

Forest products as safety net, deforestation and the tragedy of the commons

Abstract

Non-timber forest products (NTFP) are commonly used by poor agricultural households of developing countries to smooth their consumption and to cope with agricultural risk. This paper explores the potential implications of this safety-net use on the land-use choice and labor allocation. We consider that the land-use is a long-run choice variable, while labor allocation is a short-term choice variable. In this context, it appears that risk reduction may have two opposite implications. In the short run, risk reduction tends to reduce the pressure on common resource extraction, while in the long run, risk reduction may tend to increase deforestation.

Keywords: deforestation, agricultural expansion, forest products, common property resources.

JEL classification: D23, Q15, Q23.

1 Introduction

Extraction of non-timber forest products (NTFP)¹ from open access forests is frequently used by poorer rural households of developing countries to cope with agricultural risk. Populations of interest are farming communities that rely on forest as a supplementary source of income (Byron and Arnold, 1999). We consider therefore communities imperfectly integrated into markets. More precisely, imperfections of credit and insurance markets are common in developing countries and especially in rural areas. Indeed, even with informal procedures to insure people and provide credits, studies note high income variabilities (see Townsend (1995) and Rosensweig (1988)).

The aim of this paper is to give a theoretical assessment of the impact of this safety-net use of NTFP on forest resources. We rely on two precedent papers analyzing this relationship. Delacote (2007) studies the potential impact of NTFP extraction on the land-use choice and thus on deforestation. The analysis is essentially similar to portfolio diversification. The representative household chooses its land use between a productive but risky activity (agriculture) and a safe but less productive use of land (NTFP extraction). In this context, it appears that risk reduction tends to increase deforestation. Indeed, if agricultural risk reduces, the household tends to reduce the size of the safe activity in its activity portfolio. It then increases the size of agricultural land.

Delacote (2009) analyzes the potential poverty-trap implications of the safety-net use of common property resources. The choice variable here is labor allocation (we consider the land use as fixed). NTFP are extracted from commonly held forests, which is represented by a tragedy of the commons: labor allocated by other households has a negative impact on one household's return. It follows that if too much labor is allocated to NTFP extraction from the commons, some households may be trapped in less productive activities and only get their minimum subsistence requirement from their activity. Risk reduction here may thus tend to reduce the pressure on the common resource. If risk reduces, less labor will be allocated to NTFP extraction, which reduces the tragedy of the commons and relax pressure on the forests.

¹The term "non-timber forest product" encompasses all biological materials other than timber which are extracted from forests for human use.

The aim of this paper is to combine those extensive and intensive analysis, making a simple assumption: land use can be considered as a long-term choice variable, with short-run rigidity, while labor allocation can be adjusted in the short run. From this assumption, we can conclude that a change in perceived risk may have two opposite environmental consequences, depending on the time path. If risk decreases, households may reduce their labor allocation to NTFP extraction in the short run. Pressure on the common resource may thus decrease. However, in the long run, less forests will be needed to be used as a safety net, which may lead households to increase the size of agricultural land, and thus increase deforestation. Overall, risk reduction may thus tend to reduce the pressure on the common resource in the short run, while increasing deforestation in the long run.

Section 2 gives a brief review of the literature, emphasizing the use of NTFP for poor agricultural households, describing the economics of land-use in agricultural areas and the insurance properties of common property resources. Section 3 presents a two-steps household model of land-use choice and labor allocation. Section 4 addresses some policy implications of the safety-net use of forest products and discusses the possible extensions of the model.

2 Review of the literature

2.1 The safety-net use of non-timber forest products

In developing countries, about 1.2 billion people rely on agroforestry farming systems that help to sustain agricultural productivity and generate income (World Bank, 2001). The risk-management role of forest products is particularly important in the rural systems of developing countries, given that agricultural crops face many risks, such as price shocks, seasonal flooding, unpredictable soil quality, pests, crop diseases or illnesses. NTFP can be used directly in consumption or sold to fill cash gaps. Formally, rural households, which have limited credit and insurance options, choose a diversification of their activities (thus of the land), in order to reduce aggregate risk (Morduch, 1995; Godoy et al., 2000). Some studies analyze this use of NTFP (Baland and Francois, 2005; Pattanayak and Sills, 2001). One of the results is that any individual is more likely to visit the forest if the crops are more risky or if he faces a negative shock. Godoy et al. (2000), in a study in Honduras,

argue that although NTFP extraction has a low annual value, it can provide insurance in the case of unexpected losses. This risk-management role can be particularly important in the case of common risk, because intra-village credit or insurance systems are more difficult to implement (Dercon, 2002).

NTFP extraction appears to be efficient as a risk-management tool for several reasons. First, a large variety of NTFP can be extracted, thus raising the diversification of activities. Several studies mention fuel, fodder, fibres, oil seeds, edible fruits, staple foods, vegetables, spices, rope, leaf-plates, medicinal plants, vines, honey, sap, Brazilian nuts, fruits bark and rubber (Kumar (2002), for rural India; Pattanayak and Sills (2001), for the Tapajos National Forest, Brazilian Amazon). Second, many NTFP do not have strong positive correlation among themselves or with agricultural output (Pattayanak and Sills, 2001), so that they can be efficient risk-management instruments. A bad agricultural output is not necessarily linked to bad forest product quantities.

