a very basic way, the interrelationships of biological and economic phenomena. We investigate the budgetary, environmental, and human welfare implications of changes in land use induced by a range of policy instruments.

II Conceptual framework

In this section we provide a brief overview of the model we use in our analysis. Additional details regarding the model can be found in Shively (2000). The Appendix presents the mathematical structure of the model, which relates economic incentives to decisions and outcomes on representative farms. The model makes use of two main sources of information. Socioeconomic data, including panel data described in Coxhead, Shively, and Shuai (2002) are used to define resources and resource constraints, and to inform household level models of behavioral response. In addition, land use data are used to calibrate and develop baseline projections in the model. These data also are used to develop weights and scaling parameters for representative households and zones. In developing predictions of erosion outcomes and aggregate impacts, the model also relies on insights provided by several sources of agronomic and test plot data from the watershed.

The model is based on four representative households occupying four representative agro-economic zones in the Manupali watershed.[3] Table 1 briefly describes cropping patterns and characteristics of the four zones in the model. Data in table 1 are based on detailed farm survey data reported in several sources including Coxhead (1995), Coxhead and Rola (1998) and Rola, Tabien, and Bagares (1999). Each representative is defined in terms of the four-crop portfolio presented in Table 1. The crop shares listed in Table are based on household weights. This typology is a simplification, since in reality many households have the option of choosing from a much wider set of crops. Similarly, few households are strictly limited to a four-crop portfolio. Nevertheless, data in table 1 reflect essential patterns of production in the upper portion of the Manupali watershed and captures a significant degree of the variation in land use and outcomes. Few farms specialize. Instead, most grow a combination of food and cash crops. However, planting patterns suggest that some farmers may have better access than others to information and resources such as credit, inputs, hired labor, or improved planting materials.

The most widely grown crop in the upper Manupali watershed is white corn. Nearly all households in the upper reaches of the watershed grow white corn, and in 1994 white corn occupied approximately 48% of all cultivated area in the upper watershed. Although a market for white corn exists in the area, households typically grow it for home processing, storage, and consumption. Following white corn in importance (in terms of occupied area) are yellow corn (30%), coffee (12%), and vegetables (10%). Although historically vegetables occupied a small share of land area, production of cabbage, potato, and tomato has grown in popularity in recent years. Due to highly erosive and pesticide-intensive production practices, increases in vegetable production have created environmental concerns among some residents of the watershed. Table 1 also contains average slopes for each zone and average erosion rate estimates for major crops. These estimates provide parameters for predictions in the model.

The model is designed to simulate optimizing activity in upland agriculture and on-farm and off-farm consequences. The logic of the model is guided by choices regarding land shares for available crops. These choices are influenced by relative prices and yields (and by policies such as taxes or subsidies on crops), the relative market risks associated with the crops (measured by a variance-covariance matrix for prices), input costs, access to credit, risk aversion, and land quality (as measured by a composite farm-specific soil stock). The lowland sector is characterized by a receptor site where sediment accumulates, and where flows of nutrients and agricultural chemicals are monitored. Motivation for studying sediment comes from a study of lowland farms in the watershed, which indicated negative impacts from sediment on area planted to rice (Singh, et al., undated). In the model, the flow of erosion from upland households determines the rate of sediment accumulation (and nutrient and pesticide transport) at the receptor site. Holding constant slope and soil characteristics, erosion rates depend on crop shares and area planted.

The policy dimension of the model consists of crop-specific taxes and subsidies, crop- and technology-specific incentives, and policies to alter price variability in all or specific crops. Values for these parameters characterize the economic environment in which representative farmers make decisions. Outcomes of interest determined in the model include crop shares, levels of input use, levels of household income, erosion rates, downstream effects, and public sector budgets. Initial values for model parameters and stocks, as well as yield production functions and erosion rates were derived, where possible, from data collected in the Manupali watershed.

