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Title: Private Timber Supply Projections for Western Oregon and Washington: A Comparison with 1980 RPA Timber Supply Estimates

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The Timber Resource Analysis System (TRAS) was the timber supply projection model used in conjunction with the Timber Assessment Market Model (TAMM) to predict future U.S. softwood timber harvests, inventories and product prices in the 1980 RPA Timber Assessment conducted by the USDA Forest Service. Several criticisms of the TRAS model prompted the Forest Service to fund the development of the Timber Resource Inventory Model (TRIM), which will be used in the 1990 assessment. Unlike TRAS, TRIM has the ability to portray timber growth and management for individual groups of inventory acres, based on ownership, location, species and site characteristics, while allowing management intensities to fluctuate in response to predicted prices.

The purpose of this study is to compare results of

the TRAS projections for privately owned timberlands of the Pacific Northwest Westside region with three 50-year TRIM projections (1977-2027), which use TRAS/TAMM generated harvest volumes as harvest requests and Forest Service inventory figures. Projected harvests, inventories and age class distributions are compared, along with an analysis of changes in western Oregon and Washington's future harvest share.

TRAS/TAMM harvest levels on forest industry property could not be fully sustained in the TRIM simulations. Although the two TRIM simulations that included a prespecified amount of commercial thinning were only 1.5 percent short of the third decade's harvest request, inventories had to be cut back to minimum harvest ages. NIPF harvest levels were sustained in TRIM throughout the planning horizon. TRIM estimated that future inventories will drop until 2007, when they begin to recover from initially high harvest levels; whereas, TRAS shows inventories that drop sharply throughout the 50-year period.

The timber outlook is estimated to be one of sharply falling harvest volume on forest industry land, while NIPF lands maintain a steady, but much lower, harvest. Initial drops in inventory volume recover to levels similar to the 1977 inventory, although stands will become progressively younger. Washington dominates the region's harvest in the first decade, accounting for approximately 60-62 percent of harvest volume, but Oregon will show the largest harvest volume by 1997 (51-55 percent). Washington should again be harvesting the majority of volume by 2027; however, the state's harvest percentage will be slightly lower than the 1977 level with only 53-58 percent.

Private Timber Supply Projections for Western Oregon and Washington: A Comparison with 1980 RPA Timber Supply Estimates

by

Dennis D. Flick

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PRIVATE TIMBER SUPPLY PROJECTIONS FOR WESTERN OREGON AND WASHINGTON: A COMPARISON WITH 1980 RPA TIMBER SUPPLY ESTIMATES

I. INTRODUCTION

The most recent timber survey indicates that western Oregon and Washington have over 23 million acres of commercial timberland containing nearly 112 billion cubic feet of timber. Approximately 50 percent of this property, or 12 million acres, is privately owned, of which almost 11.3 million acres are available for timber production after urban property and land with very limited management potential is excluded. Forest industry lands account for 7.4 million acres and 24.4 billion cubic feet of merchantable timber. Another 3.9 million acres are classified as non-industrial private forests (NIPF) and contain 10.3 billion cubic feet of timber (USDA Forest Service, 1982).

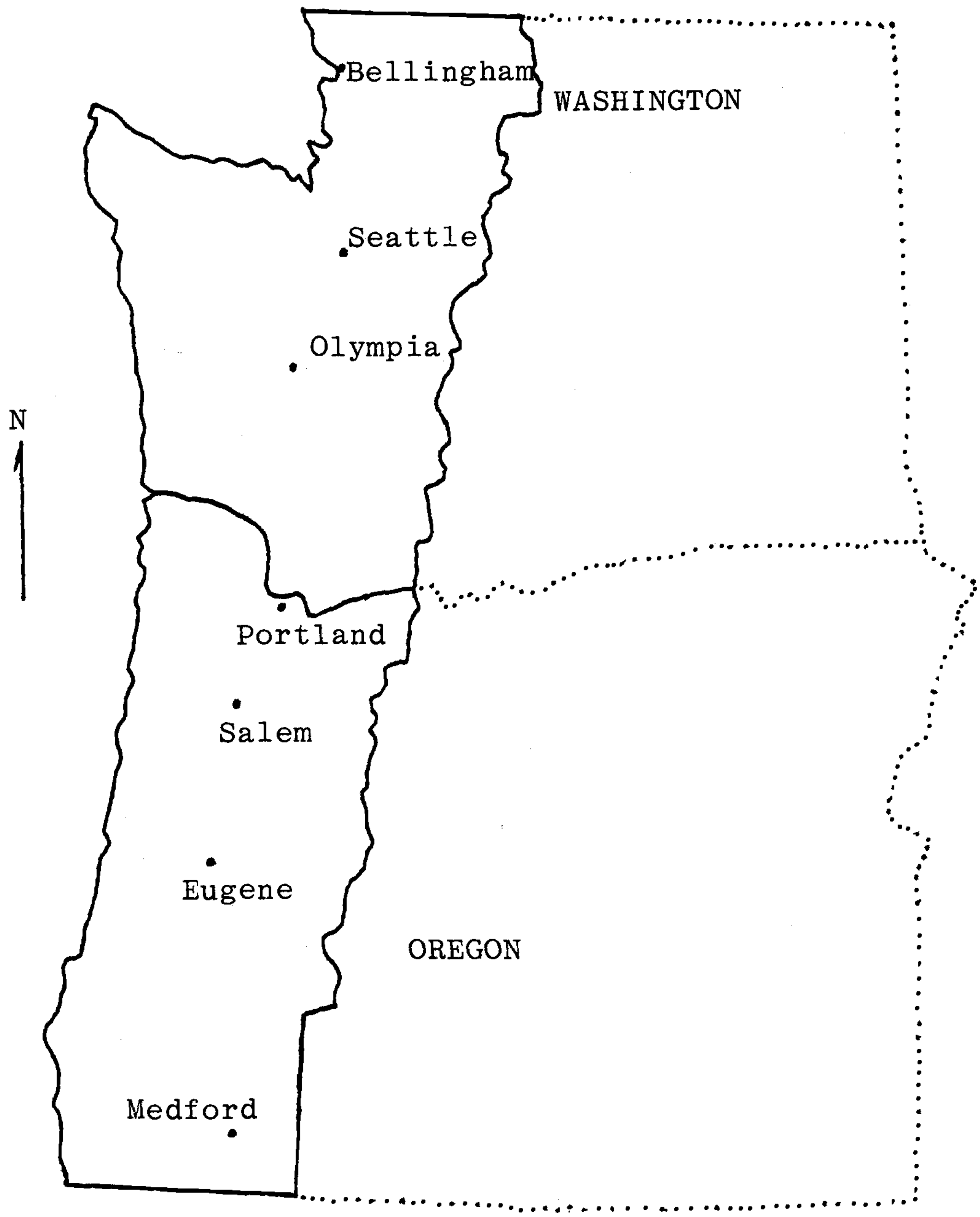
Well informed management decisions concerning these resources are essential to the economy of the region, as standing timber value could well be in the tens of billions of dollars. Timber inventories and supply projections help to measure the potential outcome of current and future timber management decisions and policies. Federal and local governments employ timber supply projections to help direct public forest policy, which may be concerned with improving economic stability, regulating tax incentives, estimating tax revenues from future timber harvests, or predicting future employment levels. Timber products companies use timber supply projections to help determine regional priorities for purchasing and selling timberlands and for economic analysis concerning mill establishment, renovation, or closure.

The geographic area dealt with in this study includes all of Oregon and Washington west of the crest of the Cascade range, as seen in Figure 1, and will be referred to as the Pacific Northwest Westside (PNWW). This region approximates what has been generally called the Douglas-fir subregion and is bounded on the south by California, on the west by the Pacific Ocean, and on the north by British Columbia. There have been several timber supply projections of varying detail which include all or part of this area. The "Douglas-fir Supply Study", was restricted to Forest Service timberlands in the PNWW and northwest California (USDA Forest Service, 1969). The detailed study published as "Timber for Oregon's Tomorrow" was undertaken for all ownerships and dealt with individual timbersheds within the state of Oregon (Beuter et al, 1976). The Timber Resource Economic Estimation System

Figure 1. Map of Oregon and Washington highlighting the PNWW

——— boundaries of the PNWW

.... other state boundaries



(TREES) was the computer model developed for the latter study's supply projections and has since been used by many agencies and corporations (Tedder et al, 1983). As the title of the model implies, it has the ability for economic as well as bioligical analysis of predicted timber supplies. TREES was also used for the timber supply projections in the Forest Policy Project, which included all ownerships in Oregon, Washington and Idaho and addressed several timber related issues (Pacific Northwest Regional Commission, 1980).

Periodic evaluations of present and future timber supplies have been undertaken by the federal government in some form since 1876, as directed in the Renewable Resources Planning Act of 1974. Section 3(b) of the Renewable Resources Research Act of 1978 states the directive to "...make and keep current a comprehensive survey and analysis of the present and prospective conditions of ....the renewable resources of forests and rangelands of the United States". The next RPA timber assessment will be in 1985, while the most recent was completed in 1980. The purpose of the assessments, according to the directive noted above, is the "...determination of ways and means needed to balance the demand for and supply of these renewable resources, benefits and uses in meeting the needs of the people of the United States" (USDA Forest Service, 1982).

Timber supply projections for the 1980 assessment were made by employing the Timber Resource Analysis System (TRAS) (Larson and Goforth, 1974). This model was used in conjunction with the Timber Assessment Market Model (TAMM), which is a "...spatial model of North American softwood lumber, plywood, and stumpage markets designed to provide long-range projections of price, consumption, and production trends" (Adams and Haynes, 1980). The two models work together to find equilibrium levels of production and price by allowing the supply of available stumpage on private land in TRAS to interact with stumpage demand in TAMM. All owners and timberland in the United States were included in the projection, while timber supplies imported from Canada were handled exogenously. Timber supplies were broken down into nine geographic regions, one of which was the PNWW.

In the TRAS model, the timber inventory is grouped into 2-inch diameter classes, and each diameter class is assigned a prespecified rate of radial growth. Net change is then calculated as the ingrowth of stems into higher diameter classes less removals and mortality, while regeneration is accounted for by ingrowth of a prespecified number of stems into the 2-inch diameter class. Volume is calculated by multiplying the number of stems in each diameter class by corresponding net cubic-foot or board-foot volumes per tree. Output values show the number of trees, mortality, removals and net growth (Larson and Goforth, 1970). In the 1980 assessment the stand described in the model was a composite of all the stands for each owner averaged across all the different age classes, forest types, stocking levels and site classes.

There has been criticism concerning the way timber inventory information was aggregated in TRAS for the 1980 RPA Timber Assessment and the appropriateness of using TRAS for modelling national timber supply. One of these concerns is that the aggregation of site characteristics into a single representative stand for each owner group is much too broad, hampering the ability of the model to single out specific stand types in order to accurately portray each stand's growth or changes in growth due to a shift in management intensity. In addition, Tedder (1983) noted that "...alternative types of management intensification couldn't be examined, since TRAS allowed modelling of only one set of management intensities at a time". The model has also been criticized for its inability to accurately simulate the growth of even-aged stands (Tedder, 1982), which is widely recognized as the current or long-range management objective for conifer wood production in the PNWW (MacClean, 1980). This same concern was also expressed for the rapidly changing forests of the Southeast (Brooks, 1983). Finally, the output information, though basically appropriate for national projections, couldn't be segregated by the individual states of Oregon and Washington.

In response to these problems, the Forest Service has funded the development of the Timber Resource Inventory Model (TRIM) (Tedder et al, 1983), a yield table projection system to be used with TAMM in the 1990 RPA Timber Assessment for the PNWW, Pacific Southwest, Southeast, and Southcentral regions. Using TRIM, the inventory is grouped into ten-year age classes, and growth is associated with the projected yields of well-stocked, even-aged stands, which are segregated according to region, owner, species, site class or other significant parameters that affect expected stand growth and management. In addition, stands may be shifted between various input management intensities within each stand type without losing the identity of the shifted acreage, thus allowing the user to inexpensively determine the effects of management intensity shifts due to changes in forest policy.

The basic objectives of this study are to use TRIM for projecting timber supplies of the private sector of the PNWW for comparison with the timber supply estimates generated by TRAS and TAMM in the 1980 RPA Timber Assessment and to outline the results of the TRIM simulations. These objectives will be stated more completely in Chapter II. Chapter III describes management and growth assumptions for each projection and the procedure for preparing the necessary input information. It also includes a discussion of potential problems that could be encountered using this type of simulation model. Chapter IV describes the timber inventory as of 1977 and results of the projections, while chapter V discusses the significance of the results and presents suggestions for future research.

II. RESEARCH OBJECTIVES

The basic reasons for conducting RPA timber assessments are to predict future national and regional timber supply and to evaluate the effects of forest management changes on timber supply. Product price and government forest policy are two essential variables that are examined for their effects on management levels of timberlands in the private sector. Timber management response to price and policy is based on changes in costs or revenues incurred by owners of private timberland. The projection model used in these assessments must be able to realistically and accurately portray owner reactions over time, and predict their effects on such things as harvest level, average tree size, inventory volume, age distribution and growth.

In the past TRAS estimated the timber inventory volumes used in TAMM, which generates annual economic equilibriums of harvest and product price levels, based on regional supply and demand relationships (Adams and Haynes, 1980). In the stumpage market sector of TAMM, stumpage supply is set equal to stumpage demand, which is derived from information such as total product demand, manufacturing costs and transportation costs. The model assumes that short run timber supply in the private sector is a function of stumpage price and quantity of available inventory. Thus periods of high equilibrium stumpage prices lead to cumulative inventory depletion. It is also assumed that owners of timberland are economically rational and will choose the level of management intensity that maximizes the present net worth of their net returns. Management intensity, in turn, directs long run timber supply, such that periods of management intensification lead to inventory accumulation, higher harvests and lower stumpage prices.

The use of TRAS creates several problems and uncertainties, however, as it is difficult to portray management changes accurately, and management intensities aren't free to adjust to prices after the simulation process has begun (Tedder, 1983). TRAS simulates growth by the use of one representative acre for each owner and region. As mentioned earlier, this acre is the aggregate of all species, site and management classes. Management changes are more likely to occur for some stand types than for others, and biological response to management changes also varies considerably by stand type. Therefore, the portrayal of predicted management intensity changes and their corresponding responses for each different stand type is virtually impossible to model in TRAS. Past procedure has been to merely adjust prespecified radial growth rates for the representative acre to account for an estimated overall change in growth. This procedure is unrealistic and limits the ability of users to visualize complex growth and management relationships, as they would occur in each stand type.

TRAS also doesn't allow management intensities to change in response to price level changes after the simulation process has begun. Since shifts in management intensity must be prespecified, users must make several runs, while continually observing projected prices and adjusting management levels. The required procedure is both costly and tedious.

The developers of TAMM recognized TRAS's severe limitations for projecting inventories and recommended that TRAS be replaced with

> " an age class-based system for softwoods in the West and South (and possibly the North) to facilitate simulation of the biological effects of changes in management and of policies that influence management intensity" (Adams and Haynes, 1980).

The USDA Forest Service funded the development of TRIM, which would produce the desired inventory information without being hampered by problems encountered in the use of TRAS. TRIM will be compatable for use with TAMM and will be used for the regions listed in the 1990 RPA timber assessment, as listed in Chapter I. Inventory information is aggregated into individual units for similar stand types and owners. Growth and management can be controlled for each unit, making TRIM much more straight forward than TRAS. Management intensity can be shifted within a simulation based on the effects of TAMM generated prices, which are used to calculate soil expectation values for up to five management regimes. Acres found within prespecified eligible age classes are then shifted into the management intensity with the highest soil expectation value.

The primary objective of this study is to compare projected softwood timber supplies, growth, and harvests of the 1980 RPA TRAS/TAMM projection with three TRIM projections for privately owned commercial timberlands of the PNWW. Comparisons will be made at ten-year intervals beginning in 1977 and ending in 2027. Softwood harvest levels generated by TRAS/TAMM will be used as harvest requests in the TRIM computer runs to determine if they can be sustained throughout the projection horizon. The three TRIM projections will vary according to the level of management intensity and the presence or absence of commercial thinning in the base management regime.

In addition to the primary objective of using TRIM projections for comparison with the TRAS/TAMM estimates, information found in the three TRIM runs is evaluated as possible outcomes of future timber supplies. The current timber inventory is described, while predicted inventory volumes and age class distributions are evaluated at each ten-year interval. Harvest volumes sustainable in the TRIM runs are compared with TRAS/TAMM estimates, and the effects of management intensity changes on harvest and inventory are analyzed, along with the change over time of each state's share of the harvest. Finally, the determination of values for the input parameters necessary for the three TRIM simulations and problems encountered using this type of projection model are discussed, and suggestions for future research are presented.