Two characteristics of NTFP are important to note. First, there are low capital and skills requirements for NTFP extraction as well as open or semi-open access to the resource, so that poor households can easily extract the resource. Neumann and Hirsch (2000) argue that the poorest people are those who are most engaged in NTFP extraction. Second, NTFP gathering habitually presents low return to labor, so that they have poor potential to alleviate poverty (Wunder, 2001; Angelsen and Wunder, 2002). Studying Bagyeli and Bantu communities in South Cameroon, Van Dijk (in Ros-Tonen and Wiersum (2003)) gives an illustration of the relatively low share of NTFP in total income -which argues for the risk-management strategies- and of the link between poverty and NTFP use.

Hence, forests are competing for land-use, with agricultural use representing the most important alternative. Indeed, forest products have a low potential of poverty alleviation, but can be used to compensate shortfalls in agricultural yields. Conversely, agricultural crops may be a potential way out of poverty for households, but represent a high level of risk, especially if the households have low access to insurance or credit markets. The trade-off between these two activities is a major choice for poor rural households, and is a potentially driving force of deforestation and pressure on natural resources. An interesting topic is thus to analyze the land-use choice process of the households.

2.2 The land-use choice with NTFP extraction

Among the papers that study land-use choice by rural communities, only a few take into account the forest product use, and none study the risk-management use described here. Lopez (1998) notes the coexistence in most developing countries of private lands, intended for agricultural crops, and common property lands, namely forests, used for their products. In his paper, however, the two land-uses compete with each other and forest products is not a risk-management strategy. Specifically, Lopez analyzes the consequences of agricultural intensification and farm productivity improvement programs on the pressures on the common resource. The main factor determining the programs' impact on pressure on the common resource is the factor-intensity of the crops. If crops are labor-intensive, then a rise in their prices is likely to diminish the pressure on the common resource. However, if crops are land-intensive, the pressure is likely to rise with the commodity prices.

Parks et al. (1998) study the competing land-uses, mainly agriculture, timber and non-timber forest products. The paper distinguishes four cases, depending on the relative productivity of the different activities: joint management of forests, forest preservation, conversion to non-forest use, and forest abandonment. These four cases depend mainly on the impact of the age of the trees and the management effort on a profit maximization function.

2.3 Common property resources as safety net

The literature on land-use choice discussed above ignores the safety-net role that forests have when they are commonly held. Another part of the literature does, however, argue the importance of common property resources (CPR) as safety net. Baland and Francois (2005) find a negative impact of land privatization on the social welfare of a community. CPR represent for low skilled households a potential outside option to private projects, since CPR extraction often requires low skilled labor.

Pattanayak and Sills (2001) find that NTFP collection is positively correlated with agricultural shortfall and expected agricultural risk. According to Bromley and Chavas (1989), non-exclusive property rights can be seen as an integral part of risk sharing. In this case, the common forest can be considered as an asset of last resort (Baland and Francois, 2005). A strong link between poor people and CPR is often underlined. Dasgupta and Maler (1993)

argue that local commons provide the rural poor with partial protection in time of unusual economic stress. A study of tribal groups in rural Bihar qualifies communally-held forests as the only means of survival for poorer members in lean seasons (Agrawal, 1991). Reddy and Chakravaty (1999) observe in India a more intensive use of the CPR by poor households. Dasgupta (1987) notes a higher level of CPR products in low labor productivity regions. Johda (1986) finds a negative relationship between CPR income and rural inequalities.

The aim of this paper is to reconcile both types of literature, mixing the safety-net use of NTFP extraction with land-use choice and labor allocation.

3 NTFP extraction as safety net

We consider a village economy, with no access to outside credit, insurance or labor markets. This assumption makes sense in the context of poor rural communities of several tropical developing countries. The N households of the community allocate labor and land to two activities. First, labor and land can be allocated to private agriculture. Second, they can be allocated to NTFP extraction from open access forests. Each household can divide its labor and allocate a share to both activities.

We consider here that land allocation is a long-term choice variable and thus presents some inertia, while labor allocation can be adequately shifted every period. All factors are assumed to remain stable in time. Thus we can consider equilibrium for every period separately.

We consider that land is open access, and that forest clearing gives *de facto* property rights on the land, which is consistent with many observations in the developing world, where property rights are often poorly defined.

3.1 NTFP extraction and private agriculture

The representative household ² chooses the size of land s it will cultivate. s is thus our deforestation indicator, since agriculture expansion implies forest clearing. Moreover, the household allocates one unit of labor between NTFP extraction (l) and agriculture ($1 - l$).

²Assuming heterogeneous households would lead to different classes of households related to their labor allocation (see Delacote, 2009).

The motivation for fixing and normalizing to one the quantity of labor is twofold. First with no access to outside labor markets, labor used by agricultural households is bounded. Second, the fixed-labor supply assumption relies on the implicit assumption that the marginal utility of consumption (hence of net income) is always larger than the marginal utility of leisure. It follows that the household allocates all its available time to labor, in order to maximize net income. This assumption, although simplifying, appears to be valid in the considered context of poorer agricultural communities, and is quite common in papers describing such contexts (Amacher et al. (2009), Delacote (2009), Baland and François (2005)).

