11 Storable, Renewable Resources: Forests

There is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all who profit by the old order, and only lukewarm defenders in all those who would profit from the new order. The lukewarmness arises partly from fear of their adversaries who have law in their favor; and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it.

—Niccolò Machiavelli, *The Prince* (1513)

Introduction

Forests provide a variety of products and services. The raw materials for housing, wood products and paper are extracted from the forest. In many parts of the world, wood is an important fuel. Trees cleanse the air by absorbing carbon dioxide and adding oxygen. Forests provide shelter and sanctuary for wildlife and they play an important role in maintaining the watersheds that supply much of our drinking water.

Although the contributions that trees make to our everyday life are easy to overlook, even the most rudimentary calculations indicate their significance. Almost one-third of the land in the United States is covered by forests, the largest category of land use with the exception of pasture and grazing land. In Maine, an example of a heavily forested state, 95 percent of the land area is covered by forest. In 2005 the comparable figure for the world was 30.7 percent.

Managing these forests is no easy task. In contrast to crops such as cereal grains, which are planted and harvested on an annual cycle, trees mature very slowly. The manager must decide not only how to maximize yields on a given amount of land but also when to harvest and whether to replant. In addition, a delicate balance must be established among the various possible uses of forests. Since harvesting the resource diminishes other values (such as protecting the aesthetic value of forested vistas or providing habitat for shade-loving species), establishing the proper balance requires some means of comparing the value of potentially conflicting uses. The efficiency criterion is one obvious method.

One serious problem, deforestation, has intensified climate change, decreased biodiversity, caused agricultural productivity to decline, increased soil erosion and desertification, and precipitated the decline of traditional cultures of people indigenous to the forests. Instead of forests being used on a sustainable basis to provide for the needs of both current and subsequent generations, some forests are being "cashed in."

In its "Global Forest Land-use Change 1990–2005," the Food and Agricultural Organization of the United Nations reports that due to a shift from forest land use to other land uses, overall global forest area registered a net decrease of 1.7 percent between 1990 and 2005 at an annual rate of change of 0.11 percent. These data suggest that current forestry practices may be violating both the sustainability and efficiency criteria.[1] How serious is the problem and what can be done about it?

In the remainder of this chapter, we shall explore how economics can be combined with forest ecology to assist in efficiently managing this important resource. We begin by characterizing what is meant by an efficient allocation of the forest resource when the value of the harvested timber is the only concern. Starting simply, we first model the efficient decision to cut a single stand or cluster of trees with a common age by superimposing economic considerations on a biological model of tree growth. This model is then refined to demonstrate how the multiple values of the forest resource should influence the harvesting decision and how the problem is altered if planning takes place over an infinite horizon, with forests being harvested and replanted in a continual sequence. Turning to matters of institutional adequacy, we shall then examine the inefficiencies that have resulted or can be expected to result from both public and private management decisions and strategies for restoring efficiency.

Characterizing Forest Harvesting Decisions

Special Attributes of the Timber Resource

While timber shares many characteristics with other living resources, it also has some unique aspects. Timber shares with many other animate resources the characteristic that it is both an output and a capital good. Trees, when harvested, provide a salable commodity, but left standing they are a capital good, providing for increased growth the following year. Each year, the forest manager must decide whether or not to harvest a particular stand of trees or to wait for the additional growth. In contrast to many other living resources, however, the time period

[1]In this context, sustainability refers to harvesting no more than would be replaced by growth; sustainable harvest would preserve the interests of future generations by assuring that the volume of remaining timber was not declining over time. This is consistent with the environmental sustainability criterion discussed in Chapter 5, but is stronger than needed to satisfy the weak sustainability criterion. Conceivably, the weak sustainability criterion could be satisfied even if the volume of wood were declining over time by providing a compensating amount of some commodity or service that is valued even more.

between initial investment (planting) and recovery of that investment (harvesting) is especially long. Intervals of 25 years or more are common in forestry, but not in many other industries. Finally, forestry is subject to an unusually large variety of externalities, which are associated with either the standing timber or the act of harvesting timber. These externalities not only make it difficult to define the efficient allocation, but also they play havoc with incentives, making it harder for institutions to manage efficiently.

The Biological Dimension

Tree growth is conventionally measured on a volume basis, typically cubic feet, on a particular site. This measurement is taken of the stems, exclusive of bark and limbs, between the stump and a 4-inch top. For larger trees, the stump is 24 inches from the ground. Only standing trees are measured; those toppled by wind or age are not included. In this sense, the volume is measured in net, rather than gross, terms.

Based on this measurement of volume, the data reveal that tree stands go through distinct growth phases. Initially, when the trees are very young, growth is rather slow in volume terms, though the tree may experience a considerable increase in height. A period of sustained, rapid growth follows, with volume increasing considerably. Finally, slower growth sets in as the stand fully matures, until growth stops or decline sets in.

The actual growth of a stand of trees depends on many factors, including the weather, the fertility of the soil, susceptibility to insects or disease, the type of tree, the amount of care devoted to the trees, and vulnerability to forest fire or air pollution. Thus, tree growth can vary considerably from stand to stand. Some of these growth-enhancing or growth-retarding factors are under the influence of foresters; others are not.

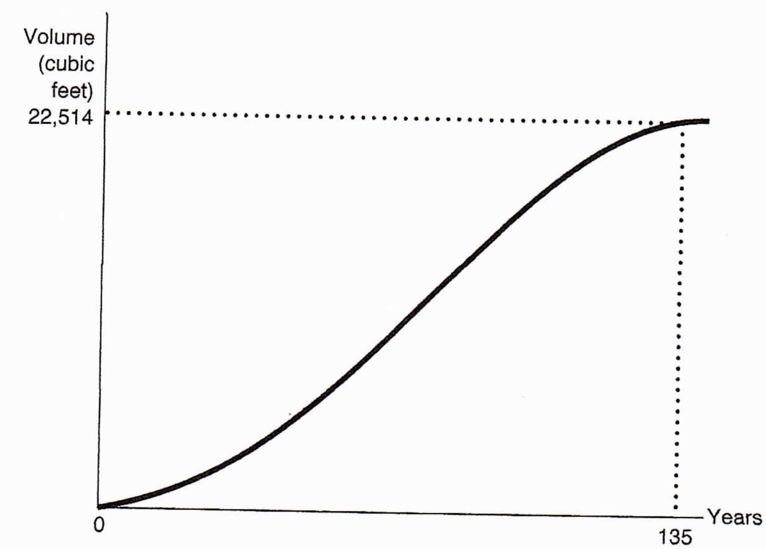
Abstracting from these differences, it is possible to develop a hypothetical but realistic biological model of the growth of a stand of trees. Our model, as shown in Figure 11.1 is based on the growth of a stand of Douglas fir trees in the Pacific Northwest.[2] Notice that the figure is consistent with the growth phases listed above, following an early period of limited growth in its middle ages, with growth ceasing after 135 years.

The Economics of Forest Harvesting

When should this stand be harvested? From the definition of efficiency, the optimal harvest time (age) would maximize the present value of the net benefits from the wood. The size of the net benefits from the wood depends on whether the land will be perpetually committed to forestry or left to natural processes after harvest.

