



The Deforestation of the Amazon: A Case Study in Understanding Ecosystems and Their Value

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Biological diversity is the key to the maintenance of the world as we know it.... Eliminate one species, and another increases to take its place. Eliminate a great many species, and the local ecosystem starts to decay.... How much force does it take to break the crucible of evolution?

—E.O. Wilson, *The Diversity of Life*

Introduction

In a crowded market in the Brazilian Amazon, a heated discussion develops between a farmer, a logger, and an environmentalist near the booth where the farmer is selling his crop.

“I just don’t know how I am going to pay for this fertilizer,” said Marco, a disgruntled peasant farmer growing beans in a cleared forest pasture. “This is only my second year of farming in the area, but already the crops are growing poorly, and it is hard to get rid of the weeds. They want \$300 per hectare for fertilizer and pesticides, but the land is not worth that much money. All I can afford is the \$70 per hectare to clear more forest.”

“But when you do cut the forest, you usually just burn the logs,” replied Antonio, a local logger. “It would be a better use of the land for me to log the valuable trees.”

“Why is logging better than clearing?” asked Carl, an environmentalist from Rio de Janeiro visiting to gather firsthand accounts of land uses in the Amazon. “Can’t you see the true value of the forests around you? We are standing in the most biologically diverse region of the world, and all you complain about is money? We rely on these forests for oxygen, medicines, and spiritual benefits. Besides, don’t these species have a right to exist beyond their value to humans?”

“Try feeding five children with spiritual benefits, Carl,” Marco snapped. “Look at how much land is out here. Whether or not I clear forests will not make a big difference. Besides, we have a right to develop our natural resources.”

“I agree with you, Marco,” added Antonio. “Forests grow back; they always have.”

Background

Nowhere on Earth is the threat of biological impoverishment because of deforestation greater than in the Amazon Basin of South America. The Amazon supports approximately 300 million hectares of tropical forest, the largest single area of tropical forest communities in the world. Estimates of global biodiversity point to the



Fig. 1 The Market Place

tropics as the source of 50 to 90% of all species on Earth (Wilson 1992); the richest forests often support over 300 tree species per hectare, approximately the same number of tree species in all of North America.



Fig. 2 Examples of wet tropical rainforest communities.

Recent estimates of deforestation suggest that between 1 and 3 million hectares are being cleared annually in the Amazon Basin (Laurence 1997). Based on estimates of 1% annual tropical forest loss, the Amazon may be losing as many as 11 to 16 species per day (Wilson 1989), and the resulting ecosystems are often highly degraded (Buschbacher 1986).

The deforestation of Amazonia presents a challenging study of the interactions among people, their values, and the environment.

- Is deforestation in the Amazon any different than what occurred in industrialized Europe and North America centuries past?
- Should Amazonians develop their lands as they see fit?
- Do peasant farmers actively clearing forests value their environment any differently than world conservation organizations, you, or I?
- What does the world stand to lose by watching the destruction of tropical forests?

These are some of the most hotly debated environmental questions today, leading to international conventions like the United Nations Convention on Biodiversity at the Rio de Janeiro “Earth Summit” in 1992.



Fig. 3 Small clearing in primary tropical rainforest

Factors leading to rapid tropical deforestation

Why are tropical forests being cleared in the Amazon Basin at such an alarming rate? Historically, deforestation has been caused by the interaction of many factors, seven of which are presented here for simplicity:

1. Abundant forest resources.
2. The need for peasant farmers to earn a livelihood.
3. Brazilian government policies to construct highways, subsidize agriculture, and relocate farmers into the forests.
4. The cattle industry's forced manipulation of peasant farmer land rights, and the marginalization of these farmers to the frontier.
5. Land speculation.
6. Rapid degradation of pastures due to poor soil quality and the costs of reclamation.
7. Oversupplies of beef and timber leading to price deflation and debt with banks in industrialized nations. Large debt, in turn, exacerbates timber exports.

In the 1940s, Brazil began a national development program for the Amazon Basin. Then-president Getúlio Vargas suggested that “The Amazon, under the impact of our will and labor, shall cease to be a simple chapter in the history of the world, and made equivalent to other great rivers, shall become a chapter in the history of human civilization.... Everything which has up to now been done in Amazonas, whether in agriculture or extractive industry ... must be transformed into rational exploitation” (quoted from Hall 1989). Ironically, Vargas was correct that the Amazon will cease to be a simple chapter in world history: international debt, rapidly degrading soils, the rapid loss of biodiversity, and the loss of human lives over bitter land disputes all underscore high tensions in this region.