Agriculture: Agriculture provides uncertain returns ³: $A(E(\alpha); s; l)$. $E(\alpha)$ is an expected productivity factor on which uncertainty plays. We consider that the agricultural productivity factor is at least $\underline{\alpha}$, which means that households have knowledge of the worst agricultural return they may receive. This minimum productivity factor is the only risk factor needed to assess land use and labor allocation. This uncertainty may describe risk related to climate damages, floods and droughts, price shocks, crops pests...

We assume standard hypothesis about the production function⁴: $A_\alpha > 0$, $A_s > 0$, $A_l < 0$, $A_{\alpha\alpha} < 0$, $A_{ss} < 0$, $A_{ll} > 0$. To keep the analysis simple, we assume that the productivity factor is additive, that is has no effect on marginal productivity: $A_{x\alpha} = 0$, for $x = s, l$. Indeed, the additive risk assumption allows to consider a change in risk in a simple manner, and to derive exploitable analytical results without further assumptions.

The agricultural production function presents some discontinuity. Indeed, we consider that labor and land are substitutes below one threshold, but become complements above it. This threshold represents a labor capacity constraint. Labor allocated to agriculture implies a maximum size of land the household is able to cultivate: for all l , $s^{max}(l)$ is such that for all $s^0 > s^{max}(l)$, $A(s^0; l) = A(s^{max}(l); l)$. Thus land and labor are substitutes for $s < s^{max}(l)$ and become complements for $s \geq s^{max}(l)$. More labor allocated to agriculture raises the maximum size of land the household is able to crop: $s_l^{max} < 0$. Thus, the maximum size of land the household is able to crop is: $s^{max}(0)$. Finally, the household cannot cultivate any

³We consider here net returns, including production costs.

⁴The subscripts refer to first and second derivatives.

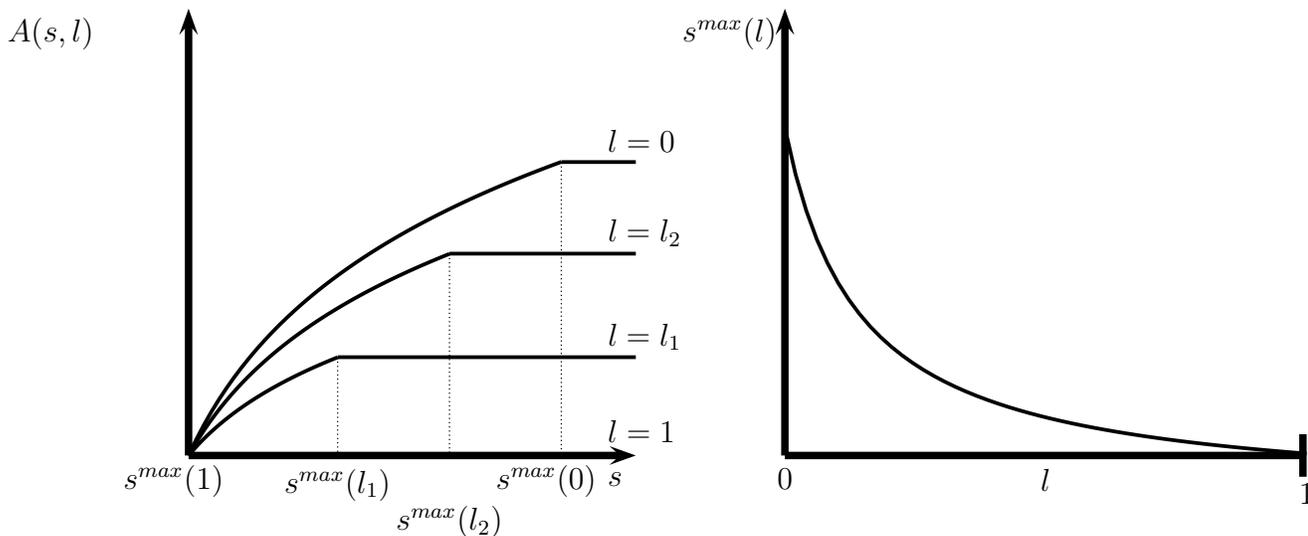


Figure 1: **The labor capacity constraint sets a maximum cultivated area**

parcel if it does not allocate any labor to agriculture: $s^{max}(1) = 0$. Figure 1 and 2 give a representation of $s^{max}(l)$.

NTFP extraction: In contrast to agriculture, NTFP collection provides safe returns. This assumption may seem extreme. However, if taking into account that tropical forests provides a large variety of NTFP, households may always find products to collect from the common forest. NTFP extraction provides: $F(l, L, S)$, with total labor allocated $L = \int_0^N l_i di$ and total agricultural land $S = \int_0^N s_i di$. We assume standard assumptions about labor allocation: $F_l > 0$, $F_l < 0$.

NTFP being extracted from common forests, we consider two types of tragedy of the commons. There is an intensive tragedy (related to congestion): labor allocated by other households have a negative impact on one household's return: $F_L < 0$. Moreover, we assume an extensive tragedy (linked to transport and travel costs): the size of land cultivated by the whole community also tends to decrease returns from NTFP extraction, by increasing transport costs: $F_S < 0$. Indeed, if more land is converted to agriculture, households need more time to travel to the forest for NTFP extraction.