[2]The numerical model in the text is based loosely on the data presented in Marion Clawson. "Decision Making in Timber Production, Harvest, and Marketing," Research Paper R-4 (Washington, DC: Resources for the Future, 1977), 13, Table 1. The mathematical function relating volume to age stand in Figure 12.1 is a third-degree polynomial of the form $v = a + bt + ct^2 + dt^3$, where v = volume in cubic feet, t = the age of the stand in years, and a, b, c, and d are parameters that take on the values 0, 40, 3.1, and −0.016, respectively.

FIGURE 11.1 Model of Tree Growth in a Stand of Douglas Fir



For our first model, we shall assume that the stand will be harvested once and the land will be left as is following the harvest. We also shall assume that neither the price (assumed to be \$1) nor the harvesting costs per cubic meter (\$0.30) vary with time. The cost of planting this forest is assumed to be \$1,000. This model illustrates how the economic principles of forestry can be applied to the simplest case, while providing the background necessary to move to more complicated and more realistic examples.

Planting costs and harvesting costs differ in one significant way—the time at which they are borne. Planting costs are borne immediately, while harvesting costs are borne at the time of harvest. In a present-value calculation, harvesting costs are discounted (as is the value of the wood) because they are paid (costs) or received (revenue) in the future, whereas planting costs are not discounted because they are paid immediately.

Having specified these aspects of the model, it is now possible to calculate the present value of net benefits that would be derived from harvesting this stand at various ages (see Table 11.1). The net benefits are calculated by subtracting the present value of costs from the present value of the timber at that age. Three different discount rates are used to illustrate the influence of discounting on the harvesting decision. The undiscounted calculations ($r = 0.0$) simply indicate the actual values that would prevail at each age, while the positive discount rate takes the time value of money into account.

Some interesting conclusions can be gleaned from Table 11.1. First, discounting shortens the timing of the efficient harvest. Notice that the maximum undiscounted net benefits occur at an age of 135 years, when the volume is maximized. However,

TABLE 11.1 Economic Harvesting Decision: Douglas Fir

Age (years)	10	20	30	40	50	60	68	70	80	90	100	110	120	130	135
Volume (cubic feet)	694	1,912	3,558	5,536	7,750	10,104	12,023	12,502	14,848	17,046	19,000	20,614	21,792	22,438	22,514
Undiscounted ($r = 0.0$)															
Value of Timber ($)	694	1,912	3,558	5,536	7,750	10,104	12,023	12,502	14,848	17,046	19,000	20,614	21,792	22,438	22,514
Cost ($)	1,208	1,574	2,067	2,661	3,325	4,031	4,607	4,751	5,454	6,114	6,700	7,184	7,538	7,731	7,754
Net Benefits ($)	–514	338	1,491	2,875	4,425	6,073	7,416	7,751	9,394	10,932	12,300	13,430	14,254	14,707	14,760
Discounted ($r = 0.01$)															
Value of Timber ($)	628	1,567	2,640	3,718	4,712	5,562	6,112	6,230	6,698	6,961	7,025	6,899	6,603	6,155	5,876
Cost ($)	1,188	1,470	1,792	2,115	2,414	2,669	2,833	2,869	3,009	3,088	3,107	3,070	2,981	2,846	2,763
Net Benefits ($)	–560	97	848	1,603	2,299	2,893	3,278	3,361	3,689	3,873	3,917	3,830	3,622	3,308	3,113
Discounted ($r = 0.02$)															
Value of Timber ($)	567	1,288	1,964	2,507	2,879	3,080	3,128	3,126	3,046	2,868	2,623	2,334	2,024	1,710	1,449
Cost ($)	1,170	1,386	1,589	1,752	1,864	1,924	1,938	1,938	1,914	1,860	1,787	1,700	1,607	1,513	1,435
Net Benefits ($)	–603	–98	375	755	1,015	1,156	1,190	1,188	1,132	1,008	836	634	417	197	14
Discounted ($r = 0.04$)															
Value of Timber ($)	469	873	1,097	1,153	1,091	960	835	803	644	500	376	276	197	137	113
Cost ($)	1,141	1,262	1,329	1,346	1,327	1,288	1,251	1,241	1,193	1,150	1,113	1,083	1,059	1,041	1,034
Net Benefits ($)	–672	–389	–232	–193	–237	–328	–415	–438	–549	–650	–737	–807	–862	–904	–921

Value of timber = price × volume/$(1 + r)^t$

Cost = \$1,000 + (\$0.30 × volume)/$(1 + r)^t$

Net benefits = value of timber − cost

Price = \$1

when a discount rate of only 0.02 is used, the maximum net benefits occur at an age of 68 years, roughly half the age of the undiscounted case.

Second, under these specific assumptions, the optimal harvest age is insensitive to changing the magnitude of the planting and harvesting costs. You can see this by comparing the age that yields the maximum value in the "value of timber" row and age that yields the maximum value in the "net benefit" row. Notice that for all discount rates, these two maxima occur at the same age. Even if both types of costs were zero, the optimal harvesting age would not be affected. The age that maximizes the value of the timber remains the same.

Third, with high enough discount rates, replanting may not be efficient. Note that with $r = 0.04$, the present value of net benefits is uniformly negative due to the assumed \$1,000 planting cost. The harvest age that maximizes the present value of net benefits from a standing forest in this case would occur when the trees were about 40 years old, but the present value of costs of replanting would exceed the present value of the benefits so it would not be efficient to replant the harvested forest.

Higher discount rates imply younger harvesting ages because they are less tolerant of the slow timber growth that occurs as the stand reaches maturity. The use of a positive discount rate implies a direct comparison between the increase in the value of nonharvested timber and the increase in value that would occur if the forest were harvested and the money from the sale invested at rate r. In the undiscounted case, using an r of zero implies that the opportunity cost of capital is zero, so it pays to leave the money invested in trees as long as some growth is occurring. As long as r is positive, however, the trees will be harvested as soon as the growth rate declines sufficiently that more will be earned by harvesting the trees and putting the proceeds in higher-yielding financial investments (in other words, when g, the growth rate in the volume of wood, becomes less than r).

The fact that neither harvesting nor planting costs affect the harvesting period in this model is easy to explain. Because they are paid immediately, the present value of planting costs is equal to the actual expenditure; it does not vary with the age at which the stand is harvested. Essentially, a constant is being subtracted from the value of timber at every age so it does not change the age at which the maximum occurs.

Harvesting costs do not affect the age of harvest for a different reason. Since total harvesting costs are assumed proportional to the amount of timber harvested (\$0.30 for each cubic foot), neither the price nor the marginal cost of a cubic foot of wood varies with age; they are also constants. In the case of our numerical example, this constant net value before discounting is \$0.70 (the \$1 price minus the \$0.30 marginal harvest cost). Regardless of the numerical value assigned to the marginal cost of harvesting, this net value before discounting is a constant that is multiplied by the volume of timber at each age divided by $(1 + r)^t$. Its role is merely to raise or lower the net benefits curve; it does not change its shape, including the location of the maximum point. Therefore, net benefits will be maximized at the same age of the stand, regardless of the value of the marginal harvesting cost, as long as marginal harvesting cost is less than the price received; a rise in the marginal cost of harvesting will not affect the optimal age of harvest. (What is the optimal harvesting strategy if the marginal cost of harvesting is larger than the price?)