III Simulation results

We conduct a series of four policy experiments with the model. In selecting these experiments our aim is to investigate natural resource management policy scenarios that extend across a spectrum ranging from those emphasizing local focus and control to those that are more broadly based. These are: (1) a locally-mandated land-use restriction that prohibits vegetable growing; (2) a locally-mandated requirement that farms install and maintain appropriate soil conservation structures, combined with a lump-sum subsidy payment for doing so; (3) a 20% tax on the producer price of vegetables; and (4) a national/local cost-sharing policy in which revenues from a 20% tax on the producer price of vegetables are used to subsidize the local installation and maintenance of appropriate soil conservation structures. In all cases we conduct our policy experiments over 10-year time horizons and assume the policy changes are sustained for the full length of the simulation. To facilitate comparison, we convert cash flows to net present values (NPV), using a discount rate of 5%. We express outcomes as indexes relative to outcomes derived in the base run of the model. Results from these simulations are presented in table 2.

3.1 Land use restrictions

Given the importance of vegetable production within the watershed (both in terms of income generation and environmental outcomes) we begin our analysis with an investigation of potential economic and environmental impacts of restricting vegetable production in the watershed. We recognize that a complete ban on vegetable production is neither feasible nor desirable. Nevertheless, simulating such a policy provides insights into outcomes that would be associated with a relatively strict policy regime. A ban on vegetable production affects only vegetable producers, and tends to shift land allocation from vegetables into coffee production. The substition of coffee for vegetables in the model reflects a favorable relative price for coffee. Under lower coffee prices, farms would instead reallocate land to corn production. We also observe a slight tendancy for some former vegetable farmers to leave some land in fallow. Under the assumption of an open labor market, these farms instead sell their labor off farm. Under a less favorable off-farm employment scenario, farms would shift land into corn production.

The first row of table 2 indicates the impact of the land use restriction. Farm- and area-weighted aggregate income levels are reduced from base levels by approximately 15%. The ban clearly reduces incomes for vegetable growing farms, especially in early years where on-farm erosion has only a minor impact on yields. But the ban reduces incomes only to the extent that “next best” alternatives provide lower expected returns than vegetables. Accumulated sediment levels in year 10 are reduced by approximately 37% from base levels. This reflects the shift from vegetables to the less erosive forms of land use (coffee and fallow). Nitrogen loadings fall to approximately one-third of base levels, primarily because the nitrogen requirements of coffee and corn are less than those of vegetables. Similarly, since vegetables are the only crops in the model that require pesticides, the vegetable ban leads to an elimination of downstream pesticide loadings. The ban has no impact on the government budget.

3.2 Soil conservation with a lump sum transfer payment

In the second simulation we investigate the overall impact of a requiring the use of soil conservation in the watershed. We implement this policy by assuming labor is required to install and maintain soil conservation structures on each farm, and by deducting this labor availability (25 man days/hectare) from the level of available household labor. At the same time, we subsidize households for this reduction in available labor via an annual cash payment equal to the market value of the required labor (valued at the prevailing market wage rate). From the farm's perspective, however, labor is typically more valuable when used in crop production, so that, even with the subsidy payment, the technology imposition is not completely income neutral. The reduction in labor availability influences decisions to plant labor-intensive crops, especially vegetables, and results in an income loss for this reason. But the presence of soil conservation has the benefit of increasing yields for all crops, especially in later years of the planning horizon at which point yields are sensitive to the accumulated reduction in the soil stock.

The second row of Table 2 shows the impact of this policy. The net present value of aggregate household income remains essentially unchanged over the 10-year period compared with the base run. The policy does induce some labor distoritions: some households shift land toward coffee production due to the labor intensity of vegetable production relative to coffee and the loss of labor associated with soil conservation. But for the most part, income losses are offset by the transfer payment and the yield-maintaining properties of soil conservation. Without the transfer payments, aggregate incomes would fall by approximately 5%. Accumultated sediment is approximately 46% lower in this case than the base case, nitrogen loadings decline by 50%, and pesticide loadings decline by 52%. The NPV of public expenditures is approximately 391 pesos per hectare per year. It is important to note that these results are sensitive to assumptions regarding yield-soil loss relationships. The overall change in crop yields over time depends on the shape of the yield functions (with respect to the soil stock) and the assumed rates of erosion. With less responsive yield functions or lower rates of soil loss, the soil conservation policy could result in lower household income due to losses in labor availability. Furthermore, we use a relatively low discount rate of 5%. At higher discount rates, future changes in yields and incomes would count less, and therefore the soil conservation policy would be less attractive in NPV terms.

