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Payments for environmental services in upper-catchments of Vietnam: will it help the poorest?

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Abstract: In Asia, there is a surge of interest in the development of Payments for Environmental Services (PES) programs. They represent a new approach that focuses directly on creating a conditional benefit transfer between providers and beneficiaries of environmental services. More specifically, in Vietnam, a Fund for the Protection and Development of Forestry has been recently established that puts in place the mechanisms for the payment of fees by downstream users of watershed services to finance forestry projects in the upper-catchments. This paper reviews the potential response of upland farming households to a PES scheme that rewards them to set aside part of land for the production of environmental services. We examine the viability of PES schemes targeted at agricultural households of the upper-catchments in Northern Vietnam. We focus our attention on households identified as the poorest in the upper-catchment areas, i.e. those with a small endowment of productive land, limited access to water for irrigation, and low access to markets. We find that farmers are unlikely to participate in a voluntary land retirement program unless they are 'compensated' for the loss in food production and a 'forced' set aside program is likely to generate an overall negative impact on both poverty and environmental protection. Development and dissemination of improved technologies that increase food yields is a complementary strategy to promote environmental protection.

Keywords: Environmental services, land set-aside, modelling, poverty, shifting cultivation, Vietnam

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1. Introduction

Payments for Environmental Services (PES) schemes present a new approach that focuses directly on creating a conditional benefit transfer between providers of environmental services, in this case the uplanders, and the downstream beneficiaries of these services. PES schemes are based on the principles that those who benefit from environmental services should pay for them, and that those who contribute to generating these services should be compensated for providing them. Hence, the approach seeks to create mechanisms that internalize what would otherwise be an externality (Pagiola et al. 2008). Such schemes can take the advantage of upland-lowland interactions in generating environmental benefits while improving the livelihoods of upper-catchment agricultural households.

The past few years have witnessed a surge of interest in the development of PES schemes in Asia (e.g. Boquiren 2004; Pattanayak 2004; Suyanto et al. 2005). In Vietnam, while some projects using the conceptual framework of PES are being initiated in the central and southern part of the country (e.g. WWF 2007), no PES schemes are currently being implemented in the upper catchment areas of Northern Vietnam (Wunder et al. 2005). However, the Vietnamese government expressed recently its interest in starting such a scheme to protect fragile upper-catchments whose degradations are causing problems, among others, on hydro-electric infrastructures. In particular, the Vietnamese government recently created a « Fund for the Protection and Development of Forestry » that puts in place the mechanisms for the payment of fees by downstream users of watershed services to this fund. The money collected will then be used to finance forestry projects in the upper-catchments. For the moment, the main potential payees are the hydro-power plants, and the tourism industry (Government of Vietnam 2008), and the main potential beneficiaries would be farming households.

Deforestation and slash-and-burn cultivation techniques are often blamed as the main causes of land degradation and deforestation in upper-catchments. A mix of incentives (subsidies), technical assistance on improved and sustainable agricultural practices, and regulation have been used to address the problem. However, such practices have not been widely adopted by farmers. In an attempt to meet their short-term livelihood needs, many agricultural households are still employing agricultural practices that are unsustainable in the long term. Land use practices, which would bring about environmental benefits, include forest plantation, agro-forestry systems, tree-based land use alternatives, and agro-ecologically sound practices such as conservation agriculture (Gouyon 2002). However, the environmental services these land use practices provide, i.e. watershed services, biodiversity conservation and carbon storage are usually un-rewarded and only indirectly connected to economic activities (The et al. 2004).

Agricultural households in upper-catchments have unequal access to natural resources. The upper-catchments are generally composed of narrow valley bottoms where irrigated rice fields are found and of surrounding sloping land where upland rice, maize and cassava are the principal crops. Forested areas are scattered on the sloping land and are now usually found at large distances from villages. The differential access to these land resources is an important determinant of household farming practices and livelihood strategies.

The main objective of this paper is to review the potential response of upland households to a PES scheme that rewards them to set aside part of land for the production of environmental services.