Vargas' national vision set into motion the establishment of several government programs, including the Superintendency for the Economic Valorization of Amazonia (SPVEA) in 1953, the Superintendency for the Development of Amazonia (SUDAM) in the 1966, and the National Institute for Colonization and Agrarian Reform (INCRA) in 1971. In the 1960s, “rational exploitation” meant cattle—millions of them. The Brazilian government and several other foreign nations, including the Johnson Administration in the US, favored the development of cattle ranching in the Amazon to generate revenue during a period of high world beef prices as well as a means to eliminate world hunger (Hall 1989). Road projects, such as the Trans–Amazon Highway, were promoted in 1970 to open up commerce. Subsidies sponsored by SUDAM often granted 50% tax exemptions for investments in agriculture and livestock in the Amazon. By 1974, these subsidies had increased to 100% (Hall 1989). Indeed, a representative of the American company, Swift Armour, optimistically predicted that the Amazon Basin “was destined to be the great meat exporting center of the world” (quoted from Hall 1989).

Throughout the 1970s INCRA established programs to take advantage of newly developed highways to translocate hundreds of thousands of Brazilian citizens from northern and eastern states westward into the Amazon. The idea was analogous to homesteading on the American frontier in the 19th century. People moving to the frontier were given land practically for free so long as they showed evidence of “productive use,” which, unfortunately meant clearing the forest for agriculture or pasture. These people represented mainly a class of peasant farmers, who lacked the financial support of Brazil's banks to start their own large-scale cattle or agricultural operations. Consequently, they practiced local forms of agriculture, the most popular of which has been slash–and–burn agriculture.

A typical slash–and–burn program involves cutting a small patch of forest, usually 3 to 4 hectares, burning the vegetation, perhaps after selling a minor fraction of timber, and growing and harvesting 2 to 3 years worth of

crops. After the third year, farms are usually abandoned because of nutrient–depleted soils and the invasion of weedy species. Slash–and–burn agriculture produces about 80% of the human food supply in the Amazon as other, more intensive agriculture programs focus on crops for export (Serrão and Homma 1993).

It appears that no one, including the government, farmers, ranchers, or lending agencies, foresaw perhaps the largest impediment to Amazon development: soil degradation. Soils in tropical regions are millions of years old, having escaped major disturbances like glaciation that reset the clock on soil development (Richter and Markewitz 1995). Old soils are highly weathered aluminum and iron oxide clays that are acidic and deficient in plant nutrients, especially phosphorus. Tropical ecosystems are adapted to nutrient–poor soils as evidenced by the relatively large fraction of ecosystem nutrients stored in vegetation (compared to soils) and widespread plant adaptations like evergreen leaves that conserve nutrient loss (Vitousek and Sanford 1986). Many

attempts to bring land under cultivation or conversion to pasture for cattle have failed in the long run without supplements from fertilizers and pesticides. Cattle numbers decline from an average of two healthy head per hectare following clearing to less than 0.3 head per hectare 20 years following clearing (Serrão and Homma 1993). After just two years of grazing, some cattle exhibited 20% mortality and complete reproductive failure due to a lack of phosphorus in pasture grasses (Buschbacher 1987). Land reclamation efforts often require \$250 to \$475 per hectare for fertilizers and weed management, an enormous sum compared to a cost of \$70 to clear an additional hectare of virgin forest (Serrão and Homma 1993, Southgate 1998).

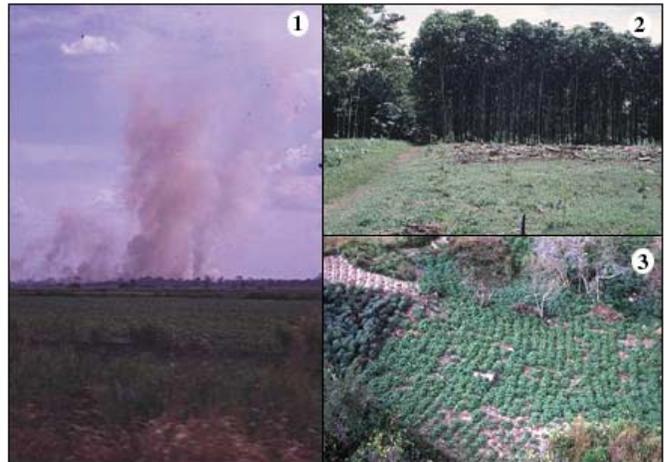


Fig. 4 (1) Fires from slash-and-burn agriculture. (2) Cleared forest. (3) A small coffee plantation.



Fig. 5 Abandoned land following pasture degradation.

