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EVALUATING THE CARBON SEQUESTRATION BENEFITS OF FORESTRY PROJECTS IN DEVELOPING COUNTRIES

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Nels Johnson, WRI: View of Ghandruk village in the Annapurna Conservation Area, Nepal, site of one of the carbon sequestration proposals evaluated by WRI.
Cover Photo

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P.F.
C.C.
R.L.

Preface

Planting trees is widely touted as a hedge against climate change, but how much carbon dioxide can a given forestry scheme actually scrub from the atmosphere? There's been no lack of debate on this question, but few attempts to answer it with real experience. The fact that nations are now on the verge of buying and selling such "sink enhancements" under the climate treaty's "joint implementation" provisions puts a premium on finding ways to make defensible quantitative estimates.

WRI researchers first tackled this problem in 1989 when Applied Energy Services, an electricity supplier with power plants around the world, asked them to help find a way to offset the lifetime carbon dioxide emissions of its new coal-fired electric plant in Connecticut. This effort resulted in the first forestry project funded explicitly to offset greenhouse gas emissions.

Now, WRI Senior Associate Paul Faeth and former research assistant Cheryl Cort, with help from Senior Editor Robert Livernash, have taken the next step by detailing the second-round effort to evaluate "carbon forestry" projects on the ground. After eliciting forestry project proposals from developing country nongovernmental organizations, these researchers pioneered a way to estimate projects' carbon storage potential by feeding scenarios based on many kinds of data and trends into a land-use model. The "carbon sequestration" model they designed then estimated how the landscape would change over the power plant's 34-year lifespan, allowing them to estimate how much carbon a particular forestry project would sequester — and at what cost.

In *Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries*, the authors describe how they used this new model to evaluate proposed forestry projects in Thailand, Panama, Mexico, and Nepal. The authors also revisit the Guatemala project, comparing the original estimates with new data and the new technology.

As they note, risks and uncertainties abound in any attempt at long-term forecasting. Unforeseeable shifts in political, economic, or demographic trends can skew the outcome; indeed, changes in key parameters could have enormous effects over such a long time frame. The best available information may be far from accurate. The amount of biomass in a particular kind of forest is hotly disputed, for instance, so researchers may have to go with their best "guestimate," another instance in which small errors at the outset may be magnified over time. Given these inescapable difficulties, the authors pointedly note that their findings should be considered "first approximations, not revealed truth."

Nonetheless, the carbon sequestration model promises to be a useful tool in an era when nations everywhere are trying to meet the obligations they accepted in signing the climate treaty.

Walter V. Reid
Vice President for Program
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I. INTRODUCTION

As policy-makers around the world assess the complex dynamics of climate change, the prospect that human activities will increase global temperatures arises, along with the potential need for action to stem such warming.

The problem, in essence, is that gases such as carbon dioxide and methane act like a greenhouse roof, blocking a portion of the infrared heat reflected from the earth's surface. Historically, concentrations of these gases have varied within a range that resulted in a relatively moderate and stable climate. Over the past few centuries, however, human activities have increased the level of greenhouse gases in the atmosphere. Burning fossil fuels such as coal, for example, has increased the atmospheric concentration of CO_2 about 25 percent above preindustrial levels, a concentration which continues to increase about 0.4 percent per year. Emissions from fossil fuel use alone have increased 3.6 times since 1950. If these trends persist and concentrations of greenhouse gases continue to rise, mean global temperatures will increase an estimated 0.3 degrees Celsius per decade, which could have potentially catastrophic implications for human health, agricultural productivity, and sea levels.

Carbon dioxide is likely to be responsible for about half of human-induced global warming in the coming decades. Stabilizing concentrations of carbon dioxide at present levels would require an estimated 60-percent reduction in carbon dioxide emissions. Such an effort seems prudent, however, given that violent disruptions to the global ecosystem could occur in a warmer world.

What can be done? Much of the debate to date has appropriately focused on cutting the use of fossil fuels, which accounts for the bulk of CO_2 emissions. The latest estimate is that industrial processes account for emissions of about 21.8 billion metric tons of carbon dioxide annually, or about 78 percent of global (human-induced) carbon dioxide emissions. Inevitably, no solution to global warming is possible without drastic reductions in fossil fuel use and the development of renewable forms of energy.

Deforestation is the other main culprit. Trees contain stored carbon. When they are cut down, as they are in the tropics at about an annual rate of 17 million hectares, carbon dioxide is released. Deforestation annually accounts for about 6.4 billion metric tons of carbon dioxide emissions, or about 22 percent of global carbon dioxide emissions.

Forests and forest soils can be part of the solution, however, since they store carbon — about 20 to 100 times more per hectare than pastures or croplands do. Projects such as tree plantations or agroforestry schemes can store "new" carbon, while projects that protect valuable areas or prevent or

slow deforestation can preserve carbon in existing forests.

Recently, there has been considerable discussion of methods to approach the problem of greenhouse gas emissions (GHGs) through international programs. Ideas such as tradable permits or allowances have been proposed, such as those used in the United States for sulfur dioxide control. Under these schemes, permits are allocated to cover emissions, and those allocated but not used can be sold. Trading mechanisms of this sort could be applied to GHGs and permits traded between nations (Pearce, 1990; Swisher and Masters, 1989). Some countries could create salable permits by investing in forestry projects.

The notion of forests as carbon storehouses of fossil fuel emissions was first proposed in 1976 (Dyson). However, the idea that new powerplants could offset their CO_2 emissions by sponsoring sustainable forestry projects had never been implemented until 1989.

Such offsets could be created in two ways:

- Accelerating the removal of CO_2 from the atmosphere — for example, by planting trees.
- Reducing the rate at which CO_2 is produced through human activities, such as protecting forests to slow the rate of deforestation.

The theory is relatively straightforward, but devising a way to test the carbon "sequestration" potential of a forestry project and comparing different projects are much more complicated.

Evaluating Carbon Sequestration Projects: A First Attempt

The World Resources Institute first began to evaluate forestry projects for their carbon sequestration potential in 1988. Applied Energy Services, Inc. (AES), a U.S.-based independent electrical power producer, initially considered several alternatives for reducing carbon dioxide at the source and found that none was technically feasible. AES then asked WRI to help develop criteria and identify and evaluate forestry projects that could mitigate the carbon dioxide emissions of a new 183-megawatt AES coal-fired powerplant in Connecticut that was expected to emit about 14.1 million metric tons of carbon (52.1 million tons of CO_2) over its 40-year life.

This project afforded WRI an exceptional opportunity to put some hard numbers into what was then a very soft debate. At that time, no project had the expressed purpose of offsetting carbon dioxide emissions, and most cost estimates were gross and not based on field experience with actual projects (Sedjo, 1989; Marland, 1988). Through the evaluation process, WRI hoped to gain some experience that would be more broadly useful.

There were a number of reasons for pursuing such a project in a developing country rather than in the United States, including:

- Higher potential growth rates and faster carbon accumulation of trees in tropical countries.
- Greater dependence of people in developing countries on the services forests provide and therefore potentially greater benefits.
- Greater grant leveraging opportunities, including debt-for-nature swaps, foreign aid, and volunteer services.
- Alternatives in the United States to avoid the release of carbon dioxide or sequester it at the source appeared to be considerably more expensive.

Since 1992, legislation in the United States. allows power companies to "bank" carbon offset credits. If a carbon tax is implemented in the future, those companies that have banked carbon offsets might receive tax credits (U.S. Congress, 1992).

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Four main criteria were developed for evaluating projects:

- *Potential of the project to offset carbon emissions from the powerplant.*
- *Active local support and participation.* Numerous studies have found that local participation is a critical factor in the success and durability of projects.
- *Ability to leverage additional funds.* AES wanted to use the $2 million it was willing to commit as leverage to attract other funds.
- *Experience and commitment of the implementing organization.* Since most projects would be carried out over many years and were intended to endure for several decades, the project sponsors wanted a relatively high degree of confidence that the organization managing the project could complete it successfully.

Of the proposals submitted, the most attractive was for a project located in Guatemala and proposed by CARE, a well-known international development and relief organization. Started in the mid-1970s, the CARE/Guatemala agroforestry program emphasized tree planting in agroforestry and woodlot applications, the conservation of biomass through such activities as forest fire brigades, and the formation of self-sustaining forestry groups to protect, plant, and manage trees. The program was supported by the Guatemalan Directorate General of Forests (DIGEBOS) and the U.S. Peace Corps, with funding provided by the U.S. Agency for International Development (USAID).

In 1989 the termination of a USAID matching grant threatened to end the program, which prompted CARE to submit a proposal to WRI. CARE proposed using the $2 million AES grant to establish an endowment that would support a 10-year multiple-use sustainable forestry project. CARE was also prepared to raise $1.8 million in matching funds and expected to receive $1.2 million from the government of Guatemala and about $7 million worth of in-kind services provided by the U.S. Peace Corps and U.S. food aid.

The project had several components, including planting about 12,000 hectares of community woodlots, mostly in pine and eucalyptus for poles and lumber; implementing agroforestry practices on some 60,000 hectares of agricultural land for fuelwood, fodder, soil nitrogen-fixation, and fruit and nut production; planting 2,880 kilometers of live fencing; building terraces to protect 2,000 hectares of vulnerable slopes; and providing training and extension for community forest fire brigades to protect the newly planted trees and natural forest.

Based on WRI's calculation (Trexler et al., 1989), the CARE project would sequester an estimated 16.3 million metric tons of carbon over 40 years, primarily through:

- Net addition to the standing inventory of biomass carbon.
- Retention of standing forest as a result of demand displacement (that is, the woodlots and agroforestry projects displace the demand for standing forests).
- Protection of some carbon in soils.
- Retention of some standing forests because of community fire brigades.

The analysis of the Guatemala project was an important first attempt to evaluate the carbon-sequestration potential of sustainable forestry projects, but many questions were left unanswered. The evaluation, for example, was static and did not measure dynamic variables, such as the impact of population growth. Nor did it measure indirect impacts on forests of some significant variables, such as the effect of improved agricultural productivity on the conversion of forest land for cultivation.

Stage 2: A New Challenge

In 1990, AES was building two new coal-fired plants. The plants were estimated to emit about 45

million metric tons of carbon over 34 years (the estimated lifetimes of the plants). AES offered a total of $5 million for projects that would offset emissions through forest management.

In general, more field experience was necessary as input to policy discussions. AES again asked WRI to develop the criteria and solicit and evaluate proposals. After the first round of evaluations, WRI realized that there were ways to improve the process, making it more fair and rigorous. In particular, it was important to attempt to include a much larger applicant group and to develop a more sophisticated methodological approach. Also, there was more to be learned about the potential of such projects to sequester carbon, the availability of organizations to implement them, and the actual cost of implementation.

In November 1990, WRI wrote to 110 NGOs in 40 countries asking for a five-page concept paper, a one-page budget, and a one-page description of biophysical data. (*See Appendices A and B.*) Sixty concept papers were received, and an evaluation committee of rural development, forestry, and carbon sequestration experts selected 11 concept papers to be developed into full proposals.

The committee used three criteria for this selection:

- *Local participation*, or projects that would provide the greatest involvement of (and benefit from) labor pledges, foreign aid programs, or support of existing projects.
- *Grant leverage*, which could include debt swaps, block or matching grants, community or labor pledges, foreign aid programs, or support of existing projects.
- *Experience*, including a demonstrated ability on the part of the implementing organization to manage and carry out the proposed project.

A fourth criterion, *carbon sequestration*, was not estimated at this stage of the process. However, a decision was made to modify the evaluation process somewhat. Whereas the initial effort was designed to find a single large project, this second effort eliminated the bias against small projects by evaluating the cost of carbon sequestration potential in terms of cost per ton of carbon. (*See Appendix B.*)

Ten proposals were resubmitted and initially evaluated without considering their carbon sequestration potential. Carbon sequestration estimates were not made until after site visits. Five of those projects, described below, provide the basis for the case studies in this report. The descriptions and evaluations are based on the proposals and amendments submitted by the various groups during the evaluation process conducted by WRI.

Population and Community Development Association (PDA), Thailand. This project is intended to provide rural communities in northeastern Thailand with direct access to forest products and control over future afforestation efforts. The project would establish village forestry committees in 300 selected villages; construct nurseries in each village; provide technical, financial, and managerial training to villagers; provide village nurseries with 1.5 million nitrogen-fixing and 600,000 native hardwood tree seedlings plus 75,000 fruit tree graftings over five years; establish multiple-use protected forests and economic agroforestry plots on 1,200 hectares of public land; and employ agroforestry/integrated farming techniques on 300 hectares of privately-owned paddy fields.

National Association for the Conservation of Nature (Associacion Nacional para la Conservacion de la Naturaleza, or ANCON), Panama. The ANCON project would protect and restore the forest cover of the Panama Canal watershed. In recent decades, the watershed area has been extensively cleared for agriculture. The cleared areas have been

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taken over by an invasive exotic grass, inviting further clearing and thus causing extensive deforestation. This process has increased soil erosion and the buildup of sediments in the canal. The project would strengthen the protection of the Chagres and Soberania national parks, restore degraded areas within the parks through the planting of native tree species, promote agroforestry practices among small farmers in the watershed, and expand a demonstration farm for sustainable agriculture and agroforestry practices. The expansion also would include increased outreach.

Union of Forestry Communities (Union de Communidades Y Ejidos Forestales Del Estado de Oaxaca, or UCEFO), Mexico. Some 18,000 people live in the nine Indian communities that form UCEFO in the state of Oaxaca in Mexico. Of the 114,600 hectares in their territory, about 4,000 are used for agriculture and about 100,000 are forested. The project's objectives include gradually increasing forestry potential from a yield of 1.3 cubic meters of timber per hectare in 1991 to 4.5 cubic meters in 2030, converting and expanding existing nurseries and establishing new ones, developing an integrated program of reforestation, and improving local agricultural productivity.

King Mahendra Trust for Nature Conservation, Nepal. The King Mahendra Trust proposed installing 12 micro-hydroelectric plants as part of its Annapurna Conservation Area Project. Since fuelwood currently provides 86 percent of the region's energy requirements, the micro-hydro projects would provide an alternative source of energy and could help slow deforestation in the region. Seedling nurseries would also be established in each village selected for a micro-hydro project, which would allow about 65 hectares of denuded land to be reforested annually.

Oxfam America with COICA, an umbrella organization of indigenous groups in the Amazon region. This project comprehensively addresses the social, political, and economic factors that have contributed to the destruction of hundreds of thousands of hectares of the Amazon rain forest. The project would attempt to halt deforestation through land-defense strategies and provide economic benefits through the sustainable management of forests.

The project has four components:

- CICOL (Intercommunal Central of the East Lomerio) in Bolivia would hire lawyers to fight against lumber and mining concessions and work to obtain legal title to the 130,000-hectares traditionally belonging to the Chiquitano Indians.
- CIDDEBENI (Center for Research and Documentation of Beni) in Bolivia would use legal strategies to seek enforcement of a law protecting 1.2 million hectares of tropical lowlands belonging to the indigenous peoples of Beni.
- CEDIA (Center for the Development of Indigenous Amazonians) in Peru would work to protect the Machiguenga Indians' legally recognized territory in Peru, which is threatened by oil and gas development.
- OPIP (Organization of Indigenous Peoples of Pastaza) in Ecuador would use a legal defense strategy to protect the lands of the Quichua Indians in Pastaza Province.

All told, the project is intended to protect almost 2 million hectares.

Evaluating the Carbon Sequestration Potential of Each Project

The carbon sequestration potential of all but one proposal was analyzed using project site data and a simple land-use model. (The Oxfam/COICA project could not be analyzed using the model because the necessary data were unavailable.) The model was designed to evaluate changes in the landscape over the 34-year life of the power plants and to provide substantial insight on how different trends and

interventions may affect the landscape over future decades.

To assess changes in land use over time, we approximated essential relationships between human population growth, the subsequent need for food and energy, technological change, resource management, and land-use change. The model provides a comprehensive standard method for fairly and objectively evaluating each project's carbon sequestration potential. The model is used principally to analyze different scenarios, and the results produced are a function of the scenario assumptions. To the extent possible, assumptions were taken from project documents.

No broader political analysis was undertaken for each country, although the political and economic environment in a country are obviously critical to the outcome of a given project. For example, when considering the UCEFO project in Mexico, WRI did not simulate the impact of the North American Free Trade Agreement on emigration, and the subsequent effect of alternative population growth rates on shifting agriculture and standing biomass. Such exercises were not appropriate because WRI did not consider itself qualified to speculate about the future and it did not want to make the analysis any more subjective than necessary, especially considering that millions of dollars of funding were at stake. Instead, WRI assumed, for better or worse, that current trends would continue.

Project interventions were compared against a baseline scenario, which simulates the conditions of the project site without the benefit of the project intervention. The difference between the amount of carbon sequestered with and without project interventions is considered the total amount of carbon sequestered.

The land-use model can also be applied more widely. Different interventions can be tested to assess their relative effectiveness in producing sustainable land-use patterns.

The model is quite sensitive to a few parameters, such as population growth rates and levels of agricultural productivity. Good estimates were available for the most sensitive parameters. Whenever possible, local data from the project site were used. When this was not possible, national data or data from similar ecological settings were used (see reference list). The data available among the projects were not consistent.

The model is also somewhat sensitive to biomass numbers for the various land-use categories. There is currently a great deal of uncertainty and discussion in the scientific literature about biomass estimates for different forest types in different parts of the world, and estimates diverge widely. The latest information using large-scale surveying techniques shows much lower biomass estimates than have been previously reported.

In this sense, the results from the model should be viewed as first approximations, not "truth revealed." Some of the results are uncertain, not only because the future itself is inherently uncertain, but also because some of the data used are of poor quality and the relative risks associated with the various project interventions differ. The CARE project, with 14 years of experience, for example, will have a lower associated risk than the Oxfam/COICA project, which proposes to implement a fundamentally new political paradigm. The uncertainty associated with each project was considered subjectively by the evaluation committee, but excluded from the modeling work since it was impossible, within the bounds of the work undertaken for these evaluations, to objectively determine a confidence interval for each project outcome.

To the extent that there are errors, these should occur consistently across the projects to produce

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objective comparisons among projects. Table 1 summarizes each project's estimated carbon-sequestration benefits and related budgetary information. In the table, the total budget reflects the total costs of implementing the project as estimated by the applicant. Costs include salaries and benefits, buildings and equipment, operation and maintenance, overhead charges, and other necessary items (*Appendix A*). The request is the amount requested from AES. Dollars per ton of carbon is shown for both the request and the total budget. The difference reflects the leveraging anticipated by the applicant. In the second round evaluation, AES chose to sponsor the Oxfam project.

This report describes the process, results, and analytical methods used in the first comprehensive evaluation undertaken to select carbon-offset projects in developing countries. WRI hopes it provides useful information to policy-makers and researchers considering similar joint ventures in developing countries.

Chapter 2 provides an overview of the structure of the land-use model. In Chapter 3 the initial evaluation for the Guatemala project is revisited, and the original methodology and data are updated and contrasted to estimates developed through the use of the land-use model. The five other projects are discussed in more detail in Chapters 4 through 8. Chapter 9 summarizes the findings and draws conclusions relevant to future carbon sequestration efforts.

Table 1.

Amount of Carbon Sequestration and Cost Estimates for Six Forestry Projects in Developing Countries

NGO/country or region/chapter	Total carbon ('000 tons)	Request (million dollars)	Total budget (million dollars)	Dollars per ton of carbon (requested/ total)	Dollars per dollar leverage	Request (percent of total budget)
CARE/Guatemala/3	39,000	2.00	8.80	0.05/0.23	3.40	23
PDA/Thailand/4	150	1.19	1.62	7.93/10.8	0.36	73
ANCON/Panama/5	7,400	2.60	18.00	0.35/2.43	5.92	14
UCEFO/Mexico/6	2,700	2.86	3.25	1.06/1.20	0.14	88
KMTNC/Nepal/7	70	0.96	1.13	13.64/16.14	0.18	85
Oxfam/Amazon/8	75,000	2.55	4.50	0.03/0.06	0.76	57

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2. Land Use and Carbon Sequestration (LUCS) Model

When Trexler et al. (1989) first attempted to estimate the carbon sequestration benefits of the CARE/Guatemala project, it became clear that the methodology was deficient. Many essential elements of forest and agricultural management in rural areas were not part of the analysis. The effects of population growth and the carbon associated with the recovery of fallow areas were notable, but the analysis focused principally on the more direct benefits of tree planting, soil conservation, and suppression of forest fires.

Trexler et al. recognized that a more sophisticated effort would be necessary for a more complete evaluation of the benefits of such projects. The model described in this chapter is such an effort.

The model was constructed with three principal considerations. It must:

- Capture the essential physical interactions among people and forests in developing countries.
- Not be overly complicated.
- Be able to represent a wide variety of situations and management schemes.

Previous experience suggested that the data available in the areas that would come under consideration would be scarce. The model, therefore, must represent the social, physical, and ecological interactions as simply as possible to reduce data demands.

The principal purpose of the model was to track the implications of different management schemes in widely different areas in order to allow fair comparisons among proposals. Previous experience had demonstrated the difficulty of estimating carbon sequestration and the near impossibility of making fair comparisons among proposals when many different methods and assumptions were used. A more objective evaluation could be made if the same tool and evaluators were used.

Finally, recognizing the impossibility of predicting carbon sequestration over a 35-year period, a scenario analysis method was chosen instead. The model does not predict prices, incomes, or other economic indicators. The analyst must determine the rates of change for key parameters such as population and agricultural productivity, and the model serves as an accounting tool, tracing the implications of these scenarios. The burden of defining the future is thus on the analyst and a more complicated model isn't needed. In addition, the assumptions of the modeling exercise are much more transparent.

The most appropriate use of the model, therefore, is as a tool for comparing and contrasting both the broad differences among sites and alternative management regimes at a given site. The results that the model produces are in this sense more qualitative than quantitative in nature. Does a given intervention make a minor or major difference in the outcome? Does a given intervention change the nature of the resulting behavior, for example, from asymptotic decay to stability, or does it simply delay the inevitable run-down of the ecosystem? What elements are most critical in determining the results?

Because the nature of the interventions proposed were so diverse (for example, agroforestry, fuelwood stoves, forest management, agricultural extension), and because the boundaries of interest were at the project level, land use was the most suitable and most simple basis for the model.

Overview

The model was designed to operate at the project or subregional level, and the areas under consideration ranged from about 100,000 hectares to as much as 3 million hectares. These project areas were defined to contain the principal physical influences from the projects.

Changes in land use are determined by population growth (demand), agricultural productivity and its growth rate, and management activities. The projects evaluated have focused on poor, underdeveloped areas that depend largely upon low-productivity agriculture for subsistence and fuelwood for energy. The local people derive most of their livelihood from the project region. As the population grows, more land is required to supply food and fuelwood. While demand grows in absolute terms, however, its impact on the land base can grow at a lesser or even negative rate depending upon changes in productivity and project activities.

Categories for Land and Biomass

The nine categories of land represented in the model are based upon principal uses and the amount of biomass present. (*See Figure 1.*) Several of these categories are subdivided into early, medium, and mature age classes to represent growth stages in forest maturation. The principal land uses include:[1]

- Three categories of agriculture — permanent, shifting, and agroforestry.
- Five categories of forest or woodland — closed, open woodland, tree plantations, forest fallow, and restored forests.
- One category combining grazed and degraded land. (*See Figure 1.*)

The biomass of each category or subcategory is constant and represents an average over the project area. The model represents changing biomass levels by movement from one land class to another. Biomass accumulation in tree plantations, closed forest (primary and secondary), restored forests, and forest fallow is represented by "aging chains." The biomass figures account for survival rates of tree seedlings. Forest degradation, for example, due to loss of biomass for fuelwood, is represented as a movement of land from closed forest to open woodland and then to degraded land.

Carbon sequestration is calculated from standing biomass, wood products, and fossil fuel use. **Carbon in standing biomass** is determined by multiplying the area of each land use category by its average biomass, then multiplying the product by the carbon content of wood. (*Figure C-1.*)

1. Some of the figures mentioned in this discussion are located in this chapter and some in Appendix C. This separation reduces the burden for readers not interested in details of the model's structure. The figures included in this chapter are considered essential to a basic understanding of the model's behavior in later chapters, while those included in Appendix C might be of interest to a more technical audience.

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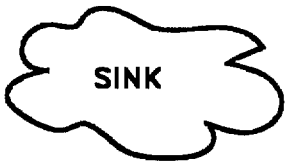
Interpreting Flow Diagrams

The flow diagrams on the following pages use a set of icons that have specific meanings. It is essential to understand these icons in order to interpret the flow diagrams.

A rectangle represents a *stock*, also called a *state variable* or *level*. Stocks are instantaneous measures of things like people or land area.

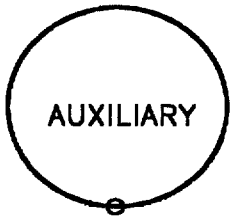
Stocks are changed by *rates*. Rates characterize the change in a stock over time. Births per year or conversion of closed forest are rates. The icon for a rate looks like a spigot.

Sources and *sinks* are represented by cloud-like shapes. Somewhat unfortunately, modeling jargon defines a source or sink as outside the boundary of interest. For example, we don't care where people come from before they are born. In the issue of global warming, sources and sinks have a different meaning and are critically important. In this analysis, few sources or sinks are indicated because land area can neither be created nor destroyed in the time frame of interest.

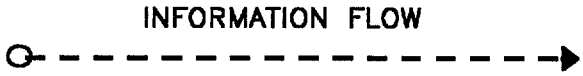


A straight line represents a *constant*. For the sake of simplicity, many items that are known to vary over time are assigned a constant value to avoid the necessity of modeling these aspects where the aspect is either not of central importance, or these data are too weak to justify further disaggregation.

Circles are called *auxiliaries*. These are catch-alls for everything else.



In this model, solid lines represent *material flows* of people or land. Dashed lines represent *information flows*. The direction of flow is indicated by the arrows. Material flows affect the values of the elements connected, but information flows do not.



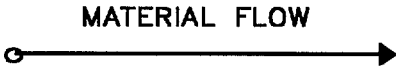
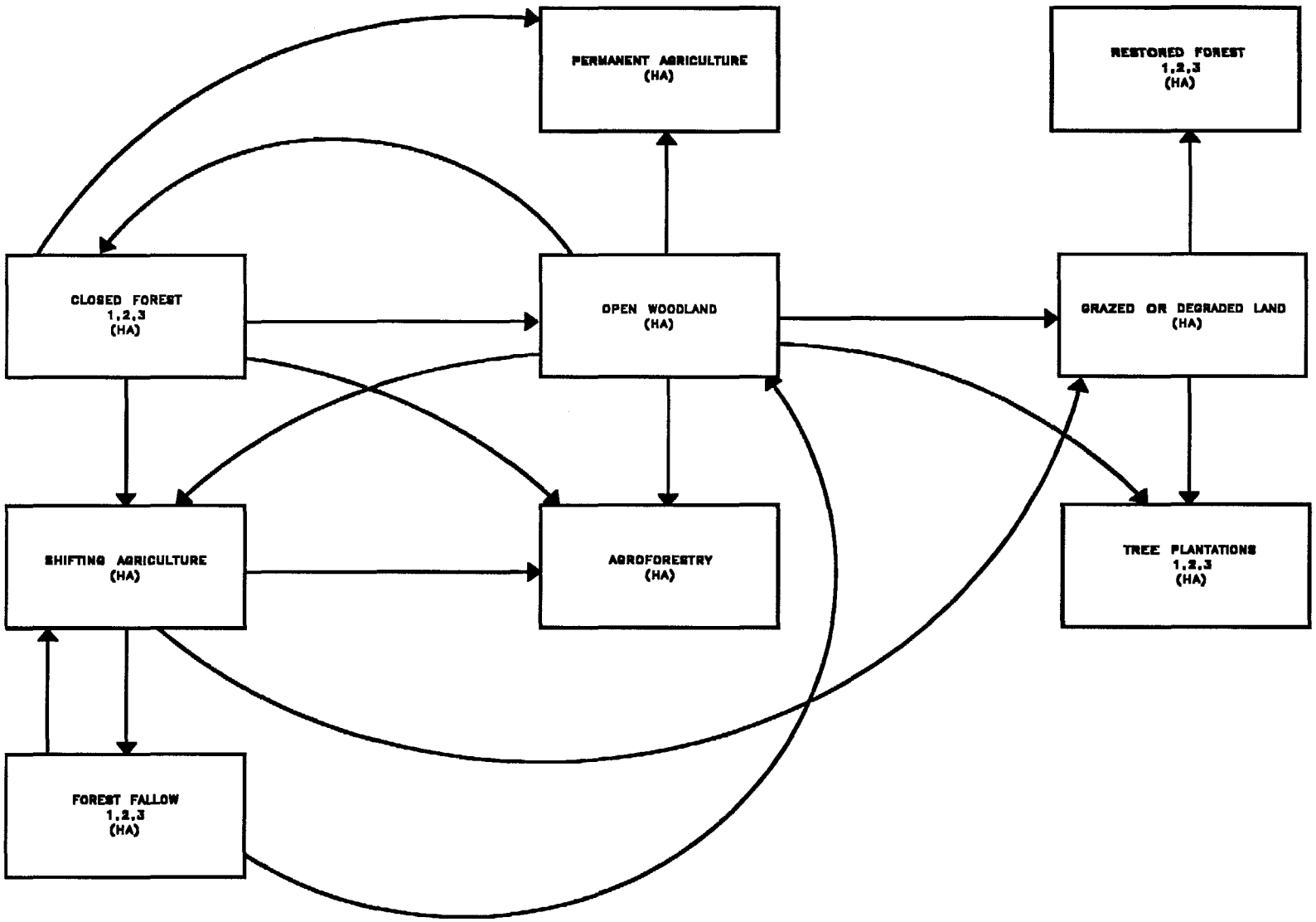


Figure 1.