What effect could policy have on the harvesting age? Consider the effect of a \$0.20 tax levied on each cubic foot of wood harvested in this simple model. Since this tax would raise the after-tax marginal cost of harvesting from \$0.30 per cubic foot to \$0.50 per cubic foot, it would have the same effect as a rise in harvesting cost. As we have already demonstrated, this implies that the tax would leave the optimal harvesting age unchanged.

The final conclusion that can be drawn from this numerical example relates to the interaction between discount rates and planting costs on the decision to replant. When high discount rates combine with high replanting costs, planting trees for commercial harvest would be less likely to yield positive net benefits than would be the case with lower discount rates. (Notice, for example, in Table 11.1, that replanting would be economically desirable only for discount rates lower than $r = 0.04$.) With high discount rates, tree growth is simply too slow to justify the planting expense; profit-maximizing foresters would favor cutting down an existing forest, but not replanting it.

Extending the Basic Model

This basic model is somewhat unrealistic in several respects. Perhaps, most importantly, it considers the harvest as a single event rather than a part of an infinite sequence of harvesting and replanting. Typically in the infinite planning horizon model, harvested lands are restocked and the sequence starts over again in a never-ending cycle.

At first glance, it may appear that this is really no different from the case just considered. After all, can't one merely use this model to characterize the efficient interval between planting and harvest for each period? The mathematics tells us (Bowes & Krutilla, 1985) that this is *not* the correct way to think about the problem, and with a bit of reflection, it is not difficult to see why.

The single-harvest model we developed would be appropriate for an infinite planning period if and only if all periods were independent (meaning that decisions in any period would be unaffected by anything that went on in the other periods). If interdependencies exist among time periods, however, the harvesting decision must reflect those interdependencies.

Interdependencies do exist. The decision to delay a harvest imposes an additional cost in an infinite planning model that has no counterpart in our single-harvest model—the cost of delaying the onset of the next planting and harvesting cycle. In our single-harvest model, the optimum age to harvest occurs when the marginal benefit of an additional year's growth equals the marginal opportunity cost of capital. In other words, when the capital gains from letting the trees grow another year become equal to the return that could be obtained from harvesting the trees and investing the gains, the stand is harvested. In the infinite-planning horizon case, the opportunity cost of delaying the next cycle, which has no counterpart in the single stand model, must also be covered by the gain in tree growth.

The effect of including the opportunity cost of delay in an infinite horizon model can be rather profound. Assuming that all other aspects of the problem (such as planting and harvesting costs, discount rate, growth function, and price) are the same, the optimal time to harvest (called the *optimal rotation* in the infinite-planning case) is *shorter* in the infinite-planning case than in the single-harvest case. This follows directly from the existence of the opportunity cost of delaying the next harvest. The efficient forester would harvest at an earlier age when he or she is planning to replant the same area than when the plot will be left inactive after the harvest.

This more complicated model also yields some other different conclusions from our original model, a valuable reminder of a point made in Chapter 1—conclusions flow from a specific view of the world and are valid only to the extent that view captures the essence of a problem.

Consider, for example, the effect of a rise in planting costs. In our single-harvest model, they had no effect on the optimal harvest age. In the infinite-horizon case, the optimal rotation is affected because higher planting costs reduce the marginal opportunity cost of delaying the cycle; fewer net benefits are lost by delaying the cycle, compared to the case with lower planting costs. As a result, the optimal rotation (the time between planting and harvesting that crop) would increase as planting costs increase. A similar result would be obtained when harvesting costs are increased. The optimal rotation period would be lengthened in that case as well. (Can you see why?)

Since increased harvesting costs in the infinite-horizon model lengthen the optimal rotation period, a per-unit tax on harvested timber would also lengthen the optimal rotation period in this model. Furthermore, lengthening the rotation period implies that the harvested trees would be somewhat older and, therefore, each harvest would involve a somewhat larger volume of wood.

Another limitation of our basic model lies in its assumption of a constant relative price for the wood over time. In fact, the relative prices of timber have been rising over time. Introducing relative prices for timber that rise at a constant rate in the infinite-horizon model causes the optimal rotation period to increase relative to the fixed-price case. In essence, prices that are rising at a fixed rate act to offset (i.e., diminish) the effect of discounting. Since we have already established that lower discount rates imply longer rotation periods, it immediately follows that rising prices also lead to longer efficient rotation periods.

A final issue with the models as elaborated so far is that they all are concerned solely with the sale of timber as a product. In fact, forests serve several other purposes as well, such as providing habitat for wildlife, supplying recreational opportunities, and stabilizing watersheds. For these uses, additional benefits accrue to the standing timber that are lost or diminished when the stand is harvested.

It is possible to incorporate these benefits into our model to demonstrate the effect they would have on the efficient rotation. Suppose that the amenity benefits conveyed by a standing forest are positively related to the age of the forest. In the infinite horizon case, the optimal rotation would once again occur when the marginal benefit of delay equaled the marginal cost of delay. When amenity values are considered, the marginal benefit of delay (which includes having these amenity values for another year) would be higher than in the models where amenity benefits are not considered. For this reason, considering amenity benefits would lengthen the optimal rotation. If the amenity benefits are sufficiently large, it may even be efficient to leave the forest as a wilderness area and not ever harvest it.

Sources of Inefficiency

The previous section considered the nature of the harvesting decision. In this section, we shall discover sources of inefficiency in that decision. These inefficiencies have the effect of biasing profit-maximizing decisions toward excessive rates of deforestation.

Perverse Incentives for the Landowner

Profit maximization does not produce efficient outcomes when the pattern of incentives facing decision makers is perverse. Forestry provides an unfortunately large number of situations in which perverse incentives produce very inefficient and unsustainable outcomes.

Privately owned forests are a significant force all over the world, but in some countries, such as the United States, they are the dominant force. As described next, private forest decisions are plagued by external costs of various types. Providing a sustainable flow of wood fiber is not the sole *social* purpose of the forest. When the act of harvesting timber imposes costs on other valued aspects of the forest (e.g., watershed maintenance, prevention of soil erosion, and protection of biodiversity), these costs are not borne by the decision maker; these amenity costs normally will not be adequately considered in profit-maximizing decisions.

The fact that the value of the standing forest as wildlife habitat or as a key element in the local ecosystem is an *external* cost can lead to inefficient decisions that threaten biodiversity. Failure to recognize all of the social values of the standing forest provides an incentive not only to harvest an inefficiently large amount of timber in working forests but also to harvest timber even when preservation is the efficient alternative. For example, the controversy that erupted in the Pacific Northwest of the United States between environmentalists concerned with protecting the habitat of the northern spotted owl and loggers can, in part, be explained by the different values these two groups put on habitat destruction. Loggers treat the loss of the northern spotted owl as an external cost; environmentalists treat the loss of timber harvest that results from habitat protection as an external cost.