Even with a bounty of unclaimed natural forest, peasant farmers found it difficult to coexist with cattle ranchers in the Amazon. In addition to the problems of soil fertility, land grabbing followed the appropriation of the Amazon frontier, leading to many bloody clashes between cattle owners and peasant farmers. A recent estimate suggested that of the 4 million residents of the Amazon, 150,000 or 4%, are forcibly evicted from their land each year (Hall 1989). From the perspective of cattle ranching, it is cheaper to appropriate pasture by the forced removal of farmers than to clear forest. High–profile efforts to secure land rights for peasant farmers, including those by a group of

rubber–tapping agriculturists, led to the assassination of their popular leader, Chico Mendes, in 1988. Amazon specialist Anthony Hall states, “It goes without saying that for farmers everywhere, access to land is the single most important factor in securing a livelihood.” Forced eviction from their land meant that rural poor simply carved deeper into primary Amazon forest. Without government support to legitimize land rights, and with constant pressures from land grabbers, colonists greatly discounted the value of their land. Environmental consultant Douglas Southgate (1998) notes that “habitat will never be safe as long as the rural poor are neglected.”

Eviction and land grabbing grew worse throughout the 1970s and '80s as land prices grew faster than Brazil's inflationary economy. Between 1966–1975 Amazon land values skyrocketed 100% per year (Hall 1989) because of high beef prices and newfound access to the Amazon via roads (Southgate 1998). Farmers and ranchers alike were clearing land and staking claims, many of which were heavily subsidized by the government. A careful evaluation of cattle productivity in 1978 indicated that SUDAM subsidies successfully led to land clearing but were not so successful in generating beef production. In fact, cleared forests supported only 36% of the cattle that were supposed to have been put to pasture (Hall 1989). Clearly, with soaring real estate value and subsidies, ranchers were driving land speculation and hoarding instead of cattle.

In addition to agriculture and cattle ranching, the Amazon offers an abundant supply of timber, which is cut for fuelwood and industrial uses (sawnwood, plywood, and veneer). Timber industries and some peasant farmers have employed a variety of forest extraction practices: selective cutting, non-timber extraction, and agroforestry. The particular practice used is determined by its opportunity cost, forest species composition, and the decision to extract resources from primary or secondary-growth forests. In addition, forestry options support different levels of employment: 300 people per veneer plant, 34 people per sawmill, and 13 people per logging firm (Serrão and Homma 1993, Southgate 1998). Hundreds of indigenous Amerindian populations have survived in the Amazon for thousands of years from the sustainable use of forest products (Grainger 1993).

Of the 300 or so tree species that may be found in a single hectare of rich Amazon rainforest, only 30 to 50 are commercially attractive (Grainger 1993). For the Amazon, species diversity is a mixed blessing, because Brazil supports the lowest commercial standing volume of any tropical country—a mere 5m³/hectare (Grainger 1993). This low volume of commercial timber makes clearcutting a nonviable option. The Amazon has been logged mainly by selective cutting of a few desirable commercial species, such as mahogany, teak, and Gmelina.

Selective cutting involves traveling across the landscape surveying and cutting valuable trees but implementing practically no forest management practices. Forest management techniques, such as cutting vines to prevent damage to adjacent trees, directional felling, and building low-impact skidder trails, may cost \$120 per hectare (Southgate 1998). As with slash-and-burn agriculture in a jungle with seemingly limitless resources, there is simply no incentive to conserve when it's cheaper to move on to the next tract of land. Consequently, for every tree cut, several trees are probably damaged or killed. One estimate puts this number as high as 27 damaged individuals per tree harvested (Southgate 1998). Moreover, logging increases forest vulnerability to future fire and further forest losses (Nepstad et al. 1999).

Another concern with the abundance of forests is that stumpage values (the cost of buying the rights to cut a tree) are very low. In the Amazon, stumpage ranges from \$5/m³ for less desirable species to over 70/m³ for mahogany (Southgate 1998). For most species, mills now pay \$35/m³ for cut timber (1998 dollars; Southgate 1998). Because of the costs of management and the low stumpage and value of land, sustainable production from primary forest appears futile. Consider that the total value of a regenerating mahogany stand may rise 5% per year, which is much less than current financial interest rates in Brazil (45% in 1999) (Southgate 1998). For slow-growing tropical species that may take over 100 years to establish and grow, the economic reality is alarmingly clear: It is more profitable to harvest a species to extinction and invest the profits in an interest-bearing bank account than to grow the species sustainably in a primary forest (Clarke 1973, Terborgh 1999). Southgate (1998) puts it succinctly, "Since timber resources are virtually boundless, market forces are stacked strongly against conservation."