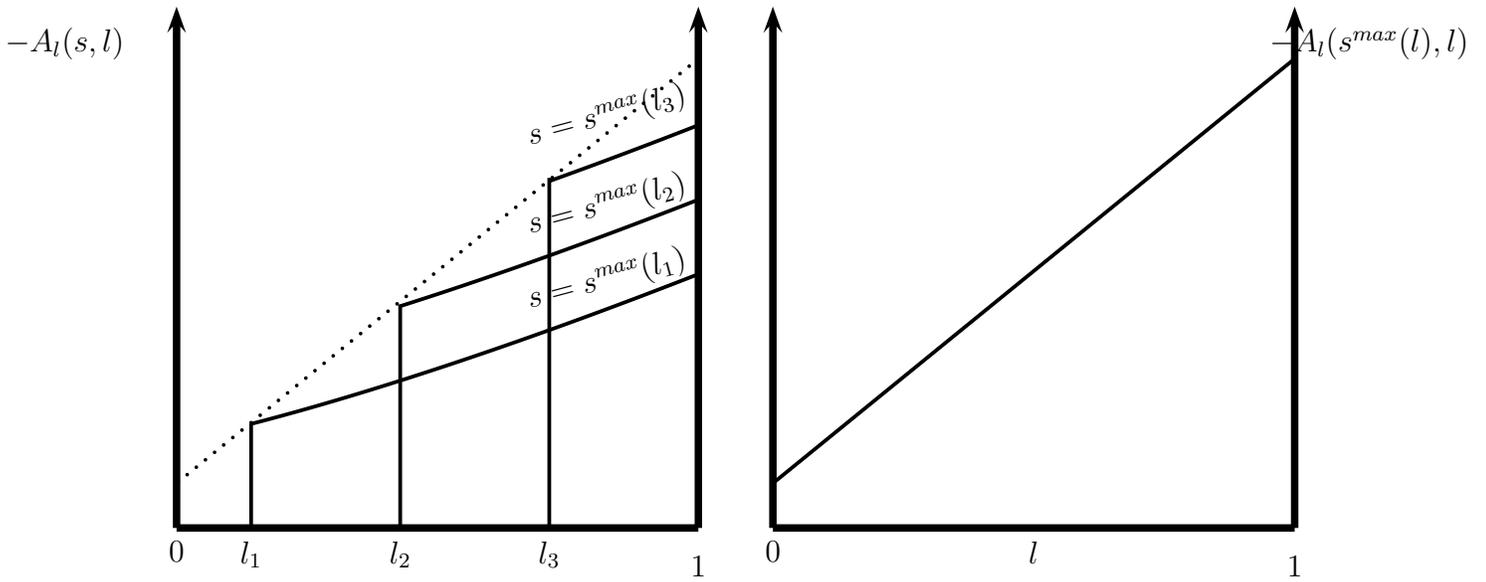


Figure 2: Marginal labor productivity in agriculture

We consider that the representative household is naive about this tragedy of the commons: it only considers the impact of its own labor and land allocation on the productivity of NTFP extraction, taking as given the other households behavior. Realization of the equilibrium nevertheless emerge with the same labor and land allocation for every household.

3.2 Expected return and safety first

The representative household chooses its labor allocation between the two activities and the area of land it will cultivate to maximize its expected return $\Pi(s, l)$:

$$\max_{l, s} \Pi(l, s) = A(E(\alpha); s; l) + F(l, L, S) \quad (1)$$

Moreover, households need to insure a minimum consumption level C_{min} in the worst state of the world (if $\underline{\alpha}$ occurs). This safety-first condition (Roy, 1952; Telser, 1955) is expressed as follow:

$$A(\underline{\alpha}; s; l) + F(l, L, S) \geq C_{min} \quad (2)$$

We assume here that the minimum requirement C_{min} is the same across the population. We consider basic needs to survive, such as nutrition. Thus the household utility function is piece-wise linear with some discontinuity in C_{min} (see figure 3). We define as poor a household

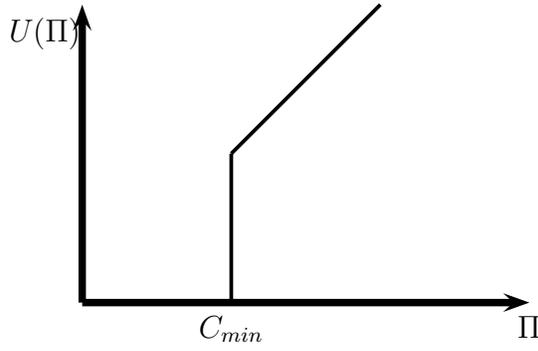


Figure 3: **Non-linear utility function and minimum consumption requirement**

not getting more than its subsistence requirement: it cannot get more from its activities than what it needs to survive. This set up is quite accurate to describe the behavior of poorer communities. Indeed, the main objective of those populations is likely to be insuring survival. Income maximization only comes after this requirement is met.

