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# Sustainable development of forest resources in industrialized countries

William McKillop<sup>a,\*</sup>, Amin Sarkar<sup>b</sup>

<sup>a</sup> College of Natural Resources, University of California, Berkeley, CA 94720, USA

<sup>b</sup> State University of New York, Fredonia, NY 14063, USA

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## Abstract

There is no general consensus about what sustainable development means. We seek to clarify the meaning and utility of the concept by focusing on forest resources in countries possessing higher levels of per capita incomes. The meaning of sustainable development becomes complex when one asks what social goals are being pursued, what types of stability are permitted, whether amenities and commodities should receive equal consideration, and to what landbase the concept should be applied. A simulation/linear programming model of California's private forest resource is used to demonstrate that strict decade-to-decade 'even-flow' stability of production may result in lower aggregate levels of output over a prolonged planning period, with ending levels of the stock resource that are scarcely greater than when output is permitted to vary over the planning period. The model was also used to show that greater levels of output and ending stocks are possible when the land base for sustainability assessment is not a restrictively small geographical area or a single class of ownership. In the case of National Forests and other public lands, the application of the sustainable development concept is significantly more complex because of the importance of amenity values and because of the inherent conflict between development and the preservation of ecosystems in a pristine state.

## 1. Introduction

A principal goal of development is the improvement of standards of living. Sustainable development implies that this improvement will never be reversed and that future generations will not suffer because of excessive use of resources and environmental degradation caused by the present generation.

A major issue is how to strike a balance between the well-being of current and successive generations. Future generations will not only enjoy the fruits of

the present generation's capital investment, including investment in natural resources, but they may also inherit adverse consequences of resource depletion and environmental degradation. Possible adverse consequences include reduction in economic productivity, harm to human health and loss of amenity values such as visual quality and recreational opportunities.

Industrialized countries use several times more of the world's natural resources than do developing countries. For example, consumption of energy from fossil fuel is 33 times larger in the US than in India, and 10 times larger in OECD countries than in developing countries. Some people argue that for

\* Corresponding author.

industrialized countries, sustainable development requires reductions in levels of consumption of natural resources (World Resources Institute, 1992). Air and water pollution and disposal of waste are serious problems in OECD countries which include some of the world's major polluters (World Resources Institute, 1992). Loss of wetlands has also been a serious problem. The US converted more than three million acres of southwestern woodlands to pastureland as recently as 1950–1970. Earlier, a governmentally subsidized system of dams and canals was installed to irrigate some 15 million acres of western drylands and desert, and more than 50 million acres of mid-western wetlands were drained to expand agriculture towards the end of the 19th century. (Richards, 1984).

In the literature there exists considerable controversy over the definition of sustainable development and there is no general consensus about what it means (Niu et al., 1993). Here, we seek to clarify the meaning and utility of the concept by focusing specifically on forest resources in regions possessing higher levels of per capita incomes. A later paper will deal with special issues that relate to low-income countries.

Forests, which occupy more than one quarter of the world's land area, are not merely sources of timber and other tangible benefits; they perform a wide range of social and ecological functions. For example, deforestation causes loss of biological diversity, climate change, floods, and other calamities. (World Bank, 1992). Unlike the situation in many developing countries, deforestation is not a problem for most OECD countries (World Resources Institute, 1992). The US is the largest producer of forest products in the world and the second largest exporter of raw timber. At the present time, intense controversy exists over the logging of old-growth forests in the US Pacific Coast, especially about whether amenity values are adequately protected and whether the current rate of timber harvesting is sustainable. However, in general, careful resource management over the past 100 years has restored or enhanced the timber productivity of most US forests (Frederick and Sedjo, 1991).

To a significant extent, the meaning of sustainable development of forest resources is self-evident. Development of forest resources has, in the past, been

used to mean altering natural states to provide greater levels of goods and services for human use. Sustainability implies maintenance of either the quantity of the forest (stock) resource or of the level of outputs from it. Complexity arises only when one considers (a) what social goals are being pursued, (b) whether sustainability permits cyclical stability or requires strict (static) stability, (c) whether the resources in question are on public or private land, (d) whether amenities and commodities should receive equal consideration, and (e) to what landbase the concept should be applied.