Government policies can also create perverse incentives for landowners. Historically, the rapid rate of deforestation in the Amazon, for example, was promoted in part by the Brazilian government (Binswager, 1991; Mahar, 1989). When the Brazilian government reduced taxes on income derived from agriculture (primarily cattle ranching), this discriminatory treatment of agricultural income caused agriculture to be overvalued. This overvaluation made it profitable to cut down forests and convert the land to agriculture even when, in the absence of discriminatory tax policy, agriculture in these regions would not have been profitable. This system of taxation encouraged higher-than-efficient rates of conversion of land from forests to pasture (applying the model in Chapter 10) and subsidized an activity that, in the absence of tax discrimination, would not normally have been economically viable. In essence, Brazilian taxpayers were unknowingly subsidizing deforestation that depreciated the value of their natural capital stock.

The Brazilian system of property rights over land also played a role in the early history of deforestation. Acquiring the rights to land simply by occupying it had been formally recognized since 1850. A "squatter" acquired a usufruct right (the right to continue using the land) by (1) living on a plot of unclaimed public land and (2) using it "effectively" for the required period of time. If these two conditions were met for 5 years, the squatter acquired ownership of the land, including the right to transfer it to others. A claimant received a title for an amount of land up to three times the amount cleared of forest. Notice the incentives that this system of property rights created. The more deforestation accomplished by the squatter, the larger the amount of land he or she acquired. In effect, landless peasants could only acquire land by engaging in deforestation; due to this policy, the marginal benefits from clearing land were artificially high.

In recognition of the consequences of these perverse incentives, government policies no longer encourage deforestation by requiring that land be cleared for ownership and the practice of subsidizing cattle has also been abandoned. However, resettlement programs have also promoted the expansion of paved roads, ports, waterways, railways, and hydroelectric power plants into the heavily forested central Amazonia region. All of these government policies radically changed the value of land uses that were competing with preserved forest (remember Chapter 10), and the result was deforestation.

As a result of the resettlement program, many migrants engage in agriculture. Studying the decisions made by these farmers, Caviglia-Harris (2004) found that, as the land conversion model would suggest, the degree to which these farmers contribute to deforestation is impacted by market conditions as well as government policies. Market forces not only affect incentives to expand the scale of operations but also affect incentives to choose particular forms of agriculture. For example, her empirical results show that cattle ownership by migrants significantly increases the percentage of deforestation. Therefore, as the market for cattle and its related products—milk and meat—advanced, deforestation levels also increased.

Even natural conditions affect land conversion since they affect the profitability of agriculture. Chomitz and Thomas (2003), for example, found that the probability that land in Amazonia was used for agriculture or intensively stocked with cattle declined markedly with increasing rainfall, other things equal. This point is significant since it suggests that due to its prevailing high humidity, western Amazonia may be less suitable for agricultural development and therefore could be less vulnerable to the threat posed by the conversion of forested land into agriculture.

In the Far East and in the United States, perverse incentives also take another form. Logging is the major source of deforestation in both regions. Why wouldn't loggers act efficiently? One reason, as noted, is the fact that many amenity values of the standing forest are external to loggers and hence do not play much, if any, role in their decision making.

Another source of inefficiency can be found in the concession agreements, which define the terms under which public forests can be harvested. To loggers, harvesting existing forests has a substantial advantage over planting new forests: old growth can be harvested immediately for profit. By virtue of the commercial value of larger, older trees, considerable economic rent (called *stumpage value* in the industry) is associated with a standing forest.

In principle, governments have a variety of policy instruments at their disposal to capture this rent from the concessionaires, but they have typically given out the concessions to harvest this timber without capturing anywhere near all of the rent.[3] As a result, the cost of harvesting is artificially reduced and loggers can afford to harvest much more forest than is efficient. The failure of government to capture this rent also means that the wealth tied up in these forests has typically gone to a few, now-wealthy individuals and corporations rather than to the government to be used for the alleviation of poverty or other worthy social objectives.

The failure to capture the rent from concession agreements is not the only problem. Other contractual terms in these concession agreements have a role to play as well. Because forest concessions are typically awarded for limited terms, concession holders have little incentive to replant, to exercise care in their logging procedures, or even to conserve younger trees until they reach the efficient harvest age. The future value of the forest will not be theirs to capture. The resulting logging practices can destroy much of the younger stock by (1) the construction of access roads, (2) the felling and dragging of the trees, and (3) the elimination of the protective canopy. Although sustainable forestry would be possible for many of these nations, limited-term concession agreements make it unlikely.[4]

Finally, some harvest is simply illegal. Illegal harvesters have no incentive to protect future values and act as if their discount rate were infinite!

The list of losers from inefficient forestry practices frequently includes indigenous peoples who have lived in and derived their livelihood from these forests for a very long time. As the loggers and squatters push deeper and deeper into forests, the indigenous people, who lack the power to stem the tide, are forced to relocate further away from their traditional lands.

Perverse Incentives for Nations

Another source of deforestation involves external costs that transcend national borders, making it unrealistic to expect national policy to solve the problem. Some international action would normally be necessary for these cases.

Biodiversity. Due to species extinction, the diversity of the forms of life that inhabit the planet is diminishing at an unprecedented rate. And the extinction of species is, of course, an irreversible process. Deforestation, particularly the destruction of the tropical rain forests, is a major source of species extinction because it destroys the most biologically active habitats. In particular, Amazonia has been

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[3]One way for the government to capture this rent would be to put timber concessions up for bid. Bidders would have an incentive to pay up to the stumpage value for these concessions. The more competitive the bidding was, the higher the likelihood that the government would capture all of the rent. In practice, many of the concessions have been given to those with influence in the government at far-below market rates. See Jeffrey R. Vincent. "Rent Capture and the Feasibility of Tropical Forest Management," *Land Economics* Vol. 66, No. 2 (May 1990), 212–223.

[4]Currently, foresters believe that the sustainable yield for closed tropical rain forests is zero, because they have not yet learned how to regenerate the species in a harvested area once the canopy has been destroyed. Destroying the thick canopy allows the light to penetrate and changes the growing conditions and the nutrient levels of the soil sufficiently that even replanting is unlikely to regenerate the types of trees included in the harvest.

characterized by Norman Myers, the British environmentalist, as the "single richest region of the tropical biome." The quantity of bird, fish, plant, and insect life that is unique to that region is unmatched anywhere else on the planet.

One of the tragic ironies of the situation is that these extinctions are occurring at precisely the moment in history when we would be most able to take advantage of the gene pool this biodiversity represents. Modern techniques now make it possible to transplant desirable genes from one species into another, creating species with new characteristics, such as enhanced disease resistance or pest resistance. But the gene pool must be diverse to serve as a source of donor genes. Tropical forests have already contributed genetic material to increase disease resistance of cash crops, such as coffee and cocoa, and have been the source of some entirely new foods. Approximately one-quarter of all prescription drugs have been derived from substances found in tropical plants. Future discoveries, however, are threatened by deforestation's deleterious effect on habitat.

Climate Change. Deforestation also contributes to climate change. Since trees absorb CO_2, a major greenhouse gas, deforestation eliminates a potentially significant means of ameliorating the rise in CO_2 emissions. Furthermore, burning trees, an activity commonly associated with agricultural land clearing, adds CO_2 to the air, by liberating the carbon sequestered within the trees.

