Using the Labeling Capabilities and Parallel Processing Extension of the Forest Vegetation Simulator for Resource Supply Analysis

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Abstract—"Label Processing" is a little known feature within the Forest Vegetation Simulator (FVS). When used in combination with the Parallel Processing Extension (PPE), it can provide a powerful analytical tool. Labels within FVS link forest stands to activities. These activities can be either silvicultural or managerial in context. The PPE can be used for several purposes, including resource supply analysis where labels relate activities to groups of stands that are being managed to meet a specific objective. An example from the Flathead National Forest is presented that employs the labeling and parallel processing capabilities of FVS to solve a resource supply problem.

Many forest planning problems can be solved using the policy labeling capabilities of the Parallel Processing Extension (PPE) (Crookston and Stage 1991) of the Forest Vegetation Simulator (FVS) (Dixon 2001). The advantage of using these tools in combination would be that inventory information and associated silvicultural prescriptions would already be set up within the projection model [FVS]. Preparing data and developing stand management options are prerequisites to any planning exercise. Labeling and the PPE facilitate the final planning step — namely decision analysis for multi-stand processing. This paper provides an introduction to policy labeling rules and demonstrates the utility of the Parallel Processor in solving resource supply problems.

Policy Labeling Feature

Specifying management policies using rules is a little known feature embedded within the FVS model. This process is spun through every aspect of FVS: the Suppose interface, the base model, the event monitor, and the model extensions. There are three levels of labels within FVS. Beginning with individual stand polygons and working toward a landscape perspective, they are:

- Stand Policy
- Activity Group Policy
- Multistand Policy

You may not have heard of stand policy labels, but if you have used the Suppose interface (Crookston 1997), you certainly have unknowingly encountered them. Stand Policy Labels are synonymous with *Grouping Codes*. Grouping codes come into play when you invoke the "Select Simulation Stands" command button from the main Suppose window. Grouping codes populate the middle windowpane on the Select Simulation Stand screen (fig. 1). They are used to help identify common characteristics among individual stands. In figure 1, the DF grouping code is used to equate forest stands that are predominantly Douglas-fir forest cover type. Unbeknown to most users, this is also a Stand Policy Label for this grouping of forest stands.

The Suppose interface obtained these grouping codes from the Stand List File, Record Type C. Data translation programs such as Pre-Suppose (Vandendriesche, these proceedings) can assist in assigning grouping codes to common plot sets.

Silvicultural activities can be related to groups of stands using *Activity Group Policy* labels. Activity Group Policy labels were incorporated into FVS with the introduction of the Event Monitor (Crookston 1990). A keyword, AGPLABEL, is used to designate an Activity Group Policy label. This keyword is used in conjunction with *conditionally scheduled* silvicultural events such as thinnings and plantings. In other words, when a user inserts an "If…Then…EndIf" sequence in an FVS projection, by default, an Activity Group Policy label is associated with this treatment. Refer to figure

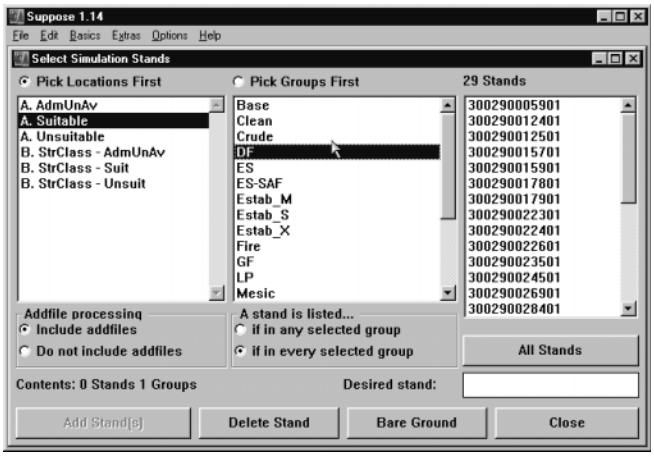

Figure 1—FVS Stand Policy Labels are built by Suppose from grouping codes.

