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THE ECONOMIC ANALYSIS OF THE FOREST TRANSITION:
A review

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The forest transition describes a reversal or turnaround in long-run land-use trends for a country or region from a period of net forest area loss to net gain. Such forest recovery has occurred in high-income economies, and increasingly in developing countries. Although this process has been studied extensively by geographers, social scientists and historians, only recently has it been analyzed by economists. This contribution has focused on how competing land use values result in changing patterns of use that lead to an increase or decrease in forest cover. A simple model of forest transition is developed to illustrate this approach in the literature. Empirical applications attempt to explain the underlying economic factors, including governance and institutions, which determine the long-run transition in land use values and patterns. The various findings of these analyses have important policy implications, including for REDD+ and other forest recovery programs.

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1. Introduction

The term *forest transition*, usually attributed to Mather (1990 and 1992), denotes a process of land-use change in a country or region that begins with a long period of decline in forest cover in the early stages of economic development followed by a subsequent period of sustained forest recovery. The recovery can occur through a combination of conserving remaining primary forest, allowing natural re-growth, establishing plantations, and investments in reforestation or afforestation. Thus, a forest transition describes the critical period of reversal or turnaround in long-run land-use trends for a country or region from net forest area loss to net gain.

Although globally forest conversion still remains pervasive, forest recovery has occurred for decades in developed regions, notably Western Europe and North America, and increasingly in some developing countries (Barbier and Tesfaw 2015; Bray 2010; Hansen et al. 2013; Hosonuma et al. 2012; Mather 2007; Meyfroidt and Lambin 2011; Rudel et al. 2005; Wolfersberger et al. 2015). Until recently, this phenomenon has been described and analyzed mainly by geographers and social scientists (Mather, 1992, Grainger, 1995), but now there is a growing literature in economics that is focusing on the reversal in forest land-use trends. The purpose of this paper is to provide a comprehensive review of the economic analysis of the forest transition as represented by this literature.

The next section provides further background on the forest transition, emphasizing in particular how this process lends itself to the standard competing land use model in economics, which has been used extensively to analyze the conversion of forest land to agriculture and other activities as well as forest recovery (Amacher et al. 2008 and 2009; Barbier and Burgess 1997; Barbier and Tesfaw 2015; Barbier et al. 2010; Hartwick et al. 2001). This is illustrated in the subsequent section with a simple economic model of a forest transition, based on a competing land use change model. In addition, an increasing number of studies analyze the economic factors underlying a forest transition, including governance and institutions; consequently, we review briefly these studies and their key empirical findings. Finally, we conclude by discussing the likely policy implications emerging from these economic analyses of the forest transition as well as areas of future research on this topic.

2. The Forest Transition and Land Use Change

The long-run trend implied by a forest transition suggests a "U-shaped curve" for forest land with respect to time: a prolonged decline in country's forest cover in the early stages of economic development followed by a phase of recovery (See Figure 1). Thus, the time period when the long-run decline in forest area is superseded by forest recovery is defined as the *forest transition* (Mather 1990 and 1992). In Figure 1, this is depicted as occurring at distinct time T, but for many countries and regions, this turnaround period from deforestation to recovery may take several years to unfold.

The pattern of forest cover change depicted in Figure 1 occurs at different scales across countries or even across regions within a country, which can be explained by changes in the overall allocation of land (Hansen et al. 2013; Mather 1992; Meyfroidt and Lambin 2011; Meyfroidt et al. 2010; Pfaff and Walker 2010; Rudel et al. 2005). That is, long-run changes in forest cover in a country or region cannot be separated from the overall pattern of land use changes for that country or region (Barbier et al. 2010). When we observe forest cover declining, it is because land in forest is being converted to another land use. Conversely, when afforestation, reforestation or natural regrowth occurs, it is because land under an alternative use is being replaced by more forest land.

In addition, although there may be different land uses that are alternatives to forest land – such as agriculture, urban development, residential housing, etc. – and forest land itself may have different uses – for timber production, recreation, nature reserves, etc. – what ultimately determines the use of the land depends on the rate of return, or rent (possibly including the value of ecosystem services and non-use value), obtained from forest land compared to its competing uses (Angelsen and Rudel 2013; Barbier et al. 2010). Consequently, the analysis of the forest transition lends itself to the standard competing land use model in economics, which has been used often to analyze deforestation due to development activities, such as agricultural expansion (Amacher et al. 2009; Barbier and Burgess 1997; Ehui et al. 1990; Hartwick et al. 2001; Wirl 1999). Such a modeling approach has been extended to take into account how the value of forest land compared to the value of all competing uses leads to forest recovery (Barbier and Tesfaw 2015; Barbier et al. 2010).