In the first section of this paper, we review briefly the economic literature on PES and their potential impact on poverty. This review focuses on papers that unveil the possibility of negative impact on poor farming households that can not participate as service providers in a potential PES program. Given the possibility of negative impacts, we propose a framework to evaluate ex-ante the response of poor farming households in the Northern provinces of Vietnam. The second section describes the study area and the current farming systems. Then we propose a stylised typology of farming households in that region. In the third section of the paper, we develop a farm household model, and show how it can be used to anticipate farmers' participation in potential PES programs and impact on their production strategy. Finally, in the fourth section, we examine the likely viability of PES schemes targeted at agricultural households of the upper-catchments in Northern Vietnam. We focus our attention on households identified as the poorest in the upper-catchment areas, i.e. those with a small endowment of productive land, limited access to water for irrigation, and low access to markets. We find that farmers are unlikely to participate in a voluntary land retirement program unless they are 'compensated' for the loss in food production through in-kind grain transfers or through the promotion of technologies that increase food yields.

2. PES and poverty

PES approach was initially conceptualized and undertaken as a mechanism to improve the efficiency of natural resource management, and not really as a mechanism for poverty reduction (Pagiola et al. 2005). However, the recent attractiveness of PES to policy-makers is that both environmental degradation and rural poverty in upper-catchments may be mitigated by this approach (Landell-Mills and Porras 2002).

However, some authors have also warned that the impact of PES programs on poverty may not always be positive (Wunder 2005). Land and labour market conditions can affect both participants and non-participants of PES programs. First, with insecure tenure, poor households in target areas may be evicted by powerful groups willing to capture the increased value of previously marginal land (Landell-Mills and Porras 2002). Second, PES schemes may have a positive impact on those who participate but a negative impact on poor households that are unable to participate, or on poor consumers. For example, a PES program that limits access to forested land may also exacerbate problems of landless households and herders, whose livelihoods depend crucially on gathering forest products (Kerr 2002). Third, PES can have a negative impact on farmers with small land area who derive most of their incomes as agricultural wage labour (Zilberman et al. 2008). Fourth, PES does not always result in poverty reduction as targeted poor households may be unwilling to participate if PES payments do not cover the opportunity costs of requested land-use adjustments (Wunder 2008). Finally, the targeted producers of environmental services may be unable to participate in the PES program because of insecure land tenure, lack of land title, small farm holdings, or lack of access to credit to undertake investments such as reforestation (Grieg-Gran et al. 2005; Pagiola et al. 2005).

This paper concentrates on the viability of participation of upland farming households in PES programs. An ex-ante analysis of the potential behaviour of farmers is proposed that takes into account their resource endowments, income levels and livelihood strategies. The focus of the paper is on households identified as the poorest in the upper-catchment areas, i.e. those with a small endowment of productive land, limited access to water for irrigation, and low access to markets. The specific policy intervention considered is a set-aside program that rewards farmers for retiring all or part of their land from food production.

3. A large diversity of situations in the upper-catchments of Vietnam

3.1. Study area

Most of the empirical work was conducted in the district of Van Chan of the Yen Bai province (Figure 1). This district, containing part of the *Hoang Lien* mountain range, is surrounded by the Red and the Black Rivers. Two communes, Nam Bung and Suoi Giang, have been selected for their contrasted characteristics in terms of water regimes, i.e. the ratio of lowland to upland areas, and access to markets. Both communes are situated at an average height of 900 m.a.s.l. and are populated by ethnic minorities, mainly Thai, Hmong and Dao. Both communes contain a large diversity of small catchments typical of the Northern provinces of Vietnam.