III. PROCEDURE

A description of the three TRIM simulations and the various management intensities used in these simulations are found in Tables 1 and 2 respectively. The purpose of the different simulations is to create lower and upper boundaries for a range of growth and harvest potential. More specifically, they are meant to demonstrate a possible range of outcomes based on commercial thinning and management intensity. Commercial thinning has a very important impact on available harvest volume in the short run, as it accounts for a substantial portion of the total harvest. In addition, it frees more acres above minimum harvest ages to continue growing, while thinned acres regain much of the volume harvested due to increased growth. An increase in management intensity, when combined with commercial thinning, will have the same effects listed above; however, the impact on harvest of a management shift is normally not seen for at least two to four decades (when stands reach sufficient size for commercial thinning), since management intensity changes in these projections occur at regeneration. So the primary impacts

TABLE 1. Description of management practices for the three TRIM projections

RUN 1 Low management / No commercial thinning

1. Management Intensity 1 (MI1) used for all acres in the initial inventory (no commercial thinning represented)
2. No shifts in management intensity
3. No hardwood and unmanaged acreage conversion
4. No regeneration of unstocked acres
5. Stands regenerated after final harvest are assigned stocking percentages based on the average percentage of young stands for each Grouped Resource Unit (GRU)

RUN 2 Low management / Commercial thinning

1. MI1 and MI2 (base management with commercial thinning) used in the initial inventory
2. No shifts in management intensity
3. No hardwood and unmanaged acreage conversion
4. No regeneration of unstocked acres
5. After final harvest, MI1 acres are assigned stocking percentages based on the average stocking of the young stands remaining in MI1 in the initial inventory. MI2 acres are regenerated at an 80 percent stocking level.

RUN 3 High management / Commercial thinning

1. MI1 and MI2 used in the initial inventory
2. MI1 and MI2 acres are shifted to MI3 (includes the use of genetically improved seedlings, commercial thinning, and fertilization) upon regeneration at prespecified rates per decade, depending on the ownership, species, and site class
3. Hardwood and unmanaged acres are converted to conifer management upon regeneration at prespecified rates, depending on the ownership and site class
4. Remaining unstocked acres are regenerated at a rate of 50 percent per decade
5. After final harvest, MI2 and MI3 acres are regenerated at a stocking level of 80 percent, while acres remaining in MI1 are regenerated at stocking levels based on the average stocking percentage of young stands found in MI1 in the initial inventory

Table 2. Description of management intensities for each stand type

Douglas-fir

MI1 300 planted seedlings per acre
no further action

MI2 300 planted seedlings per acre
commercial thinning
high site class
ages 30 and 40
residual square feet of basal area 100
d/D ratio 1.00
medium site class
ages 40 and 50
residual square feet of basal area 100
d/D ratio 1.00
low site class
age 50
residual square feet of basal area 80
d/D ratio 1.00

MI3 300 planted genetically improved seedlings per acre
commercial thinning (see MI2)
fertilization
200 lbs. of nitrogen per acre after each thinning

Western Hemlock

MI1 fully-stocked natural stand

Hardwood and Unmanaged

MI1 volume weighted average of Douglas-fir (MI1) and natural fully stocked alder stands

MI2 conversion to conifer management (Douglas-fir MI2) of a shift in management intensity are long range, affecting inventory volumes three or four decades later and final harvest volumes well past the projection horizon.

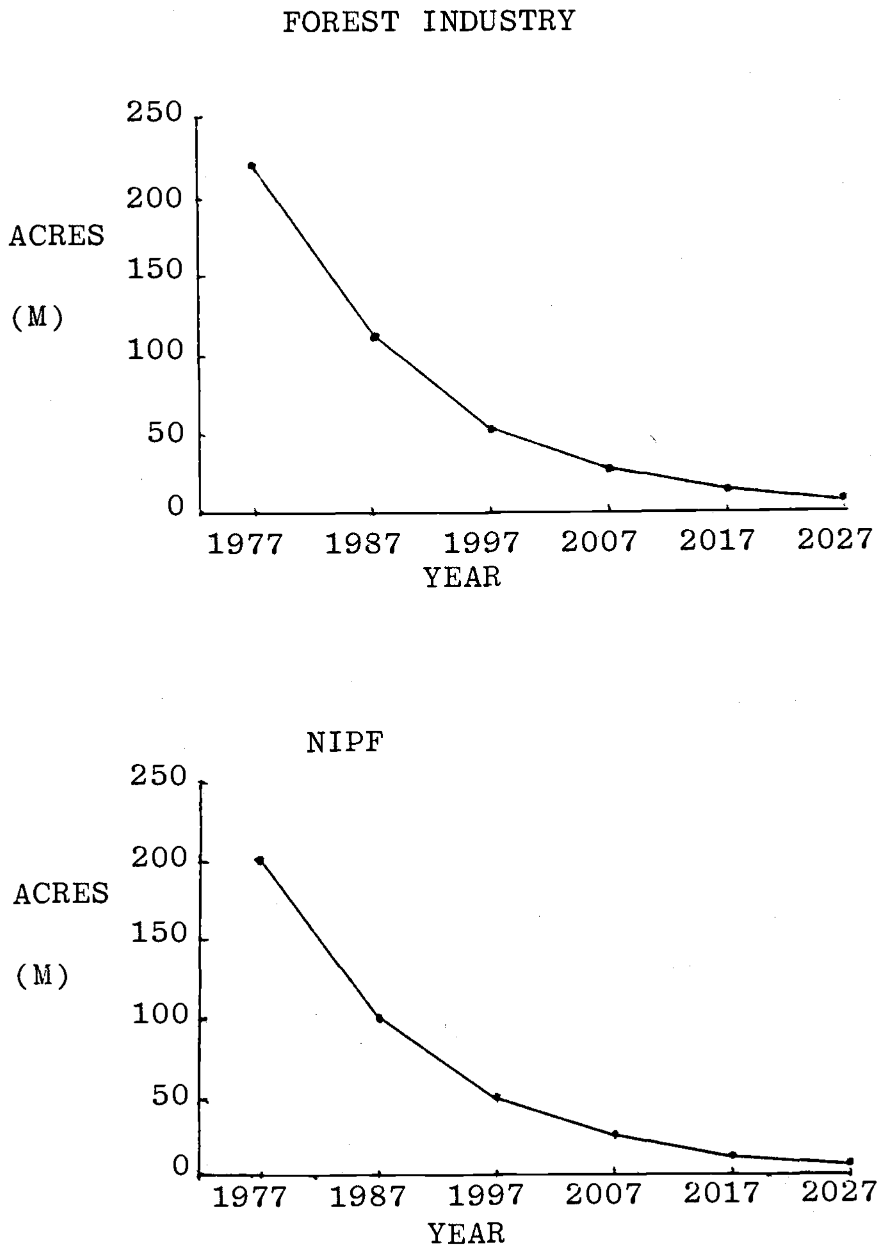
The first TRIM projection is the base run, which is meant to reflect the lower end of the range of management, harvest and growth potential. It assumes all acres are managed without commercial thinning, fertilization, genetically improved seedlings, or other silvicultural prescriptions normally associated with intensively managed stands. The yield functions used are based on stands planted with 300 seedlings per acre for acres classified as Douglas-fir and fully-stocked natural stands for western hemlock and hardwood acres. Stands are regenerated at levels which reflect average stocking percentages of current young stands, while unstocked acres found in the initial inventory are never restocked. In addition, no acres are allowed to shift to higher levels of management. This simulation is meant to represent the growth of stands at low management levels (but not necessarily lower than the level of past management practices) and to represent the zero level for the range of commercial thinning in low level management.

The second run was meant to illustrate the upper boundary for the range of outcomes using commercial thinning but without major increases in management intensity and the lower boundary of outcomes for increased management intensities with commercial thinning. In other words, it reflects a middle range of growth and harvest potential. No management shifts were allowed within this run, but the initial inventory was divided into two basic levels of management which were dependent on the expected inclusion of commercial thinning. This allowed certain acres to be placed in a thinning regime from the outset of the run. By far the most commercial thinning in the private sector of the PNWW takes place on forest industry lands. All Douglas-fir acres in the high and medium stocking levels and site classes were transferred to a thinning regime, accounting for approximately 47 percent, or 3.5 million acres of all forest industry property. NIPF acres in the highest stocking level of high and medium site classes were transferred to a thinning regime, which accounted for 7 percent, or 0.3 million acres, of all NIPF land. This compares with commercial thinning estimates used for the simulations in "Timber for Oregon's Tomorrow" of 57 percent of Oregon's westside timberlands in forest industry ownership and 7.5 percent of the NIPF timberlands (Beuter et al, 1976). No management intensity shifts beyond the initial redistribution of thinning acres were allowed for this simulation, and no unstocked acres were regenerated. This simulation is basically identical to the first run with the exception of the redistributed thinning acres.

The third run illustrates the highest potential for growth and harvest of all three projections, and it forms the upper boundary for the range of management intensities. It includes the initial redistribution of commercial thinning acres, and 50 percent of remaining unstocked acres are regenerated each decade, as seen in Figure 2. In addition, hardwood and unmanaged acres are shifted to conifer management with commercial thinning, which is done for 100 percent of forest industry acres in the high and medium site classes and 50 percent of the NIPF acres in these site classes. Also, Douglas-fir acres are shifted to the highest of the three management intensities, which includes planting with genetically improved seedlings, commercial thinning, and fertilization. High and medium site class acres are shifted at a rate of 40 percent of all harvested acres in the first decade, 60 percent in the second decade, 80 percent in the third, and 100 percent in the final two decades. Low sites were shifted after harvest to the standard management intensity with commercial thinning at the same above rates. NIPF acres in high and medium site classes were shifted at a rate of 20 percent of all harvested acres in the first decade, followed by 30, 40, and then 50 percent in the final two decades.

The three basic sets of information that must be provided to make timber supply projections with TRIM are

Figure 2. Unstocked acreage for Run 3



inventory, growth, and harvest information, which are named the Basic Resource Unit (BRU), Grouped Resource Unit (GRU), and Allowable Cut Unit (ACU) respectively. The following sections contain a discussion of all the more important parameter calculations and the problems encountered with their determination.

THE BRU FILE

The BRU file contains the original inventory information. The data used for these projections is taken from the Forest Service's Renewable Resources Evaluation inventory, which was based on a 3.4 mile grid of field plots on all ownerships throughout the PNWW (Jacobs, 1976). The inventory used in TRIM is aggregated according to classifications such as location, ownership, species and site, which are descriptive codes for each BRU. Within each BRU the values for acres and volume per acre are found for each of eighteen ten-year age classes, three stocking levels and two management intensities. The ten-year age classes range from 0, which represents stands ages 0 through 9, to age class 17, which contains all stands older than 170 years old. In addition, an acreage value is listed for unstocked timberland.

The inventory for western Oregon is aggregated by ownership, subregion within the state, site class, and a code indicating the presense of some form of management. The three site classes were originally grouped using 100-year Douglas-fir site index classes (McArdle et al, 1961) as follows:

High site	165+
Medium site	105-164
Low site	<105

These were later converted to 50-year site indexes for calculation of growth and yield (King, 1966).

The western Washington inventory was classified by ownership, species, site index and a code identifying stands where timber production would most likely be the primary objective or of secondary importance (the latter being urban and suburban classifications). The 123,000 acres of timberland in the urban classification were dropped from the analysis, as they were assumed to be managed for purposes other than timber production and would have an insignificant effect on timber supplies. Suburban timberlands represented a much larger acreage and were retained for the projections; however, these acres were never considered for shifts to higher management levels, as it was assumed that management intensity would remain the same throughout the projection horizon. One hundred year site index classes (Barnes, 1962) were used to group Washington's western hemlock stands in the same manner as Douglas-fir and then converted to 50-year site indexes for growth and yield calculations.

Volume per acre was adjusted for stands in the 0 and 1 age classes for high and medium sites and 0, 1 and 2 for low site class stands. These ages represent stands that are not yet merchantable according to pure even-aged management yield tables used for projecting growth. Actual volumes reported for these age classes were very erratic and probably represented low value residual trees following final harvest. The new volumes per acre were based on Forest Service stocking percentages that were determined in the inventory process, as described by MacLean (1979). These volumes were set at levels which corresponded to low artificial yields put into the yield table's nonmerchantable age classes. This held reported volume to a minimum, while allowing stocking to determine volume per acre when these stands reached merchantable size. While this adjustment would predict future inventory volume and growth more accurately, the initial inventory was underestimated by approximately 3.5 percent, as total softwood volume dropped from 28.4 to 27.4 billion cubic feet.

In addition to dropping urban acres from the TRIM simulations, all acres classified as marginal were excluded from the analysis. Acreage exclusions and losses are illustrated in Figure 3 and Table 3 and compared with NIPF acreage changes used for the TRAS/TAMM projection

Table 3. Projected Timberland acreage changes for the PNWW

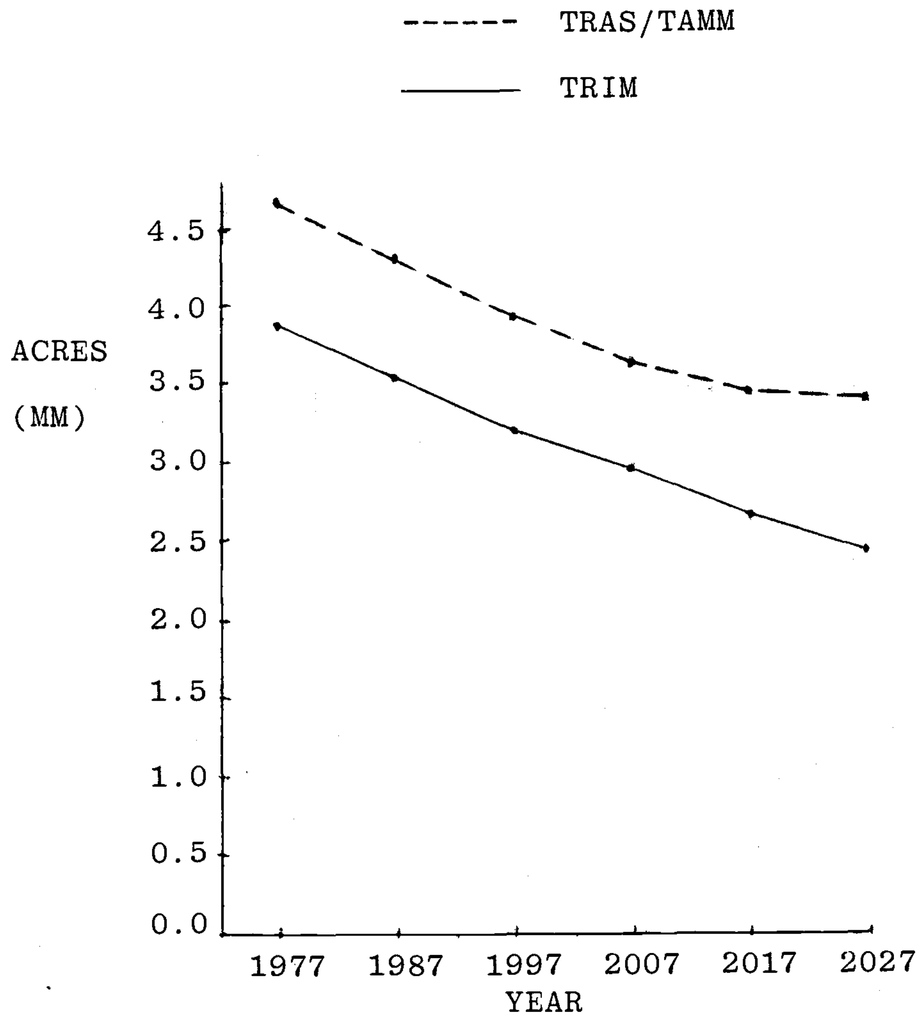
TRAS

YEAR	FOREST INDUSTRY ACREAGE (M)	FOREST INDUSTRY PERCENT CHANGE	NIPF ACREAGE (M)	NIPF PERCENT CHANGE
1977	7488		4671	
1987	7498	0.1	4293	-8.1
1997	7512	0.2	3925	-8.6
2007	7504	-0.1	3653	-6.9
2017	7449	-0.7	3477	-4.8
2027	7402	-0.6	3374	-3.0
TOTAL % CHANGE		-1.1		-27.8

TRIM

YEAR	FOREST INDUSTRY ACREAGE (M)	FOREST INDUSTRY PERCENT CHANGE	NIPF ACREAGE (M)	NIPF PERCENT CHANGE
1977	7392		3891	
1987	7392	0	3538	-9.1
1997	7392	0	3220	-9.0
2007	7392	0	2932	-8.9
2017	7392	0	2671	-8.9
2027	7392	0	2435	-8.8
TOTAL % CHANGE		0		-37.4

Figure 3. NIPF timberland acreage for the PNWW



(acreages for all comparisons include unstocked land). Marginal acres aren't expected to be producing significant volume in the future, as they currently contain very low volumes and are generally located on sites unsuitable for timber production. Also, NIPF acreage is shifted out of the stocked acreage inventory at a rate of one percent annually, or 9.56 percent per decade, reflecting historical losses to the timberland base to other uses, such as the construction of roads and residential areas or conversion to other agricultural uses. This rate of acreage loss was also used in the Forest Policy Project simulations (Pacific Northwest Regional Commission, 1980), and compares to an actual declining acreage loss for all private ownerships of 14,100 acres annually during the period between the 1961-62 inventory and the 1973-76 inventory for western Oregon (Gedney, 1981). This net loss is based on a 19,400 acre gain in forest industry property and a loss of 33,500 acres to the NIPF land base. When the net loss is applied to NIPF property of western Oregon, the resulting annual loss of stocked acreage is approximately 0.8 percent or 7.7 percent per decade. The initial acreage gap between the inventories used in the TRAS/TAMM and TRIM simulations can be seen in Figure 3, as the NIPF ownership accounted for a high percentage of all marginal and urban acres. Forest industry acreage only changed about one percent over the entire 50-year horizon in the TRAS/TAMM projection, while these acres were held constant in TRIM.