As indicated in Figure 1, the forest transition occurs over at that period of time when forest decline halts and sustained recovery begins. The result is the "U-shaped curve" for forest cover as a function of time. Thus, as described by Mather (1992), long-term forest land use consists of three distinct phases: (1) an initial phase of large forest cover and low deforestation rates; (2) a phase of forest conversion followed by (3) a new phase where forest recovery becomes technically and economically feasible.

For most countries, the decline in forest cover that occurs before the transition is mainly the result of the rapid loss of natural forest cover as agricultural area expands in response to rising demand for food and other commodities as economic development proceeds and populations grow. During this phase, the abundance of primary forests means that the benefits, and thus the value, of retaining land as forest are much lower relative to scarce agricultural land. Thus, considerable agricultural land conversion will take place, forest area declines quickly and agricultural land area expands. However, the continual conversion of forest to agricultural land will cause changes in relative land values. As agricultural land expansion occurs, the value of converting more land from forest falls; similarly, the value of remaining primary forest will rise as it becomes relatively scarce. As these land values converge, less and less land conversion takes place. Eventually, there is no net gain from converting additional forested land to agriculture as the marginal benefits from both land uses are the same, and both the stock of remaining primary forest land and agricultural land area remain constant; i.e., the economy is on the verge of the forest transition. Those dynamics are frequently disentangled in the FT literature as the "economic development path"- triggered by agricultural expansion- and the "scarcity path". The former, triggered by agricultural expansion is consistent with the Environmental Kuznets Curve hypothesis (an inverted U-shaped curve between income and environmental degradation). The later builds on the implicit assumption that a scarce resource is given larger marginal value.

Changing land use values continue to influence the post-forest transition recovery phase. As indicted in Figure 1, the rise in total forest area that signals the forest transition is often driven by a sustained increase in plantations and reforested or naturally regenerated forest land, as well as protection of remaining primary forests. Reforestation, afforestation and even management of primary forests must be technically feasible, but also must be warranted by the relative change in agricultural to forested land values. During the forest transition and its aftermath, the relative value of forested land is likely to rise, especially if it is associated with important forest ecosystem services and other scarce environmental benefits. Simultaneously, the economy may switch from an agricultural base to an industrial and services base, which are less land-intensive. As the value of forested land surpasses the value of agricultural land, more and more of the latter land will be abandoned and even converted to forest.[1]

In sum, analyzing forest transitions has several unique features. First, to make sense of the forest transition requires understanding the long-term process of forest cover and land-use change of a given country or region. Indeed, once the deforestation episode ends and the forest cover stabilizes, one has complete information about the whole process of forest cover change, from deforestation to stabilization and then recovery. This allows to consider cumulative forest cover change, which is different to considering just periodic forest loss or change (Wolfersberger et al. 2015). Furthermore, the forest transition analysis provides information on the amount of forest that a country will be able to conserve.

3. An Economic Model of the Forest Transition

We can illustrate the role of changing land values in driving the forest transition process through a simple model involving two distinct phase of land uses – the conversion of forest land for agriculture followed by the eventual restoration of agricultural land to forests. We begin by characterizing the first phase of forest conversion to agriculture, and then the forest transition leading to restoration and recovery of forest area.[2]

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[1] It is possible that the value of naturally regenerated forest land may rise sufficiently to surpass other uses of land, and thus some reforested land may come from converting lower valued commercial and residential land. In addition, if farmland is abandoned but not necessarily converted to other uses, e.g. to satisfy the demand for land for residential housing and urbanization, natural reforestation may also occur (Mather and Needle, 1998; Rudel et al., 2005).