Why is deforestation occurring so rapidly when the benefits conferred by a standing forest are so significant by virtually anyone's reckoning? The concept of externalities provides the key to resolving this paradox. Both the climate change and biodiversity benefits are largely external to both the private harvester and to the nation containing the forest, while the costs of preventing deforestation are largely internal. The loss of biodiversity precipitated by deforestation is perhaps most deeply felt by the industrialized world, not the countries that host the forests. Currently, the technologies to exploit the gene pool this diversity represents are in widest use in the industrialized countries. Similarly, most of the damage from climate change would be felt outside the borders of the country being deforested. Yet stopping deforestation means giving up the jobs and income derived from either harvesting the wood or harvesting the land made available by clearing the forests. Therefore, it is not surprising that the most vociferous opposition to the loss of biodiversity is mounted in the industrialized nations, not the nations hosting tropical forests. With global externalities, we have not only a clear rationale for market failure but also a clear rationale for why host national governments cannot be expected to solve the problem by themselves. While some external costs to individual agents are in fact internalized at the level of the nation (meaning those who bear those costs live in the same nation), global externalities aren't.

Poverty and Debt

Poverty and debt are also major sources of pressure on the forests. Peasants see unclaimed forest land as an opportunity to become landowners. Nations confronted with masses of peasants see unowned or publicly owned forests as a politically more viable source of land for the landless than taking it forcibly from the rich. Without land, peasants descend upon the urban areas in search of jobs in larger numbers than can be accommodated by urban labor markets. Politically explosive tensions, created and nourished by the resulting atmosphere of frustration and hopelessness, force governments to open up forested lands to the peasants or at least to look the other way as peasants stake their claims.

In eastern and southern Africa, positive feedback loops have created a downward cycle in which poverty and deforestation reinforce each other. Most natural forests have long since been cut down for timber and fuelwood and for producing crops from the cleared land. As forests disappear, the rural poor are forced to divert more time toward locating new sources of fuel. Once fuelwood is no longer available, dried animal waste is burned, thereby eliminating it as a source of fertilizer to nourish depleted soils. Fewer trees lead to more soil erosion and soil depletion leads to diminished nutrition. Diminished nutrition reinforces the threats to human health posed by an inability to find or afford enough fuel, wood, or animal waste for cooking and boiling unclean water. Degraded health saps energy, increases susceptibility to disease, and reduces productivity. Survival strategies may necessarily sacrifice long-term goals simply to ward off starvation or death; the forest is typically an early casualty.

At the national level, poverty takes the form of staggering levels of debt. Repaying this debt and the interest payments flowing from it reduces the capacity of a nation to accumulate foreign exchange earnings. In periods of high real interest rates, servicing these debts commands most if not all foreign exchange earnings. Using these foreign exchange earnings to service the debt eliminates the possibility of using them to finance imports for sustainable activities to alleviate poverty.

According to the "debt-resource hypothesis," large debts owed by many developing countries encourage these countries to overexploit their resource endowments to raise the necessary foreign exchange. Timber exports represent a case in point. Although a number of studies find empirical support for this hypothesis, not all do. And the support for extending the hypothesis to natural resources other than forests seems particularly weak. For example, Neumayer (2005) reports:

> *We did not find evidence that countries with higher debt levels or higher debt service burdens have higher exploitation of subsoil fossil fuel and mineral resources or higher production of cash crops than other countries. (p. 138)*

Sustainable Forestry

We have examined three types of decisions by landowners—the harvesting decision, the replanting decision, and the conversion decision—that affect the rate of deforestation. In all three cases, profit-maximizing decisions may not be efficient and these inefficiencies tend to create a bias toward higher rates of deforestation. These cases present both a challenge and an opportunity. The current level of deforestation is the challenge. The opportunity arises from the realization that correcting these inefficiencies can promote both efficiency and sustainability.

Does the restoration of efficiency guarantee sustainable outcomes? Let's suppose that we apply the environmental sustainability definition to forestry. By this definition, sustainable forestry can be realized only when the forests are sufficiently protected that harvests can be maintained perpetually. Also, sustainable forestry would require harvests to be limited to the growth of the forest, leaving the volume of wood unaffected (or nondecreasing) over time.

Efficiency is not necessarily compatible with this definition of sustainable forestry. Maximizing the present value involves an implicit comparison between the increase in value from delaying harvest (largely because of the growth in volume) and the increase in value from harvesting the timber and investing the earnings (largely a function of *r*; the interest rate earned on invested savings). With slow-growing species, the growth rate in volume is small. Choosing the harvest age that maximizes the present value of net benefits in slow-growing forests may well involve harvest volumes higher than the net growth of the forest.

The search for sustainable forestry practices that are also economically sustainable has led to a consideration of new models of forestry. One involves a focus on planting rapidly growing tree species in plantations. Rapidly growing species raise the economic attractiveness of replanting because the invested funds are tied up for a shorter time. Species raised in plantations can be harvested and replanted at a low cost. Forest plantations have been established for such varied purposes as supplying fuelwood in developing countries and supplying pulp for paper mills in both the industrialized and developing countries.

Plantation forestry is controversial, however. Not only do plantation forests typically involve a single species of tree, which results in a poor wildlife habitat, they also tend to require large inputs of fertilizer and pesticides.

In some parts of the world, the natural resilience of the forest ecosystem is sufficiently high that sustainability is ultimately achieved, despite decades of earlier unsustainable levels of harvest. In the United States, for example, sometime during the 1940s, the net growth of the nation's timberlands exceeded timber removals. Subsequent surveys have confirmed that net growth has continued to exceed harvests, in spite of a rather large and growing demand for timber. The total volume of forest biomass in the United States has been growing since at least World War II; for the country as a whole, harvests during that period have been sustainable, although the harvests of some specific species in some specific areas have not.

Public Policy

One public policy approach involves restoring efficient incentives. The following examples flow naturally from the previous discussion:

- Concessionaires should pay the full cost for their rights to harvest publicly controlled lands, including compensating for damage to the forests surrounding the trees of interest.
- The magnitude of land transferred to squatters should not be a multiple of the amount of cleared forest.
- The rights of indigenous peoples should be respected.

Another approach involves enlisting the power of consumers in the cause of sustainable forestry. The process typically involves the establishment of standards for sustainable forestry, employing independent certifiers to verify compliance with these standards, and allowing certified suppliers to display a label designating compliance (see Example 11.1).

For this system to work well, several preconditions need to be met. The certification process must be reliable and consumers must trust it. Additionally, consumers must be sufficiently concerned about sustainable forestry to pay a price premium (over prices for otherwise-comparable, but uncertified, products) that is large enough to make certification an attractive option for forestry companies. This means that the revenue should be sufficient to at least cover the higher costs associated with producing certified wood. Nothing guarantees that these conditions would be met in general.

Most of these changes could be implemented by individual nations to protect their own forests. And to do so would be in their interests. By definition, inefficient practices cost more than the benefits received. The move to a more efficient set of policies would necessarily generate more net benefits, which could be shared in ways that build political support for the change. But what about the global inefficiencies—those that transcend national boundaries? How can they be resolved?