Land Categories Represented in the LUCS Model



The model tracks wood harvested for permanent uses — for example, lumber, fencing, or poles (*Figure C-2.*) This wood comes from the harvest and thinning of trees in the closed forest, open woodland, and tree plantation categories. The area harvested is multiplied by the biomass and the fraction of biomass that goes into a permanent use, as opposed to a consumptive use such as fuelwood. Limbs, roots, damage, and waste are excluded from the fraction. The useful life of the wood products is based upon their use. Wood for housing has a longer useful life than poles for fencing. (*Figure C-2.*)

A preference for fuelwood over fossil fuels such as kerosene is assumed. Fossil fuel comes into play when demand for fuelwood exceeds the local supply. Fossil fuel is modeled as a stock with a large arbitrary beginning value that declines over time. The carbon released from the stock is added to the total carbon sequestered as a negative value.

Population, Land, and Fuelwood Demand

Figure 2 shows the model structure for population growth, required agricultural land, and fuelwood requirement. **Population** is represented by a simple stock with a **rate of population change**. The rate of population change slows to zero as the year that the population is expected to stabilize approaches. In this simple way, the model can represent a demographic transition from exponential growth to stability.

Required agricultural land is a function of population, agricultural land required per person, fraction of food imported, and agricultural land required for export production. Agricultural land per person, a variable that captures the productivity of the project region, is estimated initially on the productivity of permanent annual cropping. Areas of low productivity require more agricultural land to support a given level of population and export production. The value of this variable changes over time according to the estimate given for growth rate in agricultural productivity. (*See Figure 2.*) Agricultural land requirements are reduced by the fraction of food imported into the project area and increased by the amount of land used for export production and its rate of growth.

Fuelwood requirement is determined by population and the fuelwood requirement per person. The fuelwood requirement can be reduced if the efficiency of fuelwood stoves is improved. Key here are the addition of stoves, the fuelwood savings from stove use, and average family size, which determines the number of people affected by the use of a single stove.

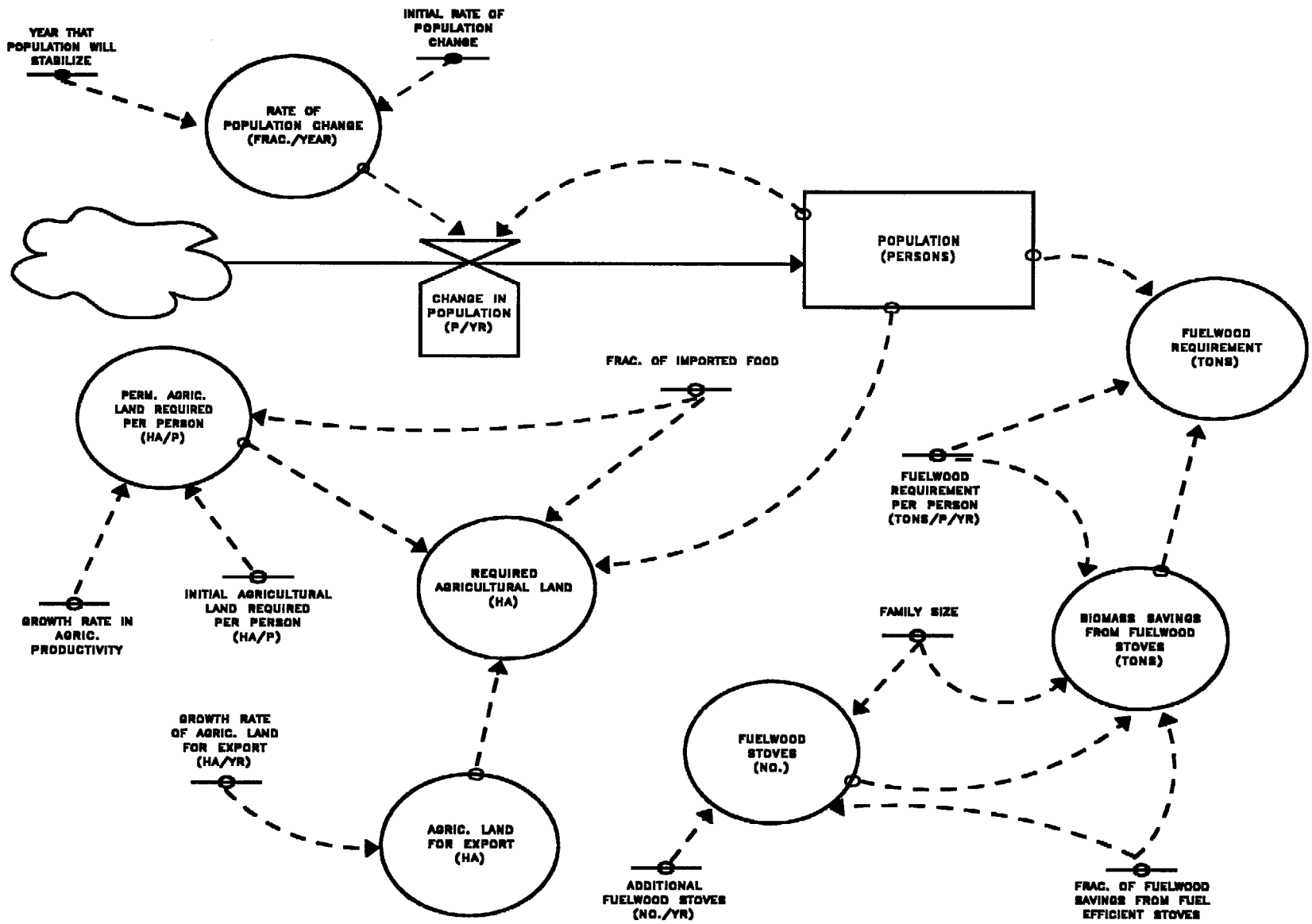
Three broad types of agricultural land are specified in the LUCS model so that significant differences in cropping, fuelwood production, and associated land use can be captured. Permanent agricultural land as used here can be thought of as continuously cropped land used mostly for annual crops. Agroforestry is also permanent cropping, but these sorts of systems are mixed with perennials, and commodities produced may include a cash crop such as coffee or a fuelwood crop. Shifting agricultural land is not continuously cropped, but rather is temporarily put into fallow after some period of cultivation.

Each of these three categories of agricultural land is characterized by its own level of productivity. In the LUCS model, agricultural productivity is defined as the amount of land required to support one person. More productive systems require less land to support a person. For agroforestry and shifting agriculture, productivity is defined relative to permanent agriculture.

To determine if the amount of agricultural land at any given time is sufficient to meet local and export requirements, the model multiplies the area of each category of agricultural land by its respective productivity ratio (1 for permanent agriculture). These are summed to determine the total amount of agricultural land, which is compared to the required

Figure 2.

Population Levels Are Used to Determine Demand for Agricultural Land and Fuelwood



agricultural land to determine the **agricultural land shortfall**. (*Figure C-3.*) Required agricultural land is estimated for the coming year, so there will be a shortfall as long as population is growing.

Agricultural land shortfalls result in movement of land to agriculture. Land can be moved to agriculture from conversion of closed forest, conversion of open woodland, and reversion of forest fallow. **Conversion of open woodland to permanent agriculture** is indicated by the relative amounts of open woodland and closed forest, the agricultural land shortfall, and the fraction of new land brought into permanent agriculture. (*Figure C-4.*) Limits are placed on the conversion because no more open woodland can be converted than exists and no more land can be put into permanent agriculture than is suitable for that type of production (maximum permanent agricultural land). The time required to convert agricultural land is assumed to be one year so that projected and actual requirements can be matched.

The **fraction of land converted from open woodland** is the amount of open woodland divided by the area of open woodland and closed forest. The model assumes a spatially even landscape and directs conversion by the relative availability. For example, if there were 900,000 hectares of closed forest and 100,000 hectares of open woodland, then the fractions for conversion would be 0.90 and 0.10, respectively, for closed forest and open woodland.

This fraction is multiplied by the agricultural land shortfall and a constant that indicates the fraction of new agricultural land that would normally be brought into permanent agriculture. The fractions for each agricultural land category sum to 1.0 and reflect the prior historical pattern of agricultural land use. As conditions change — for example, if the maximum amount of permanent agricultural is reached — these fractions change.

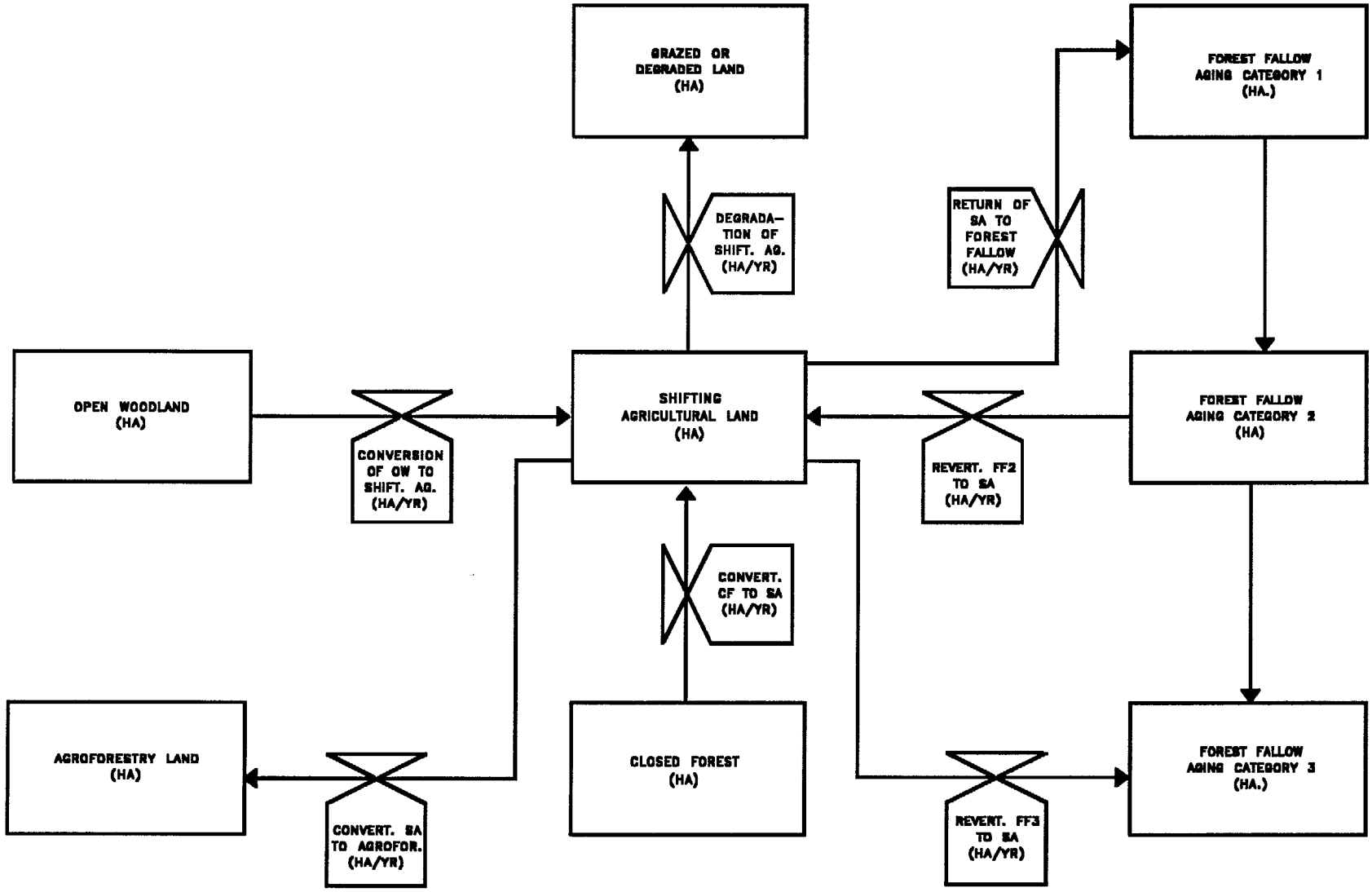
This same structure is used for conversion of open and closed forest to permanent agriculture, agroforestry, and shifting agriculture. (*Figure C-4.*) For agroforestry and shifting agriculture, there are no limits to the area that can put into those categories (except for the availability of closed forest and open woodland). For closed forest, an additional constraint is placed on the conversion to represent the effective protection of parks. (*Figure C-5.*) Only **unprotected closed forest** can be converted to agricultural or other categories.

Because fallow land must be taken into account, shifting agriculture has a more complicated structure than permanent agriculture or agroforestry. (*See Figure 3.*) As in the other two categories, land can be converted from closed forest or open woodland to shifting agriculture. In addition, shifting agricultural land can be converted to agroforestry (as happened in Guatemala) through project activities, or degraded to a low biomass category that includes grazed and degraded land.

Some fallow periods for shifting agriculture may last 20 years or more, during which time the idled land can accumulate significant amounts of biomass. For this reason, the forest fallow category is split into three age classes to capture the biomass dynamics. (*Figure C-6.*). After a given cultivation period, usually two to eight years, shifting agricultural land moves into the first aging category of forest fallow. The maturation time to the next age category is one-third of the total fallow period. At the end of the fallow period, the land returns to cultivation if an agricultural land shortfall exists. If no shortfall exists, the third aging category reverts to open woodland (not shown). If the agricultural land shortfall is larger than the amount of land that will be moving into shifting agriculture from the third forest fallow age category, more land will be returned to production from the second age class.

Figure 3.

Flows of Land to and from Shifting Agriculture



The aging chain structure approximates the growth of trees. As the trees mature, the appropriate amount of land is transferred to the next age class. The growth curve represented is S-shaped, so that the biomass of the first age class is one-sixth of the mature class, and the biomass of the second age class is two-thirds. This method approximates volume growth for those categories that require it.

The movement of land from a younger to an older aging category is determined by a constant that represents the time required for the trees to mature. This constant, in part, describes the ecological characteristics of the site. Soil productivity is not explicitly captured in the model, but instead the maturation times are used. A tree plantation planted on degraded soils would have a longer maturation time than a plantation planted on highly productive soils. This again is a means to simplify the model's structure and data requirements.

Fuelwood and Forest Management

Two main sources of **available fuelwood** are captured in the LUCS model (*Figure C-7*):

- Fuelwood available from land conversion that is destructive — that is, where biomass losses are great enough to change the land-use type.
- Fuelwood available from collection or harvest that is non-destructive.

Fuelwood collection from closed forest and open woodland debris is a small fraction of the biomass of these two categories, multiplied by their respective area. Fuelwood from agroforestry is calculated in a similar manner, but the fraction of wood collected is much higher. Agroforestry systems are often designed to produce large biomass harvests from trees that regrow after cutting.

Harvest from tree plantations can be both destructive and non-destructive. As tree plantations mature, they need periodic thinning to produce optimal growth. The thinnings provide biomass that can be used for fuelwood or more permanent uses, such as poles. At maturity, tree plantations are cleared and replanted. The harvest, once again, can be used for fuelwood, timber, pulpwood, or other uses. In the model, tree plantations are represented as an aging chain. (*Figure C-8.*) Land can be converted from grazed or degraded land or open woodland through project activities. The available fuelwood is calculated as a fraction of the total biomass (average biomass × area) maturing or being harvested for each aging category. The fractions may be large if the plantation is intended solely as a fuelwood source, zero if it is not, or something in between if, for example, the trunks are used for timber and the branches for fuelwood.

As forested land is converted to agricultural uses, large amounts of biomass are destroyed. Since people can use this biomass to meet their fuelwood needs, the model calculates the fuelwood available from destructive clearing as a fraction of the rate of land converted, multiplied by the difference in biomass between the two categories. (*See Figures 4 and 5.*)

In extreme circumstances, fuelwood deficits can degrade or destroy forests. This possibility occurs in the model when the available fuelwood is less than the fuelwood requirement. If there is a deficit, this is made up by destructive fuelwood harvesting. (*Figure C-9.*) The rate of conversion is determined by the size of the previous fuelwood deficit, the fraction of land converted from open woodland, which is the ratio of open woodland to total natural forest (*Figure C-4*), and the difference in biomass between open woodland and grazed or degraded land. If the fuelwood deficit is 10,000 tons, the fraction of open woodland to closed forest is 0.25, and the biomass of open woodland and grazed or degraded land is 125 and 25 tons per hectare, respectively, then the area of open woodland converted to grazed or degraded land from destructive fuelwood collection will be 25 hectares ([10,000 × 0.25] / [125 - 25]).

Figure 4.

Land Flows to and from Closed Forest

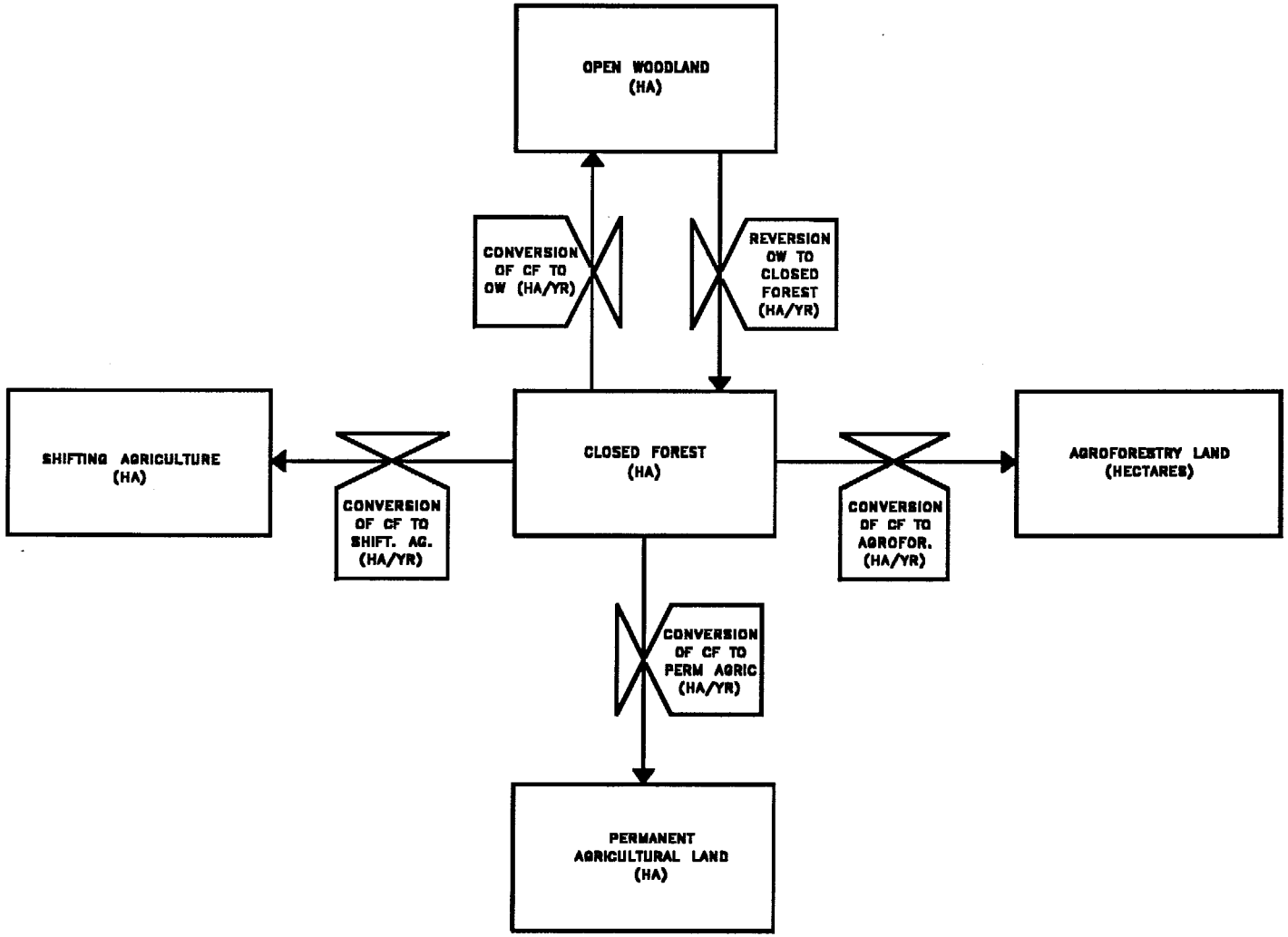
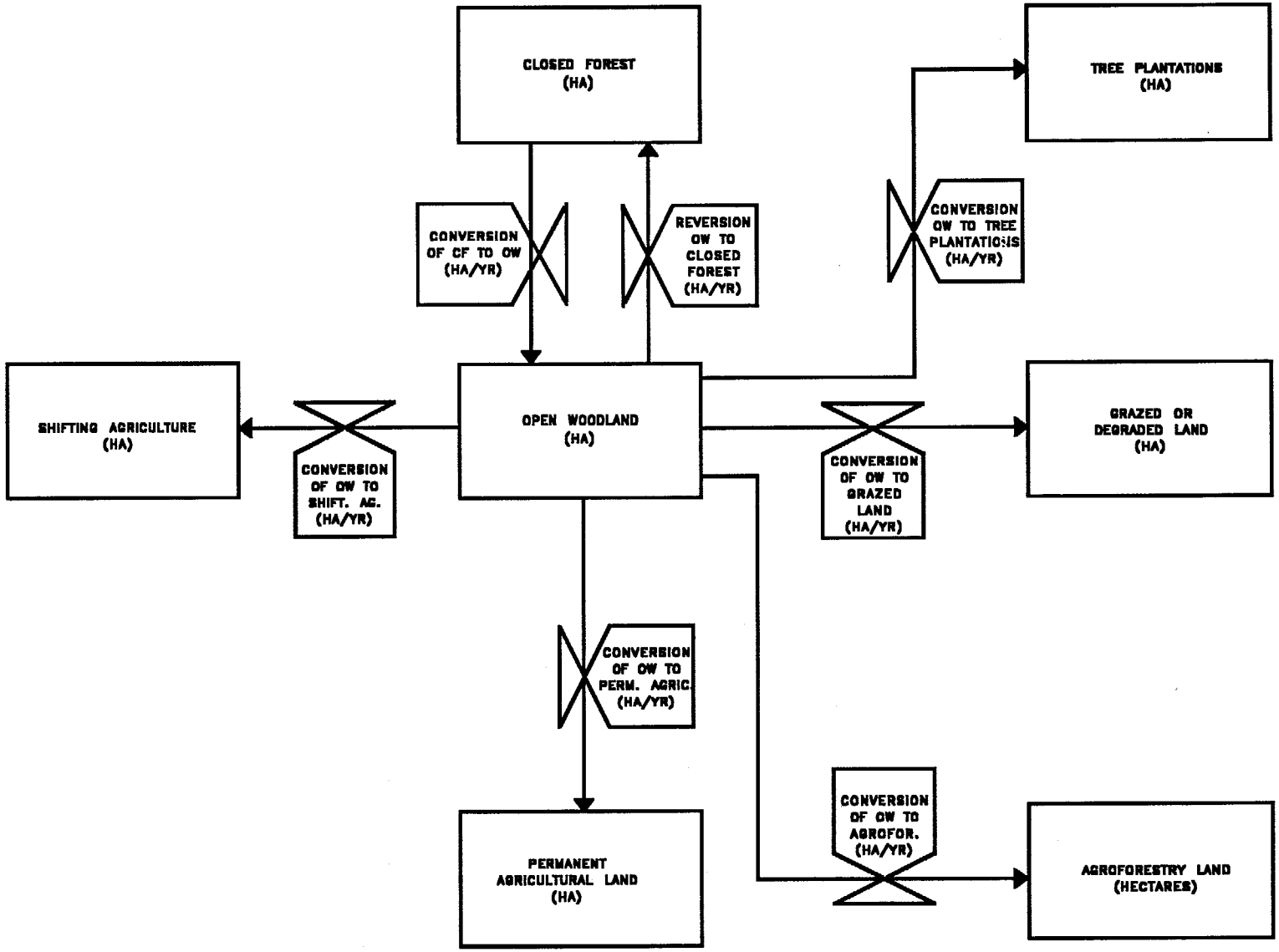


Figure 5.

Land Flows to and from Open Woodland



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The remainder of the fuelwood deficit will come from closed forest conversion to open woodland, calculated in a similar fashion. (*Figure C-10.*) Closed forest conversion is limited to the unprotected area. Closed forest can also be converted to open woodland from logging, and open woodland can revert to closed forest over time.

A common harvesting practice employed in tropical forests is selective logging, the successive removal or "highgrading" of the largest trees. If the forest is not allowed to fully recover before the area is logged again, the forest can be seriously degraded in terms of species and biomass. Three types of logging are represented in the LUCS model:

- Logging that removes so much biomass that the character of the forest is changed (from, say, closed forest to open woodland, as described above).
- Selective logging.
- Regeneration management, characterized by clear cuts of all but a few seed trees, natural regeneration, and thinning.

The model structure for the calculation of closed forest biomass under selective logging is an aging chain, wherein three aging categories are represented (*Figure C-11*):

- Aging category 1 is the minimum biomass while still maintaining a closed canopy.
- Aging category 2 is an average of categories 1 and 3.
- Aging category 3 represents mature closed forest with the maximum biomass attainable for the area.

The biomass for the closed forest is a weighted average of the three aging categories.

Selective logging moves land from aging category 3 to aging category 1. As the forest matures, area is moved to category 2 and then to category 3. Degradation occurs when selective cutting exceeds maturation. In that case, more land is moved to categories 1 and 2, increasing their predominance and reducing the average biomass. Over time, as the forest in aging category 3 is depleted, forest in aging category 2 will be cut. Eventually, the average biomass will decline to a little above that for category 1, and logging will equal the rate of maturation.

An alternative system of management used in some tropical areas is regeneration cutting. In this system, closed forests are cut leaving a few mature individuals as seed sources for regeneration. Periodic thinning increases the rate of maturation. In practice, this system resembles the management of a tree plantation, and is represented as such in the model. As closed forest is harvested, land moves into the first tree plantation aging category, maturing and remaining in that use. (*Figure C-8.*) Similarly, land can be moved into tree plantation management from open woodlands. (*Figure C-12.*)

Areas once degraded are often considered for ecological restoration. These areas may be additions to national parks or areas within parks subjected to clearcutting and grazing. Accordingly, the model has a special category of land use called restored forests. (*Figure C-13.*) Grazed or degraded land can be moved into an aging chain that has no outlet to other land-use categories. The restored forest matures over a period determined by the site's ecological characteristics. The maximum biomass accumulation is assumed to be the same as that for closed forest. Since significant investments are required to restore degraded land in this fashion, the assumption is made that further protection efforts will prevent the conversion of this land back to other uses.

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3. REVISITING THE CARE/GUATEMALA AGROFORESTRY PROJECT

Until the authors of the report on the CARE/Guatemala Agroforestry Project developed a carbon sequestration estimate (Trexler et al., 1989), no prior estimates of this sort had ever been made at the project level. Previous estimates were of a global nature and of limited use for the exercise. Limited time and money also made the job more difficult.

This chapter revisits the original carbon sequestration-estimates for the CARE/Guatemala Project, comparing them with:

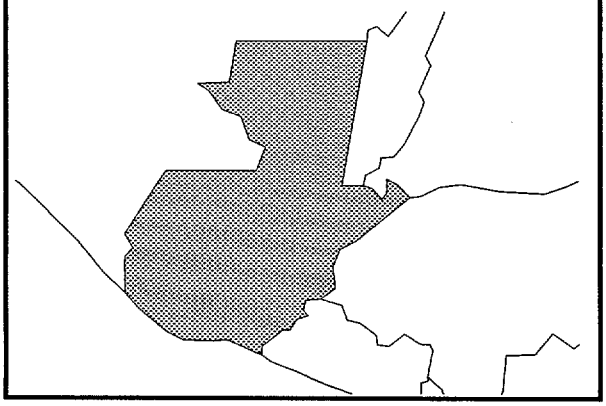
- Estimates derived using the same method, but with revised project parameters and biomass figures.
- Estimates based upon the LUCS model.

Both the revised and LUCS estimates are supported by new information from the field. The results show that given the methodology used, the original estimate was generous. Compared to a more sophisticated method which includes secondary benefits and forest preservation, however, the original estimates were quite low. The static nature of the original method failed to adequately account for the principal benefit expected to arise from the project: the protection of the natural forest from conversion to agriculture.

Static Analysis: Original and Revised

The original analysis for the CARE/Guatemala Project was not dynamic in any sense. All of the parameters used were assumed to be constant over the 40-year life of the power plant. As originally proposed, the project was to plant about 51 million trees over a 10-year period. Project activities included conversion of land from low-productivity agriculture to agroforestry, planting degraded land to community woodlots, soil conservation efforts, and control of forest fires. These activities were to be supported by extensive farmer education and organization efforts, as well as nursery management for tree production. CARE also had a variety of other

Figure 6. Guatemala Is the Site of a CARE Agroforestry Project.



on-going efforts in Guatemala, including nutrition and small business development, although these were not directly associated with the agroforestry project.