## 2. Theoretical framework

In the general case, theoretical representation of forest resource management or conservation as an economic activity requires that production functions be multi-period, multi-product and multi-input in character. The traditional theoretical sustainable forest resource production function identifies a range of outputs over an infinite time-span, such as timber products, recreation, game and non-game wildlife, and water yields of varying quality. Inputs are typically characterized as labor and equipment hours, and purchased structures and materials.

The product set considered in a multi-product analysis must include amenities such as water quality and visual quality, as well as marketed commodities such as timber for which fees can be charged, or recreation or hunting opportunities for which values may be imputed. There are great difficulties in attaching unit values, either market or imputed, to many of the outputs. Furthermore, it may be necessary to consider the distribution of costs and benefits among different social groups. In cases where some benefits, such as amenities and environmental quality are not quantifiable in monetary terms, the most feasible approach is to set minimal standards for the provision of those benefits and then to optimize the output stream of quantifiable benefits (USDA Forest Service, 1990b). Thus, the ultimate theoretical framework for forest resource analysis is the constrained maximization of social welfare or comparison of alternative states of the forest resource by means of Kaldor–Hicks types of compensation criteria.

While this type of theoretical framework is attractive to economists, policy-makers need operational guidelines to help them determine the degree to which the sustainable development concept will be useful in specific situations (Van Pelt, 1993). In this regard, Barbier et al. (1990) argue that sustainability can be given an economic interpretation by requiring that “no less than the current capital stock, in terms of its value, be passed on to future generations”. Howarth and Norgaard (1992) provide a useful analytical framework for examining trade-offs between preservation and current use in terms of intergenerational equity and economic efficiency.

### 3. Goals of sustained development

Types of sustained forest resource development goals and mechanisms for implementing them may be illustrated by examining policies and management strategies on the US National Forests. The goal of sustained yield of timber, and of maximum sustained yield, has pre-occupied the forestry profession for a century or more. Concern over the issue was first formalized in the US by passage of the Creative Act of 1891 and the Organic Administration Act of 1897 which established the National Forest system. Thereafter, reports by the USDA Forest Service periodically analyzed the issue of sustainability and long-term timber supply from both private and public lands (USDA Forest Service, 1933; USDA Forest Service, 1958; USDA Forest Service, 1973; USDA Forest Service, 1990a).

Mechanisms to ensure sustained development may appear in the form of physical targets to be achieved, as in the case of land management planning by the US Forest Service. The National Forest Management Act (NFMA) of 1976 mandated that decadal timber output shall not exceed the long-term sustained yield potential of each US National Forest above a certain size. This has been translated by administrative directive to require that planned timber output on a National Forest shall be on a ‘non-declining even-flow’ basis, meaning that output may rise from its current level to a plateau, represented by the sustained-yield potential of the forest, but may never decline. In recent years, however, many National

Forest plans have had to be revised to reduce planned timber harvests because of court findings, based on provisions of the NFMA, the National Environmental Policy Act or the Endangered Species Act, which favored the provision of amenities over commodity-based benefits and reduced the land base from which timber can be produced.

The NFMA language was chosen to meet a number of implicit or explicit social goals, including concern for stability of regional economies and of long-term timber supply from the National Forests. It also responded to a desire to minimize human disturbance of significant areas of the National Forests, on the grounds that natural ecosystems provide important benefits to society. This desire is an example of concern for sustainability (preservation) of a stock resource (natural ecosystems).

Development implies change from a current condition as a result of human intervention. Although groups favoring preservation of natural ecosystems have argued that it is a desirable social goal, some of them consider that any form of human intervention is unacceptable. Outright rejection of such intervention means that preservation of natural ecosystems cannot logically be included as a goal of sustainable development. However, acceptance of limited intervention as a tool to preserve a natural ecosystem would allow preservation to be considered as an appropriate goal.