Because of the dimming hope for sustainable timber extraction from primary tropical forests, other work has highlighted the potential value of extractable, non-timber resources as well as intensive agroforestry systems.

One study suggests that annual harvesting of non-timber products, such as Brazil nuts, rubber, varnish, and fruits, may provide an annual income of \$422 per hectare (Peters et al. 1989).

However, this value is probably a significant overestimate because it is based on a forest stand containing a high fraction of commercial species, and it does not account for declining prices as more goods are brought to markets (Southgate 1998). Intensive agroforestry programs that farm rapidly growing commercial trees or a mix of trees with crops, such as coffee, are gaining popularity (Grainger 1993, Southgate 1998). Grainger (1993) suggests that a commercial plantation of teak may produce 245m³ of timber per hectare over a 65-year period. Gmelina may produce 150m³ per hectare over a 10-year period. Assuming a tropical timber value of \$20–35/m³, this style of production may



Fig. 6 (1) large coffee plantation, (2) banana tree, (3) coffee beans.

forestall the widespread destruction of forests while providing an income more attractive than land-clearing alternatives. Whether these yields can compete with the opportunity cost of one year of agriculture (\$460 per hectare), especially as increased forest production drives down timber prices, remains to be seen. In addition, peasant farmers without access to investment opportunities may have no alternative to slash and burn agriculture.

It is clear that deforestation in the Amazon is driven by the relative costs and benefits of different land use options. How do value judgments implicit in these decisions reflect current political, social, and environmental conditions? Do these values reflect the true costs and benefits of the forests? How much do these values reflect individual interests and social welfare? This case study examines the valuing process involved in making the decision to clear a plot of primary forest in the Amazon Basin, from the perspective of a peasant farmer, a logger, and a conservation organization.

What is the environment really worth? Non-market values and intergenerational fairness

A growing number of ecologists and economists realize that economic valuation of tropical goods leaves out or “externalizes” too many costs, such as pollution that damages the environment, while failing to “capture” the whole value of environmental goods and services (Costanza et al. 1997a, Daily et al. 1997). Ecological economists argue that economic decisions need to incorporate, in addition to the market value of tropical forests, the non-market values that people have for the environment.

These include

- Non-consumptive use values: uses that are not “extracted” from the environment, such as birdwatching, sunbathing, paying for a documentary or TV show about the environment, photography, tree climbing, among others.
- Existence values: non-consumption “appreciation” or moral values, including the intrinsic value of species existence, stewardship, and the value of preserving the environment for future generations. This last category has received considerable attention, and the human welfare benefits provided by the environment are called ecosystem services. There are many functions that ecosystems perform that, if permanently damaged, would cost humans to replace. Table 1 presents global ecosystem services recently identified by a group of ecological economists.

Table 1. Ecosystem services and examples (modified from Costanza et al. 1997b).

<i>Ecosystem service</i>	<i>Ecosystem functions</i>	<i>Examples</i>
Gas regulation	Regulation of atmospheric chemical composition	CO ₂ /O ₂ balance, O ₃ for UV protection
Climate regulation	Regulation of global temperature, precipitation	Greenhouse gas regulation
Disturbance regulation	Damping of ecosystem response to environmental fluctuation	Storm protection, flood control, drought recovery
Water regulation	Regulation of hydrological flows	Providing water for agricultural, industrial, and human uses
Water supply	Storage and retention of water	Provisioning of water by watersheds and aquifers
Erosion control & sediment retention	Retention of soil within an ecosystem	Prevention of soil loss from wind and runoff
Soil formation	Soil formation processes	Weathering of rock and the accumulation of organic matter
Nutrient cycling	Storage, internal cycling, processing of nutrients	Nitrogen fixation, N, P and other nutrient cycles
Waste treatment	Recovery of mobile nutrients and breakdown of excess nutrients	Waste treatment, pollution control, detoxification
Pollination	Movement of pollen	Insects and birds that pollinate crops
Biological control	Trophic–dynamic regulations of populations	Keystone predators, reduction of herbivory by top predators
Refugia	Habitat for resident and transient populations	Overwintering grounds for waterfowl
Food production	Portion of NPP extractable for food	Production of fish, game, crops, nuts, fruits
Raw materials	Portion of NPP used for raw materials	Production of lumber and fuel
Genetic resources	Sources of unique biological materials	Medicines, genes for the resistance of pathogens
Recreation	Providing opportunities for recreation	Ecotourism, sport fishing, other outdoor activities
Cultural	Providing opportunities for non–commercial uses	Aesthetic, artistic, educational, spiritual, and scientific value

Most of these ecological services we take for granted every day because they are free. Costanza and others try to “capture” non–consumptive values in order to make economic benefit–cost analyses reflect the true value of nature, or, equivalently, the true costs of polluting and degrading the environment. The more humans damage the global environment, and permanently alter or disable the free ecological services that nature provides, the greater amount of money we will have to spend to provide these services ourselves. Some services, like global gas regulation or ozone, may be impossible to replace.