The assumptions and results for both the original and revised static carbon sequestration estimates are shown in Table 2. CARE does not have the ability to track actual area planted for the project, but these can be estimated from the number of seedlings disbursed and planting density. In the proposal WRI received in 1988, CARE planned annual production of 2.44 million trees for woodlots and 2.56 million trees for agroforestry. At the time, CARE determined that seedlings would be planted at relatively high per-hectare densities of 400 trees for agroforestry and 2,000 trees for woodlots. The corresponding annual outplanting is 6,625 hectares for agroforestry and 1,220 hectares for woodlots.

Biomass growth rates reported by CARE were used to determine the carbon fixed through agroforestry and woodlot activities. These growth rates, 20 and 13 cubic meters per hectare per year for woodlots and agroforestry, respectively, imply total biomass growth over the project life of 700 tons for woodlots and 341 tons for agroforestry, given a 35-year average growth period (10 years of plantings are assumed so the first hectare planted is used for 40 years and the last for 30).

Total biomass growth is not the same as biomass at maturity. Woodlots are cut and replanted, while trees grown on agroforestry land are replanted or regrow from the roots after cutting. Assuming maturation times of 15 years for woodlots and 5 years for agroforestry, this implies maximum biomass of 300 and 98 tons per hectare, respectively. In retrospect, these biomass numbers are extraordinarily large.

The area protected from fire by local fire brigades was assumed to be small in the original calculation, but the extent of fire damage in the absence of protection and the biomass assumption were very high. In contrast, the revised numbers allow for the protection of fully half of the open woodland area, but use more realistic estimates of forest biomass for open woodland and a much lower extent of damage assuming some capacity for natural recovery. Soil conservation area estimates are larger for the revised estimates based upon updated project information.

The revised estimates are based upon recent performance of the CARE/Guatemala Project and lower growth rates. CARE nurseries in Guatemala now grow about 4.5 million trees per year. Based upon species composition and experience, CARE field staff estimate that about half of these trees are used for "low-density" agroforestry (150 trees per hectare), 20 percent for "high-density" agroforestry (400 trees per hectare), and 30 percent for woodlots. The current recommendation for woodlot planting density is 1,000 trees per hectare. Nursery production and planting densities imply annual area planted to woodlots, high-density agroforestry, and low-density agroforestry at rates of 1,350, 2,250 and 15,000 hectares per year, respectively.

Revised biomass parameters are based upon field estimates of mature biomass in each category made by experienced foresters. Growth rates of stemwood are derived from these new biomass estimates, rotation lengths, root-branch multipliers, and wood density. These growth rates are about half of the original estimates provided in the CARE proposal.

The static method makes several assumptions to convert carbon fixed to carbon sequestered. This is because considerably more carbon can be fixed in biomass than is sequestered over the long-term. First, not all biomass fixed is usable as fuelwood. The original estimate assumed that only two-thirds of biomass fixed was usable as fuelwood; the balance was leaves and roots. Second, only a small part of the biomass fixed (assumed to be 15 percent)

Table 2.

Original and Updated Carbon Sequestration Estimates Based Upon Static Method

ASSUMPTION	UNITS	ORIGINAL	UPDATED
Area planted to woodlots	ha/yr	1,220	1,350
Area planted to high-density agroforestry	ha/yr	6,625	2,250
Area planted to low-density agroforestry	ha/yr	N/A	15,000
Total trees planted, woodlots	trees	24,400,000	13,500,000
Total trees planted, high-density agroforestry	trees	26,500,000	9,000,000
Total trees planted, low-density agroforestry	trees	N/A	22,500,000
Total trees planted (10 yrs)	trees	50,900,000	45,000,000
Planting period	years	10	10
Project life	years	40	40
Planting density, woodlots	trees/ha	2,000	1,000
Planting density, high-density agroforestry[1]	trees/ha	400	400
Planting density, low-density agroforestry	trees/ha	N/A	150
Root-branch multiplier		2	2
Wood density	t/m^3	0.5	0.5
Woodlot total growth	t/ha	700	315
High-density agroforestry total growth	t/ha	341	177
Low-density agroforestry total growth	t/ha	N/A	66
Woodlot growth rate	$m^3/ha/yr$	20	9
Agroforestry growth rate	$m^3/ha/yr$	13	6.75
Woodlot biomass at maturity	t/ha	300	135
High-density agroforestry biomass at maturity	t/ha	65	34
Low-density agroforestry biomass at maturity	t/ha	N/A	14
Woodlot maturation time	years	15	15
Agroforestry maturation time	years	5	5
Area protected from fire	ha	2,400	452,000
Damage from fire	percent	60	5
Biomass of damaged land	t/ha	800	100
Soil conservation area	ha	8,600	9,725

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Table 2 (continued).

ASSUMPTION	UNITS	ORIGINAL	UPDATED
Biomass harvested	percent	85	85
Usable wood multiplier		0.66	0.66
Demand displacement multiplier		1.5	1.5
Carbon sequestered from			
Woodlots	million tons	4.2	2.1
High-density agroforestry plantings	million tons	11.3	2.0
Low-density agroforestry plantings	million tons	0	4.9
Fire protection	million tons	0.58	1.1
Soil conservation	million tons	0.29	0.33
Total carbon sequestered	million tons	16.4	10.5

1. Assumes a 75 percent survival rate.

actually adds to the permanent standing stock. The rest cycles and does not achieve long-term storage. Third, most of the biomass fixed was assumed to displace demand from natural forests. A multiplier of 1.5 was used to reflect forest damage and disturbance beyond the material collected.

Table 3 shows the formulas used to calculate some of the values shown in Table 2. Values not calculated came from the original CARE/Guatemala proposal, various CARE staff, or experts visiting the site. Total carbon sequestered was assumed to come from four sources:

- Woodlots.
- High-density agroforestry.
- Fire protection.
- Soil conservation (which protects and increases organic matter).

For the revised estimates, low-density agroforestry was added based upon conversations with CARE field staff.

Several aspects of the analysis account for the differences in the revised estimate:

- Lower growth rates.
- Lower nursery production.
- Lower planting densities.
- A different base assumption about fire protection.

Dynamic Analysis Based on the LUCS Model

In contrast to the original method used to estimate carbon sequestration for the CARE/Guatemala Project, the LUCS model has many dynamic components. The model also has the advantage of being able to account for secondary project benefits. The more holistic approach of the LUCS model provides a broader and more systematic view of the project and its impacts.

The secondary carbon benefits proved to be much larger than the primary benefits. For this reason, the estimates produced from the dynamic analysis are much larger than those produced from the static analysis.

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Table 3.
Formulas Used to Calculate Values in Table 2

VARIABLE OR PARAMETER	FORMULA	UNITS
Area planted (hectares)	Trees planted / planting density	(trees / (trees/hectare) = hectares
Total growth (tons/hectare)	Growth rate * project life * wood density * root-branch multiplier	(m^3/ha/ yr) * years * tons/m^3 = tons/hectare
Biomass @ maturity (tons/hectare)	Growth rate * maturation time * wood density * root-branch multiplier	(m^3/ha/yr) * years * tons/m^3 = tons/hectare
Growth rate (m^3/hectare/year)	Biomass @ maturity / (maturation time * wood density * root-branch mult.)	(tons/hectare) / (years * tons/m^3) = m^3/hectare/year
Carbon sequestered from		
Woodlots and agroforestry	(Annual area planted * planting period * total biomass growth * carbon content) * ([1 - % biomass harvested/100] + [usable branch wood mult. * % biomass harvested/100 * demand displacement mult.])	
Fire protection	Area protected * (damage from fire/100) * biomass * carbon content	
Soil conservation	Area conserved * soil density * % organic matter/100 * depth of plow layer * m^2/hectare * layer * carbon content of organic matter	

A baseline and three project scenarios were run. The baseline scenario is a "best-guess" about what the project area will look like without the project. This scenario assumes continued population growth, but at a decreasing rate. There are just under 3 million people in the project area and population is growing at 2.8 percent a year. Average family size is six people, and the population is assumed to stabilize in the year 2100.

In the **baseline scenario** most agricultural production is characterized by very low productivity. Each person requires 0.4 hectares of land for full self-sufficiency. Since about one-fourth of the food requirement is imported, however, the actual requirement in production is about 0.3 hectares per person. Agricultural productivity is expected to increase at 1 percent per year. All four scenarios use the same assumptions for population, agricultural technology growth, and beginning land use.

Total land area is just over 3 million hectares. The area is initially divided into 728,000 hectares of closed forest, 962,000 of open woodland, 776,000 of permanent agricultural land, 78,000 of agroforestry, 40,000 of shifting agriculture, 40,000 of forest

fallow, 20,000 of woodlots, and 410,000 of grazed or degraded land.

The three project scenarios reflect alternatives for long-term project success and funding. (*See Table 4.*) The first scenario, the **10-Year Project**, assumes that the project activities last for 10 years and that there is no enduring impact. At the end of the project farmers would go back to what they were doing prior to the project: of forested land converted to agriculture, 89 percent would go into permanent agriculture, 7 percent into agroforestry, and 4 percent into shifting agriculture. The project succeeds in the annual conversion of 1,350 hectares of degraded land to woodlots, 15,000 hectares of permanent agriculture to low-density agroforestry, and 2,250 hectares of shifting agriculture to agroforestry and then after three years to woodlots.

The second scenario assumes that CARE's efforts to educate and transfer project activities to farmer groups are successful and have a lasting impact. CARE has an explicit project to do just this, called the Transferencia Program. The **10-Year Project plus Transferencia** scenario assumes that at the end of the project life new land brought into production goes half into permanent agriculture and half into agroforestry.

Table 4.
Project Scenarios and Relevant Parameter Changes

PARAMETERS	BASELINE (NO PROJECT)	10-YEAR PROJECT	10-YEAR PROJECT AND TRANS-FERENCIA PROGRAM	40-YEAR PROJECT
Duration of activities (years)	N/A	10	10	40
Annual woodlot planting (ha/yr)	0	1,350	1,350	1,350
Annual conversion of permanent agriculture to agroforestry (ha/yr)	0	15,000	15,000	15,000
Annual conversion of shifting agriculture to agroforestry (ha/yr)	0	2,250	2,250	2,250
Annual conversion of agroforestry to woodlots (ha/yr)	0	2,250	2,250	2,250
New agricultural land going into permanent agriculture (percent)	89	89	89/50	89
New agricultural land going into agroforestry (percent)	7	7	7/50	7
New agricultural land going into shifting agriculture (percent)	4	4	4/0	4
Time required for open woodland to recover to closed forest (years)	1,000	200	200	200

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This scenario probably reflects the CARE/ Guatemala Project most accurately because there is considerable evidence that farmers are undertaking project activities themselves. For example, some farmers are producing and selling seedlings directly to other farmers at a profit.

The final project scenario assumes that CARE continues nursery production indefinitely. The **40-Year Project** could occur if the project were endowed.

All three project scenarios assume a limited success in forest fire brigades. In the baseline it is assumed that open woodlands are unable to revert to closed forest because of fire. The time required for open woodland to recover, therefore, is set at 1,000 years, precluding any significant recovery. Under project management this recovery is assumed to be slow, but possible.

Figure 7 shows the population projection used for all four scenarios. Even though population is assumed to stabilize in 2100, the part of the projection covered in this analysis is still characterized by significant growth. Population increases from 3 million to about 7.5 million people.

Agricultural land-use is a function of population and agricultural productivity, which depends upon the choice of production practices and technology growth. Agricultural land-use also depends upon imports and export production; the assumptions for these are the same for each scenario. Figure 8 shows the results for permanent agricultural land use for each scenario. In the baseline scenario, permanent agriculture land nearly doubles. This land comes from closed forest and open woodland.

Project conversion of permanent agriculture land to agroforestry is at a rate high enough to put its growth on a downward trend. For the 10-Year Project and 10-Year Project plus Transferencia, this trend is reversed when nursery production ends. The Transferencia Program shows slower growth. The 40-Year Project shows a continuation as permanent agriculture is converted to agroforestry.

A principal objective of the CARE/Guatemala Project is to convert low-productivity annual cropping (permanent agriculture) to higher-productivity agroforestry. Agroforestry builds and protects soil productivity, produces higher yields and more diverse products, including fuelwood. Figure 9 shows the area of land in agroforestry under each scenario.

Under the baseline assumptions there is a small area in agroforestry without the project. The 10-Year Project would produce roughly 150 percent more land in agroforestry, but when the project ended growth is assumed to stagnate. With the Transferencia Program, agroforestry land would continue to increase, but at a slower rate. Under the 40-Year Project, there would be significantly more agroforestry land than under any of the other scenarios.

Based upon experiments in the project area, crop yields are about 50 percent higher under agroforestry than permanent agriculture. The implications of widespread agroforestry are clear. Compared to the baseline, the 10-Year Project has about 8 percent less land in agriculture (including shifting agriculture), with the addition of the Transferencia Program there is 12 percent less, and with the 40-Year Project about 23 percent less. Each project scenario implies successively greater protection of forested land because the need to increase the land base for agricultural production is reduced.

Figure 7.

Population Projection Used for All Four Scenarios of the CARE/Guatemala Agroforestry Project

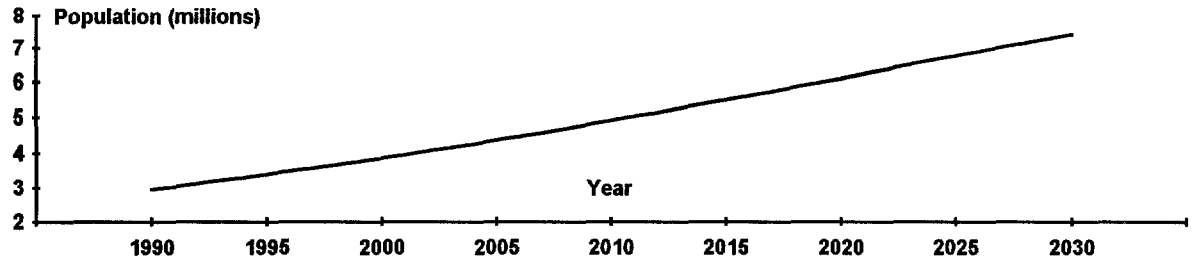

Figure 8.

Area of Permanent Agricultural Land for Each of the Four Scenarios

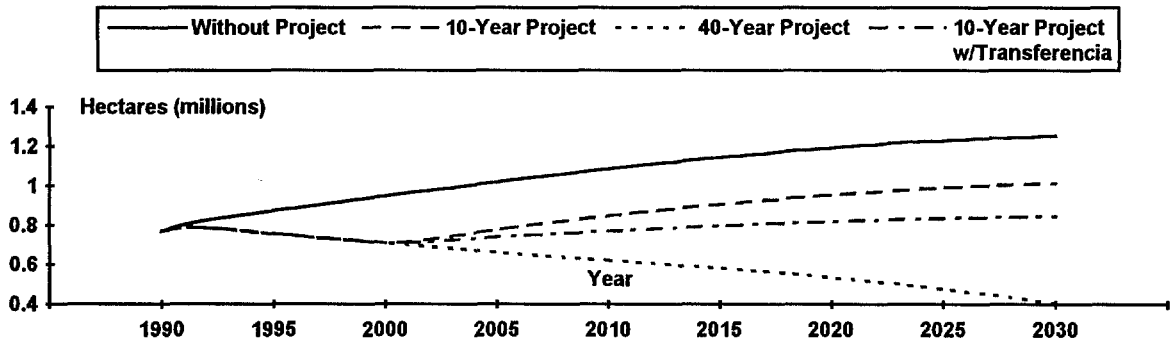

Figure 9.

Area of Agroforestry Land for Each of the Four Scenarios

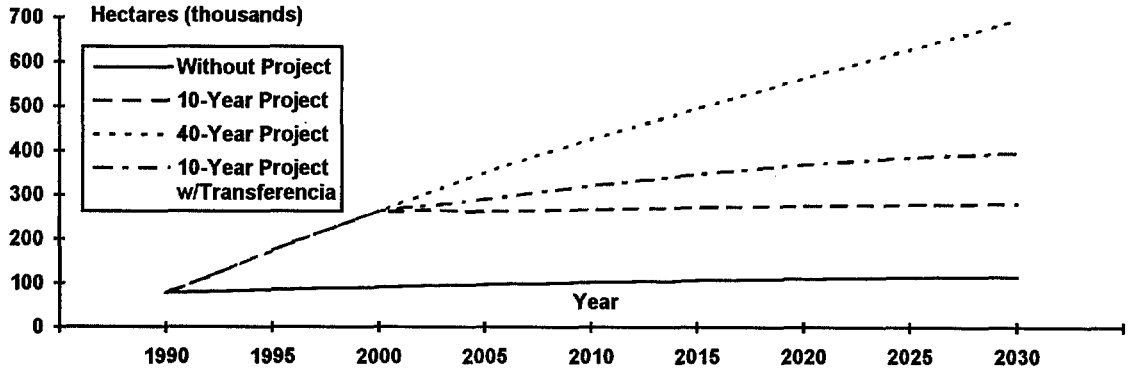

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Figure 10 shows the implication of increased agricultural productivity for closed forests. The baseline scenario shows a dramatic decline in area under closed forest, with much smaller declines for the two 10-year scenarios and an absolute increase in the area under closed forest for the 40-Year Project.

The loss of closed forest is not simply a function of hunger for agricultural land, however. Fuelwood demand also plays an important role. Figure 11 shows the results of LUCS simulation for available fuelwood and fuelwood demand. Under the baseline scenario, available fuelwood declines until fuelwood demand crosses available supply. Up to this point there is a surplus of fuelwood available, primarily from land conversion and forest debris.

The decline of available fuelwood reflects the loss of forested land. After the lines cross and a fuelwood deficit is apparent, the model shows the degradation of forested land from fuelwood collection begins. Closed forest will be degraded to open woodland, and open woodland degraded to grazed/degraded land in a cascade to supply fuelwood needs. A comparison with Figure 12 shows that the amount of grazed/degraded land is stable until a fuelwood deficit appears. At that time the behavior will shift to exponential growth of grazed/degraded land as the fuelwood deficit widens.

For the 10-Year Project, the conversion of degraded land to woodlots (*Figure 13*) and permanent agriculture to agroforestry increases the supply of fuelwood. Fuelwood demand does not surpass availability until 18 years after the baseline. Degradation of closed forest and open woodland is much less severe, but still occurs at the later date.

For the 40-Year Project, availability of supply is maintained well beyond demand. No conversion of closed forest or open woodland occurs or appears imminent. Instead, there is significantly less grazed/degraded land at the end of the project life.

For each of the scenarios except the 40-Year Project, the fuelwood deficit is made up by kerosene, an additional source of carbon emissions.

The direct effects of the CARE/Guatemala Project were captured in the static analysis. The dynamic analysis also captures these direct effects,

Figure 10.

Area of Closed Forest for Each of the Four Scenarios

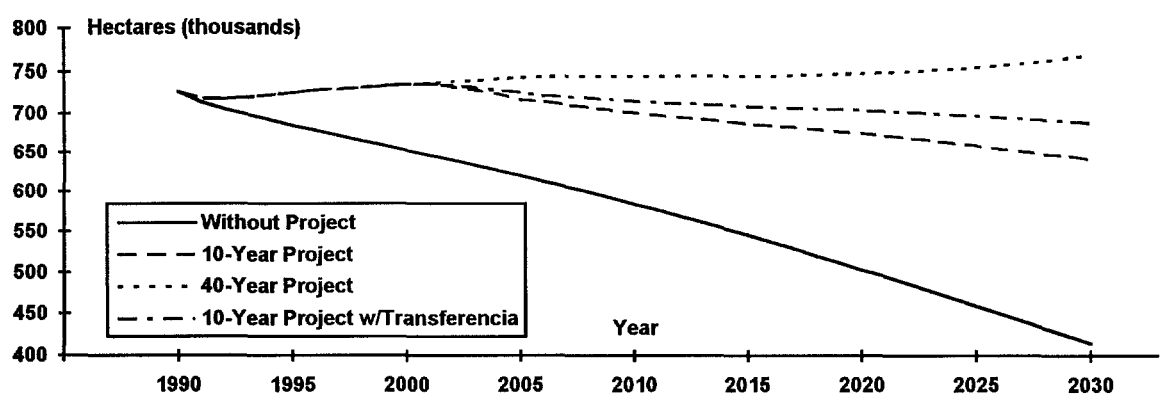

Figure 11.

Amount of Available Fuelwood and Fuelwood Demand for Each of the Four Scenarios

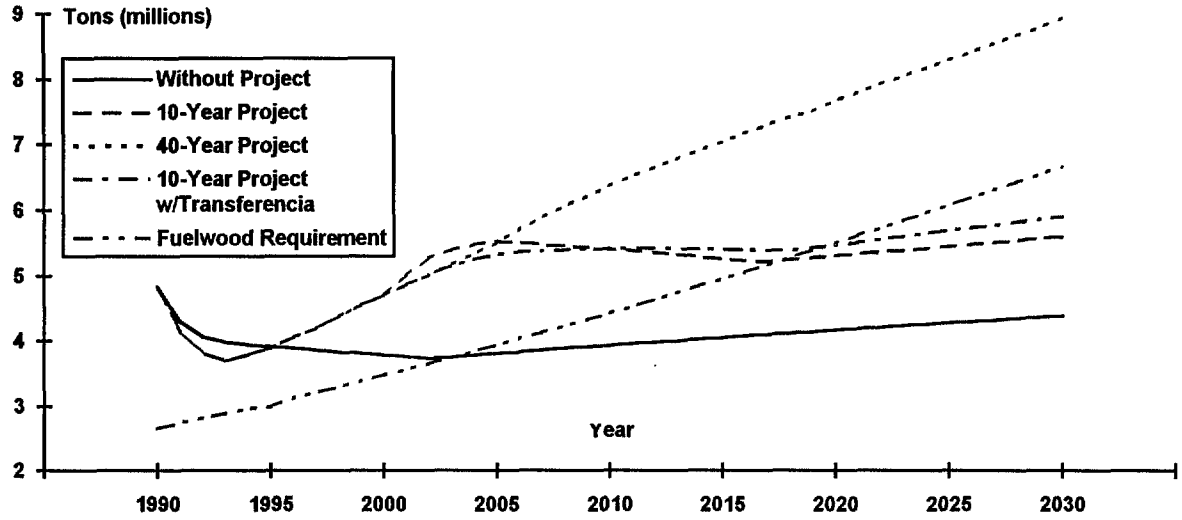

Figure 12.

Area of Grazed or Degraded Land for Each of the Four Scenarios

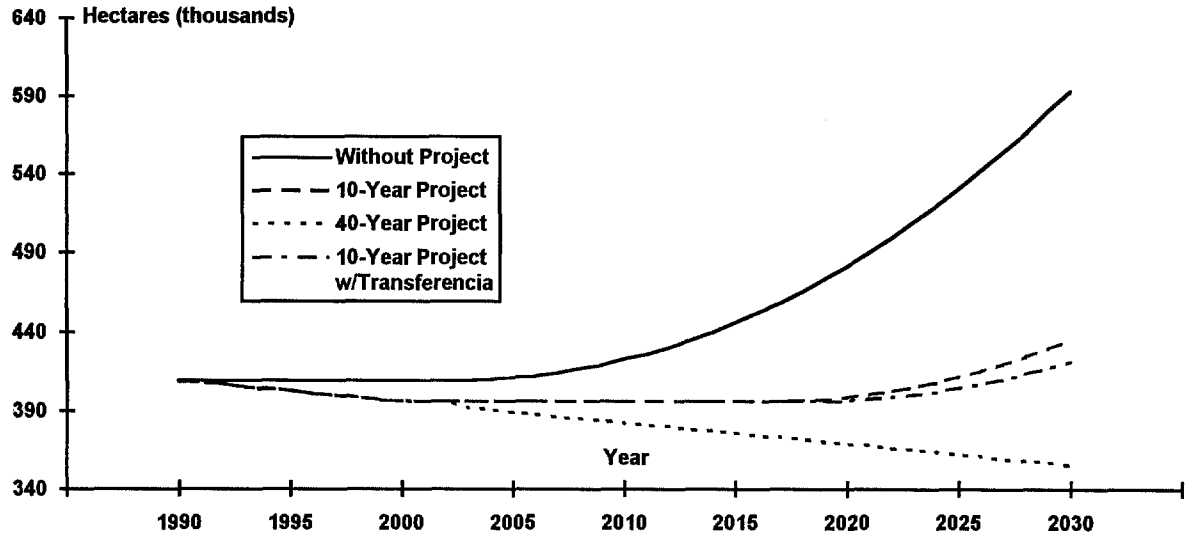

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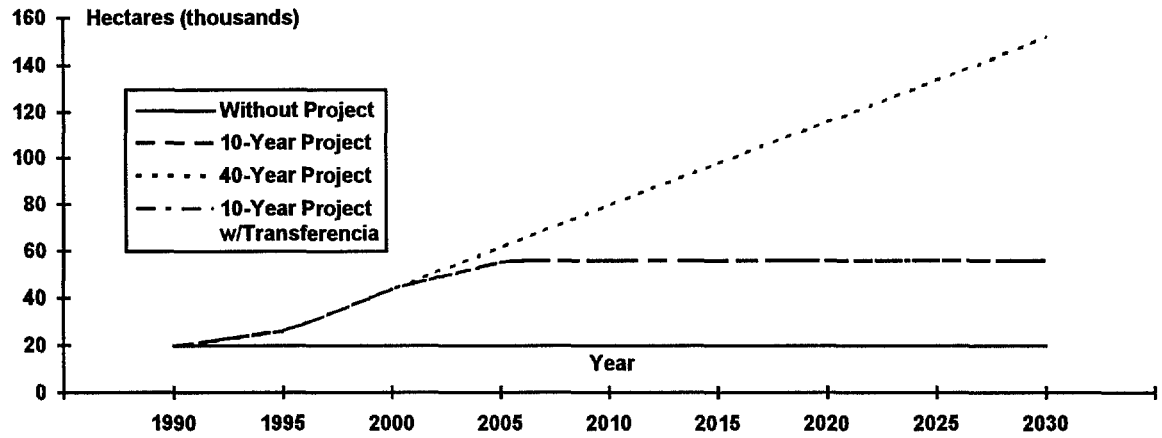
Figure 13.

Area of Woodlots for Each of the Four Scenarios



but more importantly, also captures the indirect effects of increased agricultural productivity and forest protection. Figure 14 show the estimates for carbon sequestered over the lifetime of the power plant for the baseline and each project scenario. At the beginning of the simulation, there are roughly 135 million tons of carbon in the standing biomass of the project area. The baseline scenario shows a loss of about 54 million tons of carbon from standing biomass and fossil fuel use.

The carbon sequestered under each scenario is taken to be the difference from the baseline at the end of the project lifetime. Even though there may an absolute loss of carbon for a given scenario, there could be less carbon lost than for the baseline, and therefore an absolute gain for the atmosphere. The scenario analysis shows a gain of 30 million tons for the 10-Year Project, 39 million for the 10-Year Project plus Transferencia, and 58 million for the 40-Year Project.

Table 5 summarizes the estimates provided in this chapter and provides cost estimates on a unit basis. Total project costs for the CARE project are $8.8 million.

Table 5.

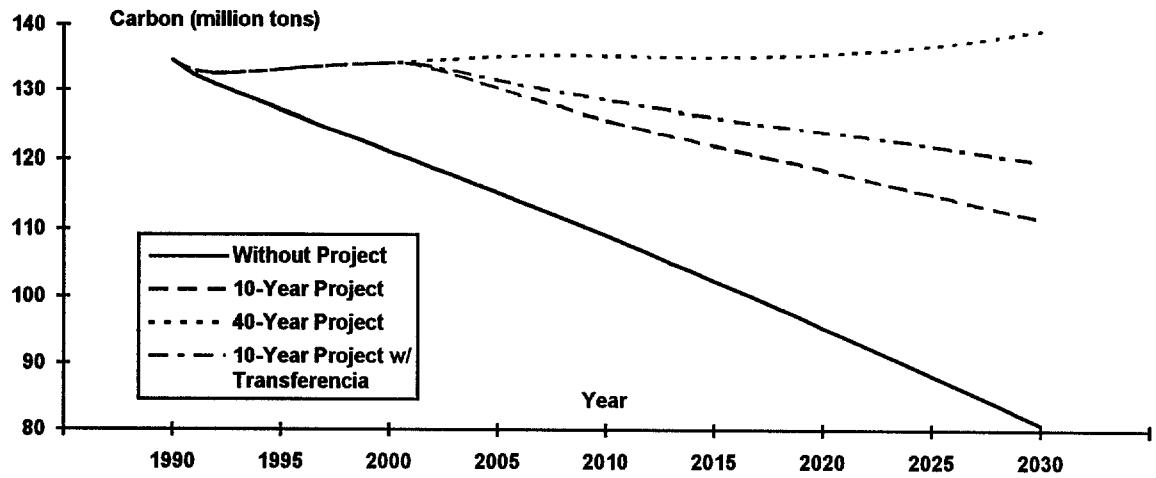
Summary of Carbon Sequestration and Costs for Calculation Method or Scenario for CARE/Guatemala Project

METHOD OR SCENARIO	CARBON (MILLION TONS)	COST (DOLLARS /TON)[1]
Original static analysis	16.4	0.53
Updated static analysis	10.5	0.83
10-year project	30	0.29
10-year project with Transferencia	39	0.23
40-year project	58	0.15

1. Using a total project cost of $8.8 million

Figure 14.