[2] As noted above and in Figure 1, the sustained forest recovery that occurs during the post-forest transition phase is likely to occur through a variety of means, including increases in plantations, afforestation, reforestation or naturally

Let $F(t)$ be the forest area of a region or country at time t and $F(0) = F_0$ is the initial area. If $c(t)$ is the area of forest converted in each period to agriculture, then

$$F(t) = F_0 - \int_0^t c(s)\,ds \text{ and } \dot{F} = -c(t) \tag{1}$$

It follows that, if $A(t)$ be the area of land used in agriculture and $A(0) = A_0$ is the initial developed land area, then

$$A(t) = A_0 + \int_0^t c(s)\,ds \text{ and } \dot{A} = c(t) \tag{2}$$

Because in the first phase forest land is relatively abundant, it follows that $F_0 > A_0$.

Forests produce a variety of goods and services, or benefits, ranging from timber products to non-wood products to ecosystem services, such as watershed protection, carbon storage and biodiversity. Let $B(F(t))$ represent the periodic flow of these aggregate benefits from the remaining forest area. These benefits vary non-linearly across forests such that $\partial B / \partial F(t) > 0,\ \partial^2 B / \partial F(t)^2 < 0$. Agricultural land is also heterogeneous in quality. Let R be the periodic rent associated with agricultural land. If the conversion decision is rational, then the highest quality land is allocated to agriculture first, and differential rent will vary with land quality; i.e., there are decreasing marginal returns (rent) to the increase in the stock of agricultural land, $R(A(t)),\ \partial R / \partial A(t) > 0,\ \partial^2 R / \partial A(t)^2 < 0$. However, conditions (1) and (2) indicate that $A(t) = A_0 + F_0 - F(t)$. The latter expression implies in turn that the rents from developed land can be rewritten as $R(F(t)),\ \partial R / \partial F(t) < 0$.

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regeneration of previous forest land, as well as better protection of remaining primary forests. In what follows, we refer collectively to all such activities contributing to recovery of forest areas as *forest restoration.*

If C are the costs of conversion, then more deforestation increases these costs, i.e. $C(c(t)),\ \partial C/\partial c(t) > 0,\ \partial^2 C/\partial c(t)^2 > 0$. It is also assumed that $C(0) = C'(0) = 0$.

Before specifying the optimal conditions for converting forest land to agriculture during this first phase of competing land uses, it is necessary to demonstrate a possible endpoint condition for this phase. Although it might not be feasible initially to restore forest, at some future time t_1, where $0 < t_1 < \infty$, it must become technologically possible to restore agricultural land as forest. The value of restoring all agricultural land at time $t_1 \le t \le \infty$ can be denoted by the function $G(A(t)),\ G'(A(t)) > 0$. At some finite time T, which occurs at the time or shortly after forest restoration becomes feasible, i.e. $t_1 \le T < \infty$, the future land rents earned from agricultural land are equal to the value of restoring all agricultural land to forests at T

$$V(A(T)) = \int_T^\infty R(A(t))e^{-rt}dt = G(A(T)),\ \ G'(A(T)) \ge V'(A(T)) > 0. \qquad (3)$$

Given that $A(t) = A_0 + F_0 - F(t)$ it follows that $V(A(T))$, which is the value of agricultural land from T onwards, can also be expressed as $V(F(T)), V'(F(T)) < 0$.

The decision maker determining land use during the deforestation phase $[0,T]$ can maximize the present value of net returns from the land W by choosing optimal levels of forest to convert

$$\underset{c(t)}{Max}\, W = \int_0^T [R(A) - C(c) + B(F)]e^{-rt}dt \qquad (4)$$

subject to (1)-(3). Denoting μ as the shadow value of remaining forest area, the two relevant first-order conditions of the problem are

$$\mu = -C'(c) \qquad (5)$$

$$\dot{\mu} = r\mu - B'(F) - R'(F) \tag{6}$$

Combining (5) and (6) yields

$$-B'(F) - R'(F) = \dot{\mu} + rC_c \rightarrow -R'(F) - rC'(c) = R'(A) - rC'(c) = B'(F) + \dot{\mu}\,, \tag{7}$$

where $-R_F = R_A$ is annual periodic rent from agricultural land use.

Condition (7) indicates that, along the optimal path of forest conversion, the returns from the two competing land uses must be equal. The marginal profits from agricultural land less conversion costs $R'(A) - rC'(c)$ must equal the marginal benefit of holding on to the remaining forest area $B'(F) + \dot{\mu}$. Note that (7) can also be rewritten as $-\mu(t) = \frac{R'(A)}{r} - \frac{B'(F) + \dot{\mu}}{r} = C'(c)$. The difference between the capitalized marginal value of agricultural land and remaining forest land retained is the marginal cost of forest conversion. Denote P as the "price", or capital value, of land that is associated with each of these respective capitalized land use values, then

$$\frac{R'(A)}{r} - \frac{B'(F) + \dot{\mu}}{r} = P(A(t)) - P(F(t)) = C'(c) \tag{8}$$

The difference in land prices between agricultural and forest land is the marginal cost of converting a unit of forest area into agricultural land.