Many other countries are similarly concerned about the optimal degree of trade-off between amenity and commodity values. For example, Canada and a number of its provinces face significant dilemmas when trying to devise policies that provide for a continuous and high level of timber output while protecting amenity values (Natural Resources Canada, 1994). Timber harvesting and manufacturing are a mainstay of many Canadian regions and any reduction in wood output can have serious economic consequences. Furthermore, large areas of Canadian forest are still untouched by timber harvesting and the issue of how much forest should be retained in wilderness status is being strongly debated. Retaining a large portion of existing untouched forests in wilderness may threaten the stability of regional economies, or even of the nation economy. On the other hand, heavy exploitation of existing untouched forests clearly will reduce the

prevalence of pristine ecosystems and some of the fauna and flora which constitute them.

In Western Europe the situation is somewhat variable. In Britain, forest plantations were established after World War II with the specific purpose of avoiding future timber supply shortages in the event of another major war. However, the Forestry Commission (1991) has recently noted that over the last several decades “the emphasis has widened from encouraging timber production to the provision of social and environmental benefits” in the context of sustainable management of its woodlands. Finland, Norway and Sweden face a problem similar to that of Canada because of the importance of the forest sector to their economies. However, unlike Canada, most of the Nordic forests have long since completed the transition from an old-growth condition to managed young-growth status. Thus the stability of their timber harvest levels does not depend on logging of untouched forest areas, and the debate over retention of natural forests is much less intense than in North America.

In Western Europe, in general, there have been increasing requirements in recent decades that more consideration be given to amenity values of the forest. This seems to have been accomplished without significantly affecting timber harvest levels. FAO (1986) used data through 1980 to develop ‘low’ and ‘high’ forecasts of timber output from European countries for 1990 and 2000. In almost all cases, FAO forecasts for 2000 were higher than those for 1990, implying sustainability of timber supply. Actual levels of output reported by Kuusela (1994) for 1990 have been within or close to the forecasted range for Europe as a whole and for most individual countries. Kuusela also reports that forecasts for 1990 made in 1980 of standing volumes of growing stock have tended to be under-estimates of actual 1990 volumes, with forecasted standing volume for Europe as a whole being about 92% of the actual 1990 level. This also suggests that, in general, European forests are on a sustainable basis.

#### 4. Sustainability of amenity values

Sustainable development as an abstract concept has widespread support but, in actuality, not all types

of sustained development meet with universal favor because it means different things to different people (Redclift, 1991). Controlling the flow of timber from young-growth forests to provide stable or increasing levels of employment, payrolls or raw material production appears to be acceptable, provided soil and forest productivity, water quality and amenity values are protected. The World Commission on Environment and Development (1987) partly recognized this when it said “Economic growth and development obviously involves changes in the physical ecosystem. Every ecosystem everywhere cannot be preserved intact”.

Protection of soil productivity and water quality is generally not difficult to achieve but it is virtually impossible to avoid short-term impairment of certain amenity values such as visual quality when timber is harvested. In particular, intense conflict may occur over the conversion of an old-growth forest to a young-growth one, especially when it is done by clear-cutting. The suddenness of the transformation, the change in the forest ecosystem with respect to both fauna and flora, and the uncertainty of the lay public about the future appearance of the landscape all contribute to the conflict. Even if the physical attributes of the former old-growth forest could be re-created with the passage of time its amenity values cannot be considered to be sustainable if the original forest had value precisely because it was pristine old-growth.

An interesting related question is the sustainability of demand for forest amenity values. Will future generations value these forest attributes more intensely or less intensely than current generations? The nature of future demand for wood products and substitute materials and changing tastes and preferences for them has been well studied (USDA Forest Service, 1990a). This is not so with respect to amenity values. Here the tendency has been to assume that current tastes and preferences for forest recreation will continue and that future use can be predicted by applying a fixed ratio of number of visits per million of population to population forecasts (USDA Forest Service, 1990b). As noted earlier, constrained maximization of social welfare provides the theoretical framework for concepts of sustainable development. Amenity values deserve consideration as one of the components of this framework.