Upper-catchments are composed of narrow flat valley bottoms, usually used for paddy production, surrounded by sloping land. Terraces are also found in higher areas of the catchments. These terraces are either irrigated when sufficient water flows can be captured, or are conducted as rainfed lowland terraces. In either ways those terraces allow the use of draft power, and are affecting water flows within the catchment. Finally, distant forested areas provide the ground for

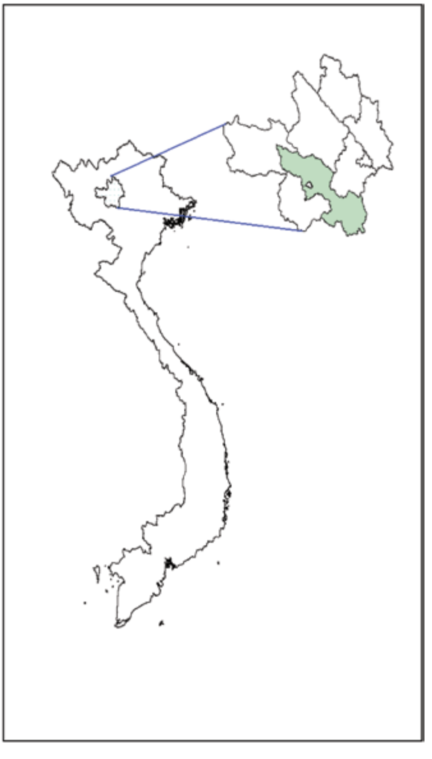

Figure 1: Map of Vietnam, with indication of the study area in Yen Bai Province.

complementary food needs e.g. hunting, fruit collection, and other non-timber forest products (Figure 2).

Agricultural households are conducting contrasted agricultural activities in those different compartments. In the valley bottoms, irrigated rice is cultivated continuously. Several rice crops are sometimes cultivated within one calendar year, depending on local conditions and farms constraints. Depending on their connection to markets and their financial constraints, farmers will use highly variable levels of external inputs such as hybrid rice, fertilizers and insecticides. However, for cash constrained households, only traditional rice varieties with no chemical inputs cropping systems are possible. On upper terraces, lack of water during the dry season reduces the possibilities to one rainfed lowland rice crop per year. However, other crops, such as maize and soybean are also found.

In contrast, agricultural activities are not continuous on the sloping land. Farmers alternate cultivation periods with fallow periods. In the study area, a typical cropping rotation will alternate eight to nine successive years of cropping with fallow. This sequence includes one to two years of dry-land rice cultivation, followed by two to three maize cropping years and several years of cassava cropping. Then, land is returned to fallow for several years before this cropping cycle is started again.

3.2. A typology of household situations

In upper-catchment areas, the major determinants of household livelihoods are land endowments, access to markets, and access to irrigation. Land endowments include not only the farm size but also the relative proportion of sloping uplands where rice is grown under dry-land conditions and paddy fields (such as terraced areas in lower slopes and valley bottoms) where rice is grown under wetland

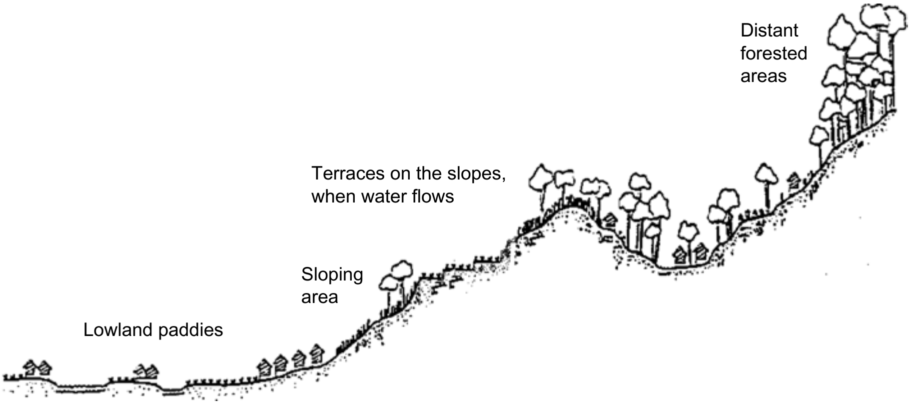

Figure 2: A cross-section of a typical upper-catchment in the Northern mountainous provinces of Vietnam.

conditions. Rice grown in paddy fields generally produces higher yields than grown in sloping fields. For a given farm size, households who have a higher proportion of paddies are hence more food secure than those with a higher proportion of sloping uplands. In addition, those who meet most of their rice requirements from paddy fields are likely to grow non-food crops in the sloping uplands. This effect is reinforced if the lowland fields are irrigated.