Given the assumption that forest land is relatively abundant $F_0 > A_0$, condition (5) indicates that along the optimal conversion path, the marginal value of an additional unit of remaining forest is negative $\mu < 0$. Initially, forest conversion c is very large, which reflects the fact that agricultural land is relatively scarce compared to forests, which are essentially valued as a "reserve" to be converted for agriculture. But because initial forest area is large, the marginal value of forest benefits $B'(F)$ is very low whereas the marginal rent earned from agricultural land $R'(A)$ is extremely high. The result is that along the optimal conversion path the shadow value of forest $\mu(t)$ continues rising and c falling.[3] It follows that, as forest conversion continues and the stock of agricultural land grows and forest area declines, the wedge between land prices will disappear, and $P(A(t))$ converges towards $P(F(t))$.

The transversality condition associated with the maximization problem (4) is

$$\mu(T) = -C'(c) = V'(F(T)) < 0 . \tag{9}$$

At time T the marginal (negative) value of additional forest area must equal the marginal cost of converting it to agricultural land and also equal the marginal increase in future rents from developing another unit of forest land. From (3) and using $-V'(F(T)) = V'(A(T))$ in (9), the transversality condition can also be written as

$$-\mu(T) = V'(A(T)) \leq G'(A(T)), \tag{10}$$

where $-\mu(T)$ can be interpreted as the marginal value of an additional amount of forest at T, which is equal to the marginal increase in the future rents from another unit of agricultural land. But this increase in the future stream of rents is equal to or less than the marginal value of restoring one unit of forest land at time T.

Two implications emerge from this transversality condition. First, conversion of forest to agricultural land will terminate at time T. Second, over the remaining time period $T \leq t \leq \infty$, a new phase of land use will occur involving the restoration of agricultural land to forests. Thus,

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[3] Formally, from the necessary condition (5) $d\mu = -C''(c)dc \rightarrow \frac{dc}{d\mu} = -\frac{1}{C''(c)} < 0$, which implies that (2) can be written as $\dot{F} = -c(\mu)$ and confirms that, as the shadow value of remaining forest becomes less negative over time, optimal land conversion falls. The slope of the optimal path is $\frac{d\mu}{dF} = \frac{\dot{\mu}}{\dot{F}} = \frac{r\mu - B'(F) - R'(F)}{-c(\mu)}$, which indicates that, as conversion proceeds and F falls, the shadow value of the remaining forest area becomes less negative and is converging towards zero at the time of transition.

the time period T denotes the *forest transition* from the first phase of land use when deforestation prevails to the second phase of sustained forest recovery. We can now model the latter post-transition phase of land use explicitly.

Let $g(t)$ be the area of agricultural land restored in each period over $T \le t \le \infty$ to forest. It follows that $F(t) = F_T + \int_T^t g(s)\,ds$, $F(T) = F_T$ and $\dot{F} = g(t)$. If $C(g)$ is the cost of restoration, which increases with the amount of forest area restored $C'(g) > 0,\ C''(g) > 0,\ C(0) = C'(0) = 0$, then the maximization problem at the beginning of the forest transition is

$$\underset{g(t)}{Max}\, W = \int_T^\infty \left[R(F) + B(F) - C(g)\right] e^{-r(t-T)} dt \text{ s.t. } \dot{F} = g,\ F(T) = F_T.$$

The two relevant first-order conditions are

$$\mu = C'(g) \tag{11}$$

$$\dot{\mu} = r\mu - B'(F) - R'(F) \tag{12}$$

Combining (11) and (12)

$$-R'(F) = R'(A) = B'(F) - rC'(g) + \dot{\mu} \tag{13}$$

$$\mu = \frac{B'(F) + \dot{\mu}}{r} - \frac{R'(A)}{r} = P(F) - P(A) = C'(g) \tag{14}$$

After the forest transition, the difference between the capitalized marginal value of forest as opposed to agricultural land can also be designated as the difference in the "price" of the two types of land, but now this difference must be equivalent to the marginal cost of restoring a unit of forest area.