## 5. Private forests

Because significant complexities, such as consideration of a wide spectrum of nonmarket values, are introduced by discussing public lands, it is preferable to clarify some major issues by focusing on the less complex case of sustainable development of private timber production, using California as an example.

Following the Second World War, efforts were made to have the federal government regulate timber harvesting on private lands. These efforts were defeated and individual states undertook the task, such as California with passage of its first Forest Practice Act in 1947. California's current forest practice regulations are among the most stringent in the world, with strict requirements for restocking after harvest, and protective measures to safeguard non-timber resources such as water quality and sensitive or endangered species (McKillop, 1993a). In spite of this, claims have been made recently in oral testimony before the California Board of Forestry that the state's private forests are not on a sustained-yield basis.

Determining whether the forests of a region such as California are or are not on a sustained-yield basis is not a simple matter. The state has almost 8 million acres of private timberland and 12 million acres of public forest that are capable of producing timber crops, in addition to 20 million acres of non-timber forest. Each of these forest areas is composed of an extremely large number of eco-types, few of which contain resources that are sufficiently high in value per acre to make it worthwhile to maintain accurate records of their physical condition. In some regions, where the forest stands are mostly even-aged and relatively homogeneous over large areas it is easier to collect and update resource inventory data, and project future harvest, growth and standing timber volume. Many California forest stands, however, are in an uneven-aged condition because they have been logged by selectively removing individual trees rather than by clear-cutting. This greatly complicates inventory and projection procedures and requires complex modeling techniques. The California Timber Supply model (McKillop and Krumland, 1989; Krumland and McKillop, 1990) projects the growth of individual trees for each stand-type under various management options (silvicultural and harvest regimes) by

computer simulation and controls the acreage of each stand type allocated to each regime by means of linear programming. Linear programming is also used to control future harvest flows in terms of volume and species composition.

The structure of the linear programming model is shown in Appendix A. Future versions of the model will permit choice of harvest levels and silvicultural regimes so as to maximize present net values. At the present time, economic influences are represented only to the extent that the model, on the basis of field experience and interviews with land managers and forest industry officials, was designed to portray as accurately as possible the effect on actual management decisions of market forces and investment and operating costs.

## 6. Employment and income goals

One of the explicit or implicit goals of those who advocate sustainable development is the maintenance of regional employment and income. Even if the volume of private logs destined for wood processing in each major California region could be maintained, employment and payrolls per unit of logs processed will decline as the wood processing industry converts from use of old-growth to young-growth timber. Some have advocated, with the ostensible goal of providing more jobs later, that owners of old-growth in California should be forced to reduce harvesting rates. But decrease in the current harvest of old-growth would lead to an immediate drop in employment levels and an increase in the harvest of fast-growing young stands. These young stands would provide more employment if harvested at a later date. A choice has to be made between (a) an immediate drop to a level that would be somewhat stable over the medium term, or (b) a somewhat steady decline over the medium term to a level will be no less than in (a). Arguments in favor of (b) are that it permits more efficient use of existing manufacturing capacity and that it allows the regional economy more time to diversify. Arguments made by proponents of (a) is that it provides a supply of high quality timber, albeit smaller quantities at higher prices, for a longer period of time and that it retains

more old-growth or late-seral forests in reserve status.