THE GRU FILE

The four primary functions of the GRU file discussed in this section are to calculate (1) growth, (2) regeneration levels, and (3) available harvest volumes and to (4) shift acres between various management intensities or out of the land base. This is done for groups of BRU's that are expected to have similar growth and management characteristics. There are 12 separate GRU's for western Oregon with three site index classes, identification of management as present or absent, and ownership divided into forest industry (FI) and other private (OP) as follows:

FI - Managed - High site
FI - Managed - Medium site
FI - Managed - Low site
FI - Unmanaged - High site
FI - Unmanaged - Medium site
FI - Unmanaged - Low site
OP - Managed - High site
OP - Managed - Medium site
OP - Managed - Low site
OP - Unmanaged - High site
OP - Unmanaged - Medium site
OP - Unmanaged - Low site

Western Washington contains 22 GRU's aggregated according to ownership, site class and species. They are also classified as being primary timberland (T) or secondary and suburban timberland (S) as follows:

FI	T	Douglas-fir	High site
FI	T	Douglas-fir	Medium site
FI	T	Douglas-fir	Low site
FI	T	Western hemlock	High site
FI	T	Western hemlock	Medium site
FI	T	Western hemlock	Low site
FI	T	Hardwoods/unmanaged	High site
FI	T	Hardwoods/unmanaged	Medium site
FI	T	Hardwoods/unmanaged	Low site
OP	T	Douglas-fir	High site
OP	T	Douglas-fir	Medium site
OP	T	Douglas-fir	Low site
OP	T	Western hemlock	High site
OP	T	Western hemlock	Medium site
OP	T	Western hemlock	Low site
OP	T	Hardwoods/unmanaged	High site
OP	T	Hardwoods/unmanaged	Medium site
OP	T	Hardwoods/unmanaged	Low site
OP	S	Douglas-fir/hemlock	High site
OP	S	Douglas-fir/hemlock	Medium site
OP	S	Douglas-fir/hemlock	Low site
OP	S	Hardwoods/unmanaged	All sites

The following paragraphs will contain a discussion of how the more important variables in the GRU file were calculated, what assumptions were made in their determination, and what problems were encountered with their use.

Growth.

Growth from one period to the next is based on input yield table values for each GRU and management intensity. The determination of appropriate growth and yield values is complicated by the wide spectrum of volume specifications and conflicting yield values found in the various publications. The process of locating desirable tables was aided by the use of the publication, "A Key to the Literature on Forest Growth and Yield in the Pacific Northwest: 1910-1981" (Hann and Ritters, 1982).

The DFSIM stand simulator (Curtis et al, 1981) was used to represent growth and yield for all Douglas-fir acres. It should be noted that the authors acknowledged that limited data was available for plantations more than 40 years old, and that past management practices in stands used in the data base were not necessarily as effective as present and future management practices, which may cause the model to somewhat underestimate growth and yield values for intensively managed stands (Curtis et al, 1982). Yield table values for western hemlock stands were based on yields of natural stands as determined by Wiley and Chambers (1981) and Chambers and Wilson (1978). These values represented fully-stocked natural stands with only one level of management intensity, since information concerning intensively managed stands of western hemlock is almost nonexistant. Hardwood and unmanaged stands were based on a mixture of alder yield tables (Chambers, 1974) and Douglas-fir yields. These mixed volumes were weighted by the corresponding percentages of hardwood and conifer volume found in the initial inventory for each GRU. Conversion of hardwood and unmanaged stands to conifer management was represented by using the mid-level management regime for Douglas-fir.

Merchantable cubic foot yield table volumes represented the growth of "well-stocked" natural or planted stands (depending on species and management intensity) for stems with a DBH of at least 5.6 inches up to a 4 inch diameter top. As shown in Table 4, actual volume per acre for each age class within a GRU is divided by the corresponding yield table volume to produce a ratio that can be thought of as a stocking percentage; however, it is recognized that the yield table volumes don't necessarily represent stands with 100 percent stocking. Bennett (1980) illustrated that such terms as "well-stocked", "normal stocking" and "fully-stocked" have never been determined and their representative yield values conflict depending on whose yield tables are being used. So even though the term "stocking percentage" will be used throughout this paper, it is simply meant to denote the ratio between actual and yield table volumes, which is used to calculate growth and the resulting volume per acre reported in the next period's inventory. Stocking percentages are adjusted for a stand's approach to normality based on the assumption that understocked stands tend to increase in stocking over time, while stocking decreases in overstocked stands. The calculation is based on the formula used in "Timber for Oregon's Tomorrow" (Beuter et

Table 4. Example of growth using TRIM

GRU = Western Washington, Forest Industry, Douglas-fir,
Medium site class
Management Intensity = 1
Stocking level = 2
Age class = 4 (40-49 years)
1000 acres
Period 0 = 1977
Actual volume (CF/AC) = 3000
Yield table volumes (CF/AC)
Age class 4 (midpoint age 45) = 5310
Age class 5 (midpoint age 55) = 7535

1977

1. 3,000,000 CF reported in inventory

2. Calculation of stocking percentage
Actual volume / Current Age Class Yield Table Volume = Stocking %
3000 / 5310 = .565

3. Adjustment for the approach to normality
0.11 + (0.9 * Old stocking %) = New stocking %
0.11 + (0.9 * .565) = .6185

4. New volume reported in the 1987 inventory
Stocking % * New Age Class Yield Table Volume * Acres = New Volume
.6185 * 7535 = 4660 CF/acre * 1000 acres = 4660000 CF

al, 1976).

$$0.11 + (0.9 * S) = AS$$

where: S = the original stocking percentage
AS = the adjusted stocking percentage

Adjusted stocking percentages are then multiplied by yield table volumes of the next oldest age class to estimate the volume per acre reported for the following decade.

Yield table values weren't based on actual volumes found in the inventory, because many stands had been thinned or partially cut. The use of these values would drive down volumes in the middle and upper age classes by predicting supply levels that fail to account for volume lost to prior harvests. This can be seen in Figure 4, where DFSIM yields for natural and planted medium site stands are plotted along with actual volumes per acre (after being adjusted by their corresponding Forest Service stocking percentage values to represent 100 percent stocking). Figure 5 illustrates the erratic average volumes per acre for each age class.

After the projections were made, average growth was compared with other sources to determine its acceptability. Forest industry acres in TRIM simulations showed an average of 91.1 cubic feet of softwood growth per acre per year for the first decade, while NIPF growth was 69.6. Using Forest Service inventory figures, Gedney (1982)

Figure 4. Actual volumes (adjusted to 100 percent stocking) for medium site class Douglas-fir in western Oregon and DFSIM yields (site index 109) for a well-stocked natural stand and a stand planted with 300 seedlings per acre

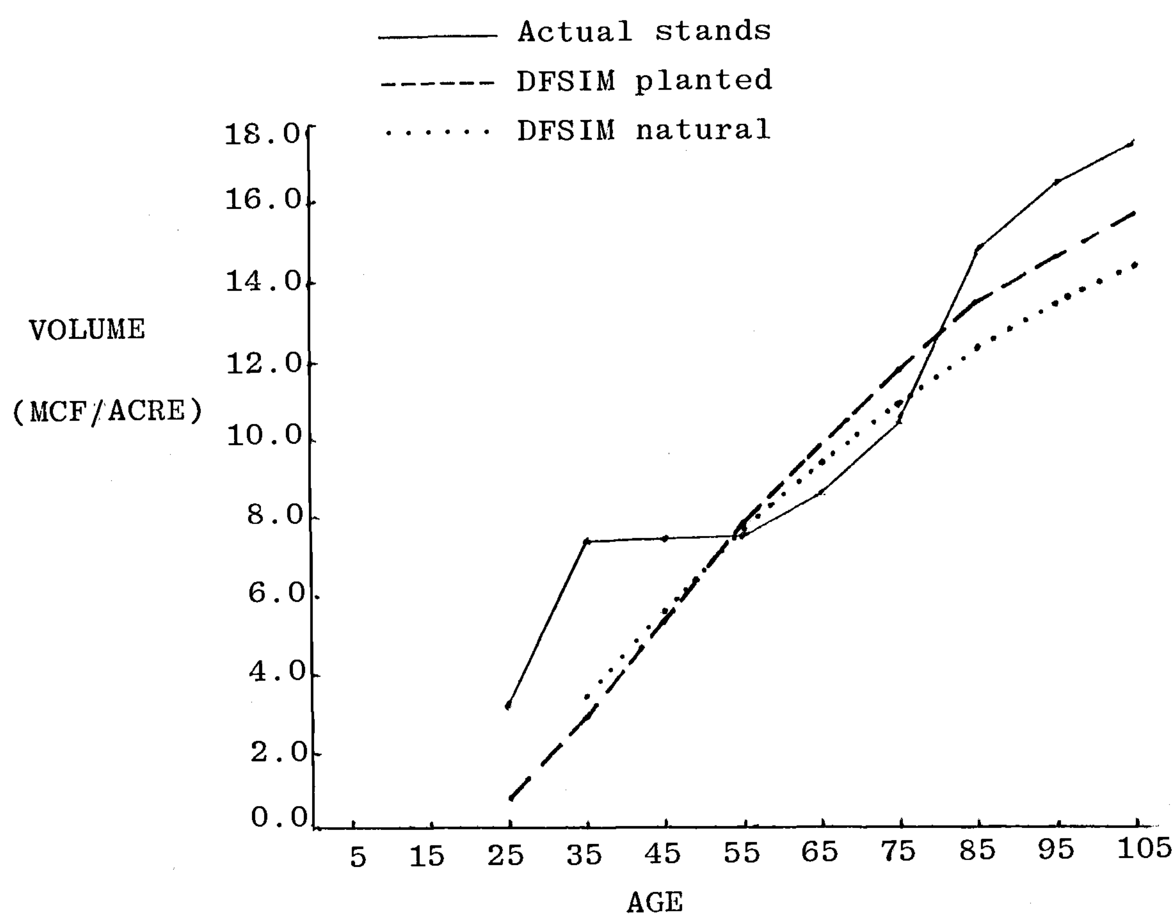


Figure 5. Actual inventory volume per acre for each age class of Forest Industry and NIPF timberlands of the PNWW 1977

estimated current softwood growth in western Oregon to be between 65 and 91 cubic feet per acre per year for all ownerships, with forest industry property in the upper end of the range and NIPF in the lower.

Harvest.

The two main forms of harvest are commercial thinning and final harvest. Commercial thinning volumes are based on thinning volumes listed in the yield tables and mid-point stocking percentages (normally used for regeneration purposes) for individual GRUs and management intensities. Final harvest volume is determined by the harvest request level found in the ACU file less thinning volume. The total final harvest volume available must be calculated to determine if there is sufficient volume to meet the harvest request. Available volume is dependent on three parameters, minimum final harvest age, harvest priority and growth on harvest. Minimum final harvest age for each GRU must be set as follows to prevent TRIM from harvesting acres that haven't reached a desirable size.

Douglas-fir/hemlock	- High site	- 50 years
Douglas-fir/hemlock	- Medium site	- 60 years
Douglas-fir/hemlock	- Low site	- 70 years
Hardwoods/unmanaged	- High site	- 50 years
Hardwoods/unmanaged	- Medium site	- 50 years
Hardwoods/unmanaged	- Low site	- 60 years

Harvest priority was given to the oldest age stands. This doesn't reflect an overall oldest age first priority, however, because TRIM distributes harvests among GRUs based on their total available volume above minimum harvest age. Thus within each GRU there is an oldest age first priority, but each GRU will be cutting in slightly different ages (depending on its original age class distribution). For example, a GRU with a large number of old growth acres could possibly be cutting in age classes 12+ for several decades, while a GRU whose initial age class distribution reflected much younger average ages could be cutting in age classes 7-9; however, as a whole, older acres are cut first.

The growth on harvest parameter allows harvest acres to grow five years to the midpoint of the period, since inventory volumes in the model are based on midpoint ages for each age class. The need for this adjustment was recognized by Barber (1984) and can be seen when comparing the actions of a model using 10-year periods with the continuous process of growth and harvest in reality. For example, age class 9 probably contains stands 90 years old all the way through 99, but they are assumed to be evenly distributed across all ages in the age class and to have a midpoint age of 95. A simple example can be shown for a stand that is already regulated. Using an oldest age first priority, 99.99 year old stands will be cut first.

Since the inventory is growing at exactly the same rate as it is being harvested, harvests should occur in an equally old stand in perpetuity. Without the five years of growth on harvest volume, the model would actually be harvesting volumes that represented 95 year old stands and growth that should have occurred would be lost entirely. Figure 6 shows the time sequence of basic growth, harvest and inventory procedures.

Acreage shifts.

The GRU file also contains input information which determines the percentage of acres that shift out of the land base or between management intensities. The one time recovery of volume from NIPF property shifted out of the land base, as discussed in the section on the BRU file, represented the only loss of harvest volume that was impossible to simulate when these projections were made. The only portion of this volume actually included, or captured, as harvest volume was that which was found in stands that just happened to be harvested with the normal harvest prior to the acreage loss. An example of the loss of harvest volume can be found in Chapter IV.

Shifts between management intensities for these simulations are allowed to take place only at regeneration. The effects of this constraint is discussed in

Figure 6. Time sequence of inventory, harvest and growth

Time 0 = 1977
Period length = 10 years

Inventory is the sum of all past events and is assumed to represent the inventory on January 1, 1977. It is reported every 10 years.

```
 !                                                !
 !                        !                       !
 !____!____!____!____!____!____!____!____!____!____!
1977                     1982                    1987
 *                                                *
```

It is assumed that an even distribution of harvests occur throughout the period (Jan. 1, 1977 - Dec. 31, 1986) with the midpoint of the harvest occurring at the midpoint of the period (Jan. 1, 1982). Thinning harvest is calculated first and subtracted from the harvest request, then final harvest is taken based on total available harvest volume and the remaining harvest request. Growth follows harvest and occurs over the same 10-year time period.

```
 !                                                !
 !                        !                       !
 !____!____!____!____!____!____!____!____!____!____!
1977                     1982                    1987
  ........................*........................
```

TRIM Time Sequence

1. Inventory is reported.

2. Harvest volume is grown 5 years to the midpoint of the period.

3. Harvest volume and acreage is recorded.

4. Residual volume is grown 10 years.

5. The cycle is repeated for the specified number of periods.

Chapter IV. The percentage of acres shifted was based on such things as species, site class, and ownership.

Regeneration.

The stocking level midpoint is the parameter that controls regeneration stocking percentages for each of three stocking levels. Specific midpoints were determined by calculating average Forest Service stocking percentages for all acres in age classes 0, 1 and 2 within each GRU and stocking level. Then they were adjusted to include hardwood stocking and discounted back to age class 0 using the inverse of the approach to normality formula. Middle aged and older stands were excluded from these calculations, because many of these stands had been partially cut and carried low stocking percentages. Had these been used, a problem similar to that encountered with the use of empirical yields would have arisen, where inventory and harvest volumes would have been far too low for regenerated acres. The use of younger aged stands is equivalent to the assumption that regeneration stocking levels for stands in Management Intensity 1 reflect the regeneration quality of the past 30 years. Acres in Management Intensities 2 and 3 were regenerated with an 80 percent stocking percentage.

The proportion of acres entering each stocking level upon regeneration can also be specified in TRIM. Management Intensities 2 and 3 automatically put all acres into Stocking Level 1, so that a single stocking percentage is used for all high management intensity acres. The average proportion of acres in each stocking level for all age classes in the GRU was calculated and used for Management Intensity 1 acres.

Unstocked acreage found in the initial inventory remains stable in Runs 1 and 2, but these acres are regenerated in Run 3 at a rate of 50 percent of the remaining unstocked acreage per decade, as was seen in Figure 2. This was applied to all site classes, stand types and ownerships. It should be reasonable to assume that this acreage represents the regeneration lag for each ownership, rather than specific acres that are found in this state for long periods of time. So the restocking of these acres may also be viewed as the elimination of a regeneration lag. Even though the total NIPF inventory acreage contains only 34 percent of the total private timberland base, it still accounts for almost half of the unstocked acres.