Estimates of Carbon Sequestered for Each of the Four Scenarios



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4. THE PDA PROJECT IN THAILAND

The Population and Community Development Association (PDA) was founded in 1974 as a family planning agency, but has since expanded its activities to include environmental sanitation, community forestry, environmental conservation, water resource development, agricultural extension, and AIDS education.

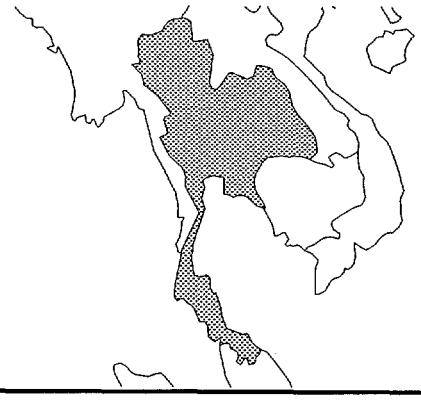
PDA maintains seven Community Based Integrated Rural Development Centers (CBIRD) in northeastern Thailand, which serve as regional offices for project management, training facilities, and demonstration sites. It works closely with the Thai government and generally tries to complement government services.

PDA relies on active local participation and sponsors comprehensive training programs to increase local capabilities. It does not initiate activities, but responds to requests from village residents.

Northeast Thailand, where the project would take place, is the least forested, poorest, and driest part of the country. Nearly all the region's natural forest was lost to agricultural activities by the 1960s. Forest cover for the northeast region is officially estimated at 14 percent, but local forest cover in areas near many of the CBIRD centers is often much lower. Most land is under rice cultivation, with one crop produced during the short wet season between July and October. The limited remaining natural forest in the area is a deciduous "monsoon" forest with relatively high levels of standing biomass.

Since the early 1980s communities increasingly asked PDA for help in community forestry. PDA established nurseries at the CBIRD centers and helped villagers establish forest committees which were provided seedlings (mostly eucalyptus) to plant on community lands. The eucalyptus trees were usually sold to paper mills, with the proceeds used for community development projects. Thinnings and downed branches also provided fuelwood.

Figure 15.
The Proposed Project in Thailand Would Provide Technical, Financial, and Managerial Training to Villagers.



Village residents, however, have grown increasingly sophisticated in their desire to plant more tree species for more uses. They have also expressed interest in establishing community forests. PDA's proposal represents a response to this community interest. The project would engage 300 villages in the northeastern provinces of Khon Kaen, Mahasarakham, and Buriram. The three provinces are characterized by insufficient tree cover, decreasing soil productivity, and falling agricultural yields. Village residents are having an increasingly difficult time meeting their basic subsistence needs.

In each village, PDA would help establish a nursery to provide villagers with nitrogen-fixing trees, native hardwoods, and fruit tree seedlings. Prior to the rainy season PDA would provide each nursery with 5,000 nitrogen-fixing and fast-growing species, 2,000 hardwood seedlings, and 250 fruit tree graftings. The introduction of these trees will help enrich the soil, regulate water flow, and provide food products that currently must be purchased from outside the village.

Village forestry committees would be formed and trained to manage the project after external assistance is withdrawn. Multiple-use forests averaging about 4 hectares would be established on available public land. Two types of forests, each averaging about 2 hectares would be established:

- Economic forests would provide fuelwood, construction materials, and commercial timber.
- Protected forests would not be harvested, but would provide a source of fuelwood and minor forest products such as mushrooms and herbs.

Selection criteria for the 300 villages would include desire to participate in the program, past relationship with PDA, past experience with forestry initiatives, the existence of 5 hectares of public land, a village size of about 100 families, and a strong sense of village unity. The CBIRD centers will serve as training facilities. Two representatives from each village forestry committee will be trained at the centers and will become village foresters.

The project also envisions an active tree planting program (averaging about 1 hectare) in each village around temples, schools, and public roadways. In addition, 1,250 seedlings per village would be sold to project members for planting on private property around houses and paddy dikes.

Key Data and Model Results

The population of the area is estimated at 180,000, with a relatively low annual growth rate of 1.8 percent. Thailand's national population growth has dropped dramatically in recent years, even in relatively poor areas. The region's low growth rate may be due in part to outmigration to large cities such as Bangkok. Population would grow to about 330,000 by the end of the project.

Permanent agricultural land is estimated at 90,000 hectares, or 0.5 hectares per person. The current amount, roughly 95 percent of the total land area, is considered the maximum for the area. Agricultural production is assumed to grow at a rate of 2 percent per year, which is comparable to the growth rate in the 1980s and is currently providing a modest rice surplus under normal growing conditions. Imported food is assumed to be zero. Agroforestry is not a major factor in the overall project and there is no shifting agricultural land.

Aside from permanent agricultural land there are 1,500 hectares of degraded land, 900 hectares of agroforestry, 240 hectares of closed forest, 100 hectares of open woodland, 100 hectares of restored forest, and 90 hectares of tree plantations.

Because of the large amount and intensive use of land for agricultural production, there is little flexibility for alternative land use in the area. Thus the PDA proposal to convert 4 hectares per village, while seemingly modest, is nevertheless close to the maximum amount available.

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With the very high proportion of agricultural land, there is relatively little biomass in the area. Agricultural land is assumed to contain an average of 2.5 metric tons per hectare of biomass throughout the year, open woodland 110 tons per hectare, and closed forest 180 tons per hectare.

The fuelwood requirement per person is estimated at a relatively low 0.6 tons per person per year. Much of the fuelwood supply is provided by dead branches from trees along roads, around villages, and in homestead gardens.

The project aims to initiate its tree plantation and restored forest projects in 60 villages per year for a 5-year period. The annual planting rate is therefore set at 120 hectares of tree plantations and 120 hectares of restored forest, or a total of 1,200 hectares over the 5-year period.

The fast-growing characteristics of eucalyptus trees have a rotation time of seven years, which is the value used for tree plantations. About one-fourth of the trees in plantations are used to make products with a lifetime of 30 years.

The scenarios run suggest a relatively small carbon benefit of 145,000 tons, roughly evenly divided between restored forest and tree plantations. Figure 16 shows the carbon benefits over the 34-year period. Total carbon sequestration declines in the later years as wood is harvested and used for fuelwood. The baseline scenario shows that fuelwood consumption over time releases about 100,000 tons of carbon into the atmosphere. Fossil fuel consumption releases an additional 124,000 tons of carbon.

Figure 17 shows the area planted to woodlots and restored forest over the 5-year project life. The woodlots are assumed to be replanted after harvest.

The fact that almost all of the land in the project area has already been converted to permanent agriculture limits the potential carbon benefits of the project. There is very limited space available for woodlots and forest restoration, and so the rate of plantation establishment is tiny compared to the CARE/Guatemala Project, for example, but the project costs however, are also small. With total project costs estimated to be $191,000, the cost per ton of carbon sequestered is roughly $1.28.

Figure 16.

Amount of Carbon Sequestered With and Without the PDA Project in Thailand

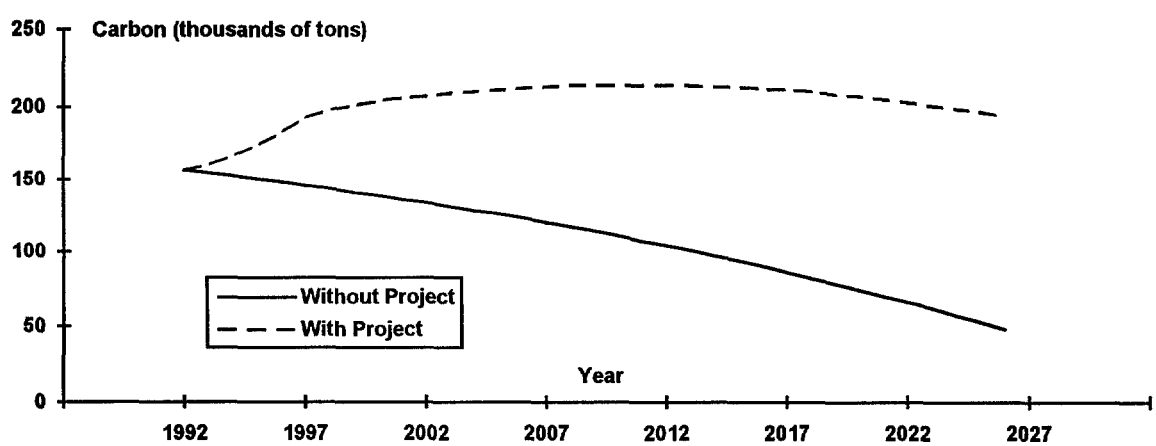
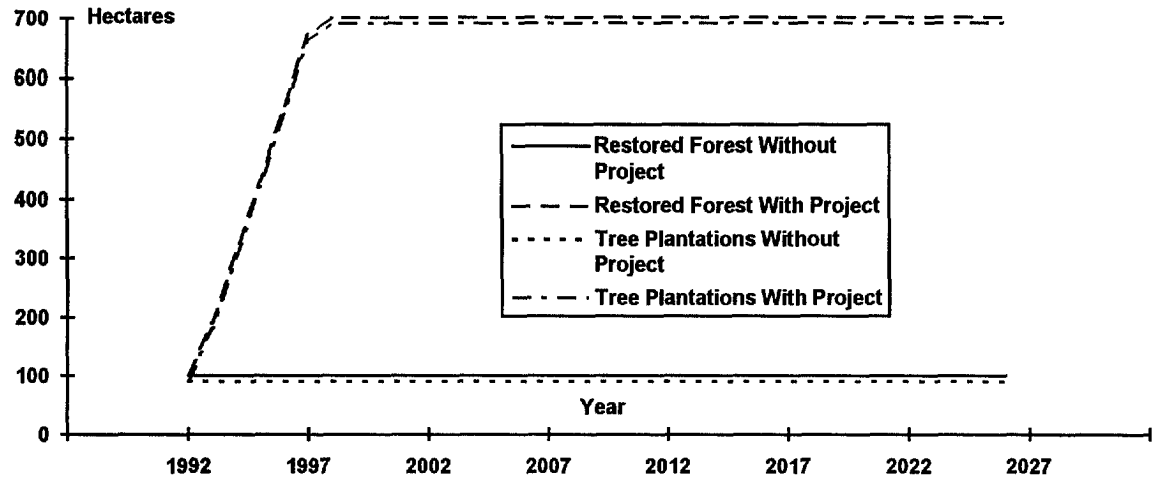


Figure 17.

Area of Restored Forest and Tree Plantations With and Without the PDA Project in Thailand



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5. THE ANCON PROJECT IN PANAMA

An increasing number of settlers have entered the Panama Canal watershed since the 1950s to convert forest area to subsistence agriculture, primarily along the tributary rivers of the Chagres. As population pressures increased, so too did the pressure to convert steep forest slopes to agricultural uses.

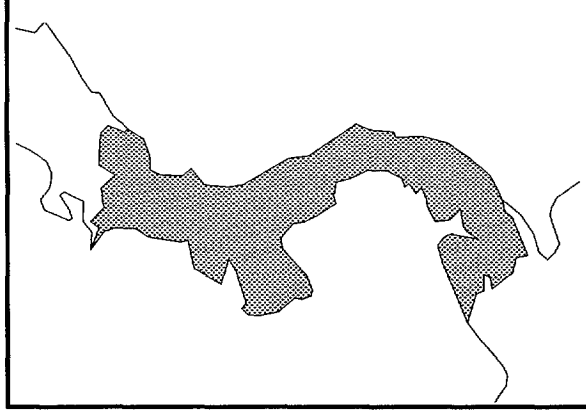
Clearing land for agriculture contributed both to flooding in the wet season from rapid runoff and soil erosion from the exposed land. The soil eroded into the Chagres and eventually into the Canal, causing a silt buildup which will require dredging.

To help slow deforestation, in the early 1980s the government created two new parks, Soberania and Chagres, totaling about 151,500 hectares. Much of the land in the parks has been degraded, however. For example, in Soberania park repeated burning for land clearing has allowed widespread entry of *paja blanca*, a tall, deep-rooted, cane-like grass that is extremely aggressive and shades out any other vegetation. In the dry season this non-native plant is incendiary and burns with a heat that destroys surrounding vegetation, which in turn allows the grass to expand its area. *Paja blanca* is thought to have been introduced by the U.S. Army Corps of Engineers for erosion control on piles of dredged silt.

ANCON proposed to restore about 15,000 hectares of degraded lands by eliminating *paja blanca* and reintroducing native tree species. Another 75,000 hectares could be saved from deforestation by strengthening the protection program of the two parks. ANCON works with park managers to mark the boundaries of the parks, post signs, build guard stations and other infrastructure, and train and equip fire brigades.

The ANCON project also would increase the productivity and incomes of small farmers in the watershed by promoting multipurpose tree planting, agroforestry cropping systems, and sustainable agricultural practices. The centerpiece of this effort

Figure 18.
The Proposed ANCON Project Would Protect and Restore the Forest Cover of the Panama Canal Watershed



is the Rio Cabuya Agroforestry Demonstration Farm, a 64-hectare facility next to the Soberania park. The farm includes demonstration units of fast-growing trees for fuelwood and on-farm uses, agroforestry models such as fruit and commercial tree species in combination with annual and perennial crops, and small-animal production units of pigs, poultry, iguanas, and pacas. The local workers hired to install these demonstration units are encouraged to adopt the same practices on their own holdings.

ANCON proposed to install a tree nursery at Rio Cabuya that would produce 250,000 seedlings per year to introduce into degraded park areas and distribute to collaborating landholders in the area. It would also test six agroforestry–mixed cropping demonstration models at Rio Cabuya. Based on this experience, ANCON would promote farm woodlots, shade trees for perennial crops, trees in pastures, live fences, and windbreaks.

ANCON also proposed using an innovative debt-for-nature swap. The $2 million from AES would be used to buy $10 million in government of Panama debt, which at a 5 percent interest rate would earn $500,000 annually over 30 years, or a total of $15 million to support the activities of the project.

Key Data and Model Results

The proposed area of project activity totals 267,900 hectares, and includes 180,000 hectares of closed forest, 61,000 of open forest, 8,800 of shifting agriculture, 1,200 of permanent agriculture, 1,600 of agroforestry, 160 of tree plantations, and 15,000 of degraded lands.

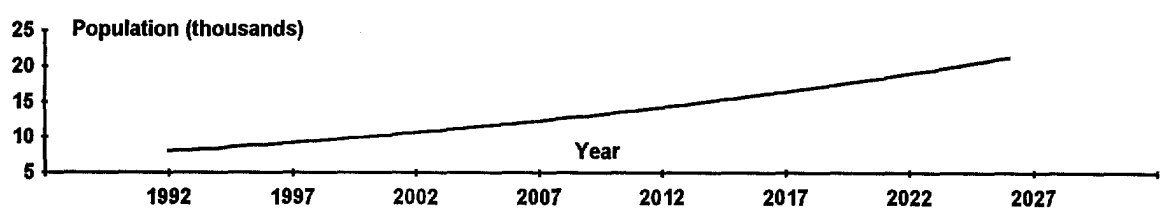
The closed forest is estimated to contain an average of 235 metric tons of biomass per hectare, while the open forest and agroforestry average 130 metric tons per hectare. Other land uses contain much smaller amounts of biomass — shifting agriculture averages 18 tons per hectare; permanent agriculture, predominantly sugar cane, is estimated at 40 tons; and degraded lands contain an estimated 10 metric tons.

About 8,000 people live in and around the national parks. The population is estimated to be growing at 2.9 percent per year, which would nearly triple the population over the project lifetime. (*See Figure 19.*)

The principal dynamic of the area is that shifting agriculture can only be practiced for two or three years before it is overtaken by *paja blanca* and becomes degraded. For this reason, there is little forest fallow in the area. In similar areas, shifting agriculture would be allowed to rest and then would return to production, however, the invasion of *paja blanca* precludes this in many sites in the Panama Canal watershed. The means of eradicating *paja blanca* include herbicides, deep plowing, and shading. In conjunction with local farmers, ANCON has developed methods of using vines to cover and shade the *paja blanca*. The biomass of *paja blanca*

Figure 19.

Population Projection for the ANCON Project



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is low because the grass usually burns once or twice a year.

ANCON's proposal would convert about 600 hectares of degraded lands per year back to permanent forest through the clearing of *paja blanca* and the reintroduction of native tree species. To ensure the restoration of natural vegetation, the project also would include initiatives to install fences and patrol the boundaries of the national parks to restrict the entry of cattle and shifting cultivators. Uncontrolled burning for land clearing, which also impedes restoration efforts, would be reduced through publicity campaigns and stricter enforcement of the laws restricting fires.

Another 600 hectares would be converted annually from shifting agricultural land to agroforestry practices. This would boost agricultural productivity by about one-third. Farmers thus will benefit with improved yields from their land and will not be forced to clear new land every three years.

As part of this effort, the Rio Cabuya farm is experimenting with planting corn, guandul, and manioc under trees in various combinations. In addition, the farm is testing various species of fast-growing exotic trees which could provide sources of fuelwood and non-timber forest products on a short-rotation basis. These trees fix nitrogen, produce green manure, and are effective in shading out other competing vegetation.

The agroforestry effort also will include introduction of soil conservation practices such as mixed permanent and annual cropping, alternative tilling practices, and stream and gully control structures.

Finally, ANCON proposed to convert annually another 600 hectares of degraded lands to farm woodlots. The wood will serve as scaffolding for construction projects and has an estimated useful life of five years.

In addition to the new income-generating potential of woodlots and agroforestry, ANCON would encourage the development of a fishing industry along Lake Alajuela. The sale of dried fish in Panama City would provide an alternative means of generating income for local people.

Figure 20 shows agricultural land use in the project area for the baseline and project scenarios. Permanent agricultural land, used primarily for sugarcane to produce rum, has reached its limit for expansion in flat low-lying areas. Any expansion of agricultural production must therefore take place on forested hillsides, either in the form of shifting agriculture or agroforestry.

Through a concerted effort to implement agroforestry, the project could eliminate shifting agricultural lands in about a decade. Without the project, shifting agricultural lands would decline from 8,800 hectares to about 2,300 hectares. The downward trend in shifting agricultural lands is compensated by a natural increase in traditional agroforestry systems. This behavior comes about because land in agroforestry is not degraded by *paja blanca* and its stock continues to rise as shifting agricultural land is continually degraded. This suggests that an adaptation to agroforestry is the only workable scenario in the presence of *paja blanca*, with or without the project.

Because of the funds available from the endowment, 1,800 hectares a year could be converted from degraded land until there were none left. Figure 21 shows that the project would reduce the amount of degraded lands to insignificant levels, whereas without the project degraded lands could dramatically increase to over 80,000 hectares.

The ANCON project represents a significant effort to change agricultural practices and restore degraded lands. These efforts could have a considerable impact on the closed forests of the area. The project would add about 19,000 hectares of

closed forest (*Figure 22*), primarily because open woodland would be allowed to revert to closed forest. About 31,000 hectares of closed forest would be lost without the project. The combined total of forest added and forest saved is 50,000 hectares. In addition, the project could ultimately create 12,000 hectares of restored forest that would eventually become closed, and create another 12,000 hectares of tree plantations. (*See Figure 23.*)

The difference in carbon sequestered between the baseline and project scenarios is about 7.4 million tons. (*See Figure 24.*) The effort to restore degraded lands and other components of the project could add roughly 3.3 million tons of carbon over the 34-year life of the project. Without the project, forest area could be expected to decline as degraded land increased to about 83,000 hectares, resulting in a loss of about 4.1 million tons of carbon.

ANCON proposed an extraordinary mechanism that could have leveraged a $2.6 million endowment into $18 million worth of project funds over 30 years. For the initial endowment, the cost per ton of carbon sequestered would be $0.35 per ton. For the total project cost of $18 million the cost per ton would be $2.43.

Figure 20.

Area of Shifting Agricultural Land and Agroforestry Land With and Without the ANCON Project

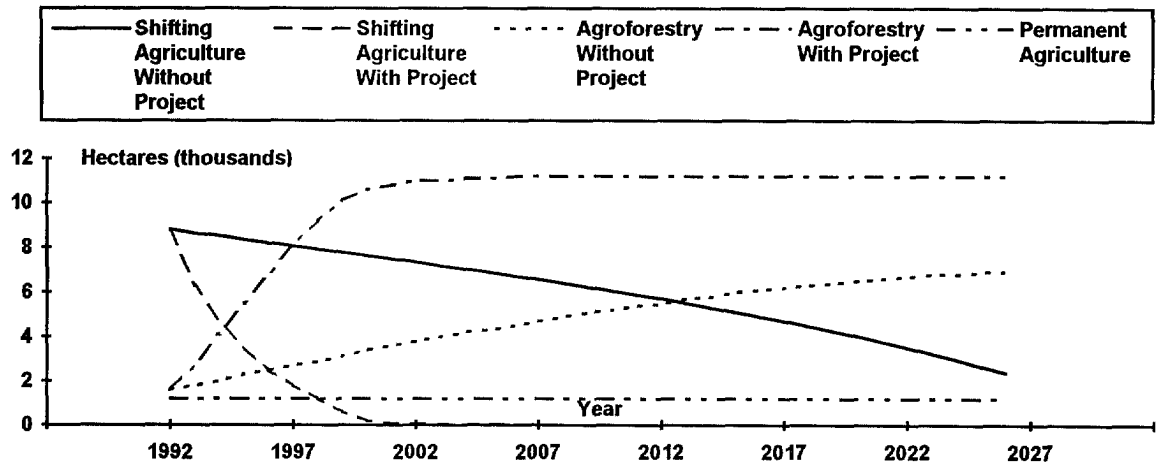

Figure 21.

Area of Degraded Land With and Without the ANCON Project

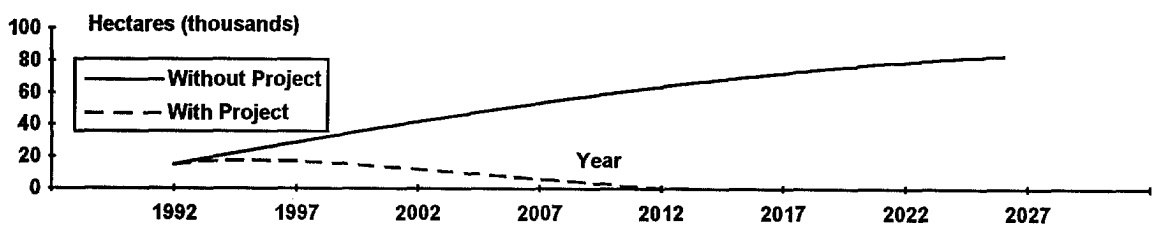

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Figure 22.

Area of Closed Forest Added As a Result of the Project and Closed Forest Area Lost Without the Project

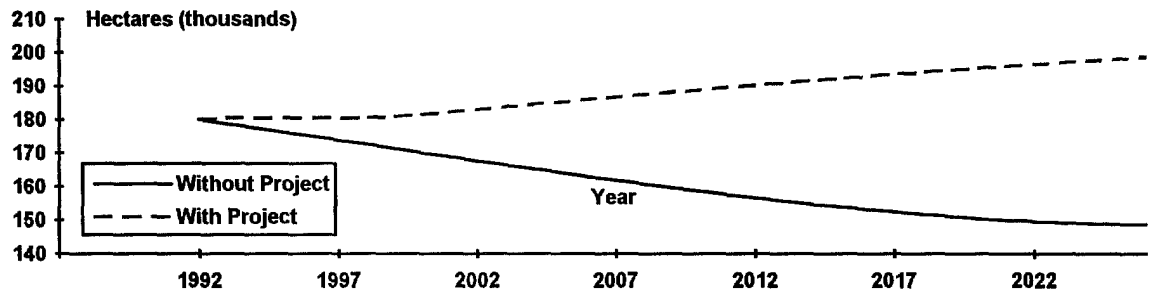


Figure 23.

Area of Restored Forest and Tree Plantations Projected for the ANCON Project

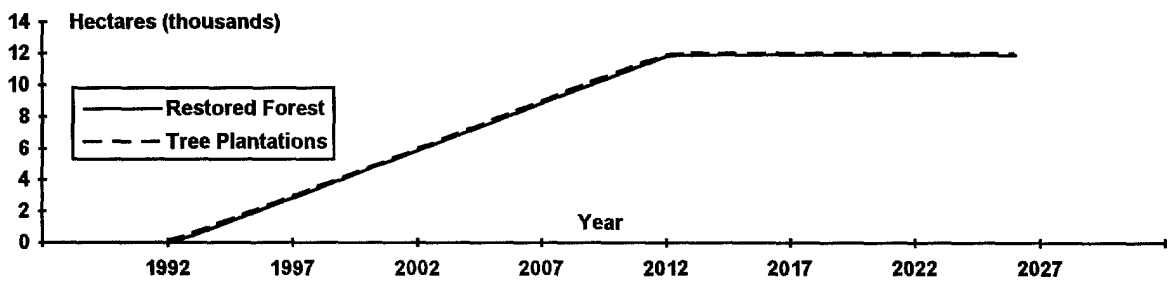
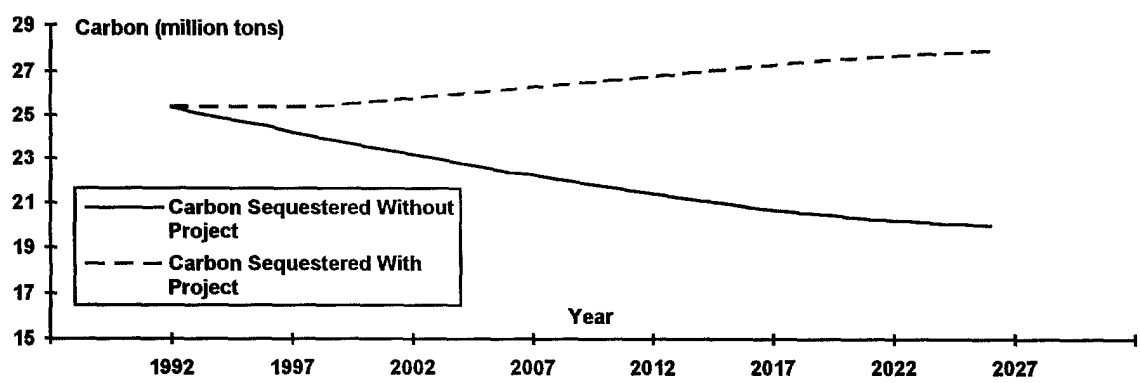


Figure 24.

Amount of Carbon Sequestered in the With and Without Project Scenarios



6. THE UCEFO PROJECT IN MEXICO

The Union de Communidades y Ejidos Forestales de Oaxaca (UCEFO) is a forestry organization which represents 18,000 people in nine indigenous communities in the state of Oaxaca in southern Mexico.

UCEFO is a non-profit organization that provides technical, legal, and administrative help to its member communities. The UCEFO board includes delegates from each of the nine communities, who in turn report to their Communal Assemblies. Each Communal Assembly accepts a forest management plan and decides how to spend the revenue from timber sales. UCEFO receives fees from the communities totaling about 15 percent of this revenue, which pays UCEFO's operational costs for technical services and the maintenance of infrastructure such as roads and mills.

The UCEFO region comprises 114,600 hectares. The area encompasses a wide range of climatic conditions: altitude ranges from 800 to 3,000 meters above sea level, climate varies from hot subtropical to temperate cold, and rainfall is between 800 and 1,600 millimeters annually. The terrain is rugged — more than 85 percent of the total area has steep slopes with grades over 30 percent. About 30 percent of the land is covered with scrub forest that has no commercial value or cannot be harvested.

About 100,000 hectares are characterized by mixed pine and oak forests which are owned collectively. These forests produce about 60,000 to 90,000 cubic meters of timber annually from about 35,000 hectares. Tree growth rates are about 1.3 cubic meters per hectare per year, which is relatively low compared to the land's biological potential. Forestry nevertheless provides employment for about half of the 3,800 communeros (individuals with legal rights to land), about 50 percent of their income, and practically all the income for capitalization and reinvestment in collective enterprises.

Figure 25.
One Objective of the UCEFO Project in Mexico Is to Triple the Per-Hectare Yield of Timber Over the Next 40 Years.

About 4,000 hectares are used for agriculture and are privately owned. Corn production provides about 50 to 70 percent of the communities' needs; most production is rain-fed and a small amount is irrigated. In addition, smaller spaces are used to grow market crops such as peas and potatoes, along with extensive fruit growing, cattle raised in forests and on fallow lands, backyard cattle raised for family consumption and barter, household orchards on small plots, and flower production in small household gardens.

The communities will face many pressures over the coming decades. The population, which is growing about 3.3 percent a year, may reach about 55,000 in 34 years. (*See Figure 26.*) Food demand is expected to grow commensurate with effects on the forest because the area under shifting agriculture will increase. UCEFO's proposal recognized the important links between forestry and agriculture, and includes both forestry and agriculture components.