## 7. Static vs. dynamic stability

The more detailed issue is whether dynamic stability, rather than strict (static) stability, is permissible as an attribute of sustainability. Krumland and McKillop (1990) used their model to demonstrate that the annual aggregate volume of private timber harvest in each major region of California can be maintained for the foreseeable future at the 1978–1985 average level, provided forest practice regulations do not become significantly more restrictive. This result is illustrated for the Californian north coast in Fig. 1. Similar results were obtained for other major regions in the state. Their analysis showed that, although the aggregate timber output from forest industry holdings will decrease for the next twenty or thirty years before rising again, this decline will be offset by increasing harvests from non-industrial lands which had been previously logged in the 1940s and 1950s. Future long-term timber yields could be significantly higher than projected if owners were willing and able to invest in intensive silvicultural activities such as using genetically improved planting stock, suppressing competing vegetation or maintaining an optimal number of

trees per acre. Some individual private ownerships are on a non-declining flow basis because of past investment in intensive silviculture and acquisition of a balance of age-classes of timber, but this is not the usual case. In general, non-declining even-flow is achievable only for aggregations of properties.

Krumland and McKillop (1990) found that requiring decade-to-decade even-flow over 7 decades for all 2.7 million acres of private land in the California North Coast region would lead to virtually the same average level of conifer timber output than if even-flow was required only for the first 4 decades. The 4-decade model provided slightly higher levels of output in the first four decades and slightly lower ones in the last three. The size of the stock resource (volume of standing conifer timber) in the 4-decade model was never less than 97% of those in the 7-decade version, and the standing volume in decade 7 was the same for both versions. This is because greater timber harvesting in earlier decades permitted more rapid replacement of less vigorous timber stands by more vigorous ones.

## 8. Land base for sustainability

The issue of the size of land base to which concepts of sustainability should be applied is interesting both analytically and practically. California

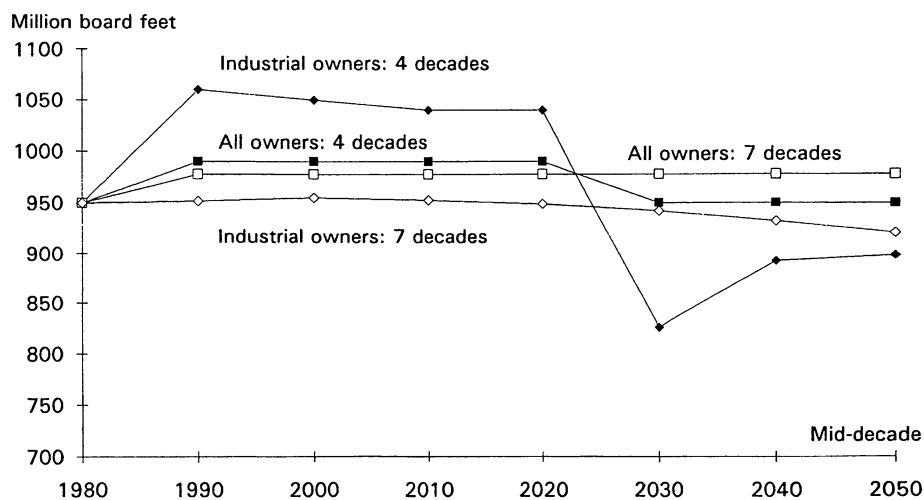


Fig. 1. North Coast total private conifer timber harvest by even-flow category of model.

provides a useful case study. Some persons have advocated that each private timber property, within each watershed in the state, should be required to be on a 'sustained-yield even-flow' basis with the decadal harvest approximately equal to the decadal growth, regardless of the current age-class distribution of the timber. This would have the effect of drastically reducing the timber output on individual management units or ownerships with mainly mature, slow-growing timber, particularly if the tract is stocked with intolerant tree species that require clear-cutting for successful regeneration and growth. The normal management regime for such tracts would be to harvest and regenerate the timber over a short period of time and then reharvest the tract 50 or 60 years later.

It can be readily demonstrated that if age-class distributions differ between ownerships, as they normally do, constraining harvesting on a property-by-property basis will result in a lower level of aggregate output from all ownerships combined. Figs. 1 and 2 illustrate for the Californian north coast that, for a 70 year planning period, the average harvest level was slightly lower and the ending-level of the total private resource stock (standing volume of timber) was 20% less when even-flow of output was imposed on industrial forest lands rather than on all private lands combined. The same type of effect will

occur if harvesting is restricted on a watershed basis when age-class distributions differ between watersheds, as is typical. So the question must be posed as to whether strict (static) stability over relatively small geographic areas is more desirable than a greater level of output that is statically stable for a region but only cyclically stable for individual ownerships or watersheds within that region.