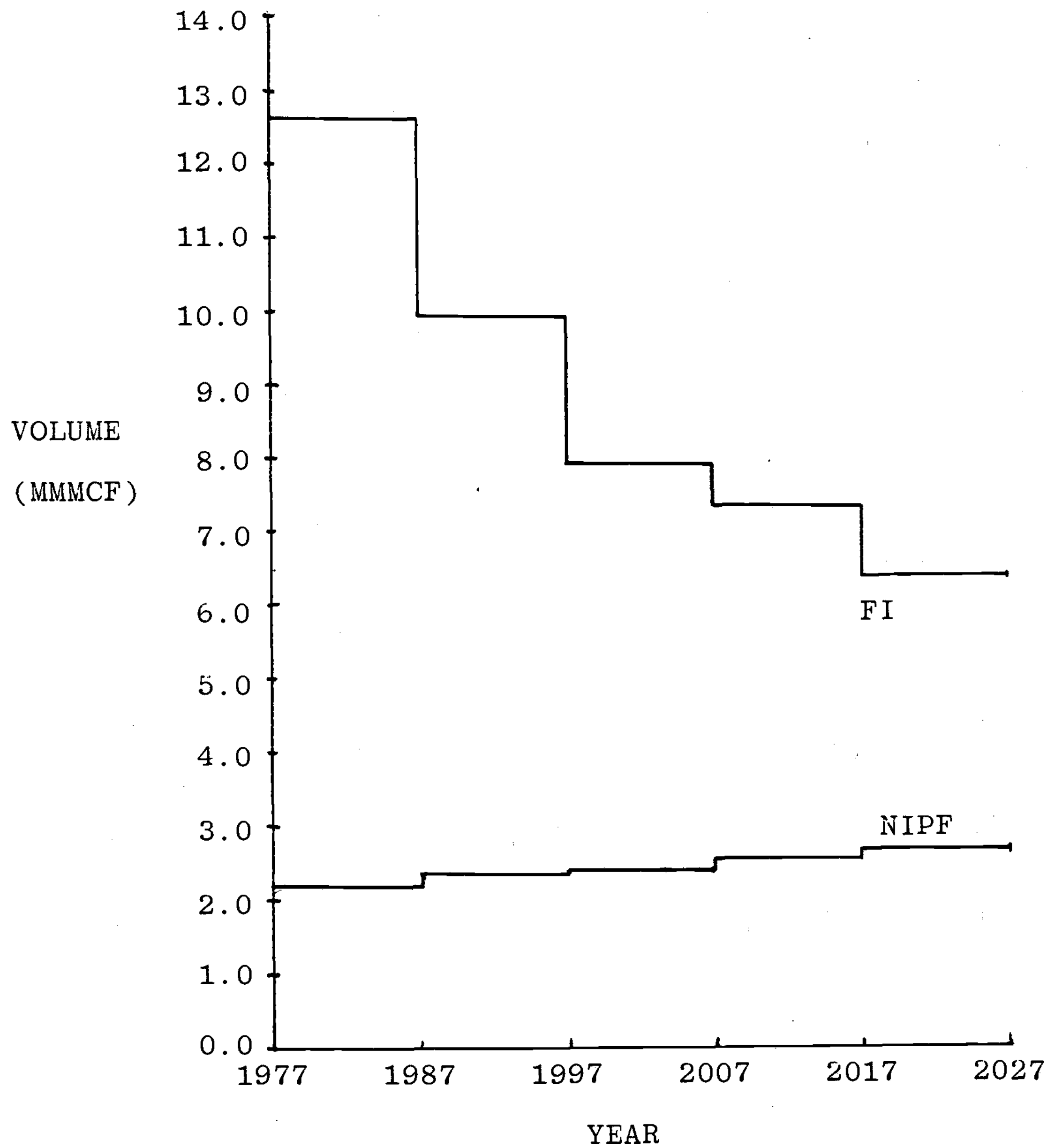
THE ACU FILE

Primary functions of the ACU file, discussed in this section, are to (1) group desired GRUs into cutting units,

(2) provide harvest request levels and (3) limit volume per acre in the inventory to a specified maximum stocking percentage. The GRUs were delineated into two groups for harvest purposes (NIPF and Forest Industry), while harvest request levels represented equilibrium harvest levels generated by TRAS/TAMM for the 1980 RPA timber assessment, as seen in Figure 7. Similar minor adjustments were done to harvest request volumes for the TRIM simulations as in the TRAS/TAMM projection, which included adjusting original harvest requests for volume gained from such things as mortality salvage and utilization of logging residues. Forest industry's harvest volumes decline sharply between 1977 and 2007 and continue to decline at slightly more moderate levels until the end of the horizon. NIPF harvests increase slightly throughout the projection horizon, but account for far less volume than the forest industry harvest. The NIPF harvest increases over the 50-year period by 22 percent, whereas the forest industry harvest declines by 49 percent.

The value for the parameter which sets the upper limit on volume per acre (based on stocking percentage) was set at 2.00 for the TRIM projections. In other words, it was assumed that under no circumstances could a stand carry volumes to represent more than a 200 percent stocking level. This value allows for the inclusion of relatively high stocking percentages for stands found in the

Figure 7 . TRAS/TAMM generated softwood harvest levels per decade for the PNWW 1977-2027



upper range of an age class, whose volume when compared with the midpoint volume would naturally produce higher than expected stocking percentages. It was also meant to provide limits which would be low enough to discourage excessively high averages in stocking percentage for growth and inventory calculations.

IV. RESULTS

A summary of the projection results produced by TRIM is presented in this chapter. The outcome of these simulations was analyzed and compared to corresponding output information generated by TRAS. Emphasis is given to predicted harvest levels and inventory information. In addition, a brief description of the intial inventory data is presented.

1977 INVENTORY

Inventory information used for these projections was actually collected by the USDA Forest Service over the period beginning in 1973 and ending in 1980. The following information is based on original inventory values with the exception of marginal and urban acreage exclusions, as was noted in Chapter III. Table 5 lists total acreage and volumes, volume per acre and average site indexes for westside Oregon and Washington. The two states have almost identical timberland acreages, but Washington has approximately 40 percent more volume than

Table 5. 1977 PNWW timberland inventory by state

	OREGON	WASHINGTON
ACRES (M)	5639	5634
DOUGLAS-FIR	3874	2032
WESTERN HEMLOCK	-	1846
HARDWOODS / UNMANAGED	1765	1756
VOLUME (MMCF)*	14404	20176
DOUGLAS-FIR	12310	6955
WESTERN HEMLOCK	-	8840
HARDWOODS / UNMANAGED	2094	4381
VOLUME (CF) / ACRE	2554	3581
DOUGLAS-FIR	3178	3423
WESTERN HEMLOCK	-	4789
HARDWOODS / UNMANAGED	1186	2495
AVERAGE SITE INDEXES (50 YR)		
DFIR / HEM (all sites)	110	115
DOUGLAS-FIR (all sites)	110	116
HIGH SITE CLASS	138	138
MEDIUM SITE CLASS	109	108
LOW SITE CLASS	76	74
WESTERN HEMLOCK (all sites)	-	114
HIGH SITE CLASS	-	140
MEDIUM SITE CLASS	-	111
LOW SITE CLASS	-	73

* All merchantable softwood and hardwood volume

Oregon with 3581 cubic feet per acre and 2554 cubic feet per acre respectively. Hardwood and unmanaged acreage is also identical; however, Washington has more than double the volume per acre for stands in this category. Western hemlock stands weren't segregated for the Oregon inventory, as they represent a much smaller percentage of the state's private timberland base than in Washington.

Average site indexes for the two states reveal that Washington also has a slight edge on Oregon in this area. Douglas-fir average site indexes for Oregon and Washington vary only slightly, however Washington has a higher percentage of stands in the upper site classes. The overall site quality of Oregon's forests is undoubtedly lower due to the generally poor sites found in the southwestern part of the state.

Volume and acreage relationships between forest industry and NIPF timberlands can be seen in Table 6. Forest industry dominates in every category that affects softwood timber production levels, representing two thirds of the overall acreage and 70 percent of the volume. Softwood volume per acre is also much higher on forest industry timberlands, with 50 percent more volume than NIPF acres. Hardwood volume per acre is the only category listed where NIPF lands show higher values, as they contain 45 percent more volume than forest industry acres. Differences in total volume per acre can be seen in Figure 5 (located in

Table 6. 1977 PNWW timberland inventory by ownership

	FI	NIPF
ACRES (M)	7392	3890
VOLUME (MMCF)	24364	10259
SOFTWOOD	20266	7136
HARDWOOD	4097	3122
VOLUME (CF) / ACRE	3296	2637
SOFTWOOD	2742	1834
HARDWOOD	554	803

Chapter III), where forest industry volumes dominate in almost every age class. If a graph for only softwood volume per acre was plotted for each age class, the gap between the two ownerships would be even wider. The effects of thinning and partial cutting on stocking in middle and older age classes can also be seen, as volume per acre gradually rises in the younger age classes, but then falls and becomes very erratic in older ages. Certain types of harvest and volume information concerning the initial inventory are discussed in the following sections, along with the examination of predicted harvest and inventory values.

PREDICTED HARVESTS

TRIM won't allow harvests in any period to exceed harvest request volumes (in this case, TRAS/TAMM harvest levels), so comparisons emphasize the ability of the three TRIM projections to meet volume requested. Harvest requests were made for softwood volume only, although, TRIM also computes hardwood harvest volumes. Figure 8 and Table 7 indicate that harvest volumes estimated in Run 1 fall substantially short of TRAS/TAMM harvest levels in the second and third periods (1987-2007) for forest industry timberland. The second period's harvest was 10.5 percent below requested volume, while the third period's

Table 7. Softwood harvest volumes per decade for the PNWW 1977 - 2027

TOTAL HARVEST VOLUME (MMCF)

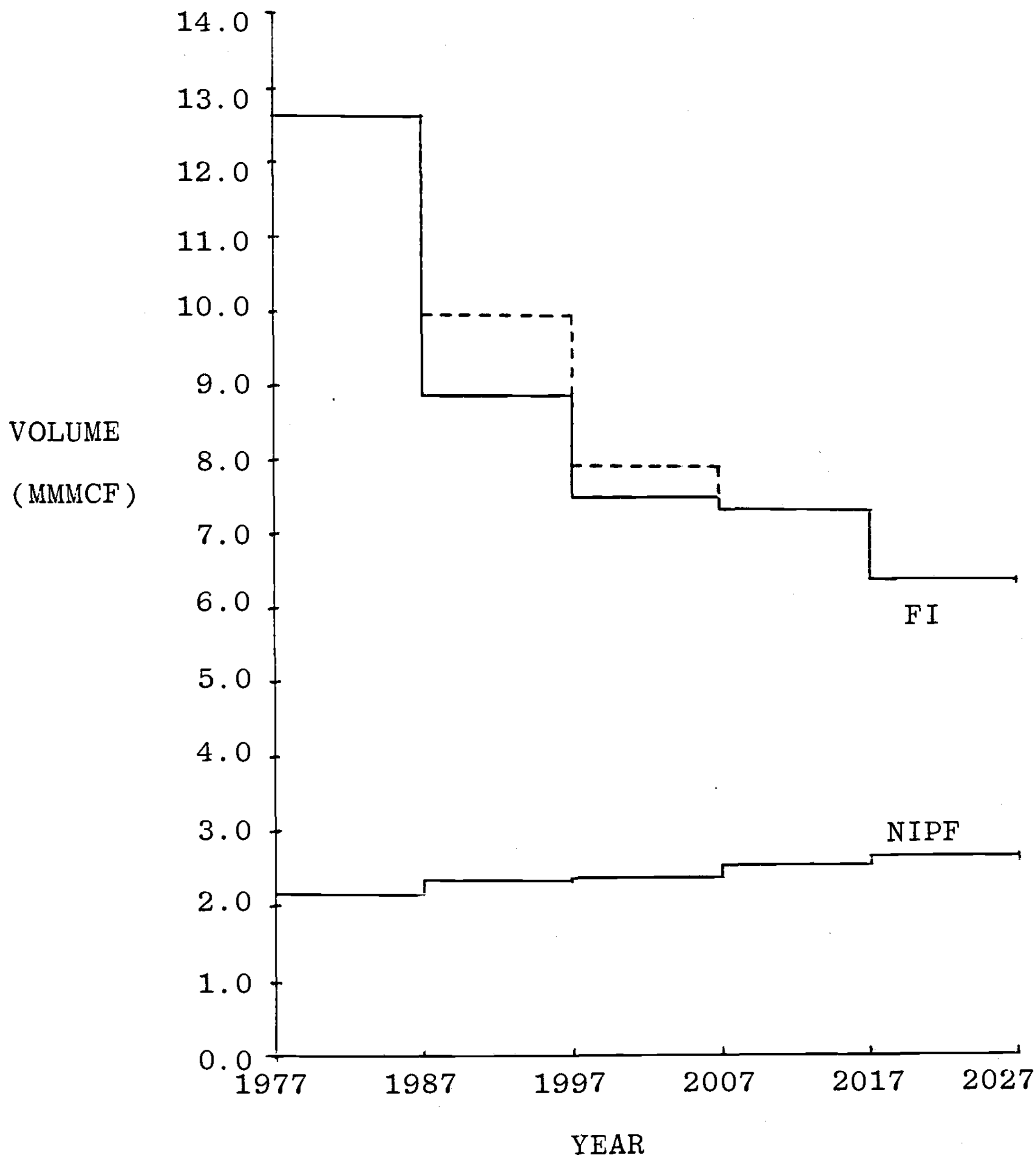
	1977-87	1987-97	1997-07	2007-17	2017-27
FOREST INDUSTRY					
TRAS	12529	9958	7917	7336	6369
RUN 1	12529	8909	7654	7336	6369
RUN 2	12529	9958	7801	7336	6369
RUN 3	12529	9958	7812	7336	6369
NIPF					
ALL RUNS	2204	2393	2418	2569	2683
TOTAL					
TRAS	14734	12350	10335	9905	9052
RUN 1	14734	11302	10072	9905	9052
RUN 2	14734	12350	10218	9905	9052
RUN 3	14734	12350	10230	9905	9052

THINNING VOLUME (MMCF)

	1977-87	1987-97	1997-07	2007-17	2017-27
FOREST INDUSTRY					
RUN 2	905	784	793	1367	1866
RUN 3	905	784	804	1668	3137
NIPF					
RUN 2	92	62	56	58	55
RUN 3	92	62	58	89	211
TOTAL					
RUN 2	997	846	849	1425	1921
RUN 3	997	846	862	1757	3348

Figure 8. Run 1 softwood harvest levels per decade for the PNWW 1977-2027

--------- TRAS/TAMM harvest levels (if different from Run1)

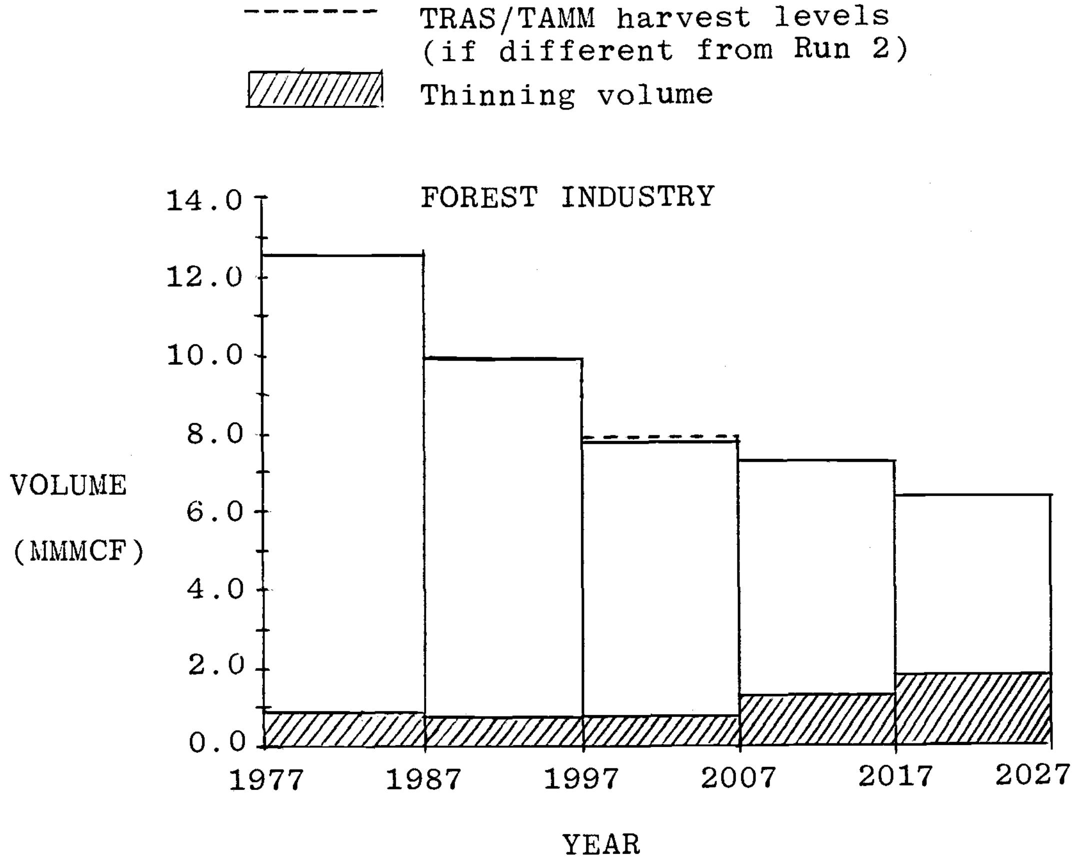


harvest was short by 3.3 percent. NIPF harvests were able to sustain TRAS/TAMM levels for all three runs throughout the projection horizon.