In the long run steady state $\dot{F} = \dot{\mu} = 0$ and $C'(0) = 0$. It follows that both forest restoration and the marginal value of an additional unit of forest land approach zero asymptotically, i.e. $g = 0$ and $\lim_{t\to\infty} \mu(t) = C'(0) = 0$. Eventually, the wedge between land prices will disappear, $P(F(t)) = P(A(t))$, and forest area will converge to a steady state level F^*. If the initial post-transition area is small relative to agricultural land, i.e. $A(T) > F(T) > F^*$ then from (11), along the forest restoration path to the long run steady state, the marginal value of an additional unit of forest area is positive $\mu > 0$ and optimal restoration *g* will be very large initially. But because initial post-transition forest area is relatively small, marginal forest benefits $B'(F)$ are very high whereas the marginal rent earned from agricultural land $R'(A)$ is low. The result is that the shadow value of forest land $\mu(t)$ is falling over time. In fact, given that $F(T) < F^*$, along the optimal path until the steady state is reached, both $\mu(t)$ and *g* continue falling.[4]

Figure 2 depicts both phases of land use, the forest conversion phase leading to the forest transition at time *T* and the post-transition forest recovery. The top diagram depicts the first phase, when forests are relatively abundant, the capitalized value of agricultural land *P*(*A*) exceeds the value of forests *P*(*F*), and forest conversion to agriculture takes place continuously. However, as forest area declines, the value of converting more land from forest falls, whereas the value of remaining primary forest will rise as it becomes relatively scarce. As these land values converge, less and less land conversion takes place. Finally, at time period *T*, the forest transition occurs and land use switches to the post-transition recovery phase, which is shown in the bottom diagram. Now, capitalized forest land value *P*(*F*) exceeds the value of agricultural

[4] Formally, from the necessary condition (11) $d\mu = C''(g)dc \rightarrow \frac{dg}{d\mu} = \frac{1}{C''(g)} > 0$, which implies $\dot{F} = g(\mu)$ and that, as the shadow value of forest area falls over time, the optimal restoration rate falls. The slope of the optimal path is $\frac{d\mu}{dF} = \frac{\dot{\mu}}{\dot{F}} = \frac{r\mu - B'(F) - R'(F)}{g(\mu)}$, which asymptotically approaches zero as restoration proceeds, *F* rises, and the shadow value of forest area declines.

land $P(A)$ and restoration begins. However, as restoration proceeds and the two land values converge, forest area will eventually reach a steady state at F^*.

Although the model of forest transition developed here is relatively simple, it nonetheless captures two important aspects identified in the literature: first, there are two distinct phases of long-run land use of forest conversion to agriculture followed by sustained forest area recovery, and second, what determines the transition from deforestation to restoration are the relative land values of the competing activities that use forest land. This model is thus more complete than other dynamic theoretical models related to forest transitions (Hartwick et al., 2001, Ollivier, 2012, among others), which focus on the deforestation phase without explicitly considering the reforestation phase. As we shall see in the next section, the key economic factors that determine whether or not such a forest transition in long-run land use takes place have been investigated empirically by a number of recent studies.

4. Empirical Analyses of the Forest Transition

Rudel et al (2005) empirically assess the determinants of reforestation in countries that experienced a forest transition. For this purpose, authors run a logistic regression on whether or not a country gained forest cover over 1990-2010, using FAO data. Authors control only for two variables, the level of GNP per capita (to account for the *economic development* path) and the forest stock (to account for the *forest scarcity* path). Potential important effects such as population pressure, institutional quality or trade are not taken into account.

Foster and Rosenzweig (2003) offer a comprehensive study of forest growth in India since the 1970s. While during this period income and population were growing, and international trade in the forestry sector was limited, authors found empirical evidence that higher demand in forest products led to more plantations and thus forest growth.

Culas (2012) links the forest transition hypothesis to the environmental Kuznets Curve (EKC), and estimates the level of GDP per capita that would enable Africa, Latin America and Asia to switch from long-term deforestation to sustainable reforestation. The author finds that Africa and Latin America have not reached yet the level of development required to stop forest depletion, while Asia has.