Safety-first condition and factor combination insuring subsistence: The safety-first condition implicitly describes a relationship between s and l insuring subsistence. $s^{ins}(l)$ is the insurance factor combination function, that perfectly bonds the constraint:

$$A(\underline{\alpha}; s^{ins}(l_i); (1 - l_i)) + F(l_i, L, s^{ins}(l_i) + S_{-i}) = C_{min} \quad (3)$$

$s^{ins}(l)$ defines a set Ω of $[s^{ins}(l); l]$ combinations that satisfy the safety-first condition. Note here that for NTFP collection to be an efficient safety net, it needs to provide higher returns than agriculture in the worst state of the world and higher return than the minimum consumption requirement.

An interesting point here is whether $s^{ins}(l)$ is increasing or decreasing in l . The implicit function theorem gives the sign of the relationship, which depends on the importance of the two tragedies of the commons:

$$s_l^{ins} = -\frac{-A_l + F_l + F_L}{A_s + F_S} \quad (4)$$

What is important to determine this relationship is the relation between factors marginal productivity $(-A_l, F_l, A_s)$ and the range of the respective tragedy of the commons $(F_L,$

F_S). It is very likely here that individual tragedies of the commons are quite small compared to the related marginal productivity: $-A_l + F_l > -F_L$; $A_s > -F_S$. For otherwise, land allocated to agriculture would imply larger losses in NTFP extraction than gains in agriculture. It follows from this intuitive assumption that both the nominator and the denominator are positive. Then the insurance use of NTFP extraction would imply a negative relationship between land converted to agriculture and labor allocated to the commons ⁵.

Proposition 1 : *If the extend of the tragedy of the commons is small enough compared to the marginal productivity of both production factors, the insurance size of agricultural area is decreasing in labor allocated to the commons.*

Assumption 1: *conditions $-A_l + F_l > -F_L$; $A_s > -F_S$ are satisfied for any factor combination $(s^{max}(l); l)$, implying that $s^{ins}(l)$ is monotonically decreasing in l .*

Note that from assumption 1, expected income is always increasing in land allocated to agriculture as long as $s \leq s^{max}(l)$.

3.3 Equilibrium and outcome typology

The following program represents the households objective:

$$\begin{aligned} \max_{l,s} L(l, s) &= A(E(\alpha); s; l) + F(l, L, S) \\ &+ \lambda(C_{min} - A(\underline{\alpha}; s; l) - F(l, L, S)) \end{aligned} \quad (5)$$

where λ is the Lagrange multiplier. It can be considered as the safety-first shadow price. The equilibrium is a combination of a share of labor allocated to NTFP extraction l^* and a size of cultivated land s^* .

The Kuhn-Tucker conditions satisfy:

$$If \begin{cases} -A_l + F_l + F_L + \lambda(A_l - F_l - F_L) = 0 \\ A_s + F_S - \lambda(A_s + F_S) = 0 \\ C_{min} \leq A(\underline{\alpha}; s; l) + F(l, L, S) \end{cases} \quad (6)$$

⁵What is in fact important is that both tragedies have relatively same extends (large or small). Indeed, if the intensive tragedy is large (small) while the extensive tragedy is small (large), then $s^{ins}(l)$ is positively related to l .

From this point, several types of equilibria may be distinguished, depending on returns to agriculture and NTFP extraction.

Provided that we consider additive risk: either the safety-first is not binding ($\lambda = 0$), and we are back to the classic problem of optimal factor allocation (cases 3.3.1, 3.3.2, 3.3.4); either the constraint is binding ($\lambda = 1$, because of additive risk), and the factor allocation is determined by the constraint (cases 3.3.3, 3.3.5).

3.3.1 Agricultural households with no NTFP extraction

Marginal agricultural productivity of labor may always be greater than marginal productivity of labor in NTFP extraction. In this case, the Kuhn-Tucker conditions bounds to the following corner solution: the household tends to allocate as much production factor as possible to agriculture.

Moreover, if the household can insure subsistence only with agriculture, the shadow price of the safety-first condition is null. It follows that the household does not allocate labor to NTFP extraction, and that it converts to agriculture the maximum size of land it can cultivate.

$$\begin{aligned}
 \text{If } & \left\{ \begin{array}{l} -A_l > F_l + F_L \forall \\ A(\underline{\alpha}; s^{max}(0); 0) \geq C_{min} \end{array} \right. \left\{ \begin{array}{l} l \in [0; 1] \\ s \in [0; s^{max}(0)] \end{array} \right. \quad (7) \\
 \implies & \left\{ \begin{array}{l} l^* = 0 \\ s^* = s^{max}(0) \\ L = 0 \\ S = N s^{max}(0) \\ \Pi(l^*, s^*) = A(E(\alpha); s^{max}(0); 0) \end{array} \right.
 \end{aligned}$$

In this case, NTFP collection provides low returns to labor (which is frequently the case). Moreover, households can insure subsistence only with agriculture. Thus they do not need the safety-net use of NTFP extraction. This case describes the context in which communities have good agricultural productivity and levels of risk not threatening their subsistence ⁶.

⁶Alternatively, this could be the case of communities having more efficient safety nets than NTFP extraction (cattle...).

3.3.2 Forest dwellers

As another extreme case, labor marginal productivity of NTFP extraction may be greater than the one of private agriculture for any labor allocation. Here again the Kuhn-Tucker conditions tend to a corner solution, where the household allocates as much labor as possible to NTFP extraction.