In: Crookston, Nicholas L.; Havis, Robert N., comps. 2002. Second Forest Vegetation Simulator Conference; 2002 February 12–14; Fort Collins, CO. Proc. RMRS-P-25. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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2 for an example of Activity Group Policy labeling within a conditionally scheduled event.

Implementation of a forest plan requires setting standards and guidelines for distinct management areas. Many stands may be affected by a policy decision established at the programmatic level of planning. An optimal prescription for a given stand may not be feasible when viewed in the context of the entire forest setting. There are many planning models available to forest analysts. To simplify solving such rich problems with FVS, the Parallel Processing Extension was developed. As with any FVS entity, there is an associated set of mnemonic keywords. To handle management directions involving many stands, *Multistand Policy Labels* were created. For the resource supply example demonstrated in this paper, four inputs direct the PPE. The first involves the management objective or target for the resource. The second involves the criteria for selecting which stand among many will contribute to meeting the management goal. The third involves the unit value of the contributing factor. The fourth is the text string defining the Multistand Policy Label (fig. 3). For example, if the management policy objective were to harvest a specified allowable sale quantity (ASQ) from a particular group of stands within a designated land type, a predetermined selection criterion would dictate the order in which stands are harvested (such as oldest stands first). The unit value would be in terms of volume rendered (such as cubic feet, board feet). The multistand policy label associates the stands and activities that may be scheduled to meet the objectives of the policy.

Parallel Processing Capabilities

Lets expand this discussion to the second facet of this paper, the Parallel Processing Extension of the Forest Vegetation Simulator. At this time, the PPE has the capability to address four types of problems:

1. Multistand treatment scheduling
2. Resource supply trends
3. Contagion in pest dynamics
4. Decision trees

```
************************************************************************
*   RegHarv Rx:
*      Minimum Bd. Ft. harvest >= 2000
*      - If stand age >= 80 years LP
                          90 years other forest types
*           QMD >= 5"
*      - Then
*           regeneration harvest via CC
*      - Initialize Regen Harvest Interval
************************************************************************
MinHarv            0        0.     2000.        0.
If                 0
_Strata EQ _Type and (Age GE _RHAge and BaDBH GE 5.0)
Then
ThinDBH            0    Parms(0, DBHDist (3,3), 1.0, 0.0, 0.0, 0.0)
ThinDBH            0    Parms(DBHDist (3,3), 999., 1.0, 0.0, 9, 0.0)
AGPLABEL
   Suitable_Convert
EndIf
```

Figure 2—The Activity Group Policy Label is specified using the AGPLABEL keyword.

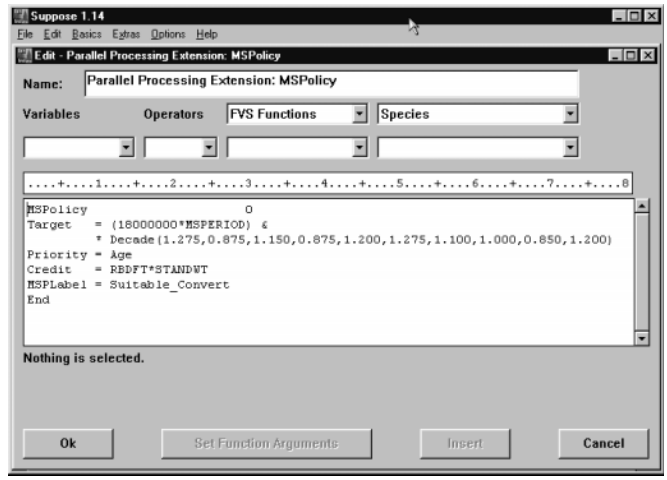


Figure 3—Multistand Policy Label is used to associate a multistand policy to a group of stands and the activities used to achieve the policy's objectives.