3.3 A tax on vegetable producers

Results from our third policy experiment, a 20% tax on vegetable producers, are reported in the third row of table 2. Simulation results suggests the tax leads to a slight increase in the incidence of coffee production and fallow in households that produce vegetables. But in general, vegetable growers maintain their emphasis on vegetables and sustain a loss in income: the 20% tax is insufficient to generate large changes in land use. Overall, the NPV of income, weighted and aggregated across all household types, falls by approximately 12%. The overall reduction in income is less than the amount of the tax for several reasons: incomes for households that do not grow vegetables in the base run of the model see no loss in income, and among vegetable producers, some tax avoidance occurs as households shift away from vegetables. On a watershed basis, the NPV of public revenue with the tax is approximately 529 pesos per hectare per year. This average, however, masks some important variability in tax revenue, which fluctuates and ranges from 1800 pesos/hectare in the year one to 47 pesos/hectare in year ten. The policy reduces sedimentation by 15% from base levels. Compared with the base, nitrogen and pesticide loadings are reduced by approximately 27% and 39% respectively, due to the decrease in vegetable production. For vegetable-producing households, some gains in income (vis-à-vis the base case) are registed in later years due to decreased cumulative erosion and the beneficial effect this has on yields.

It is important to point out that the main mechanism by which a tax influences an agricultural producer is by changing the relative price the grower receives for a crop – and therefore the expected income from growing the crop. However, the tax also influences the risk-return relationship associated with crops in the portfolio. This second factor is important in the model because some producers are assumed to be risk averse, i.e. concerned about income variability arising from price risk. For this reason, producers react to the tax with some degree of friction: they do not fully disengage from production of the taxed crop due to a desire to balance portfolio risks. In other words, the tax decreases household income, but the decrease in the household objective function (which incorporates risk considerations) is less in percentage terms than the tax itself.

3.4 Soil conservation in conjunction with a 20% vegetable tax

The final policy we consider combines local incentives to promote soil conservation with what we consider to be a more broadly based (i.e. nationally-determined) pricing policy for vegetables. Here we impose the 20% tax on the farm gate price of vegetables and use the revenues to provide subsidy payments for the use of soil conservation on all farms. Results are reported in the final row of table 2. Consistent with the tax policy outlined above, we observe increases in area under coffee and fallow. However, farms that produce vegetables have greater incomes relative to the base in some years due, in part, to the yield maintenance afforded by soil conservation.

The NPV of total farm income in the watershed falls by approximately 15% under this policy. Somewhat counter to our initial intuition, income falls by more in this case than under the tax policy alone. The reason for this is that the use of soil conservation causes a reduction in the availability of household labor. This, combined with the tax on vegetables, discourages their production by more than the tax alone. Yield maintenance is insufficient to compensate. Although detrimental to household incomes, this policy provides strong environmental benefits. Nitrogen and pesticide levels decline by 56% and 62% respectively, due largely to the shift out of vegetables. Sedimentation is likewise reduced by 49%. The government budget shows a net gain, as tax revenues more than offset the subsidy payments. However, the budget does not remain constant over time and the remaining surplus is insufficient to completely offset the losses in income induced by the policy. In years when rates of vegetable production are high the budget is in surplus. In contrast, several years show budget deficit. The government budget ranges from 1231 pesos per hectare to –328 pesos per hectare, with an average of +318 pesos per hectare per year.