Where sustainability of regional timber supply is a major concern, it is legitimate to consider whether the land base for sustainable development should be restricted to private lands, or whether both private and public lands should be included in it. This is particularly pertinent to California and other western states where the US Forest Service and the US Bureau of Land Management hold very large volumes of mature timber. Private timberlands tended to be logged first because they were closer to roads and markets. Until the last decade or so, there was a general expectation in the forest industries that public timber would be available for the next two or three decades to maintain total supply while private timber inventories were rebuilding. If timber production was a major objective on the California National Forests the level of sustainable timber harvest on them could be increased substantially. Over 9 million acres of these forests are capable of producing timber crops and contain more than 165 billion board

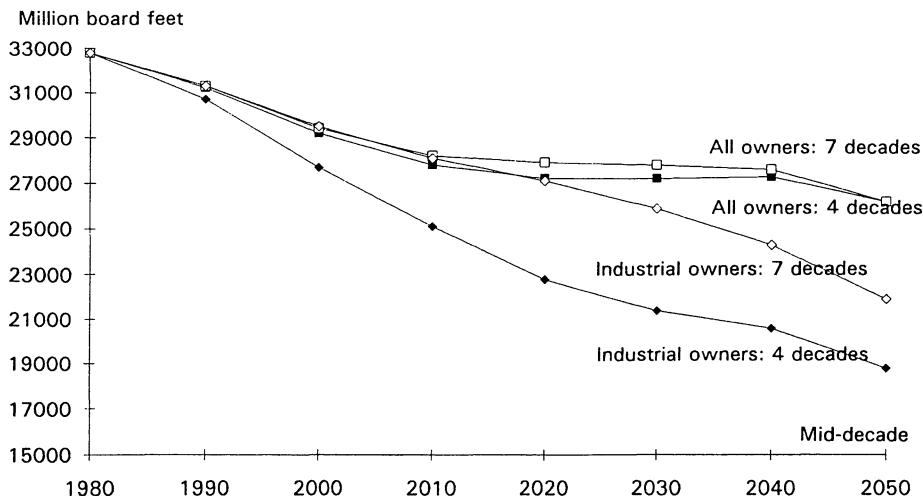


Fig. 2. North Coast total private conifer standing volume by even-flow category of model.



feet of standing timber. After excluding wilderness and reserved areas and areas which are close to watercourses or have unstable soils, the Forest Service has classified some 5.3 million acres of this 9 million acres, containing 95.5 billion board feet of timber, as 'capable, available and suitable' for timber harvesting. A conservative estimate of the growth of this 95.5 billion board feet is 2 billion per year after allowing for annual natural mortality which has been some 700 million in the recent drought years. The California National Forests sold an annual average of 1.7 billion board feet of timber over the 1980–1989 period. These figures are in sharp contrast to the 300 million board feet which the Forest Service is expected sell in each of the next several years while subject to recent court injunctions and legislative mandates (McKillop, 1993b). Thus, although the land and timber base would permit it, the recent level of sustainable output is precluded because of changes in priorities with regard to the use and purposes of the National Forests.

From a broad social viewpoint, choice of the land base to which sustainability criteria should be applied depends on the goal being pursued. If the intent is to maintain a representative set of forest ecosystems without concern for benefits vs. costs then the land base could conceivably be very small. If the intent is to provide stability of regional employment and income through timber production, without impairing the inherent productivity of the forest resource, the land base can be much larger. In California, for example, wood processors may find it profitable to procure logs from as far away as 200 miles from their mills. In this case the land base could encompass several million acres of forest in both public and private ownership.