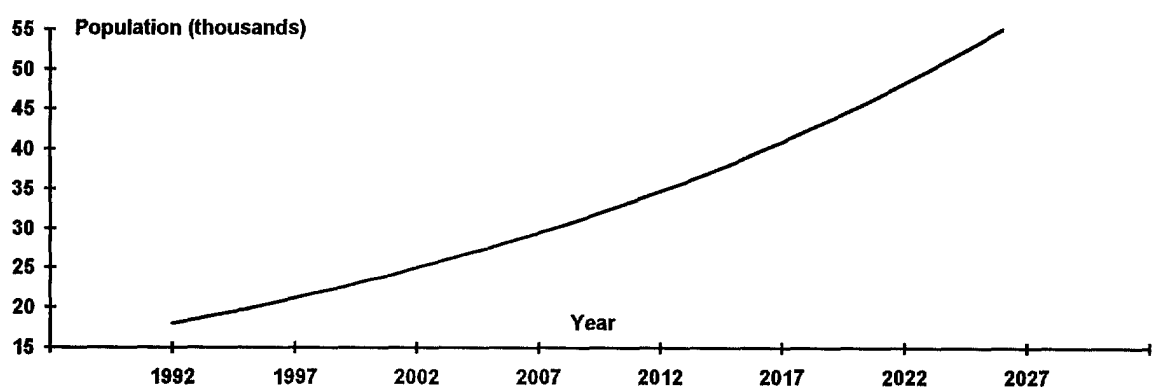
UCEFO wishes to stabilize and increase its woodlands, improve the volume and quality of its timber, and keep and expand its timber markets. In order to reduce agricultural pressure on the forests, the UCEFO proposal also included an effort to increase the productivity of subsistence and market agriculture and household orchards.

To encourage forest conservation, UCEFO proposed finishing and implementing eight forest classification plans; extending protection of community forests against fire and pests; expanding seven nurseries and creating two new ones (to produce nearly a million seedlings per year), establishing five seed-producing areas and creating two seed farms; reforesting 10,200 hectares and implementing agroforestry practices on 2,000 hectares of shifting agricultural land; and applying soil conservation techniques to existing tree plantations and agricultural lands.

To bolster forest production, UCEFO proposed boosting tree growth rates from the current 1.3 cubic meters per hectare to 4.5 cubic meters by 2030 through intensive silvicultural techniques; promoting tree classification and cuttings by quality; considering the feasibility of an industrial center that would add value to forest products, for example by producing lumber in different sizes; conducting market research for pine resin tapping; and establishing one or more workshops for the design and production of arts and crafts.

Figure 26.

Projected Population in the Area of UCEFO



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To support agricultural activities, UCEFO proposed improving agricultural technology with new seed varieties, better soil conservation practices, and composting and other practices to improve soil fertility; improving livestock production, for example by introducing perennial or dry-season fodder grasses; increasing fruit production through techniques such as pruning, fertilizing, and pest and weed control; refining crop selection to better reflect market conditions; encouraging household gardens by providing packages of inputs; decreasing water loss and increasing the efficiency of irrigated systems; and creating a service for technical assistance in agriculture.

The UCEFO communities themselves would contribute 50 percent of total project costs, or $4.1 million, and funds from the Mexican government would cover an additional 15 percent. A grant request of $2.85 million would thus be supported by a roughly 2-to-1 match from UCEFO.

A critical part of the UCEFO proposal deals with the introduction of new forestry methods that would increase both the productivity of the forests and their carbon sequestration potential. The customary method (Metodo Mexicano de Ordenacion de Montes, or MMOM) is basically a selection method where relatively small volumes (up to 35 percent of the total stand volume) are removed in cycles of 25 to 30 years. This method tends to leave stands of an uneven age with deficient natural regeneration and low growth rates.

A newer method (Metodo de Desarrollo Silvicola, or MDS) uses more intensive cutting (typically 80 percent of stand volume), which supports stands of an even age which are managed in 60-year rotations with thinnings every 15 years. MDS allows increased establishment of pine seedlings and higher growth rates, and requires relatively intensive management. Seedling establishment is also vulnerable to ecological factors and excessive trampling of seedlings by cattle.

The UCEFO proposal would bring more areas under the MDS method. In mature stands, an intensive cut (regeneration cuttings) would leave only the necessary number of seed trees. Areas subject to regeneration cuttings would be thinned 15 to 20 years later. In well-developed stands, canopy thinning would be applied to accelerate the growth of trees that would be harvested in the regeneration cutting. Salvage cutting also would take place on stands damaged by fire or infestation.

The results under MDS could be dramatic. Tree growth rates in residual stands, for example, are estimated to be 8 cubic meters per year. Over a 60-year period in the same area, MDS could produce about twice the volume of timber as MMOM.

Key Data and Model Results

The "with project" scenario assumes a shift to much more intensive management of agriculture and forests. The "without project" scenario assumes a continuation of low-productivity agriculture and forestry management practices.

Population growth increases demand for both fuelwood and food. Fuelwood is in excess supply and is not critical to this project area. However, each additional person requires more agricultural land for subsistence in an area where there is little land suitable for permanent annual cropping, and agricultural productivity is low.

Without the project, improvements in technology are expected to increase food production about 0.6 percent a year. There is no opportunity to expand permanent agricultural lands, which are fixed at about 2,000 hectares. Under current conditions shifting agricultural lands are worked for three to five years, followed by a period of forest fallow for five to eight years, and then a return to shifting agriculture. About 30 percent of food is imported from outside the project area.

Figure 27.

Agricultural Land Use for the UCEFO Project

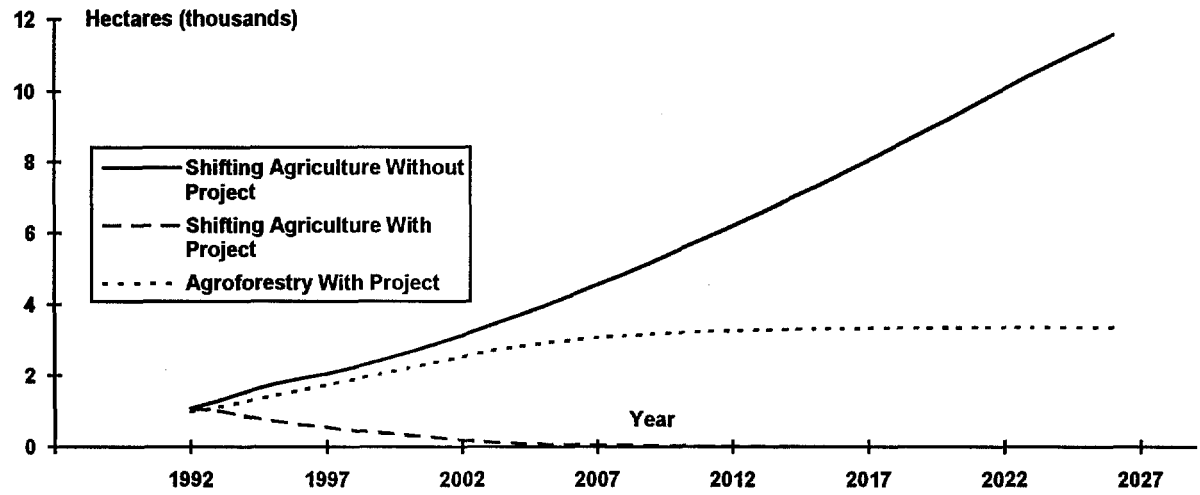
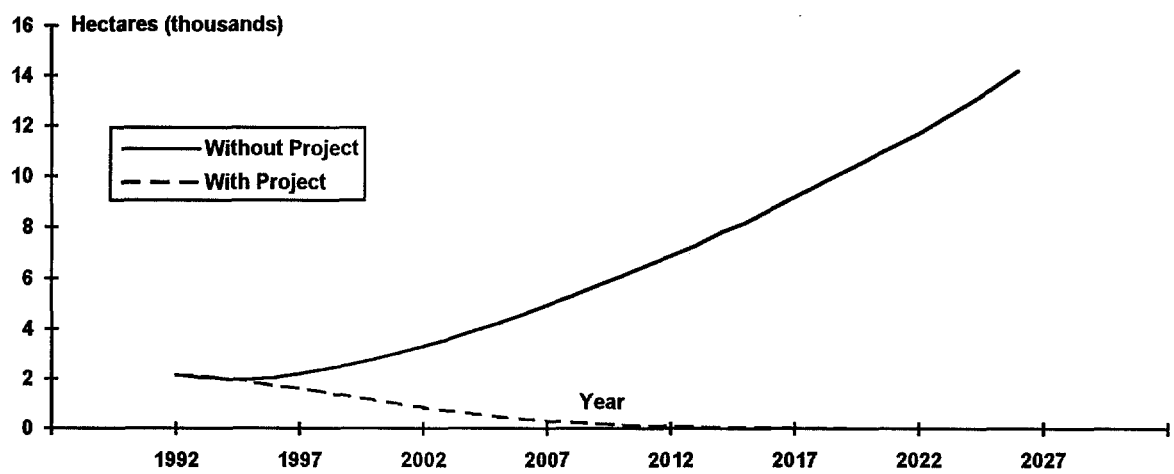


Figure 28.

Area of Forest Fallow With and Without the UCEFO Project



UCEFO proposes a substantial conversion of lands from shifting agriculture to agroforestry, which could include alley cropping or the extensive planting of orchards. Agroforestry, while only about two-thirds as productive as permanent agriculture, nevertheless is about twice as productive as traditional shifting agriculture. As new land is brought into production to feed the growing population, the "with project" scenario assumes that 50 percent of this land will be devoted to

agroforestry, and that the amount devoted to shifting agriculture will decline from 100 percent to 50 percent. In addition, it assumes large increases in productivity in all land categories through innovative alternative agricultural practices and extensive extension efforts.

The project could rapidly eliminate the need for shifting agriculture as productivity increases from conversion to agroforestry become apparent. (*See Figure 27.*) With the increase in productivity, the remaining shifting agriculture and forest fallow land could disappear (*Figure 28*), reverting to open woodland and eventually closed forest.

With the project, the area in protected and managed closed forest could increase slightly. (*See Figure 29.*) Without the mitigating influence of the project, however, population pressures could cause substantial amounts of land from closed forests and open woodland to be brought into production as shifting agriculture and forest fallow.

The current state of the area's closed forests are represented in three different categories:

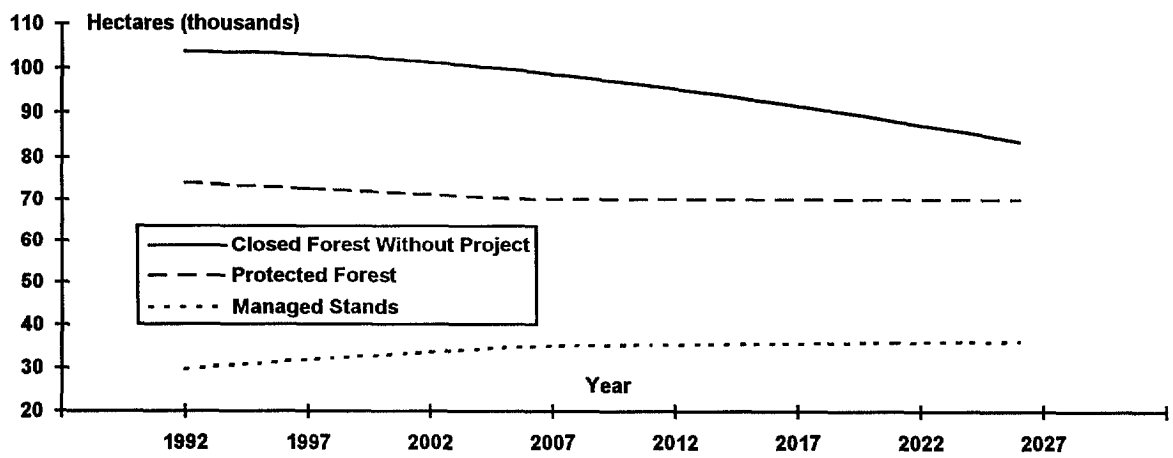
- Mature forest that is 60 or more years old and has reached its biomass potential.
- Forest that was cut selectively between 20 and 40 years ago and contains about 75 percent as much biomass as a mature stand.
- Forest that was cut selectively up to 20 years ago and contains about 50 percent as much biomass as a mature stand.

Under current methods about 1,000 hectares are being cut annually. The system contains a total of about 35,000 hectares, which means that forests are re-cut every 35 years. Since it takes about 60 years for forests to reach maturity, forests that are re-cut after 35 years are actually in a degraded condition and still far short of their biomass potential. Over time, the practice of returning every 35 years progressively degrades the forest, with the 35,000 hectares of harvested forests ultimately containing only about 50 percent of their biomass potential. The average biomass for the entire area also declines.

The UCEFO project proposes a new management scheme that would essentially treat the

Figure 29.

Area of Closed Forest, Protected Forest, and Managed Stands for the UCEFO Project



closed forests as tree plantations. Regeneration cuts, which would take place on a 60-year cycle, would clear an entire stand except for a few mature trees that could produce seeds. Thinnings would take place every 15 years, providing additional wood for poles, timber for furniture, and other wood products that would sequester carbon. The remaining trees grow faster as the canopy is opened up and more light is available. Eventually, the stand would be subject to another regeneration cut.

This system of intensively-managed forests would produce more wood products. About 5,000 hectares saved could grow to a mature closed forest, which would provide additional carbon sequestration benefits. The area not managed would be protected for wildlife and watershed benefits. Figure 29 shows the area in closed forest. With the project, managed and protected stands are split out. The effect of improved agricultural productivity and replanting degraded area increases closed forest area slightly. Without the project, closed forest could decline by about 20 percent.

The maintenance of the closed forest would result in significantly greater carbon stored in standing biomass. The initial regeneration cut causes a small decline in carbon in standing biomass in the early years, but levels out as the managed areas mature. Without the project, however, carbon in standing biomass declines from 10.4 million tons to about 8 million tons. (*See Figure 30.*)

Carbon in wood products would gain significantly under the UCEFO project because the forest management system would be more productive. Much more wood could be taken during thinnings, while helping to increase biomass at maturity. The project would add about 1 million tons of carbon in wood products such a poles and lumber. This is about 700,000 tons of carbon over the amount that would be added without the project. (*See Figure 31.*)

Figure 32 shows the estimates for total carbon sequestered under the two scenarios. The "with project" scenario shows a small absolute gain while in the absence of the project the model suggests that a large loss would occur. The net difference is about 2.7 million tons.

Sensitivity Analysis

Using the "without project" scenario, a sensitivity analysis of the LUCS model was undertaken. This analysis was intended to gauge the sensitivity of the model to changes in the project parameters, some of which are not known with great certainty. The test was conducted by changing each model parameter in turn. First, a given parameter was increased in value by 25 percent, then decreased by 25 percent. Each time a separate model run was performed and the results saved.

Table 6 shows the effect of parametric changes on total carbon sequestered. These results are shown as a percentage of the "without project" result. Given the structure of the model, the results are not surprising. The largest impact on model results is shown to be from parametric changes to the land category that has the most standing biomass — closed forests. However, mature closed forest biomass is a physical parameter defined by the ecological characteristics of the site, and not subject to human intervention.

The next most important parameter is the rate of population change. Increasing rates of change have a relatively larger impact on carbon because land-use changes to supply the population can occur quickly. If demand falls off, however, the delays required for ecosystem recovery mean reduced effects on carbon in the near term. The change in this parameter suggests that large increases in carbon could be had as a result of circumstances having nothing to do with land management — benefits to the local people such as education of women and

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Figure 30.

Amount of Carbon in Standing Biomass With and Without the UCEFO Project

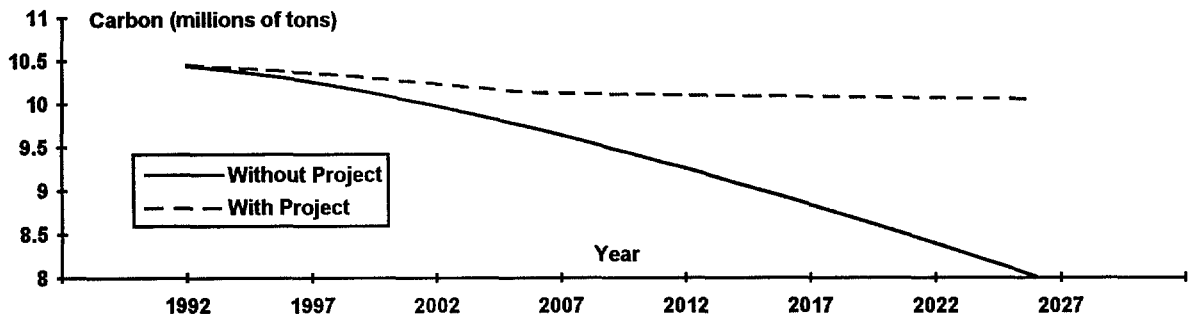


Figure 31.

Carbon Sequestered in Wood Products

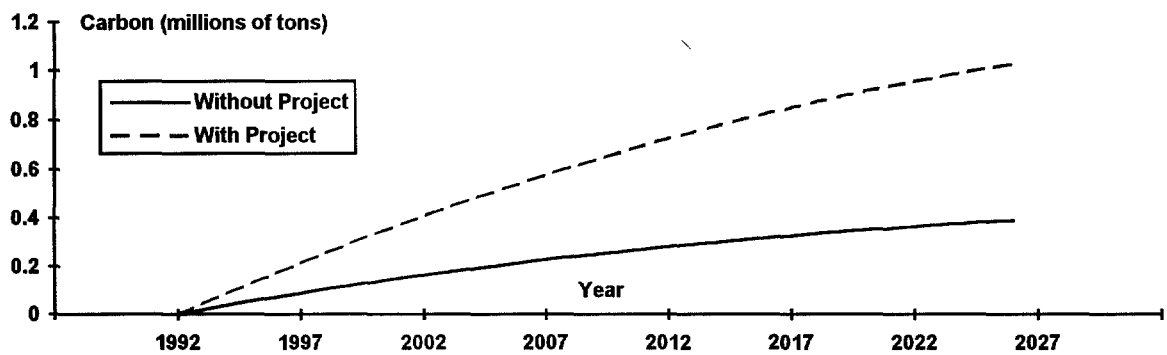
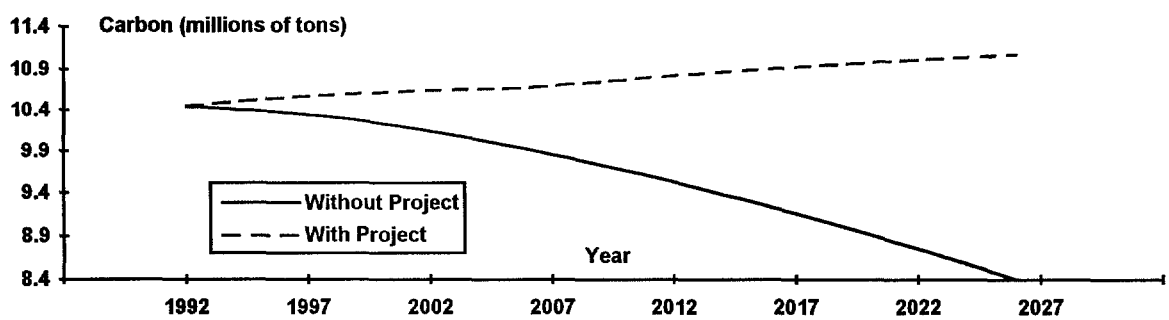


Figure 32.

Total Carbon Sequestered With and Without the UCEFO Project



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the provision of health services and contraceptives — that would reduce population growth and subsequent demand on resources.

For this project site, a number of other factors have effects of a similar magnitude. Food imports determine the demands placed on the local land base for agricultural production. This area has relatively low productivity and subsequently affects land use significantly. Income-generating opportunities such as wood processing and craftwork, which could provide the means to purchase food, could benefit the people and the resource base. Similarly, investments in agricultural productivity and extension services such as UCEFO is undertaking could reduce the need to convert forest to agriculture.

Forest management measures such as the rotation time and the rate of selective cutting are also important parameters. These determine the level of closed forest affected and the extent of degradation of closed forests that are selectively cut. These parametric changes reflect the fact that the closed forest has been cut at rates that are not sustainable. Other parameters not shown in Table 6 affect carbon sequestration less than 2 percent.

The UCEFO request was $2.86 million and total project costs were $3.25 million. These translate into unit costs of $1.06 and $1.20 per ton, respectively.

Table 6.
Results of LUCS Sensitivity Analysis on Total Carbon Sequestered

PARAMETER (DIRECTION OF VALUE CHANGE)	CHANGE FROM BASELINE (PERCENT)
Mature closed forest biomass ↑	24.56
Mature closed forest biomass ↓	-24.56
Rate of population change ↑	-8.53
Rate of population change ↓	6.32
Fraction of food imported ↓	-3.39
Fraction of food imported ↑	3.22
Rotation length for selective cutting of closed forest ↓	3.15
Growth rate of agricultural production ↓	-3.12
Growth rate of agricultural production ↑	3.09
Rotation length for selective cutting of closed forest ↑	-2.25
Annual selective cutting of closed forest ↓	2.20
Annual selective cutting of closed forest ↑	-2.20

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7.
THE KMTNC MICRO-HYDRO PROJECT IN NEPAL

The Annapurna Range of the Himalayas, which lies about 300 kilometers northwest of Kathmandu, is one of the most ecologically diverse areas in the world. It is an area of extremes, with some of the world's highest mountains and deepest valleys. The lower zones include over 100 varieties of orchids and some of the largest rhododendron forests in the world.

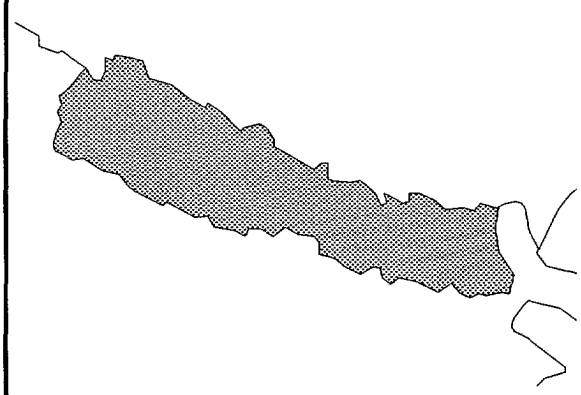
Most of the region's 40,000 inhabitants survive as subsistence farmers, depending on natural resources for fodder, fuel, food, and shelter. Over the last two decades, however, the spectacular mountain vistas have attracted an increasing number of tourists; about 36,000 trekkers now walk through the area annually.

Tourism has been growing about 12 to 15 percent annually in recent years, which combined with a regional annual population growth rate of 2.6 percent, is exerting pressure on local forest resources. Forests are being destroyed at a rate of perhaps 2 or 3 percent each year, largely due to grazing pressures and the demand for fuelwood. The destruction of forests is increasing the rate of landslides and worsening soil erosion.

Each local resident consumes an estimated 2.5 kilograms of fuelwood per day, resulting in an annual consumption of 36,500 metric tons. The 650 lodges, hotels, and tea shops in the area each use about 75 kilograms per day, an annual consumption of nearly 18,000 metric tons. This level of demand is equivalent to the destruction of about 725 hectares of open forest annually.

Because of its concern about the situation, the King Mahendra Trust for Nature Conservation (KMTNC) — a nongovernmental, nonprofit, and autonomous organization — launched the Annapurna Conservation Area Project (ACAP) in

Figure 33.
The Proposed Project in Nepal Intended to Install 12 Micro-Hydroelectric Plants.



1986. The project managers created committees in each village to encourage local participation. ACAP plays a catalytic or match-making role to help these committees obtain resources or technical assistance.

ACAP established seedling nurseries and has begun an aggressive reforestation program. It has encouraged a number of alternative energy devices to reduce the demand for fuelwood. Circulatory water heating systems, for example, are installed in traditional hearths and can save up to 40 percent of the fuelwood consumed for heating water.

In its efforts to look for other alternative energy sources, KMTNC and ACAP began to look at the hydroelectric potential of the Annapurna watershed. The two major rivers in the area are fed by numerous tributaries and streams, many of which are suited for small hydro plants. Such projects are inexpensive, can displace some of the demand for fuelwood, and can be built with locally manufactured hardware and maintained relatively easily. Using small-scale, locally adapted technology, these micro-hydro plants would harness energy from free-flowing streams but not disrupt stream ecology. Work is underway to develop appliances for electric cooking that are suitable for use with micro-hydro facilities.

ACAP has started two micro-hydro projects. Ghandruk Electrification Project in Ghandruk village, which is owned and managed by the community, will produce 50 kilowatts of electricity. It will provide lighting for 235 households, lighting and power for cooking for 12 lodges, and in off-peak hours will support small-scale cottage industries such as bakeries. The second project, the Sikles Electrification Project, will produce 100 kilowatts of power and benefit 450 households.

Building on this experience, KMTNC proposed installing 12 micro-hydro plants covering a large geographical area within the Annapurna conservation area. By spreading the projects over a wide area, KMTNC hopes to demonstrate to other villages in the vicinity that micro-hydro is an effective alternative to fuelwood.

The projects range from 13 kilowatts to 100 kilowatts and all together would produce 372 kilowatts. They would provide electricity for lighting and low-wattage electric cookers for about 810 households and 45 lodges and hotels.

ACAP proposed to help form an Electrification Committee in each project village that would consist of all the project beneficiaries. The beneficiaries would select an executive body of 13 to 15 members. To assist with the startup, ACAP would jointly manage the plant for up to two years to help set tariffs and procedures for operation and maintenance, and hire a manager and operators.

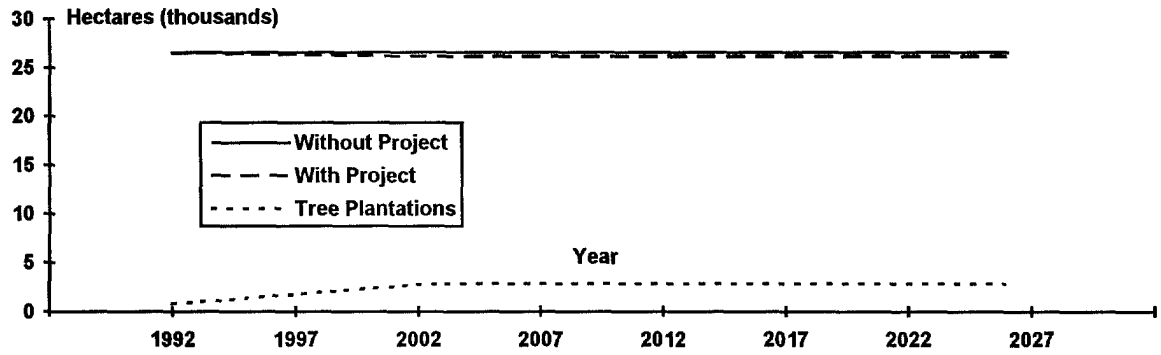
Tariffs for hotels and lodges would be set 50 percent higher than for domestic households, so that the cost would be affordable for low-income members of the community. The tariff schedule would be designed to cover the cost of the manager and operators, loan payments, and plant maintenance.

In addition, KMTNC proposed working with community and private plantation programs over 10 years to reforest 650 hectares of denuded lands. ACAP would establish nurseries in each of the 12 project villages, each with a capacity of 20,000 seedlings per year. The seedlings would be distributed free for the community and private forestry activities.

Key Data and Model Results

The population of the area is about 40,000 with 2.6 percent annual population growth. The impact of tourism is represented in terms of fuelwood use. Tourism and the hotel business will use an increasing proportion of fuelwood. Fuelwood consumption is represented in the model in terms of individual consumption, but the model also incorporates consumption by hotels and tea shops.

Figure 34.
Conversion of Degraded Lands to Tree Plantations



Fuelwood consumption is pegged to local population growth and does not consider tourism growth. The scenario runs may somewhat understate future fuelwood consumption.

During the life of the project the "with project" scenario assumes that 810 households will reduce their fuelwood consumption by 50 percent. In addition, 23 hotels and 22 tea shops will cut their fuelwood consumption by 63 percent. On average, the introduction of hydro-derived electricity will produce a 53 percent fuelwood savings per participating household each year in the ACAP region. If all the projects are completed, the substitution of electricity for fuelwood would reduce fuelwood consumption from the current 5,569 tons per year to 2,930 tons.

KMTNC proposes annual conversion of 70 hectares of degraded land to tree plantations, 20 hectares of grazed land to restored forest, and protection for 5,000 hectares of existing forest.

Permanent agricultural land is relatively stable in the region, and further production increases will likely result from productivity improvements. Both scenarios assumes a 2 percent annual increase in agricultural production. With the assumed 2 percent increase in production and imports, there does not appear to be a great need to convert closed forest to new agricultural land.

A small amount of closed forest is being lost, largely to meet demand from hotels. Most local residents, however, collect dead branches, or lop live branches, rather than chop down trees. This suggests that consumption is roughly in equilibrium with demand.

The cash economy is significant, with about 30 percent of food imported. The percent of food imported probably will increase over time, which will help feed the growing population.

The model estimated the project's carbon benefit at a relatively small 70,000 tons, primarily from the 200 hectares of restored forest and the 700 hectares of tree plantations. Figure 34 indicates there may be a negligible difference in carbon benefits with or without the project.