IV Conclusions

In this study we used an optimization-simulation model to illustrate potential impacts of local and national policies to encourage sustainable land use. The model is based on a set of four representative households occupying four distinct agroecological zones. Households in the model choose crop shares, defined over a portfolio of subsistence food crops, annual and perennial cash crops, and fallow. Using empirically derived population weights, zone-specific transfer coefficients, and crop-specific erosion rates, we aggregate outcomes in these 16 household types to predict watershed-scale changes in land use, incomes, and environmental outcomes. The model incorporates risk considerations, labor and land constraints, and labor market opportunities and provides a stylized view of how households might respond to a range of economic policy changes.

We use this model to conduct four policy experiments. We find that, in general, economy-environment tradeoffs are difficult to avoid. Policies that generate large environmental improvements (measured in terms of reduced sediment and reduced nitrogen and pesticide flows) tend to either reduce household incomes in the short or long run, or place budgetary burdens on local government. Local bans on crops are expensive (to households) and less effective in curbing erosion than either soil conservation or soil conservation in conjunction with crop-specific taxes. We find that while income-neutral policies to encourage soil conservation may be useful in reaching erosion targets, they are costly to administer. One alternative approach might be a national-local cost-sharing plan, whereby revenues raised through crop-specific taxes could be used to subsidize local soil conservation initiatives. However, we find that, due to distortions induced in labor allocation decisions, combining such taxes with local mandates for on-farm soil conservation may be tricky, and could emerge as more costly from the perspective of overall household welfare than tax policies alone. These results therefore suggest the need for a close partnership between local and national NRM policy makers in designing and implementing policies to promote sustainable upland farming.

Table 1 – Cropping patterns and characteristics for representative zones in the model

	Cultivated area (ha)	*white corn (area share)*	*yellow corn (area share)*	*coffee (area share)*	*vegetables (area share)*	*Average slope (%)*
Zone 1 (forest-buffer)	4236	0.06	0.01	0.08	0.86	35%
Zone 2 (mid-watershed)	2207	0.14	0.02	0.11	0.83	25%
Zone 3 (mid-watershed)	5822	0.41	0.06	0.10	0.41	10%
Zone 4 (mid-watershed)	7931	0.46	0.40	0.06	0.35	5%
Erosion rate (tons/ha/yr)	--	50	50	25	60	--

Source: Areas and crop shares computed by the authors based from data reported in Rola, Tabien, and Bagares (1999); Slopes calculated using data reported in Bin (1994) Table 5.2. Erosion rates adapted from David (1984) Table 5 using data reported in Cruz, Francisco, and Conway (1988) and experimental results of Midmore (pers. comm.).

Table2 – Summary of simulation results

	HH income (% change over base)	*Gov't budget (surplus or deficit, pesos/ha/year)*	*Sediment (% change over base)*	*Nitrogen (% change over base)*	*Pesticides (% change over base)*
Ban on vegetables	-15%	0	-37%	-69%	-100%
Soil conservation with subsidy payment	-0%	-391	-46%	-50%	-52%
20% tax on farm-gate price of vegetables	-12%	529	-15%	-27%	-39%
Soil conservation +20% tax on vegetables	-15%	318	-49%	-56%	-62%

Appendix – Mathematical outline of the optimization-simulation model

The optimization-simulation model is constructed using Excel and STELLA. The latter is a computer simulation software package designed to model dynamic systems. The model consists of four representative upland farms that make crop portfolio decisions under uncertainty. We use a mean-variance framework for the household model in which a farmer attempts to maximize expected utility (assumed to be a weighted-sum of mean returns and expected variance in returns), subject to a set of resource (land and labor) constraints. The decision-maker is assumed to optimize his farm plan at the start of each year, but we assume that the farmer is myopic with respect to the future impacts of current decisions. We define variables in the model as follows: q_i is the share of land planted with crop i, b_i is the mean return for crop i, s_{ih} is the price variance for $i=h$ and the covariance for i ¹ h, and r is the coefficient of risk aversion.[4] The mean return for each crop is computed as the market price for the respective crop p_i adjusted for the tax imposed on that crop t_i, multiplied by the crop specific yield y_i, after which input costs, c_i, net of any subsidies s_i , are deducted. For simplicity we assume a unit cost function for each crop and normalize planted area on the farm to be one hectare. Each household has a set of choice variables $\{\theta_i\}$ at each year in the simulation. The household level problem is:

$$\max_{q_i} \sum_{i=1}^{n} b_i q_i - \frac{r}{2} \sum_{i=1}^{n} \sum_{h=1}^{n} s_{ih} q_i q_h \tag{1a}$$

$$s.t \sum_{i=1}^{n} q_i \leq I \tag{1b}$$

$$q_i \geq 0 \tag{1c}$$

where

$$b_i = (1 - t_i) p_i y_i - (1 - s_i) c_i \,. \tag{1d}$$

To incorporate policy parameters that might possibly affect income variance, the variance and covariance terms are modified as follows:

$$s_i^* = s_i (1 + g_i)^g \tag{2a}$$

and

$$s_{ih}^* = s_{ih} \sqrt{(1 + g_i)(1 + g_h)} \,, \tag{2b}$$

where g_i is the variance-adjusting policy parameter for crop i. Examples of policies that may reduce variance are those that reinforce the marketing infrastructure for agricultural crops, for example the transportation system through road construction. It is possible to assess the impact of crop-specific policies designed to reduce income variability for targeted crops. Examples of policies that could reduce income variability for specific crops include research into pest-resistant varieties or programs targeted at improving post-harvest handling for certain crops.

Erosion is measured at the farm level. Erosion depends on both physical phenomena and crop composition. We posit the farm-level function for erosion E:

$$E_{k,t} = f(q_i, G, T, R), \tag{3}$$

where erosion on farm k at time t is a function of crop composition, slope gradient G, soil type T and rainfall R. We expect the slope gradient to be positively related to erosion and for the erosion rate to increase at an increasing rate as slope steepness increases. A similar relationship holds for rainfall: the soil's ability to absorb rainfall decreases as the amount of rainfall increases, thus increasing the rate of erosion. Erosion is measured as a flow. In each period erosion decreases the stock of soil available on the farm via the equation of motion:

$$S_{k,t} = S_{k,t-1} - E_{k,t} \,. \tag{4}$$

In other words, the soil stock at any time *t* equals the soil stock at time *t*-1 minus the flow of erosion in period *t*. As noted above, this is a farm level outcome. Erosion also increases the stock of sediment accumulating off-site. The stock of sediment Q_t accumulates over both time and space. Defining w_k as a farm-specific erosion-sediment transfer coefficient and δ_j as a zone-specific sediment-delivery delay parameter, accumulation of sediment at the receptor site is:

$$Q_t = Q_{t-1} + \sum_{t=0}^{t} \sum_{j=1}^{m} d_j \sum_{k=1}^{q} w_k E_{k,t} \tag{5}$$

where *t* equals the number of periods in the history of the simulation, *m* equals the number of zones, *q* equals the number of representative farms within each zone, and *E* is defined as above. Note that past erosion events contribute to sediment according to a delay specified by δ_j. Site-specific erosion affects sediment via a conveyor process: the stock of sediment at time *t* is equal to the stock at time *t*-1 plus the flow of erosion from zone *j* that reaches the receptor site by *t*.

Viewed from the perspective of erosion and its local affect on the soil stock, the model described thus far characterizes a simple dynamic model with a positive feedback loop. During each planting season the farmer chooses an optimal crop portfolio. This generates erosion. The flow of erosion decreases the soil stock and reduces subsequent yields. We model this feedback explicitly by formulating crop-specific production functions of the form:

$$y_{i,k,t} = f_i\left(K_{i,k,t}, L_{i,k,t}, S_{k,t}\right). \tag{6}$$

Two other technical features of the model are worth noting. First, the model allows for the measurement of welfare at the level of the household, the zone, or the watershed. These welfare measures can be computed at a point in time, or can be expressed as the present discounted values of the stream of incomes, summed across households. Using *r* to represent the discount rate and $\beta_{k,t}$ to represent net income at time *t* for household *k* (i.e. $\Sigma\theta_{i,t}\beta_{i,t}$), and using ω and *n* to represent area weights for representative households and zones, respectively, the NPV formula for the household is:

$$W_k = \sum_{t=0}^{T} \left(\tfrac{1}{1+r}\right)^t b_{k,t} \,. \tag{7}$$

For the zone it is:

$$W_j = \sum_{k=1}^{q} w_k \sum_{t=0}^{T} \left(\tfrac{1}{1+r}\right)^t b_{k,t} = \sum_{k=1}^{q} w_k W_k \,. \tag{8}$$