## 9. Conclusion

Using California as an example it was demonstrated that sustainable development of private timber resources is feasible, region by region, when both industrial and non-industrial ownerships are included in the land base being analyzed. However, on the National Forests timber production has ceased to be a major goal because of the recent emphasis on ecosystem preservation and court decisions based on

the Endangered Species Act. The question remains as to whether sustainable development is a meaningful concept when applied to amenity resources. Human intervention in natural ecosystems, by activities such as vegetation management and protection from fire, insects and disease, can provide higher sustainable yields of water, populations of deer and certain other animals, various kinds of plant communities, and types of recreation that require improved access by roads or trails. Sustainable development of these types of amenity resources is clearly possible.

Even in the case of threatened or endangered species, it is entirely possible that well-planned human intervention in natural ecosystems could enhance the viability of populations of many such species by providing artificial or quasi-natural nesting habitats and food sources. However, when the goal is to preserve the natural ecosystem per se, human intervention is obviously counterproductive except, perhaps, if it is limited to the exclusion of severe external threats such as the frequent wildfires that periodically destroyed vast areas of forests in California and other states before large-scale protection programs were instituted.

The argument of the World Commission on Environment and Development (1987) that development is sustainable if the present generation can satisfy its needs without compromising the ability of future generations to meet their own needs is attractive, but it must withstand examination of the trade-offs involved in satisfying different kinds of needs. If the present generation, by modifying a particular set of natural ecosystems is able to provide future generations with greater endowments of capital or knowledge, or a larger set of undisturbed ecosystems of a different nature, it is not a foregone conclusion that it is socially optimal to sustain that particular set of ecosystems.

## Appendix A. Summary of linear programming structure

The structure of the linear programming module is shown below in its basic schematic form for the formulations that maximized conifer harvest volumes for industrial and nonindustrial ownerships combined.

### A.1. Symbols

- $HSO(T)$  Harvest volume of species  $S$  from ownership  $O$  in decade  $T$   
 $ISO(T)$  Standing volume of species  $S$  from ownership  $O$  in decade  $T$   
 $X(J)$  Acreage of stand  $X$  subjected to management option  $J$   
 $XA$  Total acreage available of stand  $X$

where  $T = 1, 2 \dots 7$  ( $1 = 1985$ – $1995$ ,  $7 = 2045$ – $2055$ ),  $S = C$  (conifer species) or  $B$  (broadleaf/hardwood species),  $O = M$  (industrial ownership) or  $N$  (non-industrial ownership) and  $TOPT$  is the length of quasi-maximization period (2, 4 or 7 decades).

### A.2. Objective Function

Maximize  $\sum_O \sum_T abHSO(T)$

for

- $O = M, N$   
 $T = 1 \dots 7$   
 $a = 1$  for  $T \leq TOPT$   
 $a = 0.1$  for  $T > TOPT$   
 $b = 1$  for  $S = C$   
 $b = 0.33$  for  $S = B$

### A.3. Acreage constraints

$$\sum_J X(J) \leq \sum XA \text{ for all } X$$

### A.4. Terminal inventory constraint

$$\sum_O ISO(7) \geq 0.80 \sum_O ISO(0) \text{ for } S = C, O = M, N$$

### A.5. Hardwood harvest constraint

$$\sum_O HBO(T) \leq 0.25 \sum_O HCO(T) \text{ for } O = M, N$$

### A.6. Harvest flow constraints

$$\begin{aligned} \sum_O HCO(T) &= \sum_O HCO(T-1) \text{ for } T = 1 \dots TOPT \\ \sum_O HCO(T) &\geq 0.75 \sum_O HCO(T-1) \text{ for } T > TOPT \\ \sum_O HCO(T) &\leq 1.25 \sum_O HCO(T-1) \text{ for } T > TOPT \end{aligned}$$

### A.7. Non-industrial harvest constraint

$$HCN(T) \leq 2HCN(T-1) \text{ for } T = 1 \dots TOPT$$

### A.8. Industrial harvest constraint

$$HCM(T) \geq 0.80HCM(0) \text{ for } T = 1, 2$$

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