How do we determine prices for these non–market values? Unfortunately, this is a very difficult task. Some argue that we cannot put a price tag on nature for at least three reasons (Sagoff 1997): (1) benefit–cost analysis is a flawed means of environmental protection, (2) we cannot accurately assess nature’s existence value, just as we cannot put a price tag on human beings, and (3) nature’s services are not subject to market forces that would reveal their economic worth. Costanza and colleagues reply that we implicitly value the environment in every–day decisions, and that we must value nature to expose the true costs of doing business (Costanza et al. 1997a). This idea is reiterated by businessman Paul Hawken: “While there may be no ‘right’ way to value a forest or a river, there is a wrong way, which is to give it no value at all” (quoted from Costanza et al. 1997a).

Two methods that ecological economists use frequently to estimate non–consumptive use values and existence values include: (1) people’s *willingness to pay* for protecting the service and (2) the *cost of travel* to experience nature—at a national park, for example. Environmental economists recently conducted a survey of Americans to determine how much (in a one–time payment) they would be willing to pay to permanently protect 10% of the world’s tropical forests (Kramer and Mercer 1997). They found that Americans are willing to pay about \$21 to \$31 per household, about \$3 billion total, or \$110 to \$230 per hectare of rainforest. Ecotourism can generate a significant income for tropical countries. In 1994, the amount of money from tourism in Costa Rica generated an equivalent of 28%, or \$623 million, of total exports (Southgate 1998). In ecologically unique areas, or areas that are perceived as safe for travelers, such as Costa Rica and the Galapagos Islands of Ecuador, ecotourism may introduce between \$102 to \$1,273 in the local economy per foreign traveler. The total costs for travel and spending by foreign visitors to tropical destinations is often between \$1,400 to \$2,000 per person. However, in less unique areas, such as La Selva, Costa Rica, ecotourism generates only \$23 per person (Southgate 1998).

Another major concern with deforestation is the permanent loss of genetic information in tropical biodiversity. Perhaps as much as 40% of medicines worldwide contain chemicals derived from wild plants and animals (Durning 1993), suggesting that the tropics may harbor many additional plants with medical uses that are presently unknown. In 1991, Merck signed a historical agreement with Costa Rica to “bioprospect” plants to search for new compounds in exchange for a one–time payment of \$1 million. The potential value of the genetic resources in tropical forests for pharmaceutical discoveries has recently been valued at around \$21 per hectare (Simpson et al. 1996). In addition to medical uses, many of our crops like potatoes are of tropical origin. Mountain farmers in the Andes of Peru routinely grow several varieties of potato crops that could serve as important sources of genetic resistance to disease, such as the potato famine that struck Ireland in the 1840’s.

Other environmental damage costs can be attributed to deforestation. Ecological economists have estimated that the damage caused by sea level rise from global warming is equivalent to \$20 per ton of carbon emitted in fossil fuels or from deforestation (Southgate 1998). Deforestation eliminates the capacity for vegetation to remove carbon dioxide and causes this greenhouse gas to rise in the atmosphere, which may lead to significant global warming (Mann et al. 1998). Given that an average of 100 to 200 tons of timber is cleared for slash–and–burn agriculture (Southgate 1998), the global environmental cost of clearing a hectare of tropical forest is \$1,000 to \$2,000, assuming a carbon content of 50% in plant biomass (Schlesinger 1997). In many cases, farmers are willing to accept \$5 to \$10 per ton of timber to prevent them from clearing the forest (Southgate 1998). In a novel international agreement, Norway paid Costa Rica \$2 million to set aside forests for carbon sequestration. International willingness to pay is becoming a popular method for conserving tropical forests while compensating developing nations. Indeed, some tropical ecologists suggest that the only way to save the rainforest is for citizens in industrialized countries to pay for its protection (John Terborgh, personal

communication). Unfortunately, however, for most of the ecological services presented in Table 1, there are currently very little data to value non-consumptive uses in the Amazon.