Multistand treatment scheduling involves tradeoff analysis. For example, suppose a forested area comprising many stands was used for elk hiding cover and timber production. Favoring one entity impacts the other. The PPE allows examination of these tradeoffs. Resource supply analysis involves gaming analysis. For example, suppose a forest analyst wanted to determine if a specified level of timber harvest were sustainable. The PPE, based on resource supply and public demand, can determine the level of diminishing return. A detailed example will be presented later in this paper. Contagion in pest dynamics deals with spatial analysis. For example, suppose a mountain pine beetle epidemic was devastating an area. The PPE can be used to chart the progression of an insect or disease pathogen from one stand to another. Decision trees are used for decision analysis. For example, suppose a silviculturalist was trying to decide on the timing options for a thinning treatment. The PPE could be used to replicate a stand along several pathways to determine the best solution.

For each of these solution processes, labeling plays a vital role. Through the use of unions and intersections of the various text labels (in other words, stand policy, activity group policy, multistand policy), the Parallel Processing Extension performs its magic.

Flathead National Forest Example

In conjunction with the passage of the fiscal year 2000 Forest Service budget, the Senate Appropriations Committee requested a report summarizing current timber growth, inventory, and mortality, including projections for the next 10, 20, and 50 years for the National Forest System. To the extent practicable, the report was to include age class and/or structural stage distribution of the stands represented by the data. The Flathead National Forest in northwestern Montana was chosen by the Forest Management Service Center as a representative example in responding to this inquiry.

A systematic approach was developed to perform the required analysis. A framework similar to that used for forest management planning was employed. The major steps in the process were: formulating a forestland classification strategy, prescribing silvicultural choices, forecasting growth and yield, evaluating management polices, and allocating resource assignments. Relevant aspects of each of these steps are presented.

Forestland Classification

The Forest Inventory and Analysis (FIA) data set was used as the empirical basis for the analysis. The systematic sampling design of FIA provided acreage values as well as per acre estimates of important plot and tree attributes. A strategy was developed to guide forestland classification assignments. Removing nonforest parcels from the acreage base and stratifying by administrative availability and management suitability rendered a hierarchal flow for data sorting. Physiographic class and condition class further defined each of the major stand types. Refer to figure 4. Stand types were developed within each land unit using the Pre-Suppose program. Stand Policy Labels (grouping codes) embedded in the Stand List Files guided the assignments (fig. 1).

Silvicultural Options

Silvicultural treatments followed a conceptual framework. Rule sets for vegetation management were developed based on historic fire regimes. Departure of current vegetation due to missed fire return intervals resulted in an invasion of shade-tolerant tree species. Treatment opportunities were postulated to achieve an ecosystem in proper balance with regard to natural fire frequency. The diagram in figure 5 defines *condition classes* by major forest cover type and size class. Mechanized treatments and prescription fire compose the available tools for stand management. Disturbance agents such as insects, disease, and wildfire have an impact on resultant forest structure. Each of these factors were identified and addressed.

Condition Classes—Four prescription (Rx) options were recognized: maintenance, restoration, conversion, and deferment. A brief description of each follows.

Maintenance (Maintain) Rx: Applied to young stands. Favorable species exist on a given habitat type. Missed one or fewer fire intervals.

- Precommercial thin overstocked stands.
- Prescribe fire for fuel reduction.
- Deferring of activities, let grow.
- Commercial thinning as stands mature to regulate stocking and maintain health.

Restoration (Restore) Rx: Applied to older stands. Favorable species exist on a given habitat type. Missed two or fewer fire intervals. Slight invasion of shade tolerant species.

- Improve stand composition to seral species.
- Precommercial thin overstocked stands.
- Prescribe fire for fuel reduction.
- Commercial thinning as stands mature to regulate stocking and maintain health.

Conversion (Convert) Rx: Applied to older stands. Unfavorable species exist on a given habitat type. Missed two or more fire intervals. Massive invasion of shade-tolerant species.

- Improve stand composition to seral species.
- Precommercial thin overstocked stands.