Pfaff and Walker (2010), on the basis of the EKC applied to forests, discuss the role of interdependencies when studying forest transitions. Using empirical evidence from New England, they distinguish two types of regions: transitioning and facilitating. The former experiences secondary-forest regrowth thanks to the economic conditions provided by the facilitating regions that deforest. In their case study, Pfaff and Walker find that the drop in transport costs to and from the Midwest decreased New England's agricultural rents since Midwest's agriculture was more productive. As a consequence, it was more profitable for New England to import agricultural products and it followed that farmers moved to cities to work in manufactures. This spatial concentration in the big cities of the region led to a forest transition in New England. The authors highlight the importance of considering transitions over a larger regional or national scale, as a local reversal may increase deforestation elsewhere.

Wolfersberger et al. (2015) analyze the underlying causes of forest transitions and cumulative deforestation. The authors estimate the macroeconomic variables that (i) lead to the end of deforestation in a developing economy (i.e. a turning point) and (ii) limit agricultural expansion forest loss during development. An important methodological contribution comes from the fact that authors' econometric model takes simultaneously into account different type of land uses, namely forest, agriculture and “others”. The latter encompasses all residual land uses such as abandoned land or urbanization. Their approach makes it possible to identify more precisely the effect of one variable on land-use competition. Results show that economic development and control of corruption facilitate the occurrence of a turning point, while population pressure decreases the probability of observing such a point. All things equal, results show that the level of economic development also contributes limiting cumulative deforestation by reducing agricultural land expansion during the first steps of development. Hence, economic development shortens the total duration of the deforestation episode without increasing its intensity.

Barbier and Testaw (2015) investigate the critical role of governance in forest transition. For that purpose, they combine a theoretical model of forest transition and cross-section econometric analysis. The model predict that governance may have two effects on the dynamics of the forest transition. First, before the turning point occurrence, better governance tends to decrease the rate of forest conversion to agriculture. Once the forest transition has occurred, better governance tends to lower the reforestation rate. The authors then test their theoretical results on a cross-section of countries, estimating the influence of governance on the probability of occurrence of a forest transition. Their results show that different indicators of governance do not have the same impact on the occurrence of a turning point: while the forest policy and the rule of law increase the occurrence probability, regulatory quality tends to reduce it. This results underlines the fact that governance is a complex concept, which combines various indicators and dimensions.

5. Conclusion

Although the forest transition has been studied extensively by geographers, social scientists and historians, economists have only recently analyzed this process. The most promising economic approach has been to view the forest transition as an outcome of competing land uses that have governed the conversion of forest land to agriculture and other activities, and eventually, to engender the economic conditions for forest recovery. Changing land use values continue to influence the post-forest transition recovery phase. Reforestation, afforestation and even management of primary forests must be technically feasible, but also must be warranted by the relative change in agricultural to forested land values. During the forest transition and its aftermath, the relative value of forested land is likely to rise, especially if it is associated with important forest ecosystem services and other scarce environmental benefits.

As indicated in this review, a growing number of studies, both theoretically and empirically, are beginning to capture these trends. A key conceptual feature is that analysis of the forest transition invariably involves understanding the long-term process of forest cover and land-use change of a given country or region, from deforestation to stabilization and then recovery. From an empirical standpoint, the focus needs to consider the economic factors underlying cumulative forest cover change rather than just periodic (i.e. annual or several years) change (Wolfersberger et al. 2015). As a consequence, economic studies of the forest transition offer important policy implications, especially for long-terms forest recovery programs and international initiatives such as the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program of the United Nations.

For example, Angelsen and Rudel (2013) argue that the efficiency of REDD+ policies and projects and the type of forest conservation strategy adopted depend on the phase of forest land use of a country. Countries with large forest cover and low deforestation rates should focus on improved forest management projects, while countries with large deforestation rates should focus on payments for reduced deforestation. Countries closer to their turning point, or having experienced a forest transition, should focus on reforestation projects.

Ollivier (2012) focuses on the deforestation phase of forest transitions. She shows that the level of REDD+ transfer has an impact not only on the long term forest conservation, but also on the countries welfare. While the transfer has a monotonic negative influence on the level of agricultural land, its impact is not monotonic when considering welfare: when it is low enough, a transfer increase improves welfare (through the intensification of agriculture); when the transfer is high enough, increasing it tends to reduce welfare (agricultural intensification is overbalanced by the shrinking of the agricultural sector).