And for the watershed it is:

$$W = \sum_{j=1}^{m} u_j \sum_{k=1}^{q} w_k \sum_{t=0}^{T} \left(\tfrac{1}{1+r}\right)^t b_{k,t} = \sum_{j=1}^{m} u_j W_j \,. \tag{9}$$

A partial measure of the impact of policies on the government budget can be calculated based on taxes and subsidies applied to crops or inputs. The budget is partial in the sense that we can compute the costs of taxes and subsidies on crops or inputs, but cannot compute the costs of policies that might effectively stabilize markets (e.g. infrastructure improvements) or alter land tenure arrangements.

In terms of the entire watershed, the budget impact of a policy depends on the intervention (tax or subsidy rates), the behavioral outcomes at the farm level (e.g. crop choice), and the household or zone-specific weights applied to representative households. The NPV computation is:

$$B = \sum_{t=0}^{T} \left(\tfrac{1}{1+r}\right)^{t} \sum_{j=1}^{m} u_{j} \sum_{k=1}^{q} w_{k} \sum_{i=1}^{n} q_{i,k,t} \left(t_{i,t} p_{i,t} y_{i,k,t} - s_{i,t} c_{i,t}\right), \qquad (10)$$

where variables are defined as above. Time subscripts in equation (10) indicate that tax or subsidy rates may change over time.

Notes

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[1] High rates of hillside erosion and downstream sedimentation are among the most important agricultural externalities in the developing world (Anderson and Thampapillai 1990; World Bank 1992). Suspended solids and transported nutrients and agricultural chemicals reduce the quality of drinking water (Munasinghe 1992). Siltation of streams increases risks of flash floods (UNESCO 1982). Accumulation of silt reduces productivity of aquatic ecosystems (OECD 1993). And accumulation of sediment in reservoirs reduces hydroelectric capacity and equipment life (Naiman 1995). Of additional concern is that erosion from upland farming creates sediment in downstream irrigation systems, reducing both their productivity and expected life (e.g. Cruz, Francisco, and Conway 1988; DuBois 1990). This is especially important in light of evidence that a lack of reliable water supply precludes expansion and intensification of agriculture in many low-income areas of Asia (Myers 1988; Svendson and Rosegrant 1994). Estimates from the Philippines suggest 74-81 million tons of soil are lost annually, and 63-77% of the country's total land area is affected by erosion (FMB 1998). Sedimentation has reduced storage capacity at all of the Philippines' major reservoirs, and has measurably affected domestic water consumption, power generation, and irrigation. Over the last 25 years dry season irrigated area has fallen by 20-30% in several of the country's key irrigation systems (FMB 1998).

[2] The Manupali watershed is located in north central Mindanao, in the Philippine province of Bukidnon. It extends from Mt. Kitanglad in the northwest to the Pulangi River in the southeast. Average elevation is 600 m above sea level. Average rainfall is 2300mm. Soils in the area are clay and clay loams that are slightly to strongly acidic. The study site is described in greater detail in Bin (1994).

[3] Bin (1994) identifies six agroecological zones in the watershed and divides the agricultural environment into three distinct groups. Two of these are upland agricultural areas and one is a lowland paddy rice zone concentrated in lower elevations on slopes less than 2°. The latter zone is not incorporated into this analysis. We further decompose the upland zone into the four zones studied here.

[4] Risk sensitivity in the model is controlled via this farm-specific risk aversion parameter. This can be adjusted to differentiate households by risk preferences or can be used for sensitivity analysis.

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