If NTFP collection provides at least the safety-first condition ($\lambda = 0$), households allocate all their labor to the commons and keep all the land as forest.

$$\begin{aligned}
 \text{If } & \left\{ \begin{array}{l} -A_l < F_l + F_L \forall \\ F(1, N, 0) \geq C_{min} \end{array} \right. \left\{ \begin{array}{l} l \in [0; 1] \\ s \in [0; s^{max}(0)] \end{array} \right. \quad (8) \\
 \implies & \left\{ \begin{array}{l} l^* = 1 \\ s^* = 0 \\ L = N \\ S = 0 \\ \Pi(l^*, s^*) = F(1, N, 0) \end{array} \right.
 \end{aligned}$$

This case describes the context of poorer communities, which have very low return to labor in agriculture, and for which NTFP collection is basically the only mean to survive.

3.3.3 Community collapse or poverty trap

If the safety-net properties of the common resource are too small, that is if the resource is too fragile, or of too small capacity, households may not insure their livelihood in the worst state of the world. This implies that the environment cannot hold the entire population. It follows that Ω is an empty set: there is no combination of l and s insuring subsistence as described in equation (4).

When it comes to the maximization problem as described in equations (6) and (7), the statement above means that the safety-first condition can not be satisfied. The problem is thus not solvable. That is why the number of households standing in the community has to decrease, in order for the remaining households to be able to fulfil the constraint.

Migration of some part of the population seems to be the unique solution to insure livelihood. Migration is thus considered here as an action of last resort: the environment

cannot provide their livelihood to some households, which have to leave. Households are therefore assumed to migrate from the area if and only if they cannot get their minimum requirement from their livelihood.

Provided those considerations, M is defined as the number of households that have to migrate ; moreover migration occurs until the point at which every remaining household is insured, with the average return being equal to the minimum consumption requirement. It follows that remaining households are trapped in poverty (Delacote, 2009): they need to allocate all their labor to NTFP extraction, which only provides subsistence.

The equilibrium factor allocation for the remaining households is then:

$$\begin{aligned}
 If \quad & \left\{ \begin{array}{l} A(\underline{a}; s; l) + F(l, L, S) < C_{min} \quad \forall \\ \Omega = \emptyset \end{array} \right. \left\{ \begin{array}{l} l \in [0; 1] \\ s \in [0; s^{max}(0)] \end{array} \right. \quad (9) \\
 \Rightarrow & \left\{ \begin{array}{l} l^* = 1 \\ s^* = 0 \\ M : F(1, N - M, 0) = C_{min} \\ L = N - M \\ S = 0 \\ \Pi(l^*, s^*) = F(1, N - M, 0) = C_{min} \end{array} \right.
 \end{aligned}$$

This case describes poor rural communities where population pressure threatens survival because the environment is of too small capacity and outside options are weak.

3.3.4 Labor Marginal productivity Equalization

If agricultural marginal productivity crosses NTFP marginal productivity at some point, households mix their activities with respect to the rule of marginal productivity equalization. We know from assumption 1 that expected income is always increasing in the size of agricultural land. It follows that households tend to convert as much land as possible. Moreover, because of the additive risk assumption, increasing the size of agricultural land also increases income in the worst state of the world.

Then, the equilibrium labor allocation l^* is implicitly given by: $-A_l = F_l + F_L$, and the size of agricultural land is $s^{max}(l^*)$, if $s^{max}(l^*) \geq s^{ins}(l^*)$.

$$\begin{aligned}
\text{If } & \left\{ \begin{array}{l} -A_l < F_l + F_L \text{ for some } [s, l] \\ s^{max}(l^*) \geq s^{ins}(l^*) \end{array} \right. & (10) \\
\implies & \left\{ \begin{array}{l} l^* : A_l(l^*) = F_l(l^*) + F_L(l^*) \\ s^* = s^{max}(l^*) \\ L = Nl^* \\ S = Ns^{max}(l^*) \\ \Pi(l^*, s^*) = A(E(\alpha), s^{max}(l^*), l^*) + F(l, Nl^*, Ns^{max}(l^*)) \end{array} \right.
\end{aligned}$$

In this case, NTFP collection is not used as a safety net, but simply enters in the household's activity portfolio because it becomes profitable compared to agriculture.

3.3.5 Agriculture with NTFP as safety net

Labor marginal productivity is always larger in agriculture than in NTFP extraction, but agriculture can not insure subsistence in any state of the world. In this case, households choose their factor allocation in Ω (provided Ω is not an empty set), so that the safety-first condition perfectly binds.

From the assumption of additive risk, note the any couple $(l, s^{ins}(l))$ generate the same expected income. l being the most flexible factor, while s presents some short-term inertia, the household will choose the lowest possible l in Ω , in order to keep some flexibility.