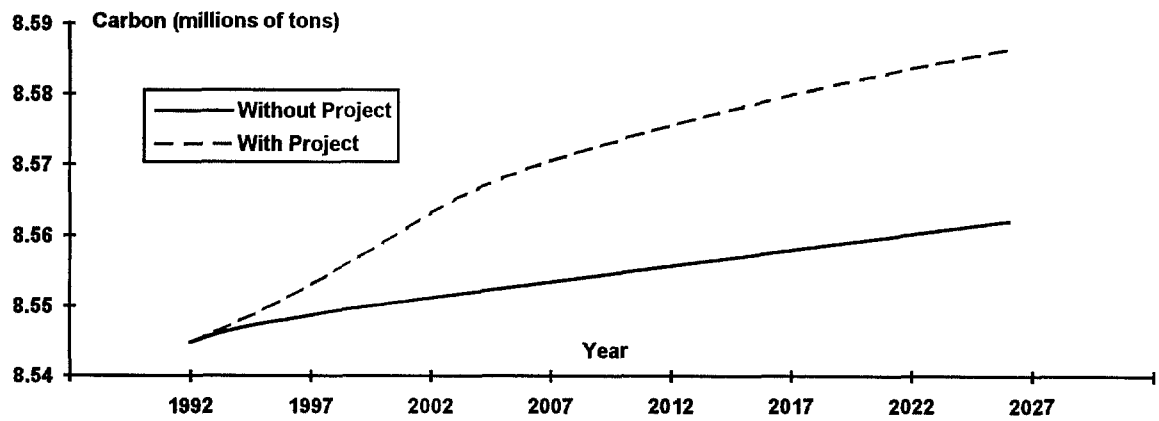
Figure 35 shows the conversion of degraded lands to tree plantations. The major benefit for carbon sequestration appears to be in reforestation projects, which are not a principal component of the KMTNC project.

Carbon benefits are also affected by the fact that forests in the region do not appear to be imminently threatened by fuelwood demand. KMTNC estimated that the new electricity supply would save 1,512 hectares of closed forest over the life of the project, which would provide additional carbon benefits of 132,000 tons. However, the model assumes relatively even distribution of demand for fuelwood over the forest area and allows for the regrowth of areas that have been cut. Because of its broader viewpoint, the model does not forecast the localized fuelwood shortages that KMTNC predicts.

The model is based on the entire Annapurna conservation area, which tends to disguise the much greater benefits of the project in the specific project villages. Project costs have been estimated at $1.3 million. The total cost per ton of carbon is more than $18, by far the most expensive of the projects reviewed.

Figure 35.

Amount of Carbon Sequestered With and Without the KMTNC Project



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8.
THE OXFAM/COICA PROJECT IN THE WESTERN AMAZON

The rapid destruction of the Amazon rain forest — by lumber, oil, and mining companies and individual colonizers — is by now well-documented. Less well known is that indigenous peoples in the Amazon have organized to stop the destruction of their traditional territories and to manage resources sustainably.

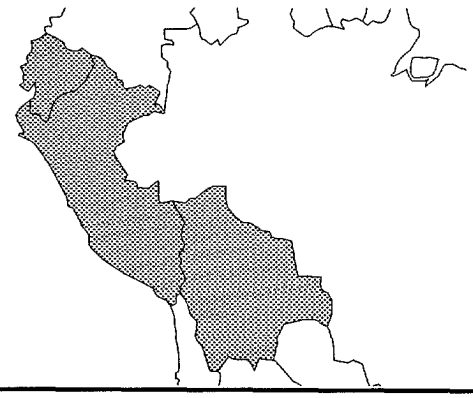
These groups are using strategies such as legal defense and public education campaigns to generate political pressure in their efforts to secure traditional territories and forestall further destruction of Amazon forests. In recent years, indigenous groups have made great gains in securing legal recognition of territorial rights. Protecting control over their lands has proved even more difficult than securing government recognition. In addition, many Indian groups are developing forest management skills that combine generations of subsistance experience with new techniques and technologies. The indigenous communities see protection of their forests from destruction as their first priority and sustainable development of their forest resources as their second.

Oxfam America proposed to work with COICA, an umbrella organization of indigenous groups, and directly with several local groups to support these strategies. By preventing further destruction of the rainforest, the project would effectively reduce human-induced carbon dioxide emissions into the atmosphere, providing an offset to the emissions of a new power plant.

Whereas the other projects considered so far focused on reducing the pressure on forested lands through inreasing efficiency or productivity, this project focuses on forest protection.

The program Oxfam proposed involves approximately 12 three-year projects which will be

Figure 36.
The Oxfam Project Would Attempt to Halt Amazon Basin Deforestation Through Land Defense Strategies and Sustainable Management Practices.



carried out over the next 10 years through an endowment. Oxfam has provided in-depth information on four of the projects that are characteristic of those that would be supported by the grant. These four projects would be executed by different indigenous organizations and non-governmental groups in the Amazon. Approximately 1.5 million hectares would be protected and 652,000 hectares would be saved from destruction.

The project areas are largely inaccessible. As a result, little is known about the biophysical characteristics of the region. The indigenous organizations currently are beginning some of the needed research.

Lacking the data to define the necessary parameters, the land- use model could not be used. Estimates of carbon benefits were therefore based on a conservative estimate (Brown et al., 1989) of biomass in closed forests (268 tons per hectare) and estimates of the likely threat to each forest region based on experience in similar areas.

Table 7 provides a summary of the carbon sequestration estimates for the first four projects in the Oxfam/COICA program. Eight other projects to be undertaken over the lifetime of the grant have yet to be defined. Total project costs for the program are about $4.5 million. The cost of the carbon offsets to appears to be in the neighborhood of $0.06 per ton. This cost could be much lower if the remaining eight projects have similar carbon benefits.

Table 7.

Total Carbon Saved by First Four Oxfam/COICA Amazonia Projects

ORGANIZATION/COUNTRY	CARBON (MILLION TONS)
OPIP/Ecuador	11
CICOL/Bolivia	0.4
CIDDEBENI/Bolivia	12
CEDIA/Peru	52
Total	75.4

OPIP Project in Ecuador

In Ecuador the government has issued several large oil concessions in and near Pastaza Province in the eastern part of the country, the traditional territory of the Quichua Indians and the only virtually undisturbed expanse of rainforest left in the country. The Organization of Indigenous Peoples of Pastaza (OPIP) has been working to obtain legal title to their 1.5 million-hectare territory and the right to full participation in decision-making about extraction of subsoil resources and environmental impact assessments. OPIP also is developing a long-term plan for sustainable management of the natural resources within its territory.

As part of the plan, 200,000 hectares destroyed by colonists and monoculture plantations will be replanted with fruit trees, spices, and native species of trees for cash income.

In May 1992, 2,000 Indians from the Pastaza marched 220 miles from their homeland to the capital of Ecuador, Quito. After several days of negotiations, the government granted legal control of 1.1 million hectares of the Pastaza Province to OPIP (although retaining subsurface mineral rights). Under Oxfam's proposal, only a pilot project of 160,000 hectares of protected forests was proposed in the Sarayacu district.

However, since the proposal was submitted, OPIP acquired legal title to much of its territorial claim in the Pastaza, significantly advancing its forest conservation efforts. Table 8 shows calculations for the project as proposed. Table 9 assumes all of the territorial area comes under effective OPIP management. The effect of this

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Table 8.

Carbon Estimates for the OPIP Project, Pastaza Province, Sarayacu Site, Ecuador (As Proposed)

	AREA ('000 HA)	AVERAGE BIOMASS (T/HA)	TOTAL BIOMASS (MILLION TONS)	TOTAL CARBON (MILLION TONS)
Closed Forest (A)	159	268	42	21
Threat assumption: 72% conversion to other uses				
Conversion to open woodland (B)	57	130	7.4	3.7
Conversion to agricultural or rangeland (C)	57	10	0.57	0.28
Remaining closed forest (D)	44	268	12	6.0
Total carbon without project (E) [B + C + D]				10
Total carbon saved (F) [A – E]				11

Table 9.

Carbon Estimates for the OPIP Project, Pastaza Province, Sarayacu Site, Ecuador (With New Territorial Claim)

	AREA ('000 HA)	AVERAGE BIOMASS (T/HA)	TOTAL BIOMASS (MILLION TONS)	TOTAL CARBON (MILLION TONS)
Closed Forest (A)	1,100	268	294	147
Threat assumption: 72% conversion to other uses				
Conversion to open woodland (B)	396	130	51	26
Conversion to agricultural or rangeland (C)	396	10	4	2
Remaining closed forest (D)	308	268	83	41
Total carbon without project (E) [B + C + D]				69
Total carbon saved (F) [A – E]				78

government recognition greatly extends OPIP's financial resources and ability to carry out an effective program.

Approximately 182,000 hectares of the 2.6 million hectares of the Pastaza Province have been taken over by colonists, while the remaining land of the Pastaza is in the control of OPIP member groups. Of the 182,000 hectares colonized by settlers, 130,000 hectares have been converted from closed forest to other land uses. Almost all of the colonized area is believed to have been forested prior to settlement by outsiders. Thus 72 percent of closed forests in this region has been converted to other land uses. This figure was used to calculate potential carbon losses in Table 8.[1]

The far northwestern corner of the Pastaza is the only part of the province that has been significantly affected by colonization. Beyond the colonization frontier virtually all of the province is under mature closed forest cover. Oxfam/COICA staff believe half of closed forest degradation leads to open woodland and the other half to agriculture, grazing, and degraded lands.

The Sarayacu site faces the threat of petroleum development, cattle ranching, plantation agriculture, and uncontrolled colonization. The 158,000-hectare Sarayacu area could be reasonably expected to lose about 72 percent of its closed forest. If such a threat were to materialize, total standing biomass in the region would be reduced by 20 million tons, or less than half the current total of 42 million tons. Total carbon content of the standing biomass, which is estimated at 21 million tons, would fall to 10 million tons. The project as proposed could save 11 million tons of carbon. If the remaining territorial claim were to come under effective protection, and if the threat were the same, then an enormous amount of carbon could be saved by this single effort.

CICOL Project in Bolivia

Another project (*Table 10*) involves the Chiquitano Indians in the Lomerio region of Bolivia. The area is under severe pressure from local and foreign lumber companies, which have already harvested mahogany and other hardwoods from surrounding forests and are applying political pressure and offering financial rewards to obtain lumbering concessions from the Bolivian government.

The Chiquitano organization (Intercommunal Central of the East Lomerio, or CICOL) has been using the legal system and other strategies to stop these incursions. CICOL's four-point strategy includes:

- Working with non-member Indian groups in the region to counteract the tactics of the lumber and mining companies, which are offering quick financial rewards in return for extraction rights.
- Hiring experienced lawyers to continue the fight against lumber and mining concessions, and working to obtain legal title to the 130,000-hectare Chiquitano territory.
- Undertaking a public campaign to generate political pressure for official recognition.
- Continuing to implement a 10-year plan they have designed to manage and harvest their forest reserves on a sustainable basis.

Of the estimated 75,000 hectares of closed forest in the CICOL project, about 15,000 hectares are considered to be in imminent danger of logging. Logging reduces biomass from 268 to about 220 tons per hectare.[2] Roughly 0.72 million tons of biomass or 0.36 million tons of carbon are threatened.

1. This information was derived from unpublished land-use maps of the Pastaza Province which were produced by OPIP. The information is supported by Hicks et al., 1990.

2. Extrapolated from Brown and Lugo (1989) estimates of different categories of forest biomass.

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CIDDEBENI Project in Bolivia

Another project is in the Beni region of Bolivia and involves CIDDEBENI, a non-governmental organization, and CPIB, an indigenous peoples' organization in Beni. After native people of Beni marched 470 miles to the capital to demand government recognition of their traditional territories, the president issued an executive decree in September 1990 giving the indigenous peoples title to 1.2 million hectares of tropical lowlands. Lumber companies, cattle ranchers, and colonizers were given until December 1990 to withdraw. The law has not been enforced, however, and lumber companies are offering financial incentives to Indian communities for extraction rights. CIDDEBENI is trying to work through the legal system to pressure the government to enforce the decree, and believes it will be able to extend its conservation and sustainable development efforts to 500,000 hectares in the region. Approximately 325,000 hectares of forest will be under its direct control. (*See Table 11.*) CIDDEBENI also is working to develop a management plan that will prevent further encroachment into the region. Overall, about 97,500

Table 10.

CICOL, Nuflo de Chavez Province, Lomerio Region, Boliva (Chiquitano Territorial Defense and Resource Management Project)

PARAMETER	HECTARES ('000)	BIOMASS PER HECTARE (T/HA)	TOTAL BIOMASS (MILLION TONS)
Closed forest	75	268	20
Grasslands	48	10	0.5
Shifting agriculture	4	25	0.10
Total land area	127		21
Closed forest			
Inaccessible forest (A)	25	268	6.7
CICOL controlled (B)	25	268	6.7
Non-CICOL Indian controlled (C)	25	268	6.7
Total (D) [A + B + C]	75		20
Threat assumption: 30% of accessible forest lost			
Logged-over forest (E) [D – A] × 0.3 × [268 – 220]	15	220	0.72
Total carbon savings (F) E × 0.5			0.36

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hectares of the existing closed forest is considered under imminent danger of destruction and would be saved through the federation's actions.

For the CIDDEBENI area, the closest parallel is a part of the Isiboro-Secure National Park that has been colonized and has lost 30 percent of its closed forest to other land uses. (*See Table 12.*) Extrapolating this figure to the other three areas proposed for the land defense strategy provides a rough approximation of carbon savings. The project area has an estimated biomass of 79 million tons. A 30 percent loss would reduce that total by 24 million tons. Given a carbon content of 0.5 tons per ton of biomass, the project could protect about 12 million tons of carbon.

The land defense strategy for this area involves three different continuous areas: Multiethnic Territory, Chimanes Territory, and the Isiboro-Secure National Park. Oxfam is already working with indigenous resident organizations and other

Table 11.
Current Site Characteristics of CIDDEBENI, Chimanes Forest, Bolivia

PROJECT AREA	LAND AREA ('000 HA)	CLOSED FOREST ('000 HA)
Multi-ethnic territory	350	175
Chimanes territory	50	50
Isiboro-Secure National Park (estimate)	100	100
Total	500	325

Table 12.
Carbon Characteristics, CIDDEBENI, Chimanes Forest, Bolivia

PARAMETER	BIOMASS PER HECTARE(T/HA)	TOTAL BIOMASS (MILLION TONS)
Undisturbed closed forest biomass, Chimanes Territory and Secure National Park (A)	268	40
Logged closed forest biomass, multiethnic territory (B)	220	39
Total biomass for all closed forest at project site (C) [A + B]		79
Total carbon in standing biomass (D) [C × 0.5]		39
Threat assumption: 30% loss of closed forest		
Total carbon in standing biomass saved (E) [D × 0.3]		12

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NGOs in each of these areas. A map of this entire territory shows the threats to each of these areas (Chirif and Smith, 1991, map 10A). A part of the Isiboro-Secure National Park that has been colonized (not included under Oxfam's proposal) has lost 30 percent of its closed forest to other land categories (Chirif and Smith, 1991, map 10D). This figure was extrapolated to the three areas proposed for the land defense strategy. Each area faces one or more threats from colonization, logging, or cattle ranching.

CEDIA Project in Peru

The Machiguenga Indian territory in Peru contains one of the largest oil and gas deposits in all of South America. The Machiguengas possess legal title to most of the 1.3 million-hectare project site. (*See Table 13.*) The title will not prevent well drilling, but does put them in position to influence the siting of wells, roads, and settlement areas. CEDIA, a non-governmental organization, is trying to increase protection for the area by applying for designation of the Machiguenga Megantoni Sanctuary (176,000 hectares) as a "reserve" and to expand the territory of other Indian communities by another 131,000 hectares.

Although the indigenous residents have legal title to significant parts of the lands proposed as part of the project site, oil and gas development pose a formidable threat because of the large potential for immigration by colonists along the roads created for mineral exploitation. Little data is available, but the

Figure 13.

CEDIA, Lower Urubamba River Region, Echarate District, Convencion Province, Peru

PARAMETER	QUANTITY
Project area ('000 ha)	
Machiguenga Indian Territories	340
Kugapakori & Nahua Reserve	444
Vilcabamba Communal Reserve	210
Machiguenga Megantoni Sanctuary	176
Additional Territory	131
Total Land Area	1,300
Total Closed Forest ('000 ha) (A)	1,300
Average biomass (t/ha) (B)	268
Total carbon in standing biomass (million tons) (C) [A × B × 0.5]	174
Threat assumption: 30% loss of closed forest cover	
Total carbon in standing biomass saved (million tons) (D) [C × 0.3]	52

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30 percent loss that occured at the colonized portion of Isiboro-Secure National Park appears to be a conservative estimate of the loss that could occur in the CEDIA area. The likely scale of the oil and gas development could significantly affect the forest cover, ranging as high as the 72 percent conversion seen in the case of the colonized portion of the Pastaza in Ecuador (Kimerling, 1991, pp 43-44).

9. LESSONS LEARNED

The interest in offset programs has ballooned since 1988 when this effort first began. A number of private companies have either funded projects or are developing programs to do so, national governmental agencies are giving considerable attention to the costs and benefits of such efforts, and international institutions are considering implementation modes.

The success of these efforts, if and when they are implemented, will ultimately rest on the success of projects such as those described in the preceding chapters. In this larger context, the costs and benefits, institutional constraints, and experiences working with such projects become relevant.

In this chapter we advance some lessons learned and conclusions based upon two rounds of project evaluation and the review of 70 proposals. Each of the five lessons is followed by a discussion on the implications of implementation aimed at a significant effort to reduce the atmospheric concentration of carbon dioxide.

Lesson 1 — At the present time, there are a relatively small number of projects that can be directly funded as carbon offset projects.

In the first round of project evaluation, 11 of the 17 organizations invited to submit proposals did so. Of this set, the evaluation team considered just two to be of sufficient quality that they could be immediately funded.

In the second round, we realized that our group of invitees was far too small, so we tried to identify as many groups as possible that might have the ability to undertake a project of this nature. We eventually identified 118 groups from all over the world, and asked all invitees to pass the request on to any other group they thought could respond. Some proposals therefore came from organizations we had not identified. In response to our efforts, we received 59 concept papers. The evaluation team considered 11 proposals sufficiently defined and responsive to the request to merit further consideration. Ultimately, three proposals were considered immediately fundable.

Of 70 responses to our requests, just five were ultimately judged to meet the defined criteria — reasonable cost per unit of carbon sequestered, significant local involvement and benefit, and institutional experience and competence. What of the rest? A few proposals came from organizations such as large industrial concerns or development institutions that were in a position to fund their own projects. Some proposals were inappropriate and included requests for funding to write books or undertake small-scale experiments. Some organizations asked for much more money than was offered. Some well-developed proposals were written

by experienced organizations, but unfortunately, had almost no carbon sequestration benefits.

By far, the largest group were those that were poorly developed conceptually. In most cases, this lack of conceptual development appeared to be due to inexperience and a misunderstanding of the request. Quite a few of the proposing organizations had never undertaken a large-scale field project and underestimated the administrative and operational difficulties.

If projects of this type are to be funded at a much larger level than the present, what does this sample of proposals imply? The first implication is that since the number of projects that can be readily funded is apparently small compared to the potential demand, longer-term investment to develop institutional capacity will be required.

Beyond the first tier of immediately acceptable projects, there were a number of others that, had assistance been available, could have been developed into acceptable projects. Where the "on-the-ground" experience was sufficient, the type of assistance required was primarily of an administrative nature — bookkeeping, budgeting, staff management, etc.

One potential option for such projects could be to fund them at a low level for the first three to five years. This would give the organization time to develop its own capacity to manage a project and experiment with the local people to identify successful practices and modes of operation. The essential constraint in multiplying these types of projects in developing countries is institutional, as opposed to lack of physical opportunity (Faeth et al., 1990).

In the near term, project costs are likely to rise as the best project opportunities are funded. As institutional capacity develops, however, project costs are likely to fall, but it is also likely that as less experienced groups get involved, the number of project failures may rise. However, as capacity develops and learning proceeds, failure rates should decline with costs.

Lesson 2 — It is difficult to quantitatively define project benefits with certainty.

In each of the cases examined in this report, the data necessary to estimate the various benefits of the project were scarce. Our request for proposals included a form specifying the minimum data set to run the LUCS model. Initially, no group was able to complete this form satisfactorily. The information necessary to estimate project benefits could only be gathered from field visits, and much of this information was questionable.

Given the types of projects and the areas of their implementation, this conclusion is not surprising. The project sites are remote and have largely been neglected by official government agencies and development institutions. Even where that was not the case, the information requirements to estimate carbon sequestration benefits are somewhat unusal and outside the normal experience of most project managers.

For potential funders and regulators interested primarily in carbon sequestration benefits, this implies less certainty, and correspondingly, more risk. However, this risk may be an acceptable trade-off as long as the cost per ton of carbon remains low and there is a means of monitoring the result.

The only certain means of reducing carbon addition to the atmosphere is to prevent its release in the first place. Any project that seeks to remove carbon from the atmosphere, particularly if that project relies on biological mechanisms, will be subject not only to human-induced risks such as political instability and economic forces, but also to environmental risks such as drought and pest attack.

These risks can be mitigated somewhat by improving data collection and project monitoring, and by endowing projects. All projects should establish a baseline to enable better estimates of future project benefits and to monitor performance as the project proceeds. The type of information to be collected during a baseline survey would include basic land-use data, biomass estimates, agricultural production, forest harvesting for fuelwood and timber, and basic socioeconomic data.

Endowment mechanisms provide the necessary financial support for long-term projects of this nature. With long-term support, project mistakes are much less critical and are seldom disastrous as they can be for short-term projects. Additionally, endowments can provide the opportunity to shift funding if a given project is unsuccessful.

The quantification problem will also be less difficult to deal with if standard methods are developed and results certified by independent agencies. The most important aspect in the early stages will be to identify the relative benefits of various projects in order to rank them for funding purposes.

Quantitatively, the uncertainty might be dealt with by discounting the amount of carbon sequestered, in the same way that financial investments are discounted to determine a present value. Different discount rates could be used depending upon the apparent risk associated with a given project, although these discount rates would be difficult to determine objectively.

Lesson 3 — The largest carbon sequestration benefits will be found in areas where a substantial amount of biomass faces a significant threat.

The cheapest and most immediate way of sequestering carbon in forests appears to be through the protection of standing forests. Obviously in areas that do not naturally have forests or in areas that have already been denuded, the protection of existing stands is not possible. The PDA project in Thailand is one such example. Since the area has largely been converted to agriculture, there is little forested land left to protect. The principal opportunity for carbon sequestration is reforestation, which is more expensive. The area available for reforestation is small because of the need for agricultural land.

In areas where there is no immediate or significant threat of forest depletion or degradation, there will be little to be gained from an investment in forest protection to sequester carbon. The King Mahendra project is an example of this case. While there is a large area of dense forest, the population density is low, as is the demand on forest resources. Therefore, the opportunity for forest preservation, although real, is nevertheless small in terms of carbon sequestration.

In contrast, the carbon sequestration benefits of the CARE, UCEFO, ANCON, and Oxfam projects all flowed principally from the projects' ability to prevent the conversion or degradation of existing, high-biomass forest stands through reduced pressure from agriculture or through forest protection. There is a large amount of biomass faced with an immediate threat at each project site. The resulting cost-benefit ratios are favorable. The protection of existing stands is also favorable from a risk perspective because establishment is guaranteed. Large secondary benefits in terms of wildlife protection and biodiversity conservation are also possible. The principal difficulty is in the quantification of the threat and the establishment of a baseline to measure the carbon sequestration benefits.

Some observers question whether it is legitimate to assign a benefit to a project that may still result in a loss of carbon, even though the project may produce a substantial improvement over the baseline. Others believe that there can only be a benefit

assigned if there is an absolute increase in carbon sequestered from the beginning of the project.

The essential question is not so much what will happen on the ground, but what will happen in the atmosphere. As a result of the project, will the atmospheric concentration of carbon dioxide be marginally lower? If so, then it is appropriate to assign a corresponding benefit, since atmospheric CO_2 is the indicator of principal interest. Carbon sequestered is the inverse indicator; it does not matter to the atmosphere if an existing sink has been preserved or a new sink established, so long as the atmospheric concentration is the same. This line of thinking also follows a strict economic efficiency argument, since the goal should be to produce the greatest reduction in carbon dioxide at the least cost.

The question of scale also comes up in this context. What if the project only serves to divert pressures to other areas? If deforestation accelerates in another area then what would be the benefit? The answer lies in the fungibility of the pressures associated with the project. If a project helps people to improve their productivity and standards of living, are they likely to leave the site and go elsewhere? Not likely. If a protection program limits the damage from oil exploration, are the oil companies likely to cut down forests in other areas where there is no oil or where the same protection schemes don't exist? Possibly. If a conservation project eliminates timber harvesting, will loggers go to an area outside the park or even in another country? Probably. Would these sorts of pressures exist in other areas over the long-term in any case? Maybe.

A corollary to this lesson is that some projects proposed by experienced organizations have large components of local benefit and involvement and appear to have a high probability of success, but have low carbon sequestration benefits relative to the project costs, and will not be funded by those seeking carbon benefits.

Lesson 4 — To account for and ensure carbon sequestration benefits, project design and analysis should account for the dynamic nature of resource demand and technology.

Static analysis that focuses only on the direct benefits (for example, carbon sequestered in planted trees) of a project will fail to account for secondary benefits that may be much larger. Worse, such analysis will also fail to identify important threats to success of the project.

The Guatemala analysis clearly demonstrated this lesson. The key aspect of the project in terms of carbon sequestration appears to be the ability of the project to increase productivity and to minimize the impact of increased demand over time. The direct carbon benefits of tree planting and agricultural extension appear relatively small compared to the indirect benefits of increasing agricultural productivity and stabilizing land use.

Similarly, in the evaluation of the UCEFO project, our initial expectation was that agriculture would be a minor element of the carbon benefits. As it turned out, however, the investment in increased agricultural productivity was just as important as improved forest management.

Lesson 5 — Project activities that benefit local people also tend to sequester carbon.

In the projects we examined, there appears to be a direct connection between the welfare of the local population and conservation of the surrounding environment. The project areas we examined were most often characterized as forest margin — relatively remote areas where agriculture and forests compete for land. In this competition, the forest inevitably loses and carbon is lost. When agricultural productivity increases, however, land hunger is reduced and forest is conserved. Most importantly, the people of the area benefit.

This lesson also holds in forest management as well. When forests are viewed as a capital asset, it is in the best interest of the users of that capital to preserve it in order to maintain a stream of income over time. Investments that improve the sustainable use of the resource base, such as the case of the UCEFO project, will also sequester carbon. Additionally, projects that use this synergy between local sustainable development and forest conservation will realize carbon benefits at a lower cost.

For those projects that have significant local benefits but that sequester relatively less carbon, co-financing schemes that coupled private and public funding might be appropriate. In this way the budgets of sponsors could be extended while laudable projects with smaller carbon benefits could receive funding.

Conclusion

Carbon dioxide mitigation projects could potentially play an important role in a global effort to avert climate change. At this time, however, it appears that there are numerous constraints that could hamper efforts to greatly accelerate the rate of implementation of such projects. In addition, relative to the rate of carbon dioxide output from the burning of fossil fuels, the problems of deforestation are much smaller. Since forestry projects funded to sequester carbon dioxide are essentially efforts to reduce deforestation, they cannot serve as a panacea while carbon dioxide releases continue at excessive rates elsewhere.

That said, however, the potential problems of global climate change may be severe enough that it may be wise to explore the potential of a variety of solutions, even though their total contribution to the overall solution may be small. Those activities that help to mitigate global climate change at a small cost while providing large benefits in other areas are worthwhile exploring. In the case at hand, the costs relative to other options appear to be small, while the benefits to those participating in the projects appear to be quite large. For this reason, carbon sequestration projects should be considered one of a large number of tools in the kit to tackle the problem of global climate change.

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APPENDIX A — REQUEST FOR CONCEPT PAPERS AND DATA SHEET

October 31, 1990

Name
Organization
Street Address
City, Postal Code
Country

Dear :

Enclosed you will find a request for concept papers for a forestry-related project in Africa, Asia or Latin America.

The funding for this activity is being provided by Applied Energy Services, Inc. (AES), an electrical cogeneration company in the United States which is seeking to mitigate the remaining environmental impacts of its coal-fired power plants. Using the best currently available technology, AES has managed to reduce the emission of regulated pollutants to well below current U.S. standards. However, carbon dioxide gas is an inevitable, unregulated by-product from the plants' operation and is thought to be a major cause of global warming.

After evaluating several alternatives for reducing carbon dioxide emissions at the source, and finding that none of them were technically feasible, AES decided to offset emissions through biological fixation, such as tree planting. Internationally, this has been a much-discussed option, although never attempted until AES provided a $2 million grant to CARE in 1988 for a joint project with the Guatemalan forestry service.

AES wishes to expand the implementation of this strategy for its two newest power plants. AES has asked the World Resources Institute to advise on the concept, develop the criteria, and solicit and evaluate proposals, as we did for the previous grant.

The current grant process will be two-staged. In this, the first stage, we are soliciting concept papers from a large number of organizations involved in forestry-related projects. We will review the concept papers and evaluate the suggested projects based upon the information provided in the concept papers and project data sheets. In the second stage, the organizations proposing the most promising projects will be invited to develop their concept papers into full proposals which will be more thoroughly evaluated, including site visits.

Based upon the evaluations of the final proposals, AES will select a number of projects to receive grants. A total of US$5 million will be made available by AES to fund appropriate projects.

We would like you to review the enclosed material and consider submitting a concept paper or to share this request with organizations that you think would be suitable. If you decide to submit a concept paper, please follow the outline provided and do not include materials or information not specifically requested. Please be particularly careful in completing the enclosed project data sheet. Our analysis of the data you provide is an important part of the overall evaluation, so accuracy and completeness are essential.

Concept papers must be postmarked no later than December 21, 1990. We will evaluate the concept papers as quickly as we can and keep you informed of our progress. Any organization may submit more than one concept paper, as long as these are submitted separately. Consortia members may submit concept papers independently and as members of the group.

For your information, we have provided a copy of a report on the first effort in this activity. The paper, entitled Forestry as a Response to Global Warming: An Analysis of the Guatemala Agroforestry and Carbon Sequestration Project, will provide you with background information which you should use in the preparation of your concept paper. Copies are available in English and Spanish.