More generally, Barbier et al. (2010) emphasize that policies influencing forest and agricultural rents are key determinants of land-use change. It follows that pervasive market distortions, biased incentives and institutional failures are key determinants of forest losses. Consequently the implementation of conservation policies can only be effective if considered in a holistic manner with agricultural, transport and infrastructure policies. In addition, Barbier and Tesfaw (2015) further find that the effectiveness of policies, including those aimed specifically at improving forest management and recovery, can be undermined by poor governance or improved through more effective governance. In particular, the rule of law, forest policy and regulatory quality influence forest transitions across developing countries, and thus these aspects of governance should receive particular attention.

There are several areas of future research on the economics of the forest transition. Currently, the literature tends to focus on individual country or region studies, yet as pointed out by Pfaff and Walker (2010), there is a need to consider such transitions over a larger regional or national scale, as forest recovery in one location or specific region may not necessarily be representative of forest change at a larger region or national level. Equally there are too few global comparative studies. More such studies are necessary to understand more fully the differences across countries in macroeconomic, governance and relative incentives that influence long-run forest recovery (Barbier and Tesfaw 2015; Wolfersberger et al. 2015). Easier access to reliable data on land-use change (e.g. Hansen et al. 2013) is here likely to boost those studies. Finally, although the implications of the forest transition to specific programs such as REDD+ has led to some important insights (Angelsen and Rudel 2013; Ollivier 2012), more studies are needed to understand how the economic factors underlying the forest transition are related to other long-term forest management, recovery and conservation policies and investments worldwide.