EXAMPLE 11.1

Producing Sustainable Forestry through Certification

The Forest Stewardship Council (FSC) is an international, not-for-profit organization originally headquartered in Oaxaca, Mexico, with the FSC Secretariat relocating to Bonn, Germany, in 2003.

The FSC was conceived in large part by environmental groups, most notably the World Wide Fund for Nature (WWF). The goal of the FSC is to foster "environmentally appropriate, socially beneficial, and economically viable management of the world's forests." It pursues this goal by being an independent third-party certifier of well-managed forests.

The FSC has developed standards to assess the performance of forestry operations. These standards address environmental, social, and economic issues. Forest assessments require one or more field visits by a team of specialists representing a variety of disciplines, typically including forestry, ecology/wildlife management/biology, and sociology/anthropology. Additionally, the FSC requires that forest assessment reports be subject to independent peer review. Any FSC assessment may be challenged through a formal complaints procedure. FSC-certified products are identified by an on-product label and/or off-product publicity materials. As of April 2013, the FSC had certified 173,973,446 hectares in 79 countries (a hectare equals 2.47105 acres).

Although the FSC is supported by a broad coalition of industry representatives, social justice organizations, and environmental organizations, it is opposed by some mainstream industry groups, particularly in North America, and by some landowners' associations in Europe. One unresolved issue is how to include small and medium-sized landholdings in this certification process since conventional certification is expensive.

Source: The Forest Stewardship Website. Retrieved April 14, 2013, from http://www.fsc.org

Several economic strategies exist. They share the characteristic that they all involve compensating the nations conferring external benefits so as to encourage conservation actions consistent with global efficiency.

Debt–Nature Swaps

One strategy involves reducing the pressure on the forests caused by the international debt owed by many developing countries. One of the more innovative policies that explores common ground in international arrangements has become known as the debt–nature swap. A debt–nature swap involves the purchase (at a discounted value in the secondary debt market) of a developing country debt, frequently by a nongovernmental environmental organization (NGO). The new holder of the debt, the NGO, offers to cancel the debt in return for an environmentally related action on the part of the debtor nation.

In 1998, this approach received a boost with the passage of the Tropical Forest Conservation Act (TFCA). This Act offered eligible developing countries options for reducing certain official debt owed the US government while at the same time generating funds in local currency to support tropical forest conservation activities. The program took advantage of public–private partnerships and the majority of TFCA agreements to date have included funds raised by US-based NGOs.

TFCA is implemented through bilateral agreements with eligible countries. As of December 2011, approximately $202 million in congressionally appropriated funds have been used to conclude 18 TFCA debt treatment agreements with 14 countries.

The first debt–nature swap took place in Bolivia in 1987. Since then debt-for-nature swaps have been arranged or explored in many developing countries, including Ecuador, the Philippines, Zambia, Jamaica, Madagascar, Guatemala, Venezuela, Argentina, Honduras, and Brazil.

A brief examination of the Madagascar case can illustrate how these swaps work. Recognized as a prime source of biodiversity, the overwhelming majority of Madagascar's land mammals, reptiles, and plants are found nowhere else on Earth. Madagascar is also one of the poorest countries in the world, burdened with high levels of external debt. Because of its limited domestic financial resources, Madagascar could not counter the serious environmental degradation it was experiencing.

Between 1989 and 1996, Conservation International, the Missouri Botanical Garden, and the World Wildlife Fund negotiated nine commercial debt-for-nature swaps in Madagascar. These arrangements generated $11.7 million in conservation funds. Agreements signed by Madagascar's government and the participating conservation organizations identified the programs to be funded. One such program trained over 320 nature protection agents, who focused on involving local communities in forest management.

Other arrangements involving different governments and different environmental organizations have since followed this lead. The main advantage of these arrangements to the debtor nation is that a significant foreign exchange obligation can be paid off with domestic currency. Debt–nature swaps offer the realistic possibility to turn what has been a major force for unsustainable economic activity (the debt crisis) into a force for resource conservation.

Extractive Reserves

One strategy specifically designed to protect the indigenous people of the forest as well as to prevent deforestation involves the establishment of extractive reserves. These areas would be reserved for the indigenous people to engage in the traditional hunting–gathering activities.

Extractive reserves have already been established in the Acre region of Brazil. Acre's main activity comes from the thousands of men who tap the rubber trees scattered throughout the forest, a practice dating back 100 years. Under the leadership of Chico Mendes, a leader of the tappers who was subsequently assassinated, four extractive reserves were established in June 1988 by the Brazilian government to protect the rubber tappers from encroaching development.

Conservation Easements and Land Trusts

One private approach to internalizing the forestry benefits that may normally be externalized (and hence undervalued) in deciding how the resource is to be used involves conservation easements. These were discussed at length in Chapter 10, so here it is only necessary to point out that conservation easements provide a means for amenity values to be explicitly considered in forestry decisions. In the right circumstances, they can facilitate efficient preservation of those values (see Example 11.2).

EXAMPLE 11.2

Conservation Easements in Action: The Blackfoot Community Project

Montana's rural and wild Blackfoot Valley has so far escaped the rapid development occurring in many scenic valleys throughout the West. Although it offers huge amenity benefits to the surrounding community, those benefits are externalities to most potential developers and therefore future private transactions could well be biased against them.

Recognizing this potential, The Nature Conservancy (TNC) purchased significant tracts of this land (a total of 69,179 acres as of 2007) from Plum Creek Timber Company, a private landowner. Their objective, however, was not to retain ownership, but to dispose of the acquired land once they could be assured that the new owners would preserve key amenity assets. Since resale provides additional funds to the organization, this acquire-and-dispose strategy allows TNC to protect much more land with the funds at their disposal than would be permitted by retaining ownership of the acquired land.

Some 32,480 acres have been sold to public agencies. For example, a sale in May 2007 transferred 5234 acres of the western Horseshoe Hills, an important wildlife corridor between the Bob Marshall Wilderness and the Blackfoot Clearwater Wildlife Management Area, to the US Forest Service. The Forest Service had previously purchased the adjacent eastern half of the Horseshoe Hills.

The Conservancy apparently intends to sell roughly half of its acquired lands to private landowners once conservation easements protecting the amenity benefits are attached to the deeds.

Source: More than 69,000 acres conserved as part of the Blackfoot Community Project. Retrieved from http://www.nature.org/wherewework/northamerica/states/montana/news/news1803.html

The World Heritage Convention

The *World Heritage Convention* came into being in 1972 with the primary mission of identifying and preserving the cultural and natural heritage of outstanding sites throughout the world, and ensuring their protection through international cooperation. Currently, some 178 countries have ratified the convention.

Ratifying nations have the opportunity to have their natural properties of outstanding universal value added to the World Heritage List. The motivation for taking this step is to gain international recognition for this site, using the prestige that comes from this designation to raise awareness for heritage preservation and the likelihood that the site can be preserved. A ratifying nation may receive both financial assistance and expert advice from the World Heritage Committee as support for promotional activities for the preservation of its properties as well as for developing educational materials.