Access to markets (inputs, outputs, and off-farm employment) is another important determinant of livelihood strategies. Production systems tend to be subsistence-oriented in areas with poor access to markets. Commercial production systems evolve when access to markets is good.

Of the three main differentiating factors, the impact of access to water is mediated mainly through paddies where more intensive production of rice is possible when irrigation is available. The access to water is considered as a sub-category within the households with lowland plots. Hence, households can be classified into four categories based on the share of lowland in total farm area and access to markets (Table 1).

Farmers of the first group cultivate fragile sloping lands for their food needs. Fallow-rotation upland rice based systems are used: secondary vegetation is cut and burned, upland rice is cultivated for one or two seasons, followed by maize and cassava. After a few years of cultivation, land is left to fallow. The families usually complement food needs with products collected in surrounding forested areas. Food productivity tends to decline over time as land use is intensified (or fallow cycle is reduced) in response to rising population pressure.

Good access to markets offers the second group of farmers, who basically face the same constraints as the first group, more choices in their livelihood strategies. Off-farm work allows them to obtain monetary incomes. Purchased inputs can be used to prevent the decline in food productivity. Also, farmers can purchase food from the market when needed. The resulting environmental effects in sloping uplands tend to be positive or negative depending on whether farmers switch to perennial crops or intensify the land use in favour of annual crops. For example, the replacement of existing rice-fallow cultivation systems to maize-cassava continuous cropping systems for animal feed is likely to increase soil erosion and the associated negative externalities on downstream users.

Table 1: Simplified typology of households in upper-catchments.

		Land endowment	
		Higher proportion of sloping upland	Higher proportion of paddy land
Access to markets	Poor	1. Subsistence upland rice farming	3. Subsistence paddy farming
	Good	2. Commercial production of crops for markets	4. Commercial production in upland with rice in paddies

Of the four groups identified, farmers of group 1 tend to be the poorest and also the most vulnerable. Intensification of land use can take the form of reduced fallow periods or encroachment to forests—both producing negative externalities in terms of the environmental effects. Farmers of groups 2 and 4 are also likely to create substantial negative externalities on downstream users, especially those that grow annual crops in sloping areas; yet, their livelihoods are more resilient due to the opportunities provided by markets or due to a higher endowment with paddies for rice production, respectively.

For the remaining part of this paper, we will therefore concentrate on the impact of the PES scheme on the first group of farmers. A small model of their production systems will be developed, and simulations will be conducted to analyse their potential reactions to different types of PES schemes.

4. Modelling land use decisions of shifting cultivators

The model developed in this paper integrates the dynamics of soil fertility over time in a fallow rotation system and farmer decisions on labour allocation to farming. Shifting cultivation systems are characterized by alternating fallow and cropping cycles. The rationale for discontinuing cropping is two-fold. First, fragile sloping soils are degrading fast and crop yields tend to fall rapidly once the vegetation has been cleared. Since no external inputs are used to compensate for fertility losses, fallow periods are used to restore naturally the stock of nutrients in the soil. The time needed to restore soil fertility varies according to the climate and soil characteristics. In tropical rainforests, this may take 8 to 12 years (Ruthenberg 1980). Second, abandonment of fields after a few years of cultivation is also related to the invasion of weeds causing a sharp reduction of labour productivity after a few years of cropping in the absence of herbicide use.

For these subsistence-oriented shifting cultivation systems, a field cropped in the preceding season is left fallow if two conditions are fulfilled: (1) the discounted projected benefit stream of continued cultivation, calculated over a certain period is less than the one associated with the alternative options of concentrating efforts on the other opened fields, or by opening a new field, and (2) food production does not fall below the household food minimum requirements.

4.1. Household objectives

Upland farmers have many objectives, often conflicting ones. Achieving food security and increasing household incomes are two examples of objectives. The final decision making depends on these multiple objectives and how the households weigh achievements of various objectives against each other. Theoretical models of household decision making are based on the maximization of 'subjective' utility (Nakajima 1970). The objective function is often simplified for empirical modelling in terms of the income level achieved and food needs satisfied. Poorly-developed marketing infrastructure and institutions in remote uplands also force such simplifications by constraining the application of household economy models that consider both the consumption and production side together with the markets linkages (Singh et al. 1986).