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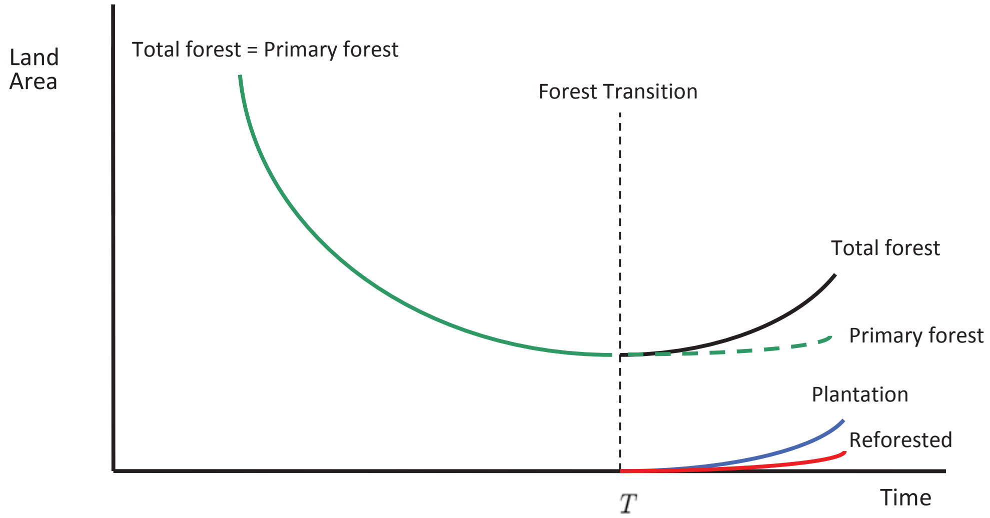
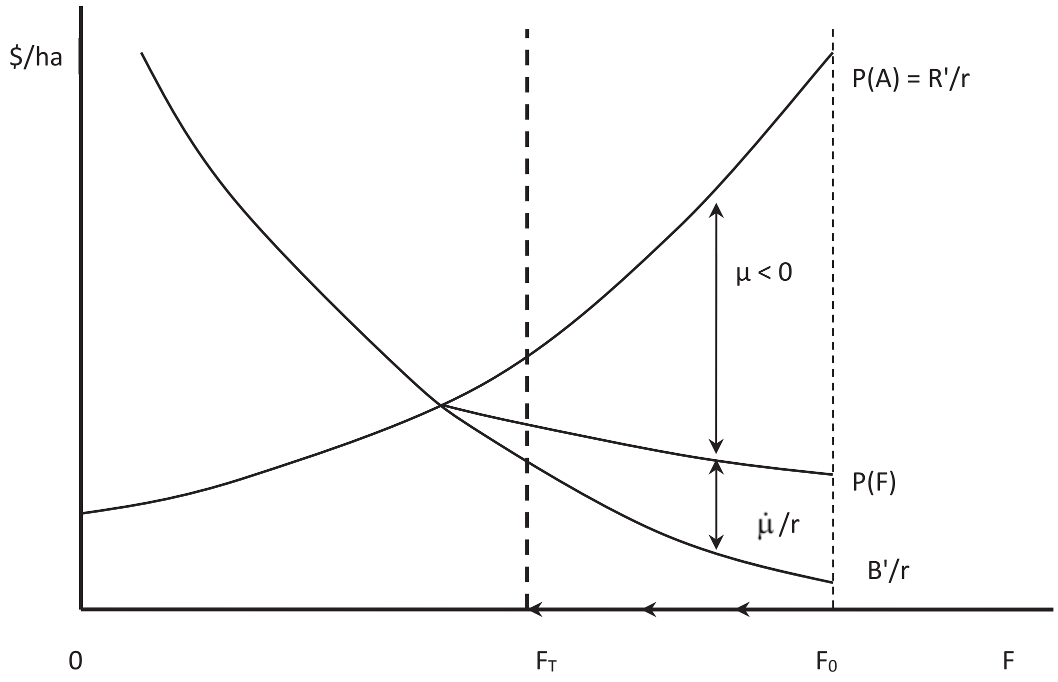
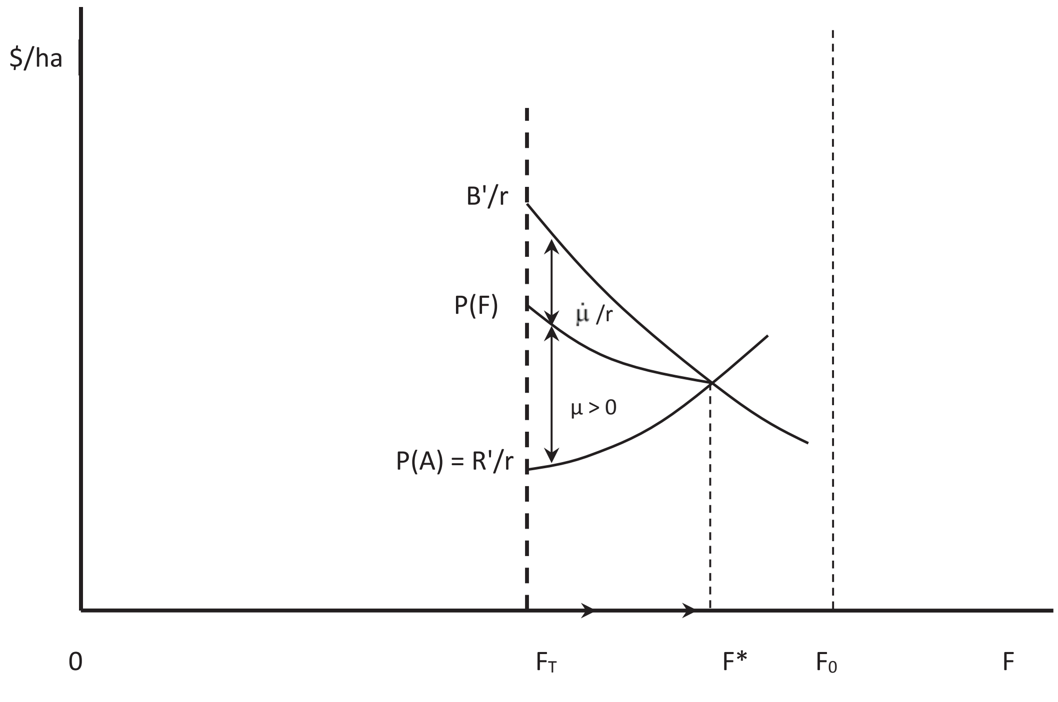
Figure 1. A Forest Transition



A *forest transition* is defined as the time period when the long-run decline in forest area is superseded by forest recovery. The initial loss of natural forest cover occurs as economic development proceeds and populations grow. Over time, the decrease in primary forest area may slow down. Increased environmental protection of remaining primary forest also stabilizes its size. As an economy develops further, the increased demand for wood products and non-market ecosystem services from forested land may lead to recovery in the total forest area, with protection of remaining primary forest, regrowth on previously converted land, reforestation and plantations all playing a role.

Figure 2. Agricultural and Forest Land Use Values and the Forest Transition





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