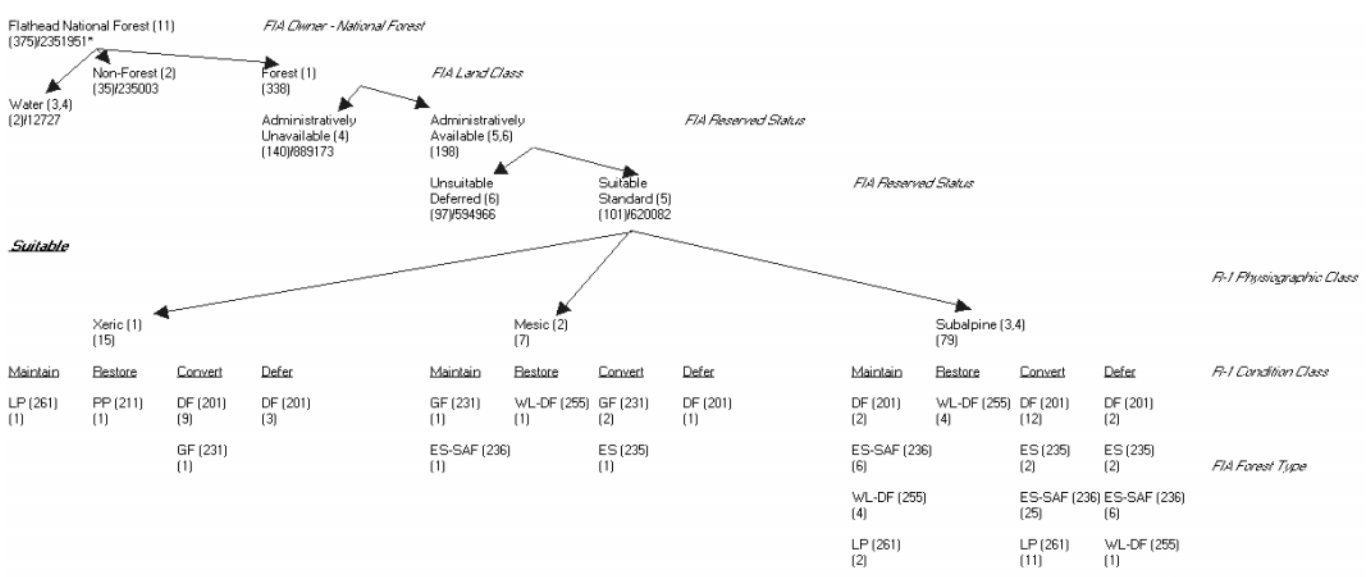


Figure 4—Forestland classification diagram.

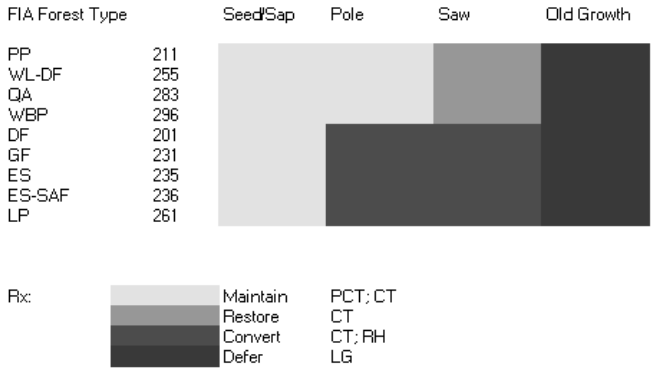


Figure 5—Silvicultural options.

- Prescribe fire for fuel reduction.
- Commercial thinning as stands mature to regulate stocking and maintain health.
- Regeneration harvest to shade-intolerant species as opportunity allows based on habitat.

Deferment (Defer) Rx: Applied to old growth, defined as stands with 10 or more trees per acre greater than 20 inches dbh.

- Deferring of activities, let grow.
- Monitor stand age and structure.