In the simplification used here, a household is assumed to minimize the total labour use in food production subject to satisfying the family food requirements. This assumption implies that the household is basically subsistence-oriented with very limited interaction with markets (Group 1 household in Table 1). In the real world, upland farmers do have some interactions with the market and make land/labour use decisions in the light of market opportunities. In fact, most farmers fall somewhere in a continuum between fully subsistence-oriented and fully market-oriented. Analysis based on these extreme scenarios, although unlikely to be observed in the real world, can help generate insights into the farmer behaviour as conditions approach either fully market- or fully subsistence-oriented production. The quantitative modelling included in this paper is based on the assumption of fully subsistence-oriented production.

4.2. Temporal considerations

Most conservation decisions involve inter-temporal trade-offs: immediate gains of an action must be balanced against associated long term losses. Nevertheless, most farmers with pressing subsistence needs have high discount rates, resulting in very short planning horizons. Still, decisions taken at one point of time will influence future outputs and decisions. Hence, we used a recursive model, where households take decisions annually with short-term planning horizon, but have to bear the consequences of their previous choices.

4.3. Model structure and dynamics

Farmers make a number of decisions that are potentially relevant for the management of natural resources: cropping and fallow periods, crop choice, labour and other inputs, soil conservation investments, etc. We focused on three main interlinked mechanisms: nutrient dynamics, cropping and fallow periods, and labour allocation decision.

The model reproduces decisions of a farmer who has been allocated a given area of sloping land for individual management.

The following additional assumptions were also made:

- Land available to the household is fixed. Therefore, expansion of agricultural activities into open-access forest is not an option as is the case in Vietnam.
- Food requirements and labour supply are time invariant.
- It is assumed that the fertility status of each field *f* at period *t* can be described by only one parameter *FERT(f, t)*. This implies that one single nutrient is assumed to be globally limiting the production.

Nutrient dynamics and crop yields are influenced by household decisions at each period, i.e. cropping versus fallowing, and the quantity of labour input into crop production. In return, those decisions will be conditioned by the fertility status of fields, household food requirements and labour constraints.

4.4. Nutrient dynamics

Household land is divided into a fixed number of fields of equal size, among which a variable number is cultivated at any time. The field fertility approaches asymptotically a maximum level when the field is left fallow, and decreases proportionally when the field is cropped. Similar formulation has been used in resource use problems (Van Noordwijk 2002).

During fallow periods, the fertility of each field, *FERT(f,t)*, is updated for each time step by assuming that nutrients are re-generated at a rate depending on the initial fertility status of the field.

$$FERT(f,t+1) = FERT(f,t) + \alpha_1 . \left(1 - \exp\left(\frac{(fertM - FERT(f,t))}{\alpha_2} \right) \right) \quad (1)$$

Equation 1 ensures that the fertility of a given field in the next period is determined as the sum of its current fertility, plus a second term expressing the accumulation of fallow vegetation in the field, and in the soil. Equation 1, through the coefficient $\alpha 1$ and $\alpha 2$, ensures that large fertility increases are possible if the fertility is far below its maximum level *fertM*, and that fertility increases are decreasing as *FERT* approaches *fertM*.

During cultivation periods, fertility of the field decreases when it is cultivated. The fertility decrease is assumed to be proportional to crop yields during the season (equation 2)

$$FERT(f,t+1) = FERT(f,t) - \alpha_3 .YIELD(f,t) \quad (2)$$

where α_3 determined the fertility decrease per ton of obtained yield.