This outcome can be described as follow:

$$\begin{aligned}
\text{If } & \left\{ \begin{array}{l} -A_l > F_l + F_L \\ A(\underline{\alpha}; s; l) < C_{min} \\ \Omega \neq \emptyset \end{array} \right. \forall \left\{ \begin{array}{l} l \in [0; 1] \\ s \in [0; s^{max}(0)] \end{array} \right. & (11) \\
\implies & \left\{ \begin{array}{l} l^* = \min[l \in \Omega] \equiv \underline{l} \\ s^* = s^{ins}(\underline{l}) \\ L = N\underline{l} \\ S = Ns^{ins}(\underline{l}) \\ \Pi(l^*, s^*) = A(E(\alpha), s^{ins}(\underline{l}), \underline{l}) + F(\underline{l}, N\underline{l}, Ns^{ins}(\underline{l})) \end{array} \right.
\end{aligned}$$

This case is consistent with many case studies from poor rural communities of the developing world. NTFP collection is usually not profitable enough to become the main activity

of households, but may be a useful risk-management tool to cope with agricultural risk and insure livelihood.

4 Risk evolution, land-use inertia and short-run equilibrium

The previous section describes several types of equilibria, with myopic households not considering potential evolution of risk and taking the other households behavior as given.

We consider now that households change at some point their opinion about agricultural productivity in the worst possible case. The lowest productivity factor becomes $\underline{\tilde{\alpha}}$. Risk evolution is assumed to be neutral in terms of expected productivity: $E(\alpha)$ does not change.

Basically a change in risk induces a change in the insurance constraint. $\tilde{s}^{ins}(l)$ is defined so that:

$$A(\underline{\tilde{\alpha}}; \tilde{s}^{ins}(l_i); (1 - l_i)) + F(l_i, L, \tilde{s}^{ins}(l_i) + S_{-i}) = C_{min} \quad (12)$$

which defines a new set $\tilde{\Omega}$ of possible combination $[\tilde{s}^{ins}(l); l]$. We focus here on the case in which NTFP collection is used as a safety net (case described in section 3.3.5). Moreover, we take into account that there may be some inertia in the land use. Indeed, land-use refers to long-term management. Labor is thus the only short-run adjustment variable. We consider separately an increase and a decrease in risk. l_{sr}^* is the optimal amount of labor used in the commons in the short run, that is in periods in which land use adjustment cannot be made.

4.1 Risk reduction

We consider $\underline{\tilde{\alpha}} > \underline{\alpha}$, which means that lowest possible agricultural productivity raises. This statement may correspond to the introduction of other types of safety net, reduction in price volatility or new agricultural patterns limiting crops pests and diseases. As mentioned before, risk reduction implies a switch in the insurance factor combination function. It is now more easy to reach subsistence.

In the previous equilibrium, marginal productivity is larger in agriculture than in NTFP extraction (section 3.3.5), risk reduction corresponds to relaxing the safety-first condition. Nevertheless, the size of agricultural land is fixed to $s^{ins}(L)$. In this case, since the safety-first

condition is relaxed, $\underline{l} > l_{sr}^*$. Some labor is switched to agriculture, in order to saturate the new safety-first condition ⁷. The new equilibrium amount of labor allocated to the common l_{sr}^* is defined by:

$$l_{sr}^* : s^{ins}(l^*) = \tilde{s}^{ins}(l_{sr}^*) \quad (13)$$

Proposition 2 : *In the case where agricultural productivity is more profitable than NTFP extraction, while NTFP extraction is used as a safety net, risk reduction leads in the short term to lower pressure on forest resources, in periods in which the land use is fixed.*

4.2 Increase in risk

We consider $\tilde{\alpha} < \alpha$. An increase in agricultural risk may for instance come from climate change, increased political instability or higher price volatility. This new risk pattern corresponds to a more stringent safety first condition: insuring livelihood becomes more difficult.

For a small risk increase, it is still possible to cope with risk, by increasing the amount of labor allocated to CPR collection. If we are in the case in which agricultural marginal productivity is greater than NTFP marginal productivity, this adjustment is done at the expense of reducing expected outcome. The new equilibrium labor allocation l_{sr}^* is made so that: $s^{ins}(l) = \tilde{s}^{ins}(l_{sr}^*)$.

If the increase in agricultural risk is too large, the community falls in the poverty trap case (section 3.3.3): the environment cannot insure livelihood for the whole community anymore. This is basically the case if: $\tilde{\Omega}$ is an empty set. Too much land has been converted to agriculture, for the forest to present enough insurance properties if risk increases. Moreover, land conversion to agriculture can arguably be considered irreversible, since recovery of biodiversity losses due to species migration is a low motion process.

Proposition 3 : *In the case where agricultural productivity is more profitable, while NTFP extraction is used as a safety net, an increase in risk may lead in the short term to poverty-traps situation, in periods in which land use adjustment is not possible.*

⁷An extreme case here is for important risk reduction, where households do not need NTFP collection to be properly insured anymore. l_{sr}^* is implicitly defined by: $s^{ins}(l) = s^{max}(l_{sr}^*)$.

5 Long-term equilibrium

In the case where the change in risk is permanent, land allocation may be adjusted in the long run, after some periods of inertia. We are then back to the problem described in section 3, where both labor and land are the households choice variable.