The Problem

At the frontier of primary Amazonian rainforest, a five-hectare plot is under consideration for deforestation by a local peasant farmer who wants to practice slash-and-burn agriculture and by a logger who wants to remove valuable timber species. Your group should examine the benefit of clearing or not clearing this land from one of three perspectives: (1) the farmer, (2) the logger, and (3) an environmental conservation organization. You will generate a list of the values appropriate to your interest using the data sheets provided. Put yourself in the position of the group you represent, and be faithful to the economic and social pressures of each. Be creative! There are no right or wrong answers. There is no limit to the kinds or numbers of values you include. Financial data presented earlier are included in the data appendix for easy reference.

If relevant to your position, you may wish to determine non-consumptive values by conducting an informal willingness-to-pay survey within your group in addition to data presented in the appendix. Ask each member how much s/he is willing to pay to protect this 5-hectare forest. Be creative by using willingness-to-pay and travel cost methods to determine values for as many ecological services as you can.

Questions

1. Based on this simplified form of benefit-cost analysis, which land use option wins?
2. Evaluate the ways that peasant farmers, loggers, and conservation organizations approach land use. Which do you agree with? Is there room for peaceful coexistence in the Amazon, especially with the prospect of population growth?
3. Support or criticize the use of benefit-cost analysis as a means of economic planning and as a means of preventing environmental degradation. Do you agree more with Costanza (1997b), Pearce (1998), or Sargoff (1997)? Do you feel that species have intrinsic rights to exist? Can such existence values be incorporated into environmental policy?
4. Do you believe that citizens of tropical countries have the right to deforest the most biologically diverse communities on Earth? Compare and contrast the economic and environmental issues of tropical deforestation with deforestation that occurred in the US and Europe over the last several hundreds of years.
5. John Terborgh, tropical ecologist at Duke University, asserts that in order to save tropical forests, citizens of industrial nations are going to have to pay developing countries. Do you agree? What are some ways that this might be done?

Glossary

Agroforestry: The production of commercial timber or a mix of crops and forest products.

Benefit-cost analysis: An economic method for weighing the pros and cons when valuing a product or service.

Biodiversity: The number of species in a given area.

Biomass: The amount of matter, usually expressed in grams, kilograms, or tons, stored in living organisms.

Bioprospecting: Exploring biodiversity resources for genetic, medicinal, food, or other human uses.

Consumptive use value: The actual price for a product as determined by the marketplace. For environmental products, it represents the price for products or services that are extracted from the environment (timber, water, fish, fruit, hunting licenses, camping fees).

Ecosystem: The interaction of organisms and their environment.

Ecotourism: Tourism industry where national and foreign citizens visit natural areas, such as a national park

Existence values: Nonconsumptive “appreciation” or moral values, including the intrinsic value of species existence, stewardship, and the value of preserving the environment for future generations. This last category has received considerable attention, and the human welfare benefits provided by the environment are called ecosystem services. There are many functions that ecosystems perform that, if permanently damaged, would cost humans to replace. Fresh water, UV protection by ozone, and clean air are examples of ecological services.

Gmelina: A commercially valuable rainforest tree species.

Hectare: A unit of area equal to 10,000 m².

Mahogany: A commercially valuable rainforest tree species.

Nonconsumptive use values: Uses that are not extracted from the environment, such as bird watching, sunbathing, paying for a documentary or TV show about the environment, photography, tree climbing, among others.

Slash and burn agriculture: Cutting a small patch of forest, usually 3–4 hectares, burning the vegetation, perhaps after selling a minor fraction of timber, and growing and harvesting 2–3 years worth of crops. After the third year, farms are usually abandoned because of nutrient–depleted soils and the invasion of weedy species.

Stumpage: The price of buying the rights to cut a tree on privately owned land.

Teak: A commercially valuable rainforest tree species.

Travel costs: The amount of money people spend to visit natural areas like national parks; a method that is used to determine nonconsumptive use and existence values.

Willingness to pay: The amount of money people would donate to protect the environment; a method that is used to determine nonconsumptive use and existence values.

Literature Cited

- Buschbacher, R.J. 1986. Tropical deforestation and pasture development. *Bioscience* 36(1):22–28.
- Buschbacher, R.J. 1987. Cattle productivity and nutrient fluxes on an Amazon pasture. *Biotropica* 19(3): 200–207.
- Clark, C.W. 1973. The economics of overexploitation. *Science* 181:630–634.
- Costanza, R., Cumberland, J., Daly, H., Goodland, R., and Norgaard, R. 1997a. *An Introduction to Ecological Economics*. St. Lucie Press, Boca Raton, FL.
- Costanza, R., d’Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. 1997b. The value of the world’s ecosystem services and natural capital. *Nature* 387:253–260.
- Daily, G.C. (ed.) 1997. *Nature’s Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D.C.