4.5. Land productivity

Yield obtained in each fields depends on its initial fertility and the labour use. Yield will increase asymptotically towards a yield ceiling $Y_0(t)$ as field fertility or labour input per unit area *LAB(f,t)* increase. The achievable yield is also assumed to be decreasing with the number of successive cultivating years (Equation 3).

$$YIELD(f,t) = Y_0(t). \left(1 - \exp\left(\frac{-c_1 .FERT(f,t)}{Year(f,t)} \right) \right) . \left(1 - \exp\left(-c_2 .LAB(f,t) \right) \right) \quad (3)$$

This production function ensures that marginal productivities of fertility and labour inputs are decreasing, and can be considered to be a continuous version of the von-Liebig production function (Paris and Knapp 1989; Paris 1992).

4.6. Land use and labour allocation

As discussed earlier, labour is allocated, fallow land is brought into cultivation and cultivated land is left fallow according to household decision rules involving factors such as household labour productivity and food sufficiency. The modelled households have no access to markets, so it was assumed that households choose the number of fields cultivated or left fallow and allocate labour among cultivated lands in order to produce enough food.

For each year, decisions about the number of plots cropped and the labour allocated in each of the cropped plot are simulated according the following process.

4.7. Construction of scenarios on which plots should be cropped/left fallow

Four scenarios are built: (1) the household cultivates the same plots that was cultivated in the previous year, (2) the household cultivates one new plot and do not leave any of the cropped ones fallow, (3) one of the cropped plots is left fallow, (4) one plot under fallow is cropped, and one cropped plot is left fallow. The plot with the highest value of *FERT(f,t)* is chosen as the newly cropped plot and clearing time *(opening(t))* is added to the labour needs. The cropped field with the lowest value of *FERT(f,t)* is chosen as the plot newly left fallow.

4.8. Identification of the most favourable scenario

For each scenario, a non-linear programming model is used to minimize the household's labour input, while producing the required food (equation 4) and respecting the family labour constraints (equation 5). For each scenario, the model obtains the allocation of labour to each of the cropped field under that scenario. This model is implemented using GAMS (Rosenthal 2007) with the non-linear programming solver CONOPT2 (Drud 2006).

$$\sum_{f}\left(size(f).YIELD(f,t)\right) \geq food(t) \tag{4}$$

Where *food(t)* represents the household food requirements;

$$\sum_{f}\left(size(f).LAB(f,t)\right) + opening(t) \leq flab(t) \tag{5}$$

where

- *LAB(f,t)* is labour allocated to field *f* (endogenous);
- *flab(t)* is the household available labour time.

The best scenario is retained and represents the decision taken during the year *t*.

4.9. Implementation of the decisions and step forward to the next year

Finally, the soil fertility index of each plot is re-calculated for the next time step under that scenario.

4.10. Base simulation settings and model behaviour

Empirical estimates of parameters for northern Vietnam conditions are not available. Parameter values assumed to initialize the model were calibrated to produce close resemblance with the upland rice yield trajectory generally applicable to upland conditions of northern Vietnam. The yield trajectory was constructed from the data generated from a household survey conducted in the Van Chan district, Yen Bai province in 2007 (Tai et al. 2007).

We modelled a farm household with 4 hectares of sloping land with no access to water for irrigation. The household labour force comprised of three adults, with the household having a total of five family members. Figure 3 (baseline scenario) shows the trajectory of the fertility index of a selected field over the years. The