Run 2, with the inclusion of commercial thinning, sustains all but 1.5 percent of forest industry's harvest request in the third period (illustrated in Figure 9); however, third period harvests required the utilization of all of forest industry's volume above the minimum harvest age, which occurs anytime harvest requests cannot be sustained. Commercial thinning volume remains fairly stable until 2007, when it begins to rise to a level in the final period more than double that of the third period. Thinning volumes take pressure off of the harvest in older age classes, which accounts for nearly complete sustainability of the harvest requests in this simulation. Effects of the inclusion of thinning are immediate, since thinning is included in the initial inventory. The percentage of acres initially placed in the thinning regime is critical to harvest capability determination.

Total harvest volumes for Run 3 are almost identical to Run 2, as forest industry's harvest is short of TRAS/TAMM harvest levels in period three by 1.3 percent, as seen in Figure 10. Harvests are essentially unaffected by the increases in management intensity which occur in Run 3, because management intensity shifts were made at regeneration, requiring two to four more decades of growth

Figure 9. Run 2 softwood harvest levels per decade for the PNWW 1977-2027



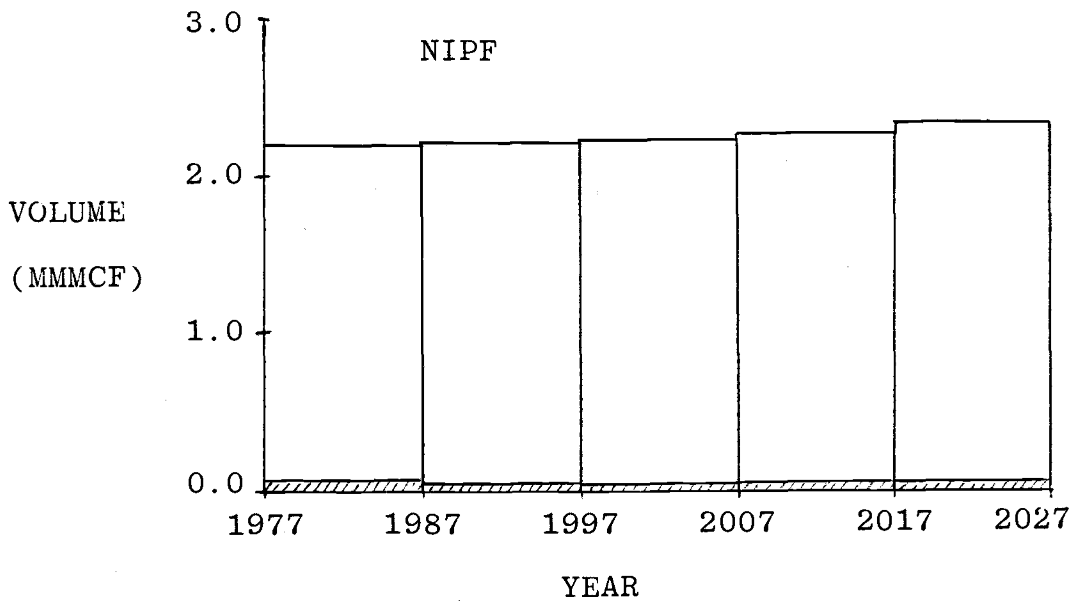
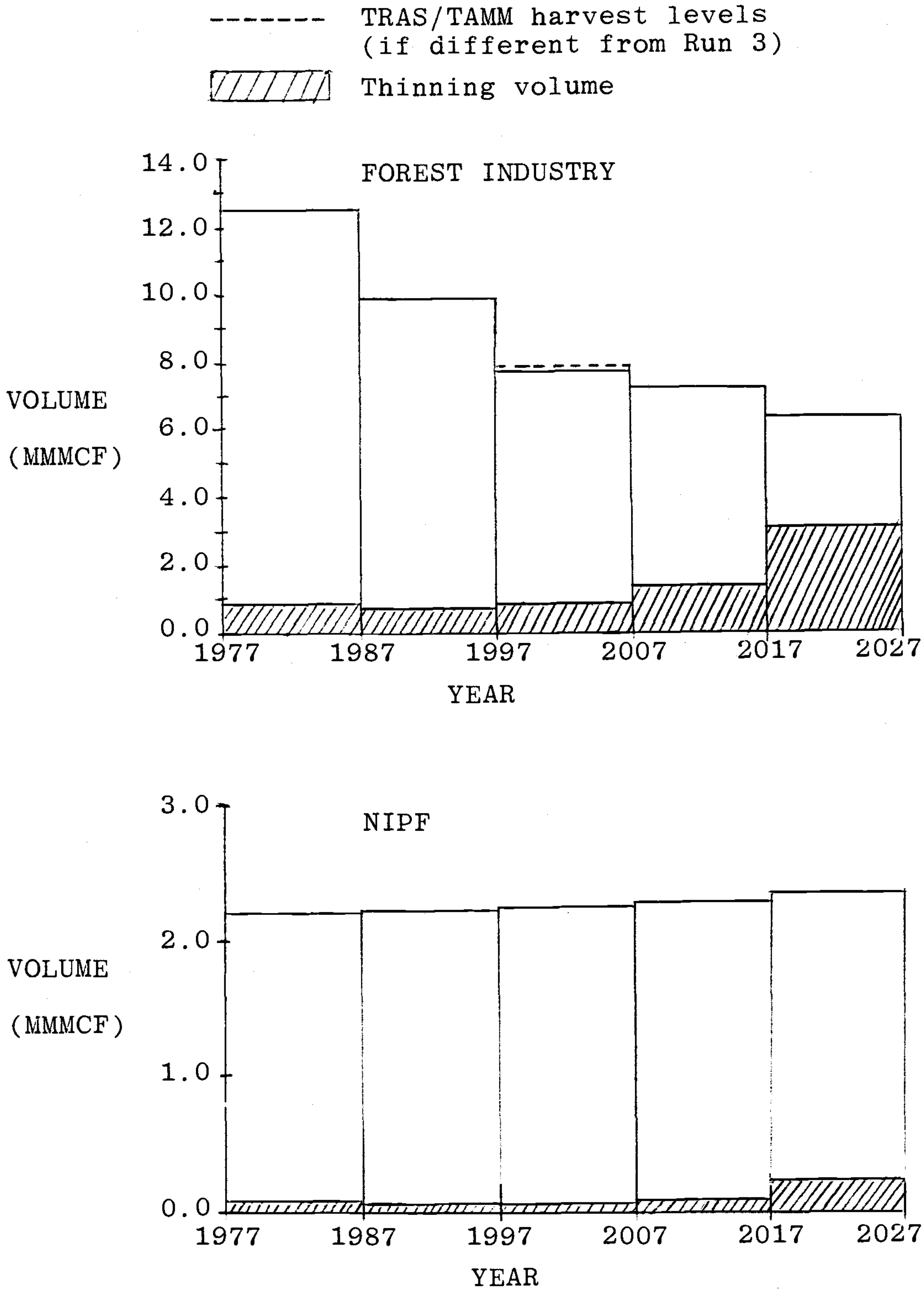


Figure 10. Run 3 softwood harvest levels per decade for the PNWW 1977-2027



before any harvest volumes can be taken in the form of commercial thinning. In actual practice, however, there are certain kinds of management improvements that can be made when stands are middle-aged and older (other than commercial thinning) that may include such things as fertilization and stand release. The major difference between Runs 2 and 3 is then found in the level of commercial thinning during the last two periods. At this time, stands found in the highest management intensity in Run 3 reach prescribed thinning ages, and harvested volume is combined with stands originally found in the base management thinning regime. Forest industry's thinning volumes in the last period increase to almost four times the thinning volume produced in period three. There is also a substantial increase in NIPF thinning volumes in the last period; however, the overall percentage of total harvest coming from thinning remains less than eight percent.

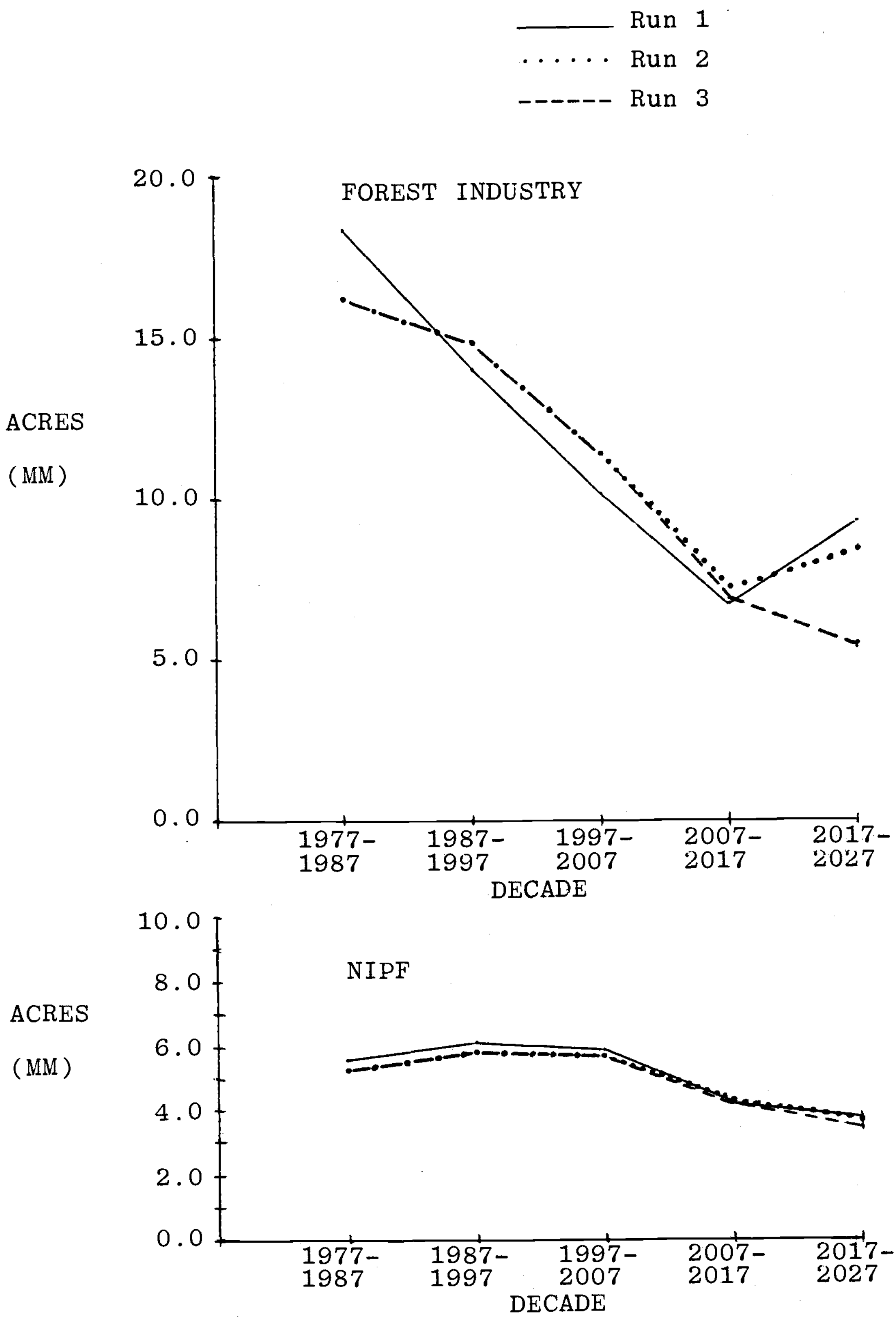
Final harvest acreage for the three TRIM runs, located in Figure 11 and Table 8, can be somewhat deceiving at first glance. Run 1 requires fewer final harvest acres from forest industry land in the second, third and fourth periods, which you would expect to find in projections that included higher management intensities and thinning; however, this occurs because harvest volumes in Run 1 were lower in periods 2 and 3 than in the other two runs. The first and last periods show a more understandable rela-

Table 8. Final harvest acreage for the PNWW 1977-2027

HARVEST ACRES (M)

DECADE	RUN 1	RUN 2	RUN 3
		FOREST INDUSTRY	
1977-87	1843	1623	1623
1987-97	1403	1495	1495
1997-07	1020	1147	1147
2007-17	679	727	691
2017-27	929	853	552
		NIPF	
1977-87	559	528	528
1987-97	612	586	586
1997-07	591	579	579
2007-17	421	429	424
2017-27	378	372	347
		TOTAL	
1977-87	2401	2152	2152
1987-97	2015	2082	2082
1997-07	1611	1726	1726
2007-17	1100	1156	1115
2017-27	1308	1225	899

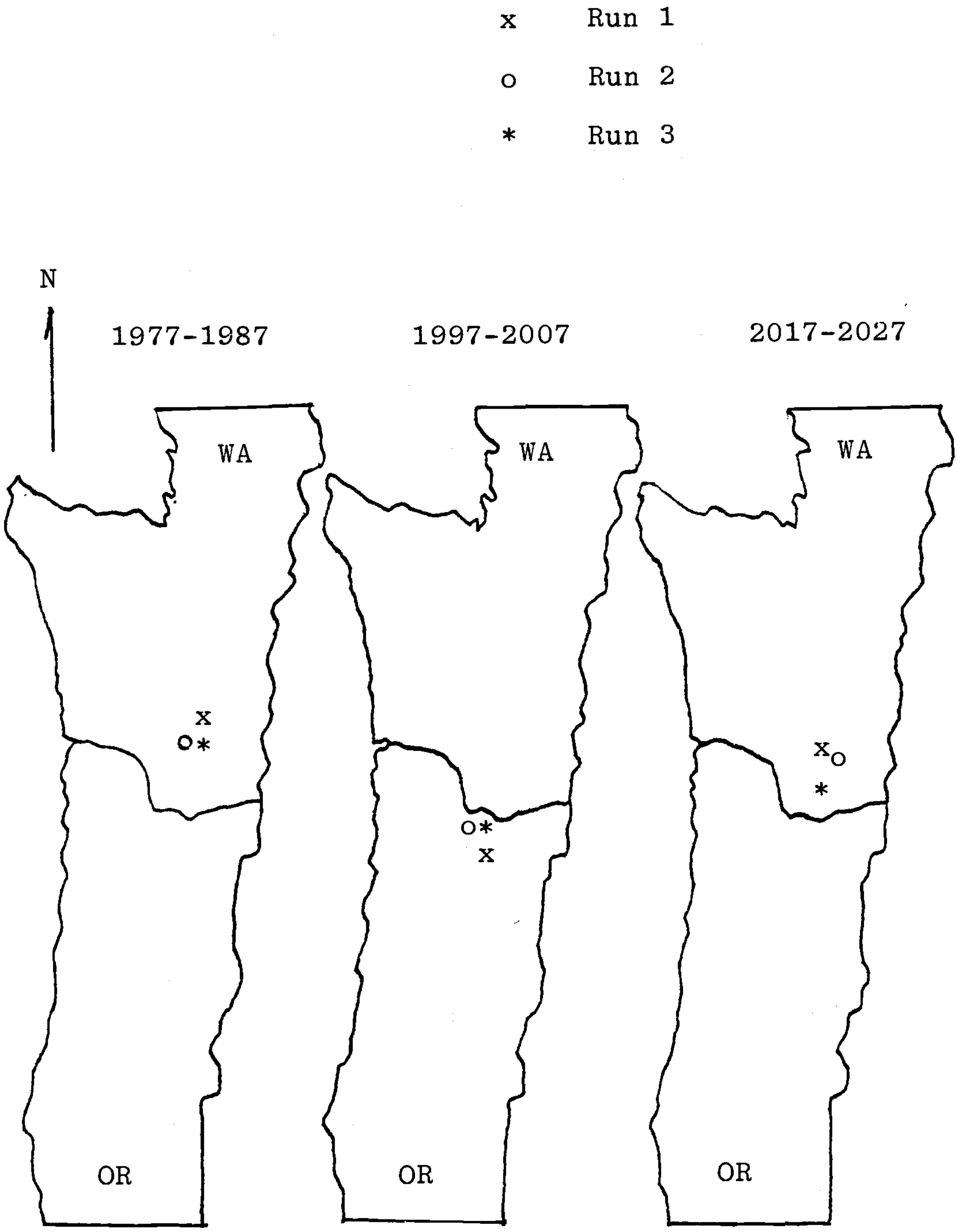
Figure 11 Final harvest acreage per decade for Runs 1, 2 and 3 for the PNWW 1977-2027



tionship between the three runs. In the first period more acres were required to be harvested in Run 1 than in Runs 2 and 3, which added more harvest pressure on the first run during following periods, as a higher percentage of older stands were depleted. Runs 2 and 3 required identical final harvest acreages until the fourth period, when additional commercial thinning volumes from management intensity shifts in Run 3 are finally realized. General declines in harvest acreage for the first four periods are a reflection of the decline in harvest volumes generated by TRAS/TAMM. Continued harvest acreage declines through the final period in Run 3 indicates some potential to increase harvest above requested volume, which is also discussed in the section dealing with age class acreage distributions. Differences in NIPF harvest acreage requirements between the three runs is less pronounced than for forest industry. Percentage differences between the two runs with the highest and lowest harvest acreage requirements per period are only about half as large as the differences in forest industry, as a result of a much smaller percentage of commercial thinning volume contained in the total harvest on NIPF timberland.