We would be happy to provide clarification on any point in our request for concept papers. However, we ask that you initially forward questions by telex or telefax and include some information on your organization and the project. Inquiries should be directed to me at WRI (Telex: 64414 WRIWASH; Telefax: 202-638-0036). Concept papers should be sent to me by air mail.

Sincerely,

Paul Faeth
Project Director

encl.: 1) Request for Concept Papers
2) Forestry as a Response to Global Warming...
3) Project Data Sheet

REQUEST FOR CONCEPT PAPERS

Activity: Forestry-related projects
Funding Available: US$5 million total
Duration: 5 to 20 years
Deadline: Postmarked by December 21, 1990

Introduction

The World Resources Institute (WRI), on behalf of Applied Energy Services (AES), an electrical cogeneration company, is soliciting concept papers for design and implementation of forestry-related projects in developing countries. A primary objective of the resulting grants will be to balance the carbon dioxide emissions from new coal-fired power stations that the sponsor, AES, is constructing in the United States. Using the best currently available technology, AES has managed to reduce the emission of regulated pollutants to well below current U.S. standards. However, carbon dioxide gas is an inevitable, unregulated by-product from the plants' operation and is thought to be a major cause of global warming. We hope to identify projects that have the potential to conserve or grow a sufficient amount of living biomass (which is 50 percent carbon) so as to balance the carbon dioxide emissions of the power plants.

Projects in developing countries are preferred for two reasons: 1) Plant growth rates are higher, suggesting greater potential carbon fixation; and 2) most of the world's deforestation is occurring in developing countries, suggesting a greater need and potential benefit for successful forestry-related projects. However, developed countries groups are also being invited to apply.

Criteria

1) Carbon sequestration. The principal purpose of the grants will be to take or keep carbon out of the atmosphere. Therefore, projects that can accomplish this at least cost will be preferred. The new power stations are expected to emit roughly one million tons of carbon per year over their useful lives of 40 years.

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The most cost-effective means of balancing the emissions will likely involve some type of forestry-related activity in a tropical country. Submitting organizations are asked to complete the attached data sheet, which will be used to analyze the potential carbon sequestered by the proposed project. Submitting organizations are not expected to estimate the carbon sequestered in their projects.

WRI and AES hope to encourage a range of ideas. These may include, but are not limited to, afforestation, nursery development and seedling out-planting, management of threatened or protected areas, efficiency improvements for wood stoves, and reclamation of degraded areas through revegetation. Projects may include a mix of these or other activities. All proposed projects should describe the steps that will be taken to ensure the long-term flow of project benefits. Projects operating at lower levels over longer periods of time, perhaps requiring the establishment of an endowment, will be acceptable.

2. Local participation.

The project should generate the maximum amount of social as well as climatic benefits. Projects that include the greatest amount of direct involvement of local people in project development and implementation will be preferred. The project should meet a primary need, problem or opportunity at the local level.

3. Grant leverage.

Projects that can leverage additional local, national or international resources such as land, labor, and financing, will be preferred. Leveraging arrangements may include but are not limited to debt swaps, block or matching grants, community land or labor pledges, food aid programs, or support of existing projects.

4. Experience.

The experience, knowledge and potential of the implementing organization is critical. The concept paper must clearly demonstrate significant experience in the country and prior success for the type of project or activity proposed, as well as the administrative ability to manage a project of the proposed size.

Guidelines for Concept Papers

Concept papers should be no longer than seven pages, not including the project data sheet and maps. The following outline should be used in preparation of the papers.

1. Project Title - Country where project will be conducted and brief descriptive phrase for the project (include map of the project area).

2. Grantee - Name, address, telephone and telex/telefax of the lead proposing organization. Give full name of contact person. Provide names of collaborating organizations and contact person.

3. Project Summary - Basic statement of what the project is and what it is intended to accomplish.

4. Justification - Describe how the project meets the criteria outlined. Be specific.

5. Work Plan - Brief outline of activities and time frame over which these will occur.

6. Budget - Outline personnel, fringe benefits, professional fees, administration expenses, travel costs, living expenses, supplies and equipment, education and training costs, operation and maintenance costs, as appropriate. Include information on other sources of support.

We suggest that one page be devoted to the project title, grantee, and project summary; two pages to justification of the project; three pages to the workplan; and one page to the budget outline.

All concept papers must be postmarked by December 21, 1990. All materials received will be considered strictly confidential by WRI and AES. Send concept papers to:

Paul Faeth
World Resources Institute
1709 New York Avenue NW
Washington, DC, 20006, USA.

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Guidelines for Completing Project Data Sheet

The enclosed data sheet will be used to evaluate the carbon sequestering potential of the proposed projects. For this reason these data sheets are very important and care should be exercised when completing them. Be sure to complete as much of the applicable information as possible. If a section is clearly not applicable to your proposed project, write "NA" -- not applicable. All sumbitters **must** complete sections 1), 2), and questions 4) and 5).

The question of project boundaries may arise when providing information on land area and population. For these sections please enter numbers which reflect the smallest geo-political boundary that encompasses the proposed project. If information is not available at this level, use information from the next highest level, up to country-wide data. Please be certain to be consistent in providing this data at the same level (i.e. all provincial-, regional-, or national level data). Do not give data for land area and population from different levels.

Inquiries to clarify information or criteria presented in this request should be directed to Paul Faeth at the World Resources Institute (Telex: 64414 WRIWASH; Telefax: 202-638-0036). In no instance should inquiries be directed to Applied Energy Services.

Carbon Sequestration Project Data Sheet

Name of Project:_____
Country:_____

1) Current Land Area (hectares)
Level from which area data is derived (e.g. country, region or province:_____
Closed forest:_____ Open forest:_____
Permanent agriculture:_____ Shifting Agriculture:_____
Agroforestry:_____ Tree Plantations:_____
Degraded land:_____ Total:_____

2) Average Total Biomass (metric tons per hectare)

Closed forest:_____ Open forest:_____
Permanent agriculture:_____ Shifting Agriculture:_____
Agroforestry:_____ Tree Plantations:_____
Degraded land:_____

3) How many persons are currently supported by one hectare of -
Permanent Agricultural Land:_____
Shifting Agricultural Land:_____
Agroforestry Land:_____

4) What is the population of the project area(s)?_____
5) What is rate of population increase?_____
6) How much wood does each person use per year?_____
7) What is the primary source of this wood?_____

8) How many hectares of tree plantations will be planted per year?_____
9) What type(s) of land will be converted to tree plantations?_____
10) How many years are required for tree plantations to mature?_____
11) How many thinnings are there until the final harvest?_____
12) How much wood, on average, is produced from each thinning?_____
13) What is the biomass of tree plantations at maturity?_____

14) How many hectares of land per year will be converted to agroforestry?_____
15) What type(s) of land will be converted to agroforestry?_____
16) How much wood per year can be taken off from agroforestry land for fuelwood or other purposes?_____

17) How many years do farmers cultivate shifting agricultural land before retiring it to fallow?_____
18) How many years are required before fallowed land can be brought back to shifting cultivation?_____
19) How much wood per year can be taken off from shifting agricultural land for fuelwood or other purposes?_____

20) How much land can be cultivated continuously on a permanent basis?_____

21) How much forest land will be protected?_____
22) What type(s) of forest land will be protected?_____

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APPENDIX B — PROJECT EVALUATION FORM

Project title: _____

_____

Proposing organization: _____

Country: _____ Evaluator: _____

Please rate the following aspects of the proposal as **excellent** (4), **good** (3), **fair** (2), **poor** (1) or **unacceptable/absent** (0).

	Unacceptable /Absent				Excellent
Concept development:	0	1	2	3	4
Appropriateness of concept:	0	1	2	3	4
Justification:	0	1	2	3	4
Funding request relative to workplan:	0	1	2	3	4
Apparent competence of grantee:	0	1	2	3	4
Experience of grantee:	0	1	2	3	4
Grant leverage:	0	1	2	3	4
Local involvement during implementation:	0	1	2	3	4
Local involvement during planning:	0	1	2	3	4
Benefits accruing to local people:	0	1	2	3	4
Ability to sustain benefits:	0	1	2	3	4
Likelihood of success:	0	1	2	3	4
Overall rating of project:	0	1	2	3	4
Adequacy of data provided:	0	1	2	3	4

Total budget requested: _____

Carbon sequestration estimate: _____

Estimated cost per ton C: _____

APPENDIX C — ADDITIONAL FLOW DIAGRAMS

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Figure C-1.

Carbon in Standing Biomass Is the Sum of Each Land Category Multiplied by Its Biomass and the Amount of Carbon Per Ton of Biomass

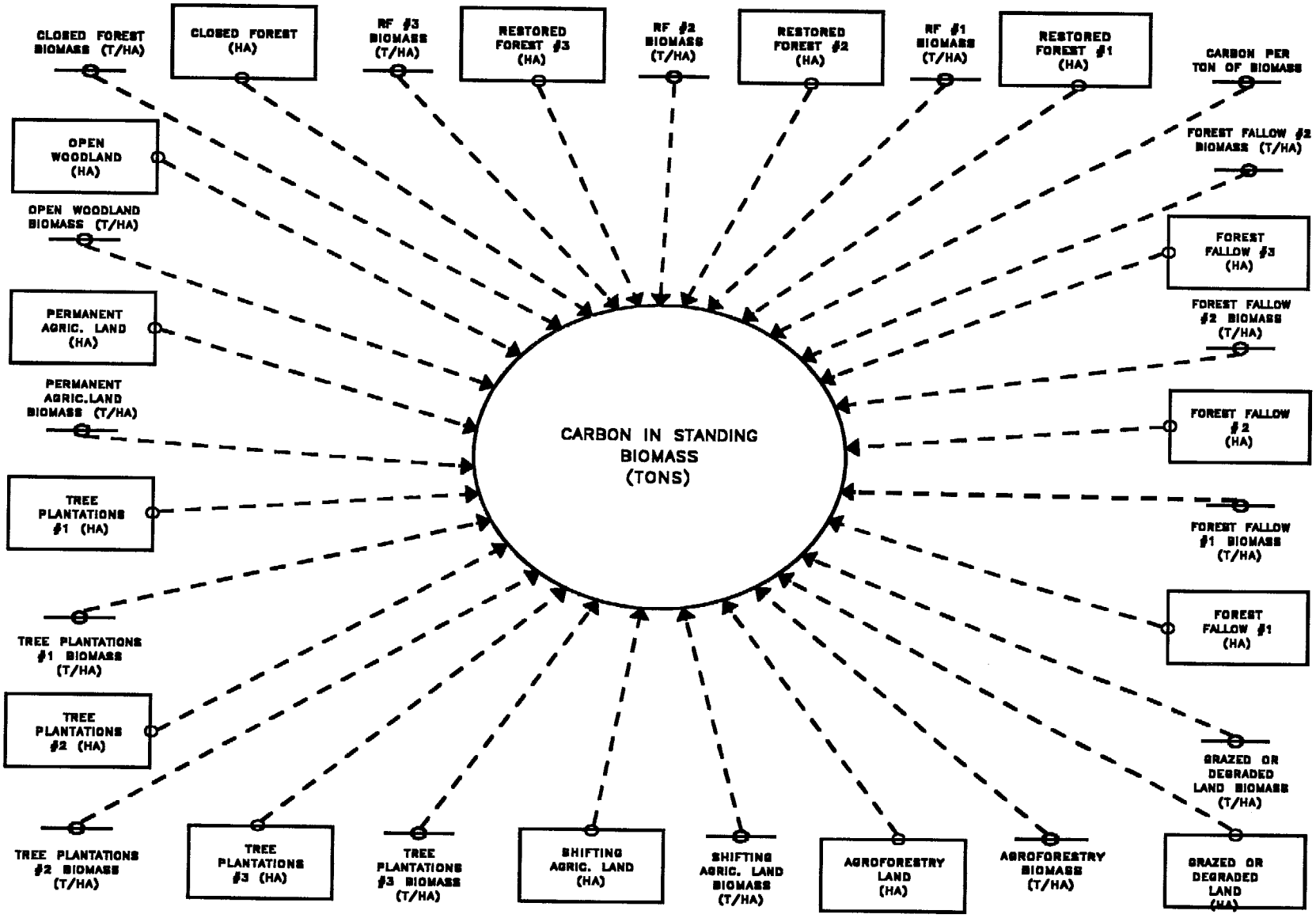

Figure C-2.

Wood Products Additions Are Determined by Harvest Rates and Uses. Outflows Are a Function of Useful Life.

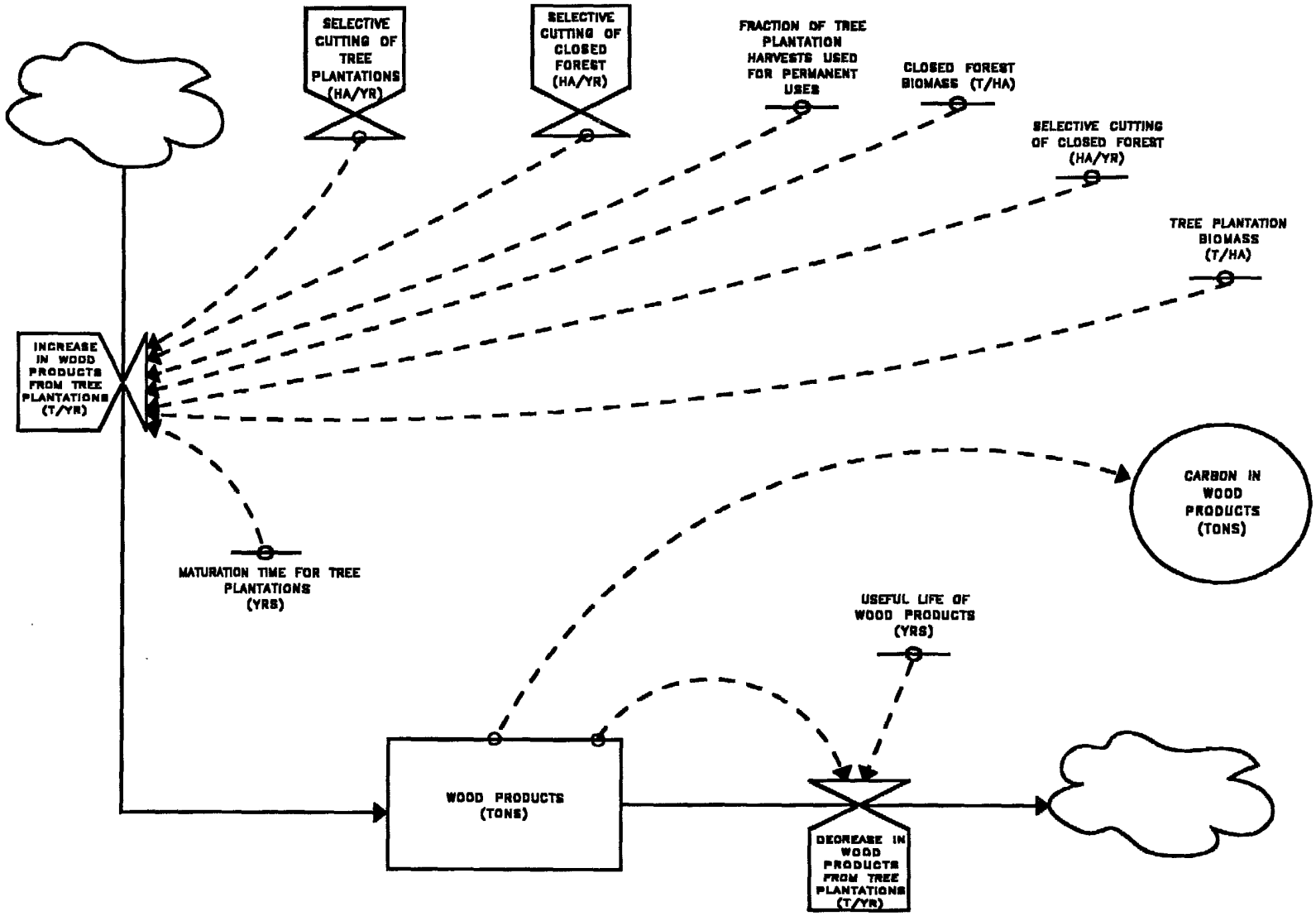

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Figure C-3.

Agricultural Land Shortfall Is the Difference Between Current Agricultural Land and Future Demand

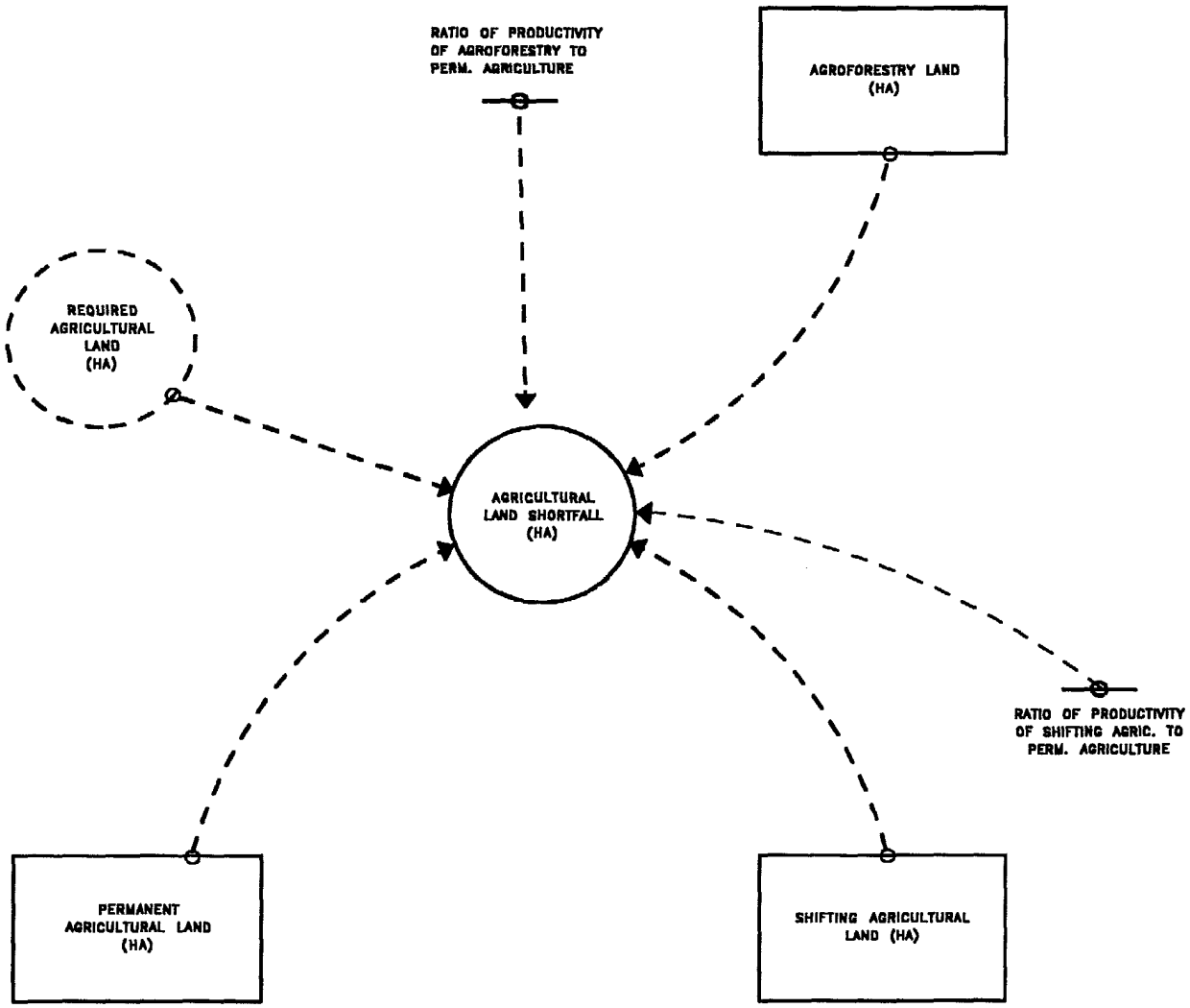

Figure C-4.

Open Woodland Is Converted to Agriculture Based on Predominance and Need

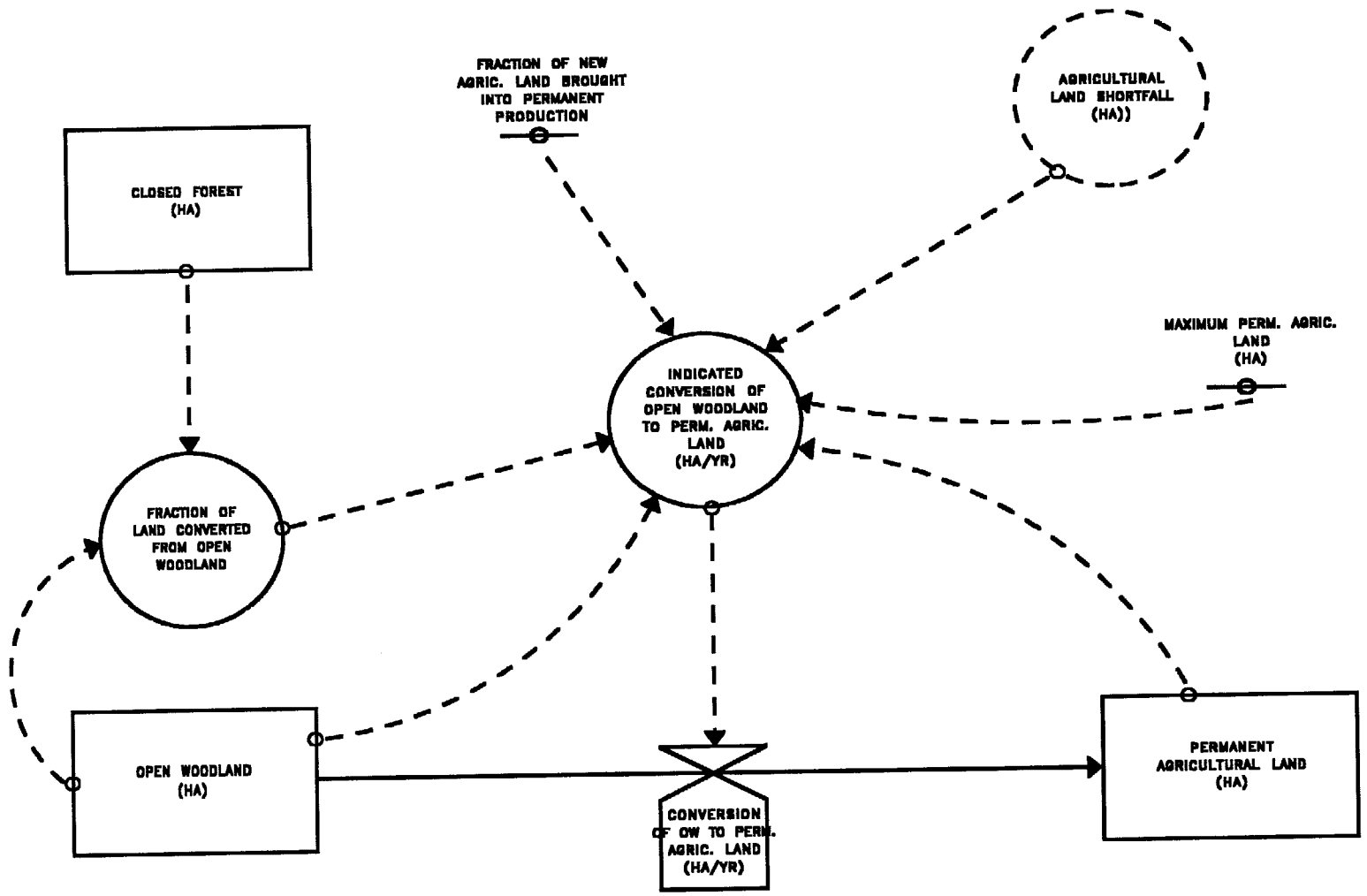

Figure C-5.

In Addition to Predominance and Need, Closed Forest Conversion Is Based on Forest Protection

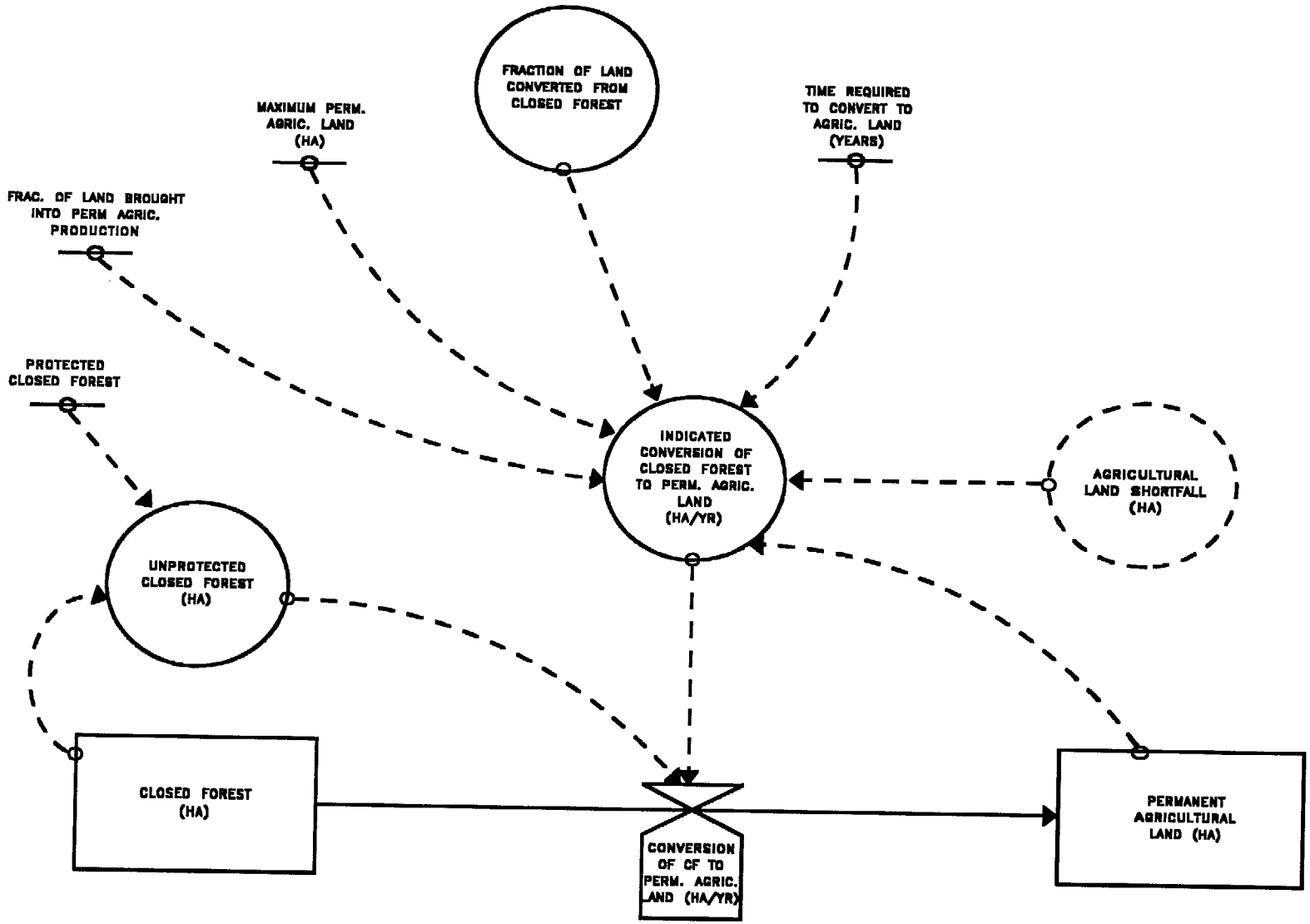

Figure C-6.