Responsibility for providing adequate protection and management of these sites falls on the host nations, but a key benefit from ratification, particularly for developing countries, is access to the World Heritage Fund. This fund is financed by mandatory contributions from ratifying nations, calculated at 1 percent of the country's contribution to UNESCO, the administering agency. Annually, about $3 million (US) are made available, mainly to low-income countries to finance technical assistance and training projects, as well as for assistance preparing their nomination proposals or to develop conservation projects. Emergency assistance may also be made available for urgent action to repair damage caused by human-made or natural disasters.

Royalty Payments

A potential source of revenue for biodiversity preservation involves taking advantage of the extremely high degree of interest by the pharmaceutical industry in searching for new drugs derived from these biologically diverse pools of flora and fauna. Establishing the principle that nations containing these biologically rich resources within their borders would be entitled to a stipulated royalty on any and all products developed from genes obtained from these preserves provides both an incentive to preserve the resources and some revenue to accomplish the preservation.

Nations harboring rich, biological preserves have begun to realize their value and to extract some of that value from the pharmaceutical industry. The revenue is in part used for inventorying and learning more about the resource as well as preserving it. For example, in 1996, Medichem Research, an Illinois-based pharmaceutical company, entered into a joint venture with the Sarawak government. The organization created by this joint venture has the right to file exclusive patents on two compounds that offer some promise as cancer treatments.

The agreement specified a 50–50 split from royalties once the drug is marketed. The Sarawak government was given the exclusive right to supply the latex raw material from which the compounds are derived. Furthermore, Sarawak scientists are involved in screening and isolating the compounds and Sarawak physicians are involved in the clinical trials.

This agreement not only provides a strong rationale for protecting the biological source, but also enables the host country to build its capacity for capturing the value of its biodiversity in the future (Laird & ten Kate, 2002). These arrangements are particularly significant because they facilitate transboundary sharing of the costs of preservation. It is unrealistic to expect countries harboring these preserves to shoulder the entire cost of preservation when the richer countries of the world are the major beneficiaries. It may also be unrealistic to assume that pharmaceutical demand is sufficient to fund efficient preservation (see Example 11.3).

Debt–nature swaps, extractive reserves, royalty payments, and conservation easements all involve recognition of the fact that resolving the global externalities component of deforestation requires a rather different approach from resolving the other aspects of the deforestation problem. In general, this approach involves financial transfers from the industrialized nations to the tropical nations, transfers that are constructed so as to incorporate global interests into decisions about the future of tropical forests.

EXAMPLE 11.3

Does Pharmaceutical Demand Offer Sufficient Protection to Biodiversity?

The theory is clear—incentives to protect plants are stronger when the plants are valuable to humans. Is the practice equally clear?

The case of Taxol is instructive. Derived from the slow-growing Pacific yew, Taxol is a substance that has been proved effective in treating advanced forms of breast and ovarian cancers. As of 1998, it was the best-selling anticancer drug ever.

Since the major site for this tree was in the old-growth forests of the Pacific Northwest, the hope of environmental groups was that the rise in the importance of Taxol might provide both sustainable employment and some protection for old-growth forests.

In fact, that is not how it worked out. The Taxol for the chemical trials was derived from the bark of the tree. Stripping the tree of its bark killed it. And supplying enough bark for the chemical trials put a tremendous strain on the resource.

Ultimately, the private company that marketed Taxol, Bristol-Squibb, developed a semi-synthetic substitute that could be made from imported renewable tree parts.

The Pacific yew, the original source of one of the most important medical discoveries in the twentieth century, was left completely unprotected. And the industry that had grown up to supply the bark collapsed. In the end, its value proved transitory and its ability to support a sustainable livelihood in the Pacific Northwest was illusory.

Source: Goodman, J., & Walsh, V. (2001). *The Story of Taxol: Nature and Politics in the Pursuit of an Anti-Cancer Drug*. New York: Cambridge University Press.

Recognizing the limited availability of international aid for the preservation of biodiversity habitat, nations have begun to tap other revenue sources. Tourist revenues have become an increasingly popular source, particularly where the tourism is specifically linked to the resources that are targeted for preservation. Rather than mixing these revenues with other public funds, nations are earmarking them for preservation (see Example 11.4).

EXAMPLE 11.4

Trust Funds for Habitat Preservation

How can local governments finance biodiversity preservation when faced with limited availability of both international and domestic funds? One option being aggressively pursued by the World Wildlife Fund involves trust funds. Trust funds are moneys that are legally restricted to be used for a specific purpose (as opposed to being placed in the general government treasury). They are administered by trustees to assure compliance with the terms of the trust. Most, but not all, trust funds are protected endowments, meaning that the trustees can spend the interest and dividends from the funds, but not the principal. This assures the continuity of funds for an indefinite period.

Where does the money come from? Many nations that harbor biodiversity preserves cannot afford to spend the resources necessary to protect them. One possibility is to tap into foreign demands for preservation. In Belize, the revenue comes from a "conservation fee" charged to all arriving foreign visitors. The initial fee, $3.75, was passed by Belize's parliament in January 1996, raising $500,000 in revenues each year for the trust fund. Similar trust funds have been set up in Mexico, Honduras, and Guatemala.

Income from the trust funds can be used for many purposes, including training park rangers, developing biological information, paying the salaries of key personnel, and conducting environmental education programs, depending on the terms of the trust agreement.

Biodiversity preservation that depends on funds from the general treasury becomes subject to the vagaries of budgetary pressures. When the competition for funds intensifies, the funds may disappear or be severely diminished. The virtue of a trust fund is that it provides long-term, sustained funding targeted for the protection of biodiversity.

In 2004, Belize joined with Mexico, Honduras, and Guatemala to form the Mesoamerican Reef (MAR) fund, a regional financing mechanism. It was created to strengthen the alliance among the four country-specific trust funds. The MAR fund is unique as the first environmental fund in the Western Hemisphere to transcend national boundaries and encompass an entire ecoregion. The fund supports projects related to improving water quality, ecotourism, sustainable fisheries, and strengthening public institutions.

Source: Spergel, B. (April 1996). Trust funds for conservation. *FEEM Newsletter, 1*,13–16.; the World Wildlife Foundation's Website on conservation trust funds. Retrieved November 18, 2010, from http://www.worldwildlife.org/what/howwedoit/conservationfinance/conservationtrustfunds2.html

Summary

Forests represent an example of a storable, renewable source. Typically, tree stands have three distinct growth phases—slow growth in volume in the early stage, followed by rapid growth in the middle years and slower growth as the stand reaches full maturity. The owner who harvests the timber receives the income from its sale, but the owner who delays harvest will receive additional growth. The amount of growth depends on the part of the growth cycle the stand is in.

From an economic point of view, the efficient time to harvest a stand of timber is when the present value of net benefits is maximized—that is, when the marginal gain from delaying the harvest one more year is equal to the marginal cost of the delay. For longer-than-efficient delays, the additional costs outweigh the increased benefits, while for earlier-than-efficient harvests, more benefits (in terms of the increased value of the timber) are given up than costs saved. For many species, the efficient age at harvest is 25 years or older.