Harvest volume was segregated by state for the determination of the north-south geographic center of softwood harvest, as illustrated in Figure 12. The center of harvest was based on the percentage of harvest for each

Figure 12. Geographic center of softwood harvest volume for all private ownerships of the PNWW (based on percentage harvest in each state)



state. The north-south midpoint is conveniently approximated by the most southerly point on the Columbia River (the state boundary). Harvest levels and percentage harvest by state can be found in Table 9. The first period's harvest comes predominantly from Washington, where it accounts for between 60 and 62 percent of total harvest depending on the simulation. By period three, however, the center of harvest has moved south a considerable distance into Oregon, which contributes 51-55 percent of the harvest. Finally, by the last period the center of harvest moved back into Washington, but not quite as far north, with 53-58 percent of the harvest. The center of harvest projected by Run 3 moves farther south than the other two runs in the final period, indicating that Oregon could have the most to gain from increased management intensity, or at least that Washington is currently closer to its timber production potential. Harvest levels were generated without consideration of local demand for stumpage, as both states were included in the same region, creating equal pressure on each state's available harvest volume. Projection of the geographic center of harvest could be somewhat different had demand within each state been utilized for determining harvest levels; however, this analysis can be viewed as illustrating each state's harvest potential.

Table 9. PNWW softwood harvest volumes and percentage of harvest by state

HARVEST VOLUME (MMCF)

	1977-87		1997-07		2017-27	
	OR	WA	OR	WA	OR	WA
FOREST INDUSTRY						
RUN 1	4928	7601	4499	3155	2534	3835
RUN 2	5133	7396	4200	3601	2593	3776
RUN 3	5133	7396	4202	3610	2921	3448
NIPF						
RUN 1	725	1479	1004	1414	1313	1370
RUN 2	722	1482	1019	1399	1292	1391
RUN 3	722	1482	1019	1399	1293	1390
TOTAL						
RUN 1	5653	9080	5503	4570	3847	5205
RUN 2	5855	8878	5219	5000	3885	5167
RUN 3	5855	8878	5221	5009	4214	4838

HARVEST PERCENTAGE

	1977-87		1997-07		2017-27	
	OR	WA	OR	WA	OR	WA
FOREST INDUSTRY						
RUN 1	39	61	59	41	40	60
RUN 2	41	59	54	46	41	59
RUN 3	41	59	54	46	46	54
NIPF						
RUN 1	33	67	42	58	49	51
RUN 2	33	67	42	58	48	52
RUN 3	33	67	42	58	48	52
TOTAL						
RUN 1	38	62	55	45	42	58
RUN 2	40	60	51	49	43	57
RUN 3	40	60	51	49	47	53

PREDICTED INVENTORIES

Future inventories will generally be analyzed in terms of total softwood volume and age class acreage distribution. Initial inventories, periodic harvest levels and growth are discussed as sources of inventory change. Table 10 contains a summary of predicted inventory volumes for each decade, ownership and simulation.

Volume.

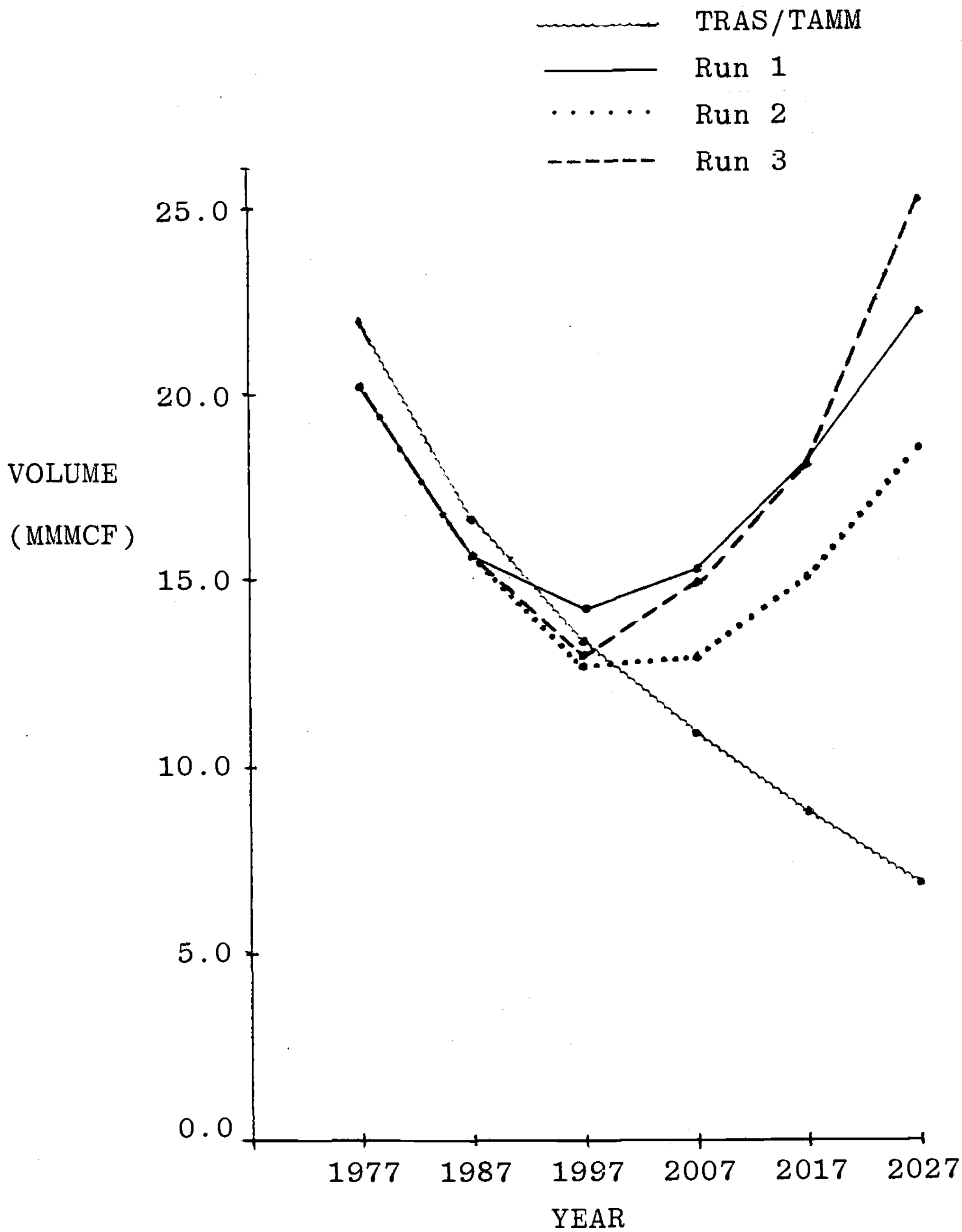
Projections for softwood inventory volumes on forest industry property are illustrated in Figure 13. The initial inventory used for the TRAS/TAMM simulation is 7.4 percent higher than the inventory used in TRIM simulations; however, growth is shown to be substantially higher for the TRIM projections, as seen by the recovery of inventory volume in the third period. Inventory declines sharply in the first two periods for all projections to a level that is at least 30 percent below the initial inventory volume. High harvest levels generated by TRAS/TAMM in the first two periods cause the inventory decline, as harvest between 1977-87 accounts for over 50 percent of harvest volume of the entire 50-year projection. The decline in Run 2 isn't quite as abrupt and begins to recover sooner due to decreased harvest volumes. By the third period, harvests have dropped by 37 percent and the

Table 10. Softwood inventory volume for the PNWW 1977 - 2027

VOLUME (MMCF)

YEAR	TRAS	RUN 1	RUN 2	RUN 3
		FOREST INDUSTRY		
1977	21764	20266	20270	20270
1987	16581	15631	15688	15699
1997	13024	14277	12768	12920
2007	10978	15388	12932	13913
2017	8810	18203	15079	18201
2027	6849	22291	18546	25108
		NIPF		
1977	8826	7136	7136	7136
1987	9336	7211	7257	7258
1997	9488	6789	6875	6891
2007	9629	6029	6122	6257
2017	9699	4844	4921	5359
2027	9721	3626	3665	4566
		TOTAL		
1977	30590	27402	27406	27406
1987	25917	22843	22945	22957
1997	22512	21066	19643	19811
2007	20607	21417	19055	20170
2017	18509	23047	20000	23560
2027	16570	25918	22211	29674

Figure 13. Softwood timber inventory volume on Forest Industry property of the PNWW

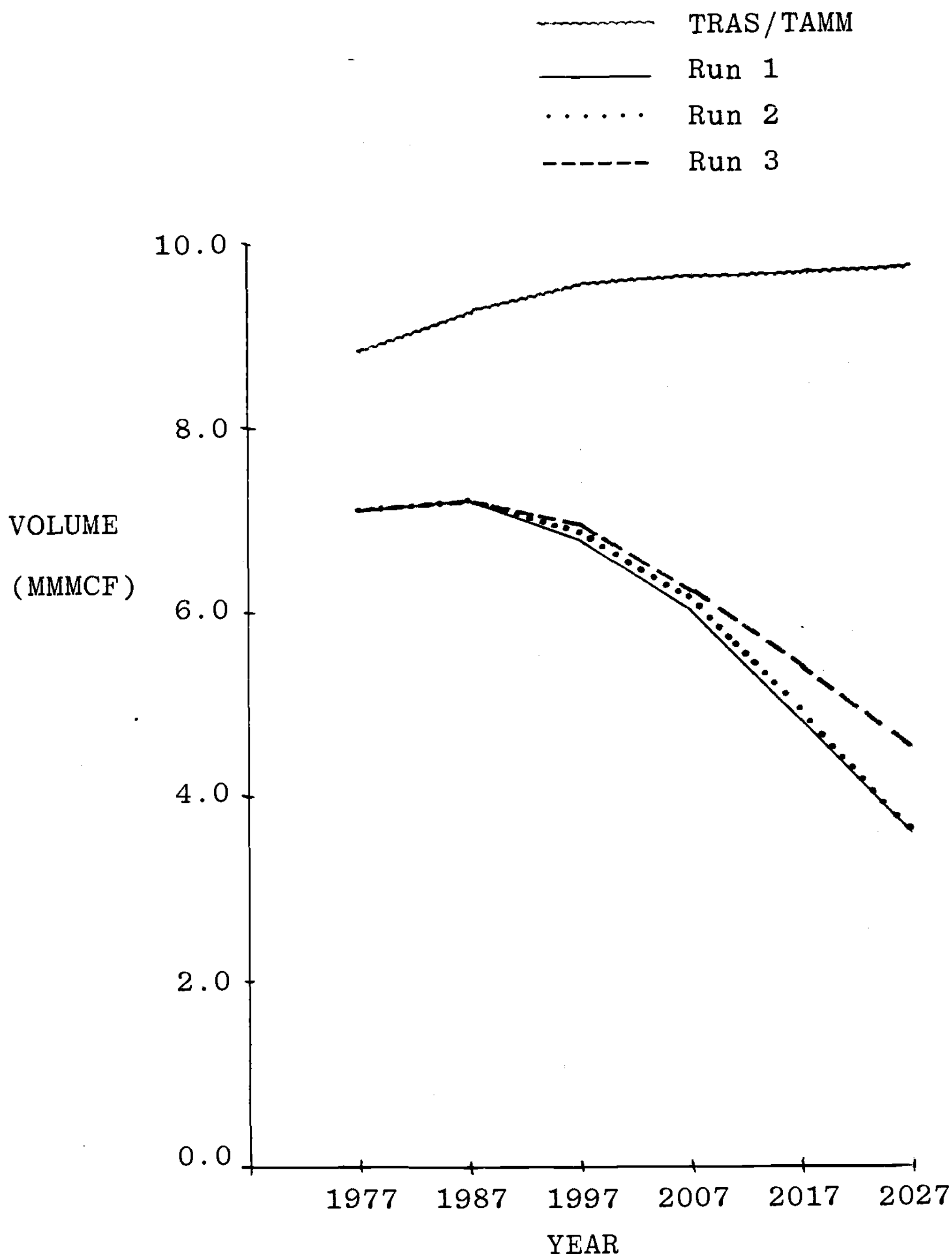


TRIM projections show a strong inventory recovery. TRAS predicts continued declines to the end of the planning horizon, even though harvest levels continue to drop. Inventory values for Run 3 begin to rise above Run 2, with increased rates of growth caused by the first management intensity shifts. Final inventories show that TRIM projections have recovered to a level approximating the initial inventory, while TRAS/TAMM shows an inventory less than one third its original size. Run 3 naturally shows the highest ending inventory volume, 35 percent greater than for Run 2.

Predicted inventory levels for NIPF land are illustrated in Figure 14, which appear to be the opposite of projections for forest industry. TRAS/TAMM inventories rise slightly throughout the projection, while TRIM simulations show an initial small increase followed by plunging inventories. There are three reasons for this major discrepancy. First, the initial TRAS/TAMM inventory includes almost 25 percent more volume than does the inventory used in TRIM, partly accounted for by the exclusion of urban and marginal acres. Second, there is a somewhat higher level of acreage loss in the TRIM projections, as discussed in Chapter III. Third, some potential harvest volume is lost in TRIM simulations when acres leave the timberland base.

The only volume harvested from acres leaving NIPF

Figure 14. Softwood timber inventory volume on NIPF land of the PNWW



ownership was that which had been previously scheduled for harvest immediately preceding the acreage loss. Volumes "captured" before leaving the inventory represent between 31 and 54 percent of the total volume on these acres; however, one would probably assume a higher percentage capture in reality. As an example, if 70 percent of the volume had been harvested from these acres in Run 2, resulting inventories would look something like that shown in Figure 15. Table 11 contains some of the values calculated for this example. When additional volume is captured for harvest, it is substituted for volume that would have come from the inventory of acres remaining in the timberland base. Decelerated use of inventory volume would maintain an inventory level that is 27 percent higher by the end of the projection, even when growth on extra inventory isn't included. If the ratio of NIPF volumes after growth to volumes before growth for each period is assumed to be a rough estimate of the growth rate per period, the resulting inventory volume at the end of the projection would be 109 percent higher than that shown for Run 2. Ending inventory volume would actually be 7.5 percent higher than the initial inventory, which compares to the gain shown in the TRAS/TAMM inventories of 10.1 percent over the same length of time.