The Fallow Cycle for Shifting Agriculture is Based on the Cultivation and Fallow Periods

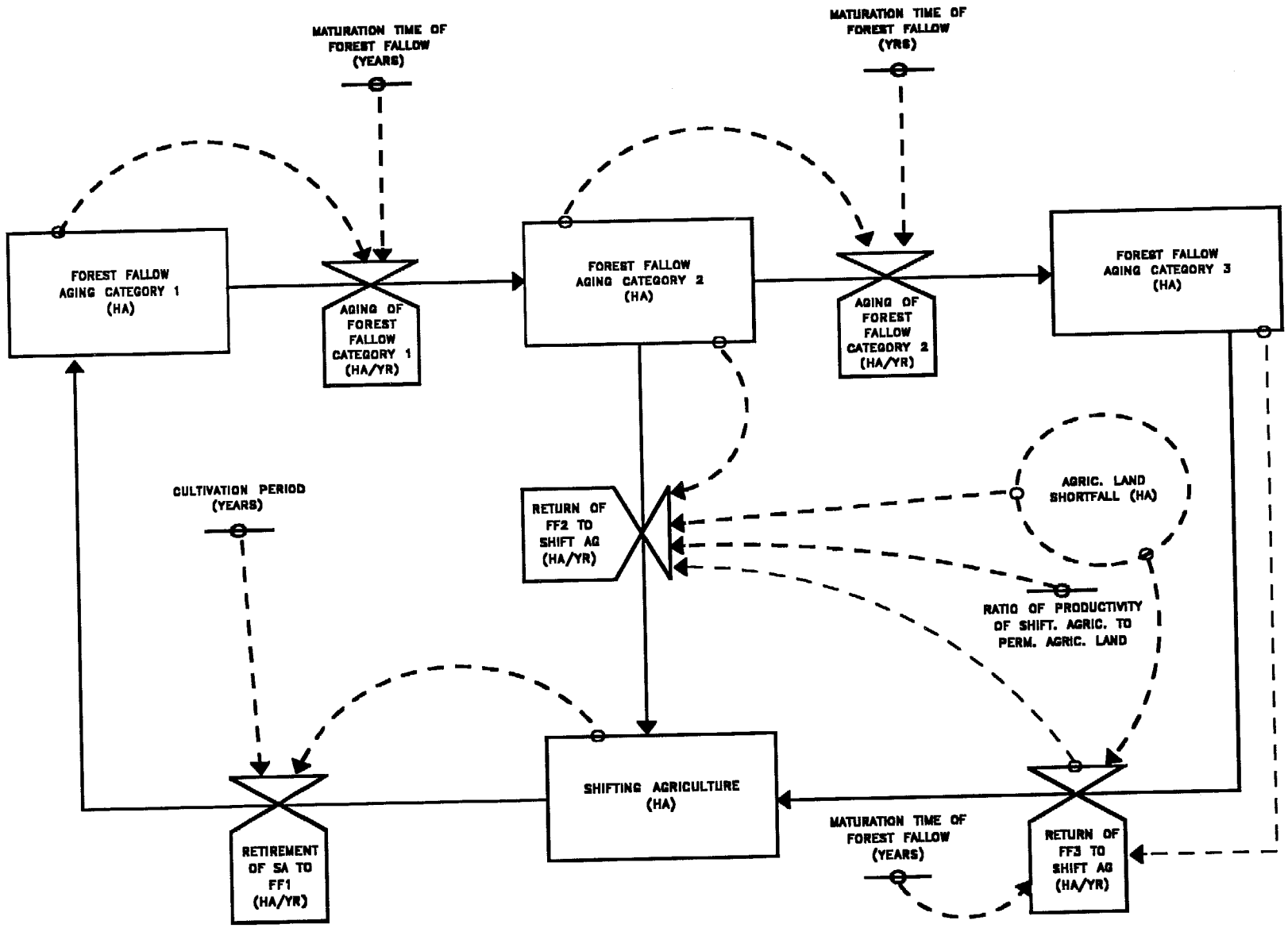

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Figure C-7.

Sources of Fuelwood Include Debris, Conversion, and Harvest

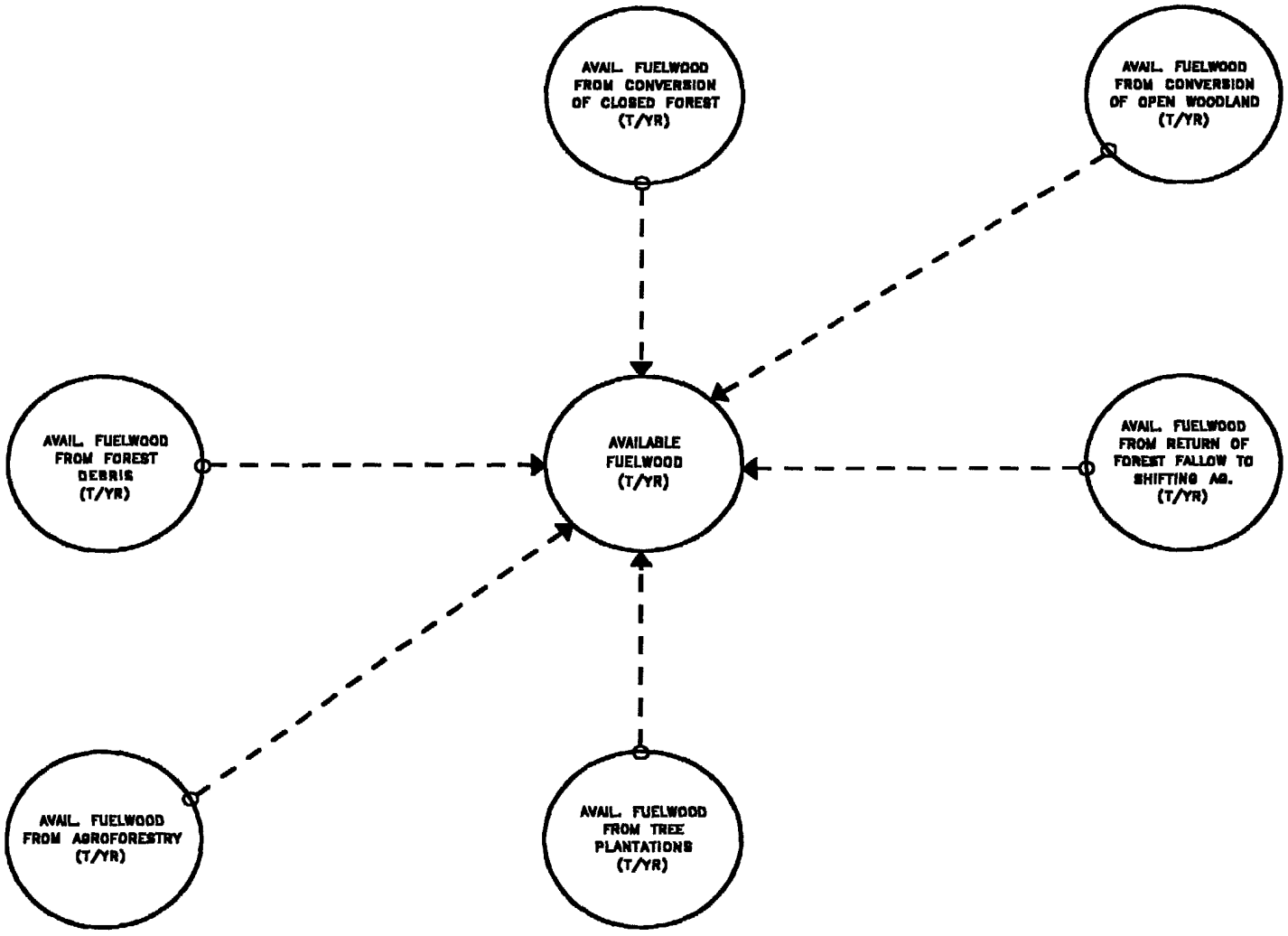

Figure C-8.

Tree Plantations Are Represented by Three Age Classes to Capture Growth

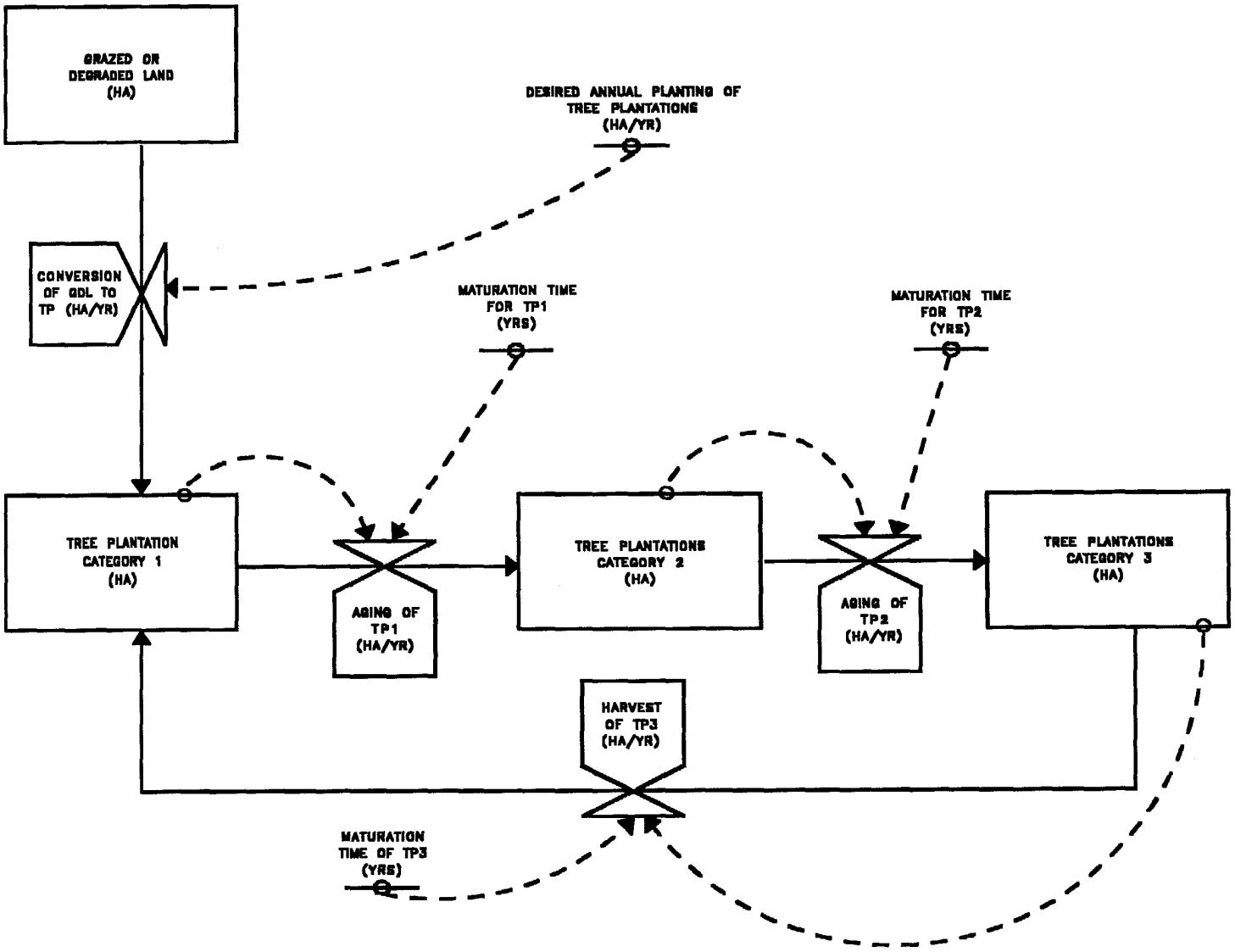

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Figure C-9.

Conversion of Open Woodland to Degraded Land Is Determined by Fuelwood Demand, Availability of Fuelwood and Open Woodland, and Biomass

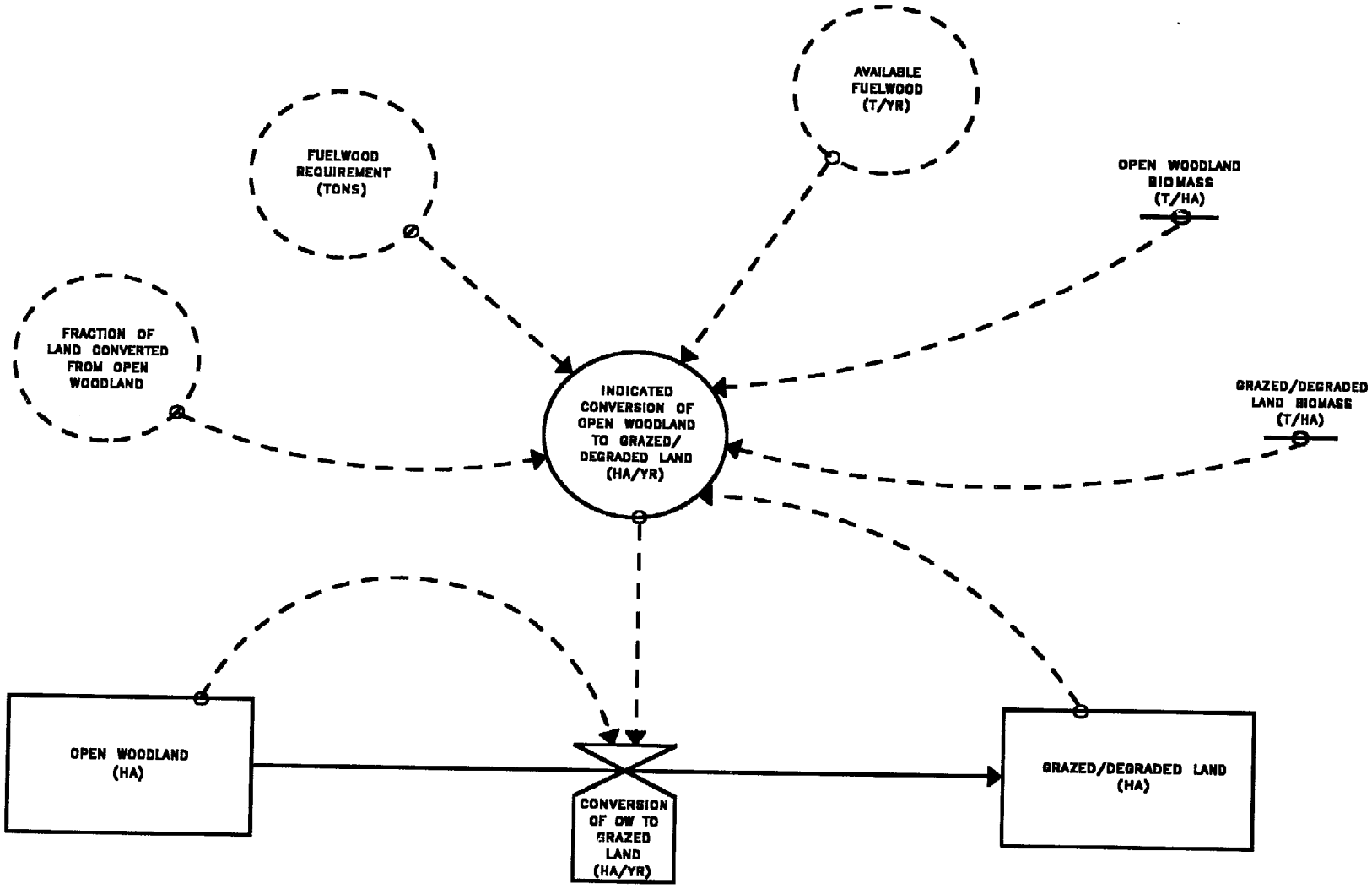

Figure C-10.

Conversion of Closed Forest to Open Woodland Is a Function of Harvest Rates, Forest Practices, Biomass Lands, Fuelwood Demands, and Forest Protection

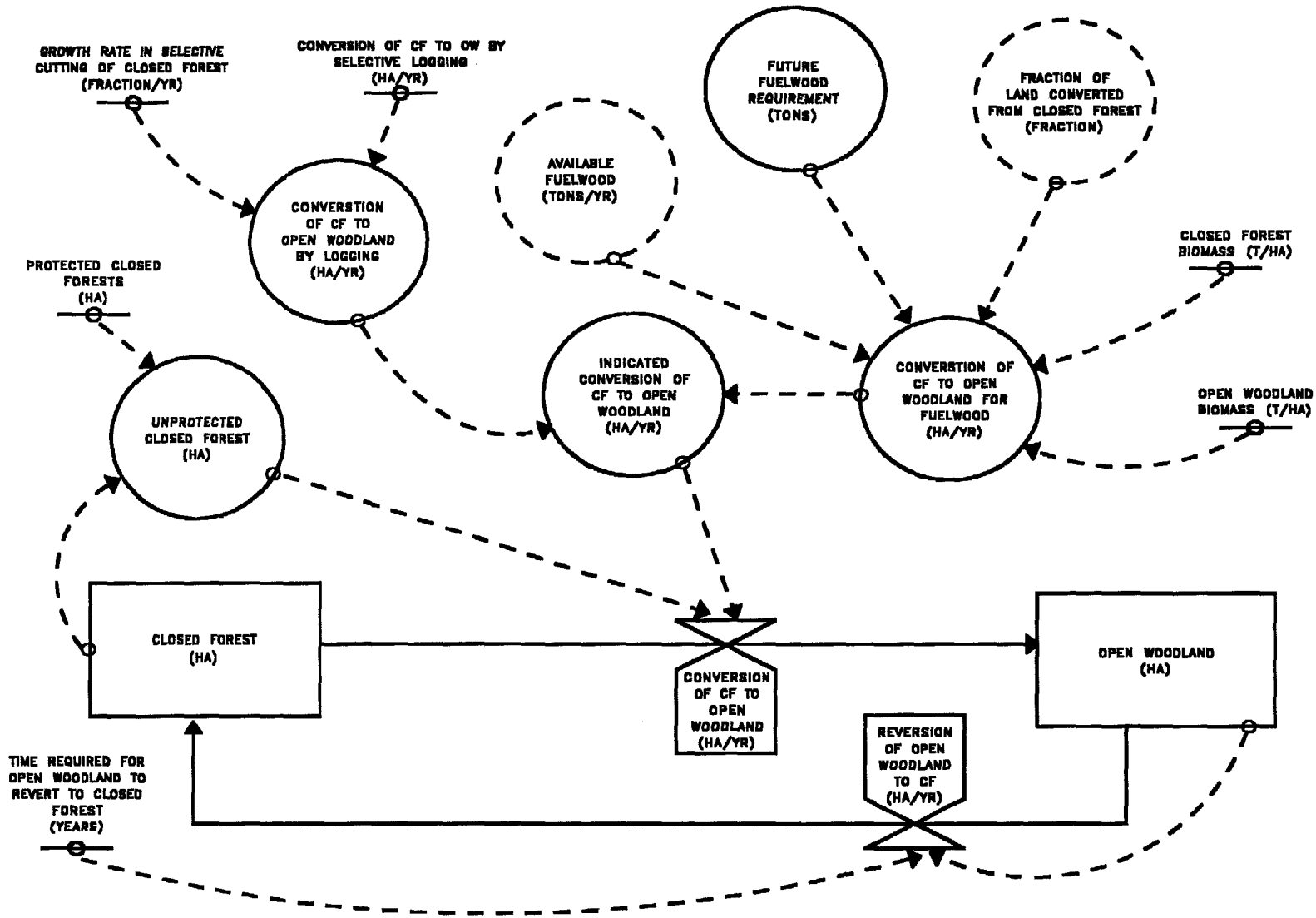

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Figure C-11.

An Aging Chain for Closed Forest Can Be Used to Represent the Impacts of Selective Logging

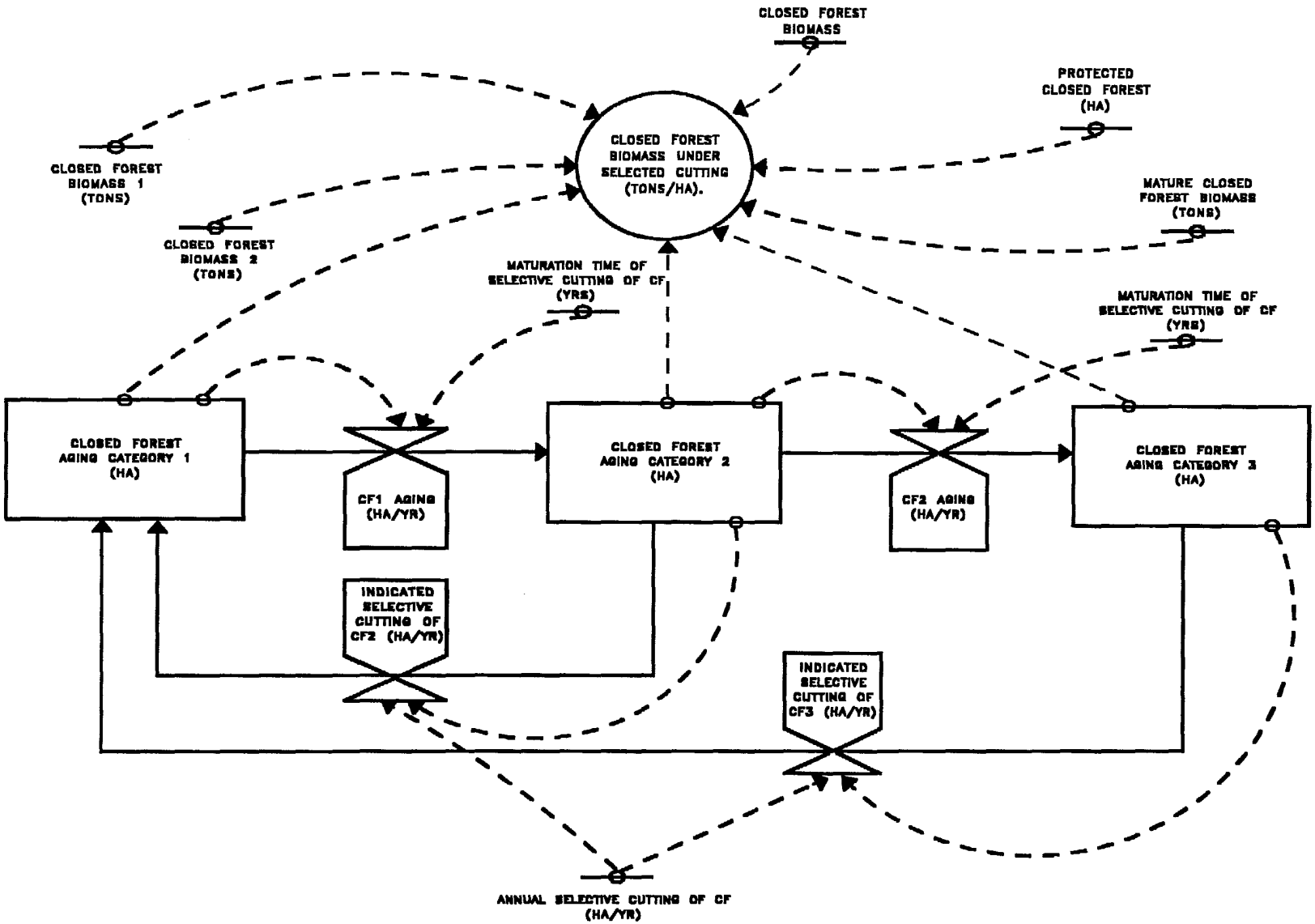

Figure C-12.

The Conversion of Open Woodland to Tree Plantations Is Determined by Project Parameters

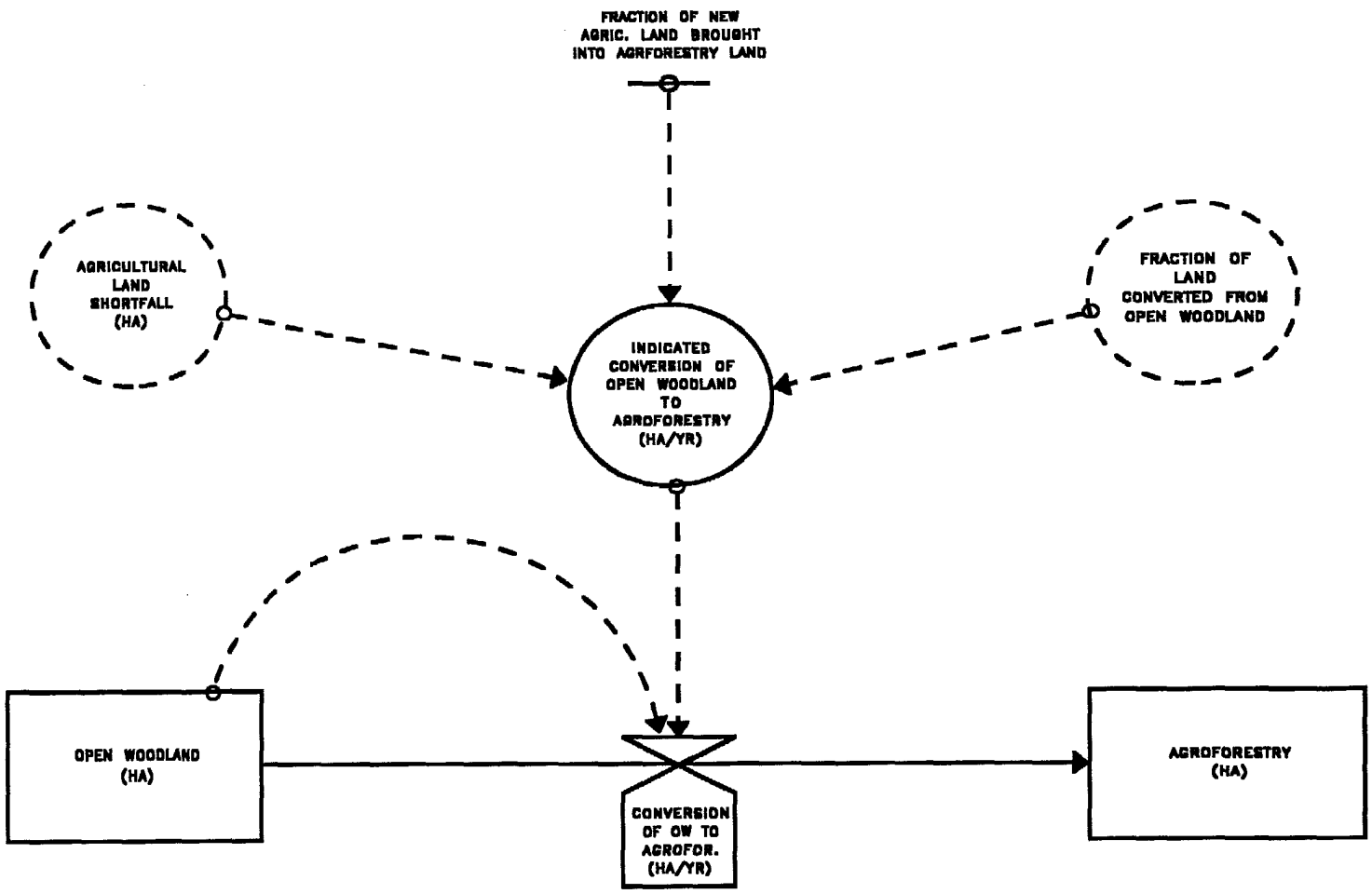

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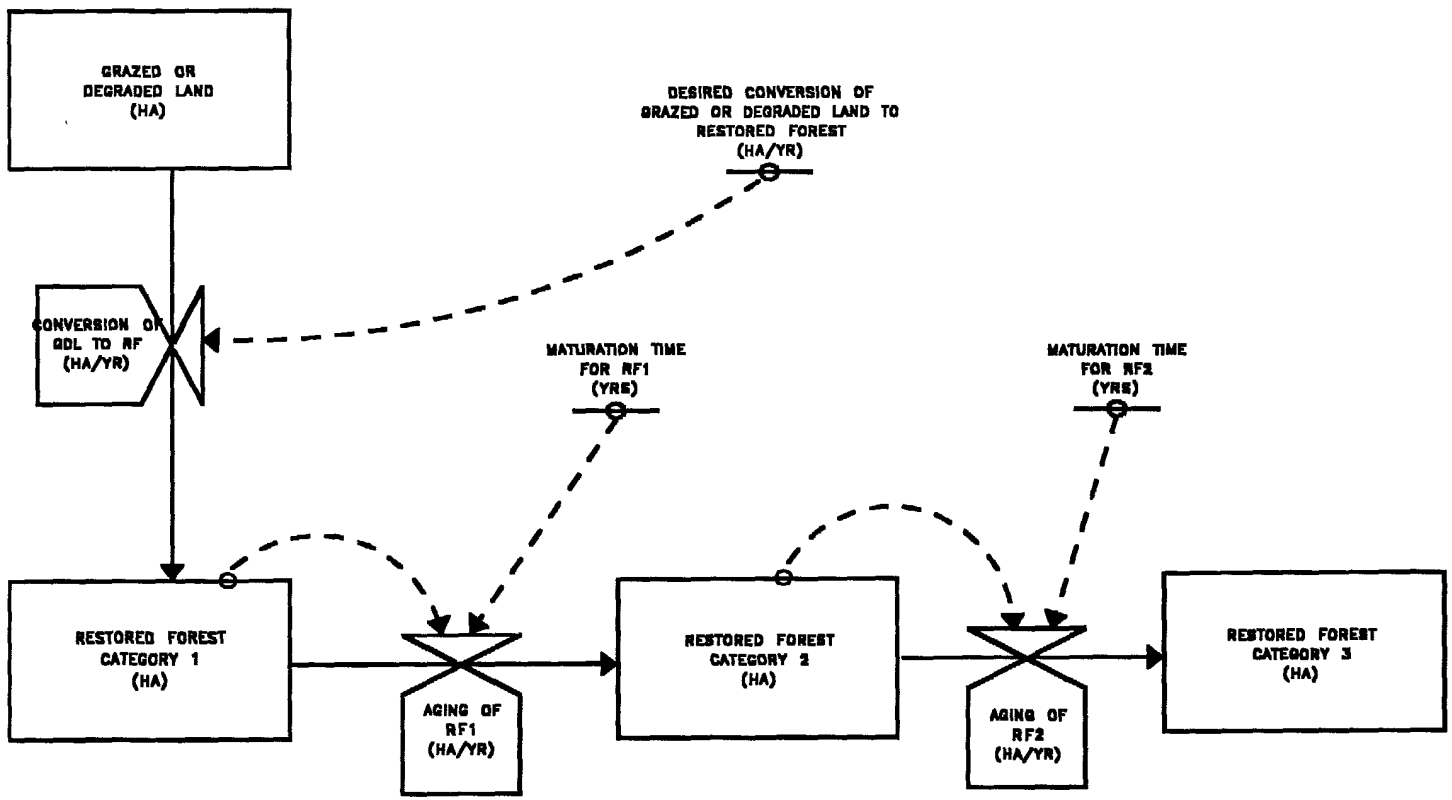
Figure C-13.

Forest Restoration Is Represented As an Aging Chain With No Outflow at Maturation