- Durning, A.T. 1993. Saving the forests: What will it take? *Worldwatch Publication* 117. Worldwatch Institute, Washington, D.C.
- Grainger, A. 1993. *Controlling Tropical Deforestation*. Earthscan, London.
- Hall, A.L. 1989. *Developing Amazonia*. Manchester University Press, Manchester.
- Kramer, R.A., and D.E. Mercer. 1997. Valuing a global environmental good: U.S. residents' willingness to pay to protect tropical rain forests. *Land Economics* 73(2): 196–210.
- Laurence, W.F. 1997. A crisis in the making: Responses of Amazonian forests to land use and climate change. *Trends in Ecology and Evolution* 13(10): 411–415.
- Mann, M.E., Bradley R.S., and Hughes M.K. 1998. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature* 392: 779–787.
- Nepstad, D.C., Verissimo, A., Alencar, A., Nobre, C., Lima, E., Lefebvre, P., Schlesinger, P., Potter, C., Moutinho, P., Mendoza, E., Cochrane, M., and Brooks, V. 1999. Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* 398: 505–508.
- Pearce, D. 1998. Auditing the Earth. *Environment* 40(2):23–28.
- Peters, C., Gentry, A., Mendelsohn, R. 1989. Valuation of an Amazon rainforest. *Nature* 339:655–656.
- Richter, D.D., and Markewitz, D. 1995. How deep is soil? Soil, the zone of the Earth's crust that is biologically active is much deeper than has been thought by many ecologists. *Bioscience* 45(9): 600–609.
- Ruitenbeek, H.J. 1989. *Social Cost–Benefit Analysis of the Korup Project, Cameroon*. WWF, London.
- Sagoff, M. 1997. Can we put a price on nature's services? *Report from the Institute for Philosophy and Public Policy* 17(3).
- Schlesinger, W.H. 1997. *Biogeochemistry: An Analysis of Global Change*, 2nd ed. Academic Press, San Diego.
- Simpson, D., Sedjo, R., and Reid, J. 1996. Valuing biodiversity: An application to genetic prospecting. *Journal of Political Economy* 104(1): 163–185.
- Serrão, E.A.S., and Homma, A.K.O. 1993. Brazil. In *Sustainable Agriculture and the Environment in the Humid Tropics*. National Research Council. National Academy Press, Washington, D.C.
- Southgate, D. 1998. *Tropical Forest Conservation: An Economic Assessment of the Alternatives in Latin America*. Oxford University Press, New York.
- Terborgh, J. 1999. *Requiem for Nature*. Island Press, Washington, D.C.
- Vitousek, P.M. and Sanford, R.L. 1986. Nutrient cycling in moist tropical forest. *Annual Review of Ecology and Systematics* 17:137–167.
- Weitzman, M.L. 1998. Why the far-distant future should be discounted at its lowest possible rate. *Journal of Environmental Economics and Management* 36(3): 201–208.
- Wilson, E.O. 1989 (September). Threats to biodiversity. *Scientific American* 261: 108–116.
- Wilson, E.O. 1992. *The Diversity of Life*. W.W. Norton and Company, Inc. New York.



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Perspective Worksheet

<i>Identify the perspective you are examining: Peasant Farmer / Logger / Environmentalist</i>			
<i>Strategy:</i>			
<i>How you value the 5-hectare forest plot</i>	<i>Value per hectare per year (\$ or other)</i>	<i>Value for the entire 5-ha plot per year</i>	<i>Value for the entire 5-ha plot for 2 years</i>
1)			
2)			
3)			
4)			
5)			
6)			
7)			
8)			
9)			
10)			
<i>TOTAL</i>			

Data Appendix

The data presented below is summarized from text with additional, referenced data.

Rainforest information

- 50–90% of Earth's species in tropics (Hall 1989)
- 40% of medicines are derived from plants and animals (Hall 1989, Durning 1993)
- 300 million hectares of tropical rainforest in Brazil (Grainger 1993)
- 6–11 species lost in Amazon per day (assuming extinction rates from Wilson 1989 and loss of 1% of Amazon forest/year (Grainger 1993)

Cattle farming

- 1 human job for every 2000 cows or 1 job every 12 miles² (Hall 1989)
- Average long-term cattle production = 0.7 cows/hectare (Serrão and Homma 1993)

Slash-and-burn agriculture

- 2–3 harvests of crops expected before land degradation (Hall 1989)
- \$250–475/hectare to fertilize degraded land (Serrão and Homma 1993)
- \$70/hectare to slash and burn new land (Serrão and Homma 1993)
- Produces 80% of Amazon food production (Serrão and Homma 1993)
- \$460/hectare revenue for 1 year of agriculture (Serrão and Homma 1993)