Softwood inventory levels for all private owners can be seen in Figure 16, where the effects of both ownerships

Table 11. NIPF softwood inventory volumes of the PNWW adjusted for the capture of 70 percent of the volume from acreage shifted out of the timberland base RUN 2

YEAR	ACTUAL VOLUME CAPTURED*	% VOLUME CAPTURED	VOLUME NOT CAPTURED
1977-87	211	31	266
1987-97	229	33	257
1997-07	231	35	229
2007-17	246	42	164
2017-27	256	54	73

YEAR	INVENTORY WITH 70% CAPTURE / NO GROWTH	INVENTORY WITH 70% CAPTURE / GROWTH
1987	7523	7661
1997	7398	7722
2007	6874	7650
2017	5837	7307
2027	4654	7673

* Volumes are given in cubic feet (MM)

Figure 15. Softwood timber inventory volume on NIPF property of the PNWW, showing the effects of capturing up to 70 percent of the volume and growth on the captured volume from property that is transferred out of the land base

~~~~~~~~ TRAS/TAMM

———— Run 2 (capture only volume included in the normal harvest)

------ Run 2 (capture 70% of lost volume / no growth on captured volume)

······ Run 2 (capture 70% of lost volume / growth on captured volume)

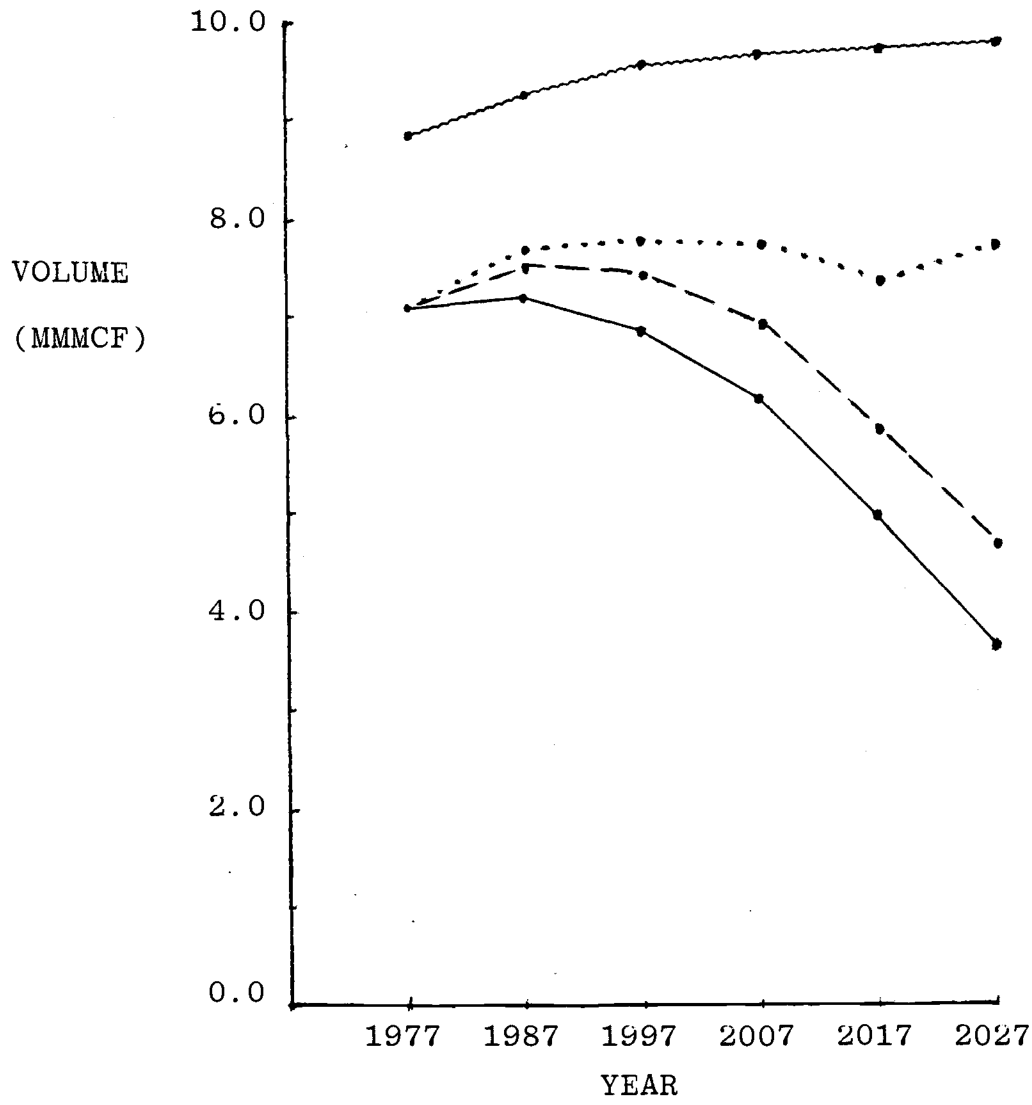

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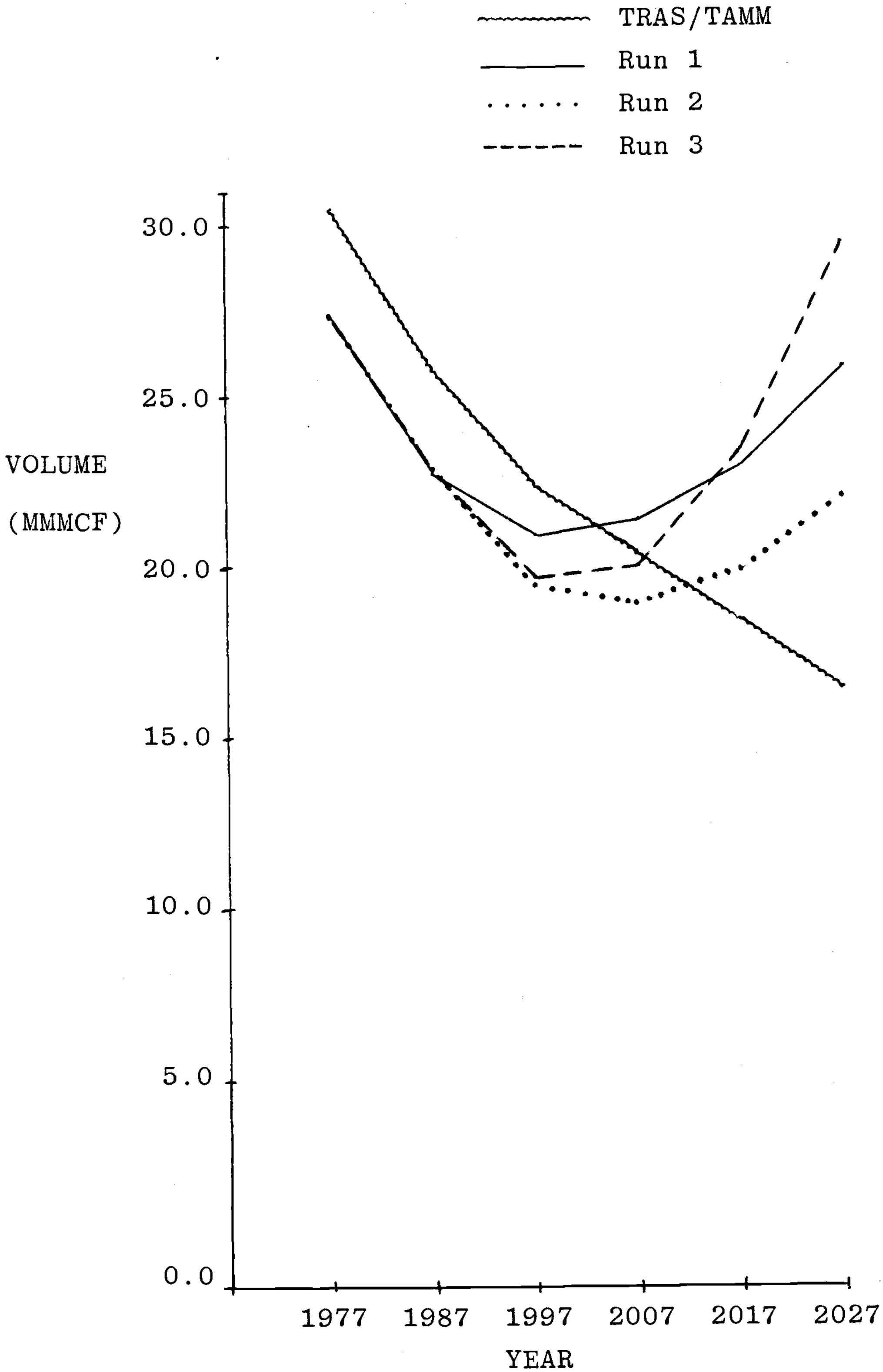
Figure 16 Softwood timber inventory volume on all private ownerships of the PNWW



can be clearly distinguished. Initial inventory differences between TRAS/TAMM and TRIM simulations can be found primarily in the NIPF inventory differences. Effects of the rapid recovery in forest industry's inventory is only slightly hampered by the drop in NIPF volumes. Had additional volumes been captured from NIPF acreage losses, the curves representing the TRIM inventories would be rotated slightly counter-clockwise. Even without this captured volume, ending inventories are considerably higher in the TRIM projections than for TRAS/TAMM. However, inventory volumes for Run 1 would be much lower had it been forced to match harvest request levels in the second and third periods, possibly forcing the final inventory below the TRAS/TAMM level.

With the addition of hardwood to inventory volumes for all ownerships, as seen in Figure 17 and Table 12, the volume curves rotate clockwise. Declining hardwood inventory during the 50-year projection period causes the trajectory shift, and lower ending volumes are produced in relationship to initial volumes when compared to softwood inventory volume.

Age class distributions.

Table 13 contains the age class distribution information of forest industry property projected in the TRIM

Table 12. Total inventory volume (softwood and hardwood) for all private ownerships of the PNWW 1977 - 2027

VOLUME (MMCF)

YEAR	RUN 1	RUN 2	RUN 3
1977	34622	34622	34622
1987	30270	30442	30446
1997	27989	26471	26560
2007	27238	24594	25230
2017	29244	25751	28143
2027	32083	27888	33680

Figure 17. Total inventory volume (softwood and hardwood) for all private ownerships of the PNWW

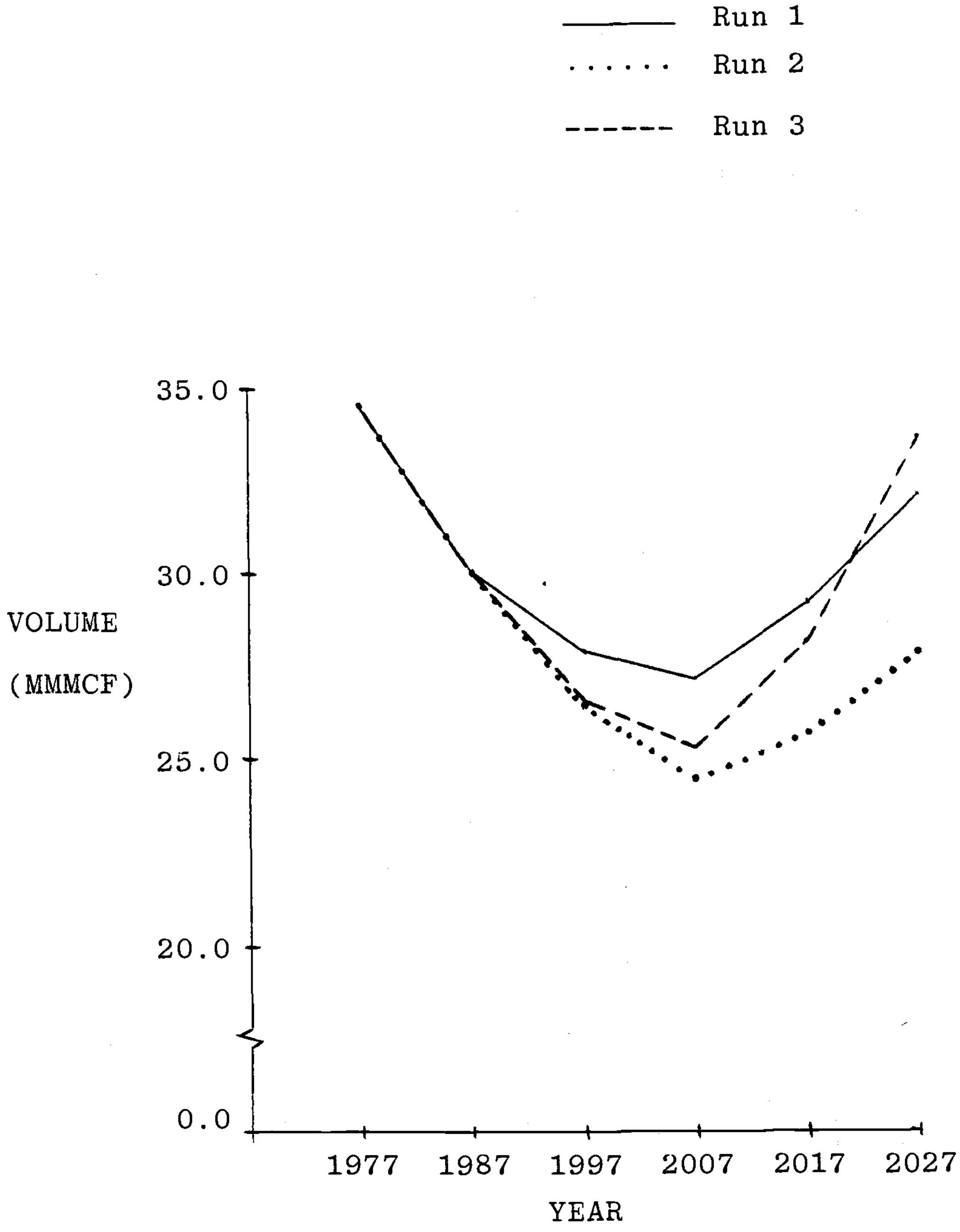


Table 13. Forest Industry age class acreage distributions for the PNWW

A C R E S (M)

YEAR / AGE CLASS	1977	1987	1997	2007	2017	2027
RUN 1						
UNSTOCKED	223	223	223	223	223	223
0-1	2336	3391	3246	2423	1698	1608
2-3	2063	1810	2336	3391	3246	2423
4-5	1272	1702	1494	1339	2130	2997
6-7	565	178	93	16	95	141
8-9	233	80				
10-11	201	7				
12-13	79					
14 +	421					
RUN 2						
UNSTOCKED	223	223	223	223	223	223
0-1	2336	3172	3118	2642	1874	1580
2-3	2063	1810	2336	3172	3118	2642
4-5	1272	1762	1564	1339	2115	2791
6-7	565	261	147	16	61	155
8-9	233	150	3			
10-11	201	8				
12-13	79	6				
14 +	421					
RUN 3						
UNSTOCKED	223	111	56	28	14	7
0-1	2336	3283	3286	2726	1879	1263
2-3	2063	1810	2336	3283	3286	2726
4-5	1272	1762	1564	1339	2126	3044
6-7	565	261	147	16	86	352
8-9	233	150	3			
10-11	201	8				
12-13	79	6				
14 +	421					

simulations. NIPF distributions can be found in Table 14. Initial age class distributions for the two ownerships are illustrated in Figure 18, where over 60 percent of forest industry's acreage is younger than 40 years old, and approximately 20 percent is older than 60. Stands over 140 years old represent 5.7 percent of total forest industry acreage. Over half of the NIPF acreage is between ages 20 and 60 in the initial inventory, and 79 percent is below age 60. Although the proportion of NIPF acres above age 140 only represents a little over one percent of total acres, a fairly large percentage of acres are found between 60 and 80 years old.

Age distributions for future periods are reported separately for each of the three TRIM runs with Figure 19 showing forest industry acres. The most obvious change by 1997 is the virtual disappearance of stands older than 60. Most of the acreage at this time is still less than 40 years old, and over 40 percent of the acres are less than 20 years old, as relatively high harvests were required for the preceding two decades. Harvest levels are at much lower levels after 1997, producing fewer acres below 20 years old and allowing the middle and upper end of the distribution to grow considerably. Almost 40 percent of the acres are between 40 and 60 years old by 2027, and some gains are even made in the 60-80 age group, which also seems to imply some potential for harvest volumes

Table 14. NIPF age class acreage distributions for the PNWW

A C R E S (M)

RUN 1

YEAR AGE CLASS	1977	1987	1997	2007	2017	2027
UNSTOCKED	205	205	205	205	205	205
0-1	697	798	1010	1035	865	687
2-3	1080	869	571	653	826	847
4-5	1098	1059	883	705	467	531
6-7	482	440	490	313	295	161
8-9	148	141	51	14	13	5
10-11	66	10	6	7		
12-13	66					
14 +	49	16	3			

RUN 2

YEAR AGE CLASS	1977	1987	1997	2007	2017	2027
UNSTOCKED	205	205	205	205	205	205
0-1	697	770	962	1004	862	687
2-3	1080	869	571	630	787	821
4-5	1098	1061	883	711	467	514
6-7	482	449	533	357	332	199
8-9	148	155	55	16	18	8
10-11	66	11	7	8		
12-13	66					
14 +	49	17	4			

RUN 3

YEAR AGE CLASS	1977	1987	1997	2007	2017	2027
UNSTOCKED	205	103	51	26	13	7
0-1	697	863	1093	1069	890	677
2-3	1080	869	571	706	894	874
4-5	1098	1061	883	711	467	577
6-7	482	449	533	357	335	224
8-9	148	155	55	16	19	10
10-11	66	11	7	8		
12-13	66					
14 +	49	17	3			

Figure 18. Age class acreage distributions for the TRIM projections 1977

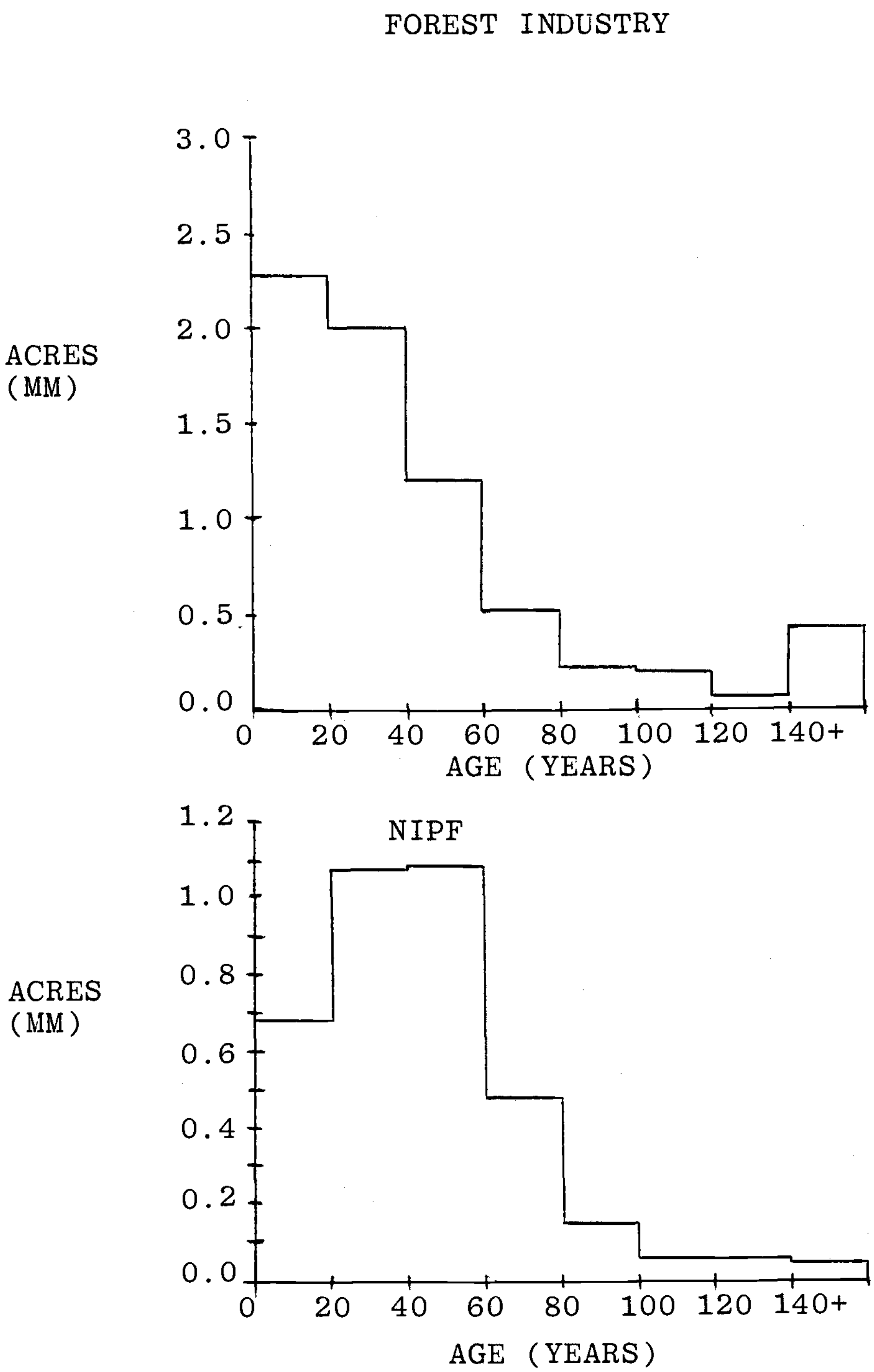
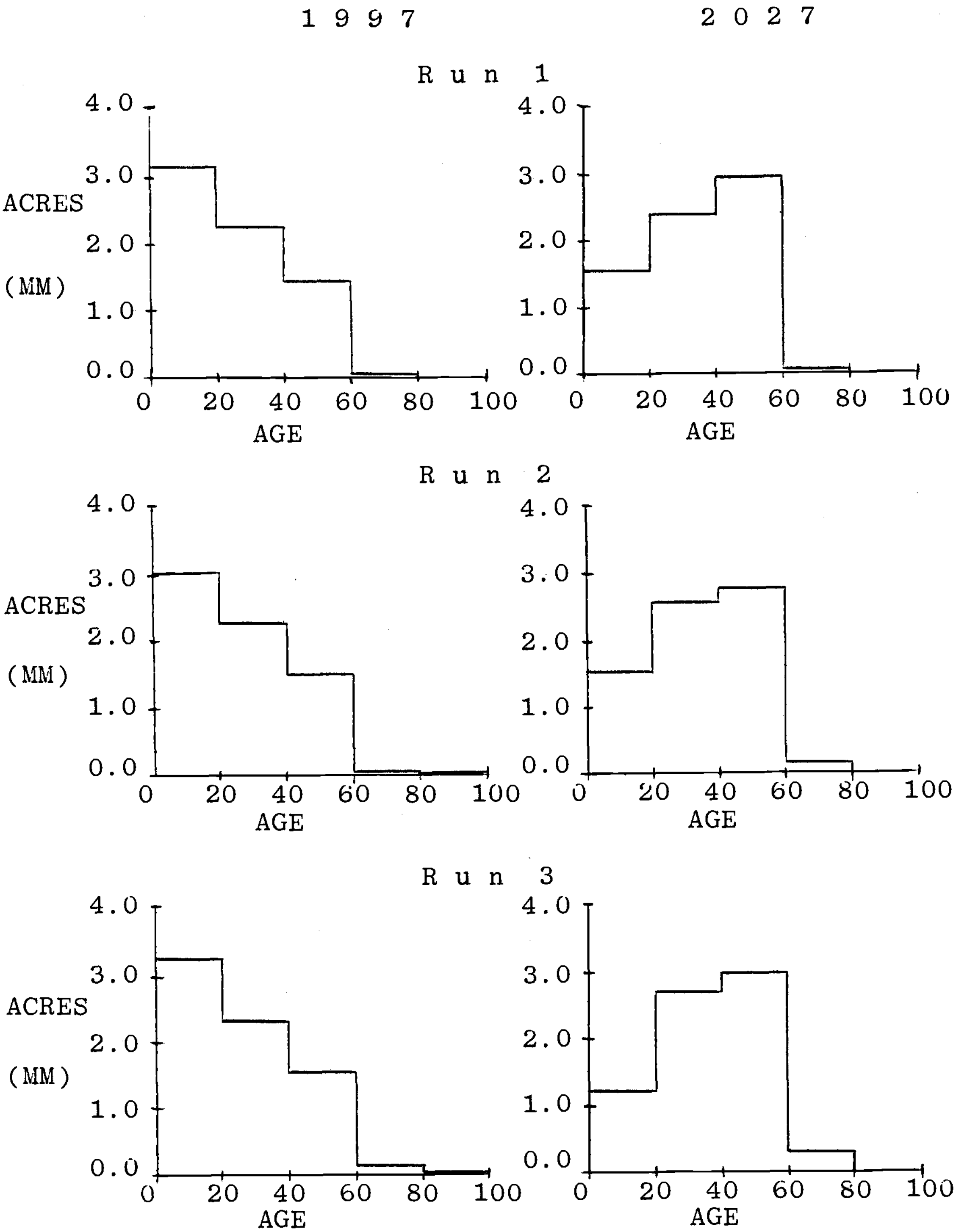


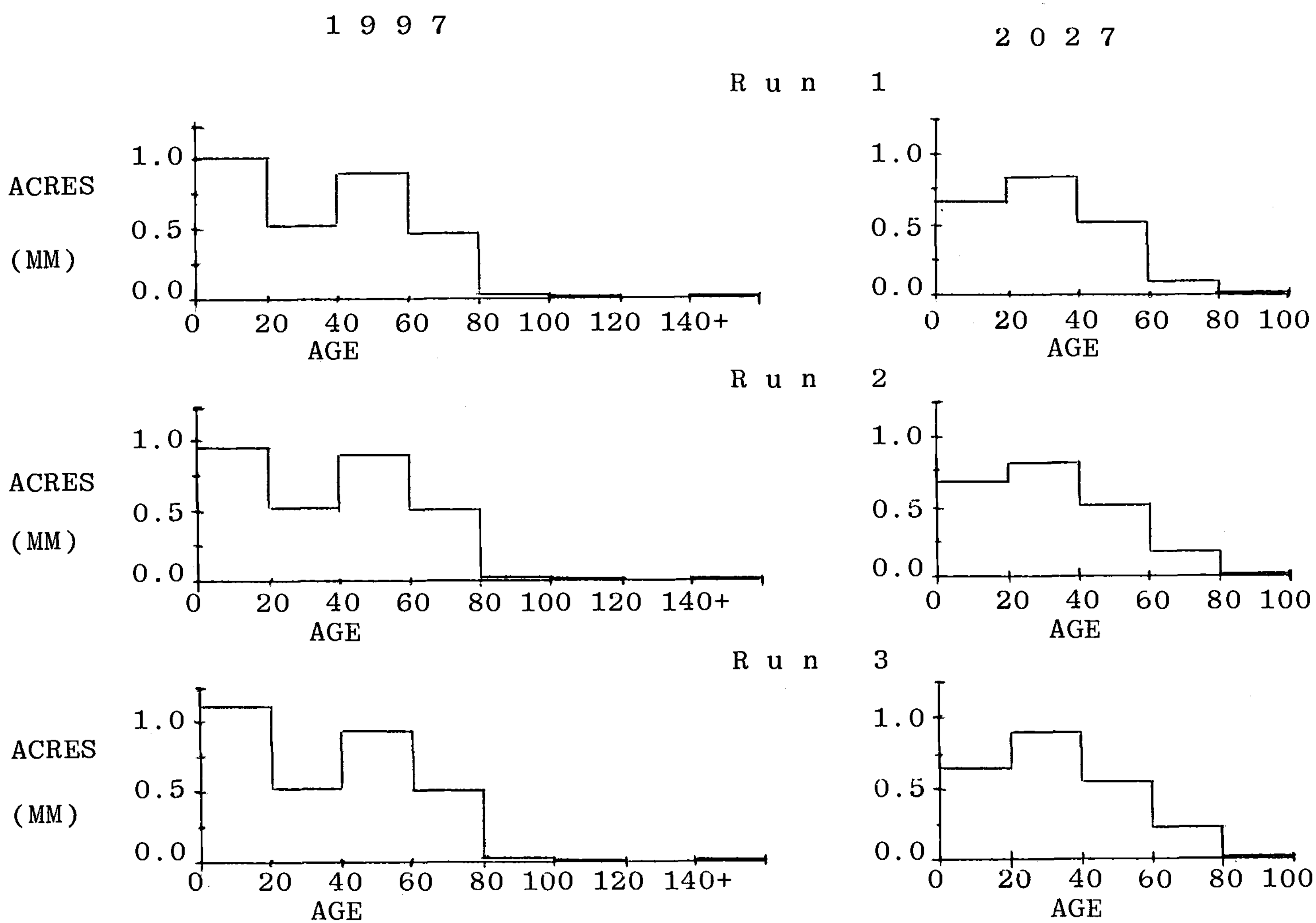
Figure 19. Age class acreage distribution for the TRIM projections: Forest Industry 1997 & 2027



above TRAS/TAMM levels for the last period of the projection and beyond. Differences between the three simulations by 2027 can be seen in the progressive decline of acres below age 20 and the increasing number of acres for ages 20-40 and 60-80 from Run 1 to Run 3.

Figure 20 illustrates predicted distributions for NIPF acres. The 1997 acreage distribution is wider than that for forest industry, with a minimum of 17 percent of the acreage found above 60 years old. Older stands are almost depleted by 2027 and account for less than 10 percent of total acreage. In addition, relative acreage dropped in the 40-60 age group, as at least 64 percent of the acres are now younger than 40 years old. Declining acreages above age 40 coupled with the sharp depletion above age 60 indicate that harvest levels over the last 50 years can't be maintained much longer. The loss of acreage to other uses increases pressure to harvest younger and younger stands in order to sustain harvest requests. Differences between the three runs are quite small due to relatively fewer acres managed for commercial thinning or shifted to higher management intensities, but anticipated results can be seen in acres older than age 60.