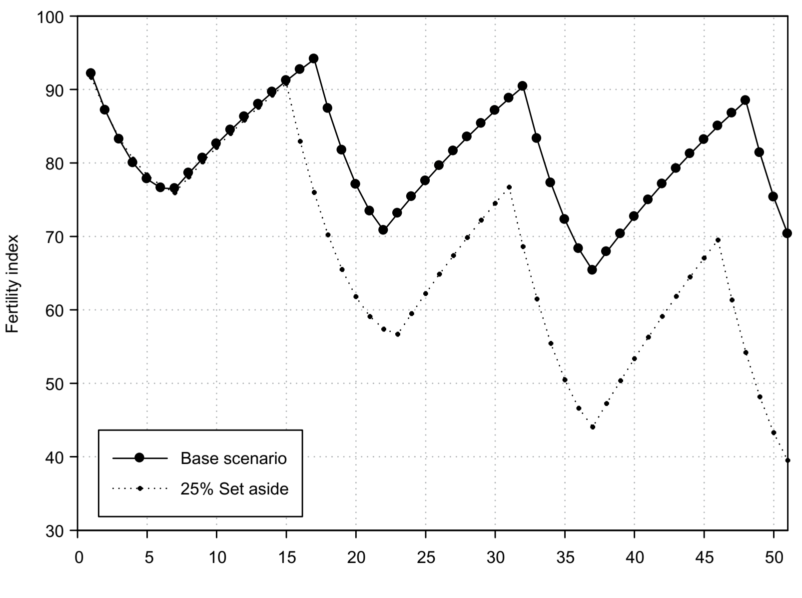

Figure 3: Nutrient status over time of one field under base and set-aside scenarios.

upward sloping part of the curve corresponds to fallow periods with the downward sloping part corresponding to the cultivation periods. A long cropping/fallow cycle of an average of 15 years is obtained, with around 5 years of cultivation and the remaining time for fallow. For the simulated farm, the average land fertility is decreasing over time suggesting that the simulated fallow-rotation systems are not sustainable over time. Similar downward long-term trends were observed even under different parameter assumptions.

5. Impact of proposed PES schemes

The model was used to analyze the impact of policy that would reduce the sloping land available for farming for the benefit of forested area. A 'set-aside' program basically reduces the land area available for use and is simulated by a reduced farm size, with other things remaining the same.

To simulate this scenario, we reduced the cropping area by 1 ha. A sharp decrease of soil fertility was observed over time in the area left for cropping. With less available land to agriculture, households were forced to reduce the fallow periods, and to cultivate their land for longer periods of time (see scenarios –25% of Figure 3). There is an overall decrease in the overall average fertility status (averaged between cropped and fallow land) despite an improvement in the fertility status of the land taken out from crop production over time (Figure 4).

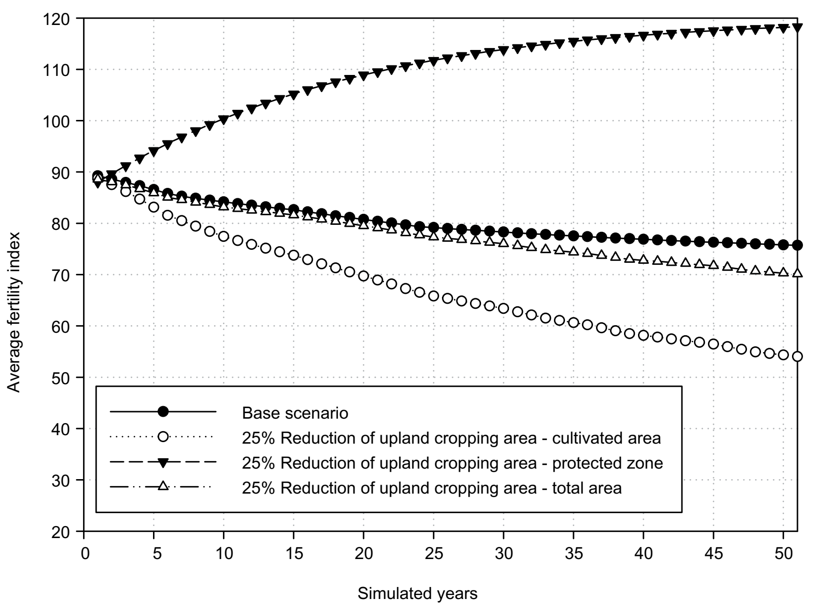

Figure 4: Impact on average plot fertility of a 25% reduction of cropping area without compensation.

Table 2: Variation of the average fertility index over a period of 20 years with a 25% reduction of cropping area without compensation.

	Base scenario	With 25% reduction of upland cropping area		
Year	Average	Cultivated area	Protected area	Weighted average
1	89.2	88.7	88.0	88.6
20	80.8	69.7	108.9	79.5
% Variation	–9.5%	–21.4%	23.8%	–10.2%

When considering the average effects of the scheme over a 20-year period with the current simulation coefficients, the impact on the average fertility of land (Table 2) is almost the same between the base scenario (no PES), and the scenario with PES (–9.5% versus –10.2%).