Land ownership

- 3.4 hectare—average peasant farm size in 1980 (Hall 1989)
- Land prices increased 100% per year between 1966–1975 (Hall 1989)
- Average population density in Amazon: 2.7 people/100 hectares (Serrão and Homma 1993)
- Amazonian deforested real estate value \$300/hectare—amount for which farmers would part with their land (Serrão and Homma 1993)
- Amazonian forested land \$150/hectare (Serrão and Homma 1993)

Amazon deforestation rates

- 1.5–3 million hectares/year (Lawrence 1997)

Ecotourism

- Costa Rica \$2,000/person entire trip; \$1273 spent in country (\$86/day/person in local economy), average stay = 3 days (highly unique area) (Southgate 1998)
- Galapagos: Ecuadorian: \$506, foreigner: \$1337 (\$102 in local economy) (highly unique area)
- La Selva \$22.38/person (less unique area) (Southgate 1998)
- Ticket prices to Monteverde Reserve in Costa Rica: \$15 (Southgate 1998)

Genetic diversity

- Merck paid \$1,000,000 over 2 years to Costa Rica for bioprospecting rights (Serrão and Homma 1993)
- Recent estimate for pharmaceutical value of tropical forest species: \$21/hectare (Southgate 1998)

Population and eviction

- 4 million people in Amazon (Hall 1989)
- 150,000 evicted/year (Hall 1989)

Agroforestry

- Intensive hardwood plantations: 245m³/hectare /65 years (Teak); 150m³/hectare /10 years (Gmelina) (Grainger 1993)
- Forestry–coffee mixed plantations: \$2–\$61/hectare when coffee prices are low, \$120–\$176/hectare when coffee prices are high (Southgate 1998)

Timber resources

- Only 30–50 species out of several hundreds are economically viable (Grainger 1993)
- Amazon has low merchantable timber: 5 m³/hectare (Grainger 1993)
- World and tropical hardwood prices (1998\$): 35/m³ (Southgate 1998)
- 1 logging group = 13 employees (Southgate 1998)
- 1 sawmill = 34 employees (Serrão and Homma 1993)
- 1 veneer plant = 300 employees (Serrão and Homma 1993)
- Forest management (vine removal and tree thinning): \$120/hectare (Southgate 1998)
- Stumpage \$5/m³ timber (Southgate 1998)
- Mills pay \$35/m³ timber (Southgate 1998)
- Annual increase in mahogany value = 5% (Southgate 1998)

Non–timber resources

- \$422/hectare for extractable nontimber resources (fruits, latex, nuts, etc.) (Peters et al. 1989)

Environmental costs/benefits

- American's willingness to pay to protect tropical rainforests: \$110–230/hectare one–time payment (Kramer and Mercer 1997)
- Global environmental damages due to C release: \$20/ton carbon emitted (Southgate 1998)
- 100–200 tons of timber/hectare cleared (Southgate 1998)
- Plant biomass is 50% carbon (Schlesinger 1997)
- Global cost of losing carbon storage: \$1,000–\$2,000/hectare (Southgate 1998)
- Price peasant farmers are willing to accept to stop deforesting: \$5–10/ton of timber (Southgate 1998)
- 27 trees damaged for every tree extracted (Southgate 1998)

Data Sources:

Durning, A.T. 1993. Saving the forests: What will it take? *Worldwatch Publication* 117. Worldwatch Institute, Washington, D.C.

Grainger, A. 1993. *Controlling Tropical Deforestation*. Earthscan, London.

Hall, A.L. 1989. *Developing Amazonia*. Manchester University Press, Manchester.

Kramer, R.A., and D.E. Mercer. 1997. Valuing a global environmental good: U.S. residents' willingness to pay to protect tropical rain forests. *Land Economics* 73(2): 196–210.

Lawrence, W.F. 1997. A crisis in the making: Responses of Amazonian forests to land use and climate change. *Trends in Ecology and Evolution* 13(10): 411–415.

Peters, C., Gentry, A., Mendelsohn, R. 1989. Valuation of an Amazon rainforest. *Nature* 339:655–656.

Serrão, E.A.S., and Homma, A.K.O. 1993. Brazil. in *Sustainable Agriculture and the Environment in the Humid Tropics*. National Research Council. National Academy Press, Washington, D.C.

Southgate, D. 1998. *Tropical Forest Conservation: An Economic Assessment of the Alternatives in Latin America*. Oxford University Press, New York.

Wilson, E.O. 1989 (September). Threats to biodiversity. *Scientific American* 261: 108–116.