Figure 20. Age class distributions for the TRIM projections: NIPF 1997 & 2027



V. SUMMARY AND CONCLUSIONS

The overall outlook for softwood timber supply on private ownerships in the PNWW should be one of sharply falling harvest volumes. Inventories should drop in the short term and then recover to near initial levels. Average stand age and harvest age should drop substantially over the next 40 years causing average stem size to decrease accordingly. New increases in management intensity generally won't significantly affect inventory and harvest volume for at least 30 years, excluding an increase of commercial thinning in existing stands. However, there is some apparent potential to increase harvests by 2017 on forest industry property, when acreage begins to accumulate in middle-aged stands. Increasing total commercial thinning acreage appears to present the best opportunity for maintaining higher harvest levels, as will slowing historic timberland acreage loss trends, which, if left unabated, will necessitate a decreasing NIPF harvest within the next 30-40 years. Substantial opportunities for increasing commercial thinning and other management practices exist for all private ownerships, but they are especially apparent for NIPF timberland, as rough estimates of the current percentage of acres with higher levels of management remain very small. Improved management practices probably won't be able avert some level of harvest decline in the PNWW without increased harvest levels on public lands.

Comparisons between TRIM and TRAS/TAMM projections produced several interesting results. TRIM simulations estimated harvest potential to be somewhat lower than TRAS for the first four decades of the analysis period. Run 1 failed to meet TRAS/TAMM harvests by a sustantial margin on forest industry property between 1987 and 2007. Harvest levels in Runs 2 and 3 were only 1-2 percent lower than TRAS/TAMM harvests for the period 1997-2007. Although these harvest requests were essentially met for the latter two simulations, it required the depletion of the entire inventory above minimum harvest age. NIPF harvests estimated in the TRIM runs met TRAS/TAMM levels throughout the 50-year period for all simulations.

Softwood inventory volumes predicted in TRIM simulations recovered from initial high harvest volumes and lower inventory levels. Inventory volumes were produced that closely resembled initial volumes by the end of the projection horizon. TRAS, on the other hand, estimated a steady loss of inventory, dropping by 46 percent by 2027.

Initial inventory volumes representing forest industry acres showed the most substantial recovery, far exceeding TRAS/TAMM inventory estimates. Initial NIPF inventory volumes found in the TRIM runs were 10 percent lower than the initial TRAS inventory, but when 70 percent of the volume is recovered on acreage leaving the land base, TRIM inventory estimates maintain approximately the same slight gains in volume as predicted by TRAS/TAMM.

It is only reasonable to assume that growing stock responds differently to various silvicultural treatments, based on stand type and site, and that the level of management for a given stand is usually determined by these and other factors including ownership, location and other characteristics. Since a projection's accuracy is dependent on the ability of the model to simulate stand growth as it changes over time, it is essential to be able to control these parameters in order to confidently generate the desired future timber supply information.

TRAS falls short of meeting these requirements, as growth across all sites and stand types is portrayed by a single representative acre. Any management intensity shifts would have to apply to acreages representing an entire ownership, and it wouldn't be allowed to fluctuate in response to economic conditions throughout a simulation. The strength of the TRIM model lies in the ability to realistically portray stand growth, by utilizing a selection of growth and management parameters for an inventory which has been grouped according to these same parameters. In addition, TRIM has the ability to generate information such as age class distributions, diameters and harvest volumes while maintaining the distinction between final harvest and commercial thinning. This straight forward approach of simulating stand growth and management is essential for making national supply projections, which would require representation of a wide range of stand types and management techniques.

Dependence of a timber supply projection on the determination and use of realistic values of growth and management parameters, requires that future research efforts utilize careful analysis, and that inventory procedures generate information specifically tailored for projection purposes. A few of the more important determinants of a simulation's accuracy have been listed below:

1. Acreage percentages initiating in or shifted into higher management intensities, including commercial thinning regimes

2. Rate of the timberland base change and percentage capture of volume on these acres

3. Portrayal of inventory volume per acre in stands that are predominantly below merchantable size

4. Portrayal of regeneration, including the use of past trends for stocking levels and management intensity shifts

5. Approach to normality, as it affects stocking percentage changes

6. Harvest request levels and minimum final harvest ages

Special attention must be given to these determinants of growth and change to assure the validity of projection estimates.

In addition to the important parameters listed above, there is a need for additional research in two major areas concerning timber supply models and models that generate economic equilibriums of stumpage supply and price. The first is to create the ability to portray growth separately for major species groups, such as softwoods and hardwoods, when found in the same mixed stands. Approach to normality equations that specifically deal with interactions over time between major species would need to be developed in order to depict their relative change in stocking, as one species becomes dominant over the other. This would provide for volume transition between different species within a stand and for more accurate portrayal of approach to normality. Second, there is a need for utilization of some degree of product differentiation in both types of models, which would more accurately predict harvest levels and management intensity changes that are determined by economic analysis. Increasing demand for natural resources and shrinking supplies, dictate that careful analysis accompany future decision-making processes. Future research concerning national and regional projections should produce continually improving estimates of timber supply, and help assure appropriate public or corporate policy decisions.

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