This result indicates that the overall environmental effects may well be negative over time since degradation is more likely to be shifted than really stopped. Besides the overall impact on farmers livelihood is negative since they have to use more labour to produce the food they need, and the land they control is degrading fast.

A mechanism for ensuring that households are able to meet their food needs is to compensate them for the lost food production resulting from the withdrawal of land. A sustainable land fertility status can be achieved by compensating farmers in the form of direct provision part of their food requirements. Such a provision may take the form of annual in-kind subsidy of grain. This mechanism was used by China’s Sloping Land Conversion Program that compensated farmers who converted degraded land to forests (Bennett and Xu 2005). It has to be noted, however, that the cost of making such transfers may be too high in remote areas to make it a viable strategy except for some limited areas.

Another solution would be to act upon farmers’ risk induced behaviours. As a matter of fact, households’ food requirements include a “buffer surplus” to be prepared for a bad climatic event or pest outbreaks. An in-kind insurance mechanism that would ensure a minimum grain supply during the low yield years is likely to increase the households’ well-being (by decreasing their vulnerability). Also, food transfers involved are likely to be less costly as they are limited to adverse years only. Nevertheless, the total cost will be substantial unless the program is limited to only a small area.

An effective and viable strategy to promote set-aside of land is to increase the yield per unit of agricultural land through the public provision of improved agricultural technologies. Pressure to intensify land use can be reduced if crop yields are higher as farmers will be able to meet their food needs from a smaller area. The success of ‘return land to forest’ program in the uplands of Yunnan, China is partly due to the availability of high yielding upland rice technologies (Pandey et al. 2005). In addition, such technologies help promote income generation by releasing resources (land and labour) that can be used to produce market-oriented crops without sacrificing the household food security. Investments in agricultural R&D and technology promotion may be considered by rural communities as a part of broader development interventions, not a part of PES. Nevertheless, at the sectoral level, such investments can be seen as a strategy to promote environmentally beneficial changes in land use.

6. Discussion and conclusion

This article developed a recursive dynamic model of shifting cultivators that integrated the dynamics of soil fertility over time and farmers decisions in order to analyse the potential effect of their participations in PES programs. The model predicted that farmers are unlikely to participate in a voluntary land retirement program unless they are 'compensated' for the loss in food production through in-kind grain transfers or through the promotion of technologies that increase crop yields.

The article also showed that if households are somehow forced into the program, through top-down selection of protected areas, this induces a reduction of environmental degradation in targeted zones, but an increase of environmental degradation on the remaining part of their land-holding. The overall net environmental effect could actually be negative. In addition, the overall effect on poverty would be negative since labour productivity diminishes progressively and farmers' food supply becomes more insecure.

This study used a simplified model of household behaviour in situations with limited access to markets. This forces farmers to intensify land use to meet the food requirement from the remaining farm area as land is set aside from agricultural production. An improvement in the access to markets and non-farm employment opportunities can relax this constraint by enhancing farmers' overall food entitlements even when production accounts for only a part of the total requirements. Environmentally beneficial land use patterns can evolve in a commercially-oriented system if property rights to land are well-defined (Pandey and Lapar 1998). Voluntary participation in PES schemes is also more likely when food entitlements can be enhanced through market participation.

Second, we have not studied the possibility of technological change that could be induced by a PES scheme. Technical solutions such as direct-seeding over mulch cropping systems (DMC) are potential alternatives to slash and burn practices for land-constrained farm households of the upper-catchments (Husson et al. 2000). When adopted, these technologies can generate positive externalities to downstream users through erosion control. However, a recent study carried out in Northern provinces of Vietnam shows that the adoption of these DMC systems is not immediately profitable for farming households (Affholder et al. 2008). Compensating farmers for the transition costs linked to the adoption of this new technology could potentially be very effective.

More generally, support to development and dissemination of improved technologies that raise land productivity is an important strategy to reduce the intensification pressure in fragile and to prevent environmental degradation. Such technologies could be considered as part of the larger schemes for encouraging farmers to adopt environmentally superior production and land use practices.

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