The efficient harvest age depends on the circumstances the decision maker faces. When the plot is to be left fallow after the harvest, the efficient harvest occurs later than when the land is immediately replanted to initiate another cycle. With immediate replanting, delaying the harvest imposes an additional cost—the resulting cost of subsequently delaying the next harvest—which, when factored into the analysis, makes it more desirable to harvest earlier.

A number of other factors affect the size of the efficient rotation as well. In general, the larger the discount rate, the earlier the harvest. With an infinite-planning horizon model, increases in planting and harvesting costs tend to lengthen the optimal rotation, while in a single-harvest model, they have no effect on the length of the efficient rotation. If the relative price of timber grows at a constant rate over time, the efficient rotation is longer than if prices remain constant over time. Finally, if standing timber provides amenity services (such as for recreation or wildlife management) in proportion to the volume of the standing timber, the efficient rotation will be longer in an infinite planning model than it would be in the absence of any amenity services. Furthermore, if the amenity value is large enough, efficiency would preclude any harvest of that forest.

Profit maximization can be compatible with efficient forest management under the right circumstances. In particular, in the absence of externalities, distortions caused by government policy, or illegal harvests, profit-maximizing private owners have an incentive to adopt the efficient rotation and to undertake investments that increase the yield of the forest because that strategy maximizes their net benefits.

In reality, not all private firms will follow efficient forest-management practices because they may choose not to maximize profits, they may be operating at too small a scale of operation, or externalities or public policy may create inefficient incentives. Finally, when amenity values are large and not captured by the forest owner, the private rotation period may fail to consider these values, leading to an inefficiently short rotation period or even harvesting forests that should be preserved.

Inefficient deforestation has also been encouraged by a failure to incorporate global benefits from standing forests: concession agreements can provide incentives to harvest too much too soon, and may fail to provide adequate incentives to protect the interests of future generations; land property rights systems can make the amount of land acquired by squatters a multiple of cleared forestland; and tax systems can discriminate against standing forests.

Substantial strides toward restoring efficiency as well as sustainability can be achieved simply by recognizing and correcting the perverse incentives, actions that can be and should be taken by the tropical-forest nations. But these actions will not, by themselves, provide adequate protection for the global interests in the tropical forests. Six schemes designed to internalize some of these transboundary benefits—debt–nature swaps, extractive reserves, royalty payments, forest certification, and conservation easements—have already begun to be implemented.

Discussion Questions

1. Should US national forests become "privatized" (sold to private owners)? Why or why not?
2. In his book, *The Federal Land Revisited*, Marion Clawson proposed what he called the "pullback concept":

   > *Under the pullback concept any person or group could apply, under applicable law, for a tract of federal land, for any use they chose; but any other person or group would have a limited time between the filing of the initial application and granting other lease or the making of the sale in which to "pull back" a part of the area applied for. . . . The user of the pullback provision would become the applicant for the area pulled back, required to meet the same terms applicable to the original application, . . . but the use could be what the applicant chose, not necessarily the use proposed by the original applicant.* (p. 216)

   Evaluate the pullback concept as a means for conservationists to prevent some mineral extraction or timber harvesting on federal lands.

Self-Test Exercises

1. Suppose there are two identical forest plots except that one will be harvested and left to regrow while the second will be cleared after the harvest and turned into a housing development. In terms of efficiency, which one should have the oldest harvest age? Why?
2. In Table 11.1, when $r = 0.02$, the present value of the cost rises for 68 years and then subsequently declines. Why?

3. As our energy structure transitions toward renewable fuels, forest-based biomass fuels benefit from this transition. What are the likely effects of this transition on consumers, producers, and the states that host these resources?
4. Would a private forest owner normally be expected to reach an efficient balance between using his or her forest for recreation and for harvesting wood? Why or why not?
5. Compare forest certification and the certification of organic produce in terms of the relative degree to which each type of certification could, by itself, be expected to produce an efficient outcome.
6. Would a rise in the price of timber make sustainable forest practices more or less likely? Why?

Further Reading

Amacher, G. S., Ollikainen, M., & Koskela, E. A. (2009). *Economics of forest resources.* Cambridge, MA: MIT Press. This book provides an introduction to forest economics and an overview of its development, with focus on the last 25 years.

Araujo, C., Bonjean, C. A., Combes, J-L., Motel, P. C., & Reis, E. J. (2009). Property rights and deforestation in the Brazilian Amazon. *Ecological Economics, 68*(8–9), 2461–2468. This paper focuses on the impact of property rights insecurity on deforestation in the Brazilian Amazon.

Pagiola, S., Bishop, J., & Landell-Mills, N. (2002). *Selling forest environmental services: Market-based mechanisms for conservation and development.* London, UK: Earthscan. Market-based approaches are thought to offer considerable promise as a means to promote forest conservation and to serve as a new source of income for rural communities. Based on extensive research and case studies, this book demonstrates the feasibility and effectiveness of payment systems and their implications for the poor.

VanKooten, G. C., Sedjo, R. A. et al. (1999). Tropical deforestation: Issues and policies. In T. Tietenberg & H. Folmer (Eds.). *The International Yearbook of Environmental and Resource Economics 1999/2000* (198–249). Cheltenham UK: Edward Elgar. A survey of what we have learned about tropical deforestation.

Additional References and Historically Significant References are available on this book's Companion Website: http://www.pearsonhighered.com/tietenberg/

Appendix

The Harvesting Decision: Forests

Suppose that an even-aged stand of trees is to be harvested at an age that maximizes the present value of the harvested timber. That age can be found by (1) defining the present value of the harvested timber as a function of the age of the stand, and (2) maximizing the function with respect to age.

$$\text{Present Value} = [PV(t) - C_b V(t)]e^{-rt} - C_p$$

where,

P = the price received per unit of harvested volume
$V(t)$ = the volume of timber harvested at age t
C_b = the per-unit cost of harvesting the timber
t = the age of the timber, and
C_p = the fixed cost of planting

Taking the derivative of the function with respect to age and setting it equal to zero yields*

$$(P - C_b)\frac{dV(t)}{dt} = (P - C_b)V(t)r$$

or rewriting yields

$$\frac{\frac{dV(t)}{dt}}{V(t)} = r$$

Translated into English, this condition implies that the rate of return from letting the stand grow over the last increment of age should be equal to the market rate of return.

Note that the fixed planting cost has no effect on the choice of harvesting age. While it raises or lowers the present value by the exact amount of the cost of planting, it does not change where the function reaches its maximum. If it is high enough, however, it can make the function reach its maximum at a negative number. In this case, not planting trees would maximize the present value even if that meant no future harvest. (A present value of zero would be larger than the present value that would necessarily be negative with planting.)

Note also that neither the price nor the harvesting cost affects the optimal choice. Mathematically, it is because they cancel out in Equation 2. Economically, it is because the value of a harvested unit does not vary with age; therefore, the *change* in present value as the stand ages is due to the change in *volume*, not the change in the *value* of each unit of volume (since the change in value is zero).

*If we had used a discrete time framework (i.e., $(1 + r)^t$ were used for discounting instead of e^{-rt}), then the optimal condition would be the same, except r would be replaced by $ln(1 + r)$. You can verify that for the values of r we are using, these two expressions are approximately equal.