We consider risk reduction, and still focusing on the NTFP as safety net case (case 3.3.5). If risk reduction is large enough, we may fall in the case of pure agricultural households who do not need NTFP collection to be properly insured (case 3.3.1). In this case, households convert the maximum possible amount of land to agriculture: $l_{lr}^* = 0$, $s_{lr}^* = s^{max}(0)$. More generally, we may stay in the case where households still need to mix their activities. However, since the safety-first condition is less stringent, households convert more land to agriculture.

$$\begin{cases} l_{lr}^* = \min[l \in \tilde{\Omega}] \equiv \underline{l}_{lr} < \underline{l} \\ s_{lr}^* = \tilde{s}^{ins}(\underline{l}_{lr}) > s^{ins}(\underline{l}) \end{cases} \quad (14)$$

Proposition 4 : *In the case where agricultural productivity is more profitable, while NTFP extraction is used as a safety net, risk reduction leads in the long run to more land converted to agriculture and to more deforestation.*

Overall, it is interesting to see that risk reduction has opposite environmental impacts in the short and long run (see figure 4). Indeed, risk reduction in the short run is likely to decrease the amount of labor allocated to NTFP extraction, and thus to reduce pressure on natural resources. Conversely, in the long run, households have incentive to increase the size of agricultural land and thus to increase deforestation.

6 Conclusion

This paper analyzes several patterns of the use of NTFP extraction to cope with agricultural risk. In the model presented, agricultural households mix labor allocation and choose the

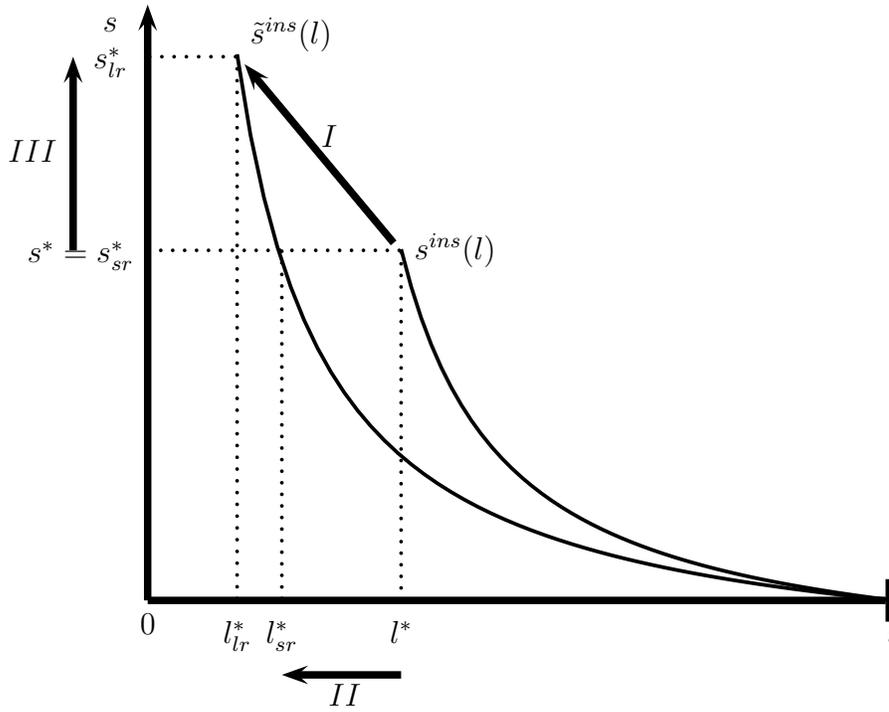


Figure 4: **Risk reduction (I; $\tilde{\alpha} > \alpha$) first reduces the pressure on the common resource (II; $l_{sr}^* < l^*$), and then increases deforestation (III; $s_{lr}^* > s^*$)**

land-use to maximize expected outcome and to insure livelihood. Agriculture is risky, while NTFP extraction may be used to fill some consumption gaps when agricultural crops are bad. Several cases are distinguished, depending on factor allocation and activity diversification.

It is considered that land-use choice presents some inertia. Indeed, while labor allocation can be adjusted quite easily, land-use choice has some long-term implications. Therefore, while households choose both instruments in the long run, they can only use labor as an adjustment variable if their environment change.

Namely, we consider risk reduction. In the short run, risk reduction implies a reduction in labor allocated to the safety-net activity (NTFP extraction) and thus of pressure on common resources. In contrast, in the long run, risk reduction is likely to increase the size of agricultural land and deforestation. Therefore, while risk reduction may have a positive impact on environmental quality in the short run, it may have structural negative impact on the land-use.

As it is frequently mentioned, states and governmental agencies have very weak means to restrict access to common forests. Nevertheless, reducing agricultural risk is essential when dealing with poor agricultural households well-being.

In terms of policy recommendation, it is important to consider the potential impact of policies aiming at reducing agricultural risk on common forests. For instance, a policy package mixing risk reduction and agricultural intensification may be a partial solution. Indeed, by increasing labor marginal productivity, agricultural intensification may shift factor allocation in a less extensive manner.

Those results give potentially interesting insights to empirical economists, who may be willing to test this short-term/long-term inverse relationship between risk and forest resources. Unfortunately, even if the literature gives insight that common property resources and forests have important insurance properties, very few empirical analysis and case studies consider how the introduction of insurance mechanisms and microcredit affects the use of common forests. Data collection and field enquiries are then necessary to estimate effects determined in this paper. Moreover, since we consider short-run and long-run issues, panel data need to be collected.

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