Silvicultural Prescriptions—Mechanical treatments such as precommercial thinning, commercial thinning, and regeneration harvesting could only be implemented on the *Suitable* forestland base. The following parameters were used in designing the keyword sets for projection with the Forest Vegetation Simulator.

Pre-Commercial Thinnings (PCT): Thin to 500 trees per acre. Favor retention of seral species.

- Stands less than 80 years old.
- Stands less than 5 inches quadratic mean diameter.
- Stands greater than 1,500 trees per acre.

Commercial Thinnings (CT): Thin to 70 square feet, basal area. Favor retention of seral species.

- Stands at least 20 years old.
- Stands at least 5 inches quadratic mean diameter.
- Stands at least 2,000 bd. ft./acre cut volume.
- A 40-year re-entry period.

Regeneration Harvest (RH): Even-aged methods. Favor establishment of seral species.

- Stand at least age 80 for LP, age 90 for other forest types.
- Stands at least 5 inches quadratic mean diameter.
- Stands at least 2,000 bd. ft./acre cut volume.
- Leave nine Legacy Trees for snag replacement.

Let Grow (LG) Rx: Defer young and old growth stands.

- Young stands less than 40 years old (generally).
- Young stands less than full stocking.
- Old stands greater than 120 years old (generally).
- Old stands with 10 trees per acre greater than 20 inches dbh.

Prescription Fire—Controlled burns could be used on both *Suitable* and *Unsuitable* forest areas as a low cost treatment to enhance species composition. Although a Fire and Fuels Extension had been developed for the FVS model, linkage with the Parallel Processor Extension had not been made at the time. The PPE was used as the modeling tool to bring the associated analytic pieces together. Keyword sets that simulated low and moderate intensity prescription fire scenarios were developed. Attributes of the prescription fire keyword sets were as follows:

Prescription Fire—Low Intensity

Applicable only to shade-intolerant and LP types (that is, PP, WL-DF, WBP, QA, LP). Used “FixMort” keyword to simulate fire-induced mortality.

- 50 percent mortality in trees 0 to less than 3 inches dbh.
- 30 percent mortality in trees 3 to less than 5 inches dbh.
- 20 percent mortality in trees 5 to less than 9 inches dbh.
- 10 percent mortality in trees 9 to less than 16 inches dbh.
- 0 percent mortality in trees greater than 16 inches dbh.
- Indiscriminate to all species.
- Applicable only to *Suitable_Maintain* and *Restore* forestland classes.
- Targeted 2,500 acres annually.

Prescription Fire - Moderate Intensity

Applicable only to shade mid-tolerant and tolerant types (that is, DF, GF, ES, ES-SAF). Use “FixMort” keyword to simulate fire-induced mortality.

- 80 percent mortality in trees 0 to less than 3 inches dbh.
- 60 percent mortality in trees 3 to less than 5 inches dbh.
- 50 percent mortality in trees 5 to less than 9 inches dbh.
- 30 percent mortality in trees 9 to less than 16 inches dbh.
- 20 percent mortality in trees greater than 16 inches dbh.
- Indiscriminate to all species.
- Applicable only to *Unsuitable_Convert* forestland class.
- Targeted 3,500 acres annually.

Forest Health—Forest pests can significantly impact the current and future development of a stand. The USDA Forest Service Northern Regional Office developed forest pest risk maps for all Montana forests including the Flathead National Forest. Root rot, bark beetle, and dwarf mistletoe incidence were recorded on the FIA plots. Overlaying risk maps with the FIA plots enabled forecasting potential hazard sites. The Northern Region Forest Health Specialists developed associated FVS keyword file sets to simulate pest effects. By using the Western Root Disease Extension, these health issues were incorporated into the projections.

Fire Impacts—The Flathead National Forest had compiled a report of recorded wildfires during 10 years from 1985 to 1994. Based on this information, FVS keyword file sets were developed to randomly burn the approximate acreage as cited. The following parameters were used:

	Wildfire - 1985-1994 period			
Forest land class	Acres burned 10 years	Low intensity 15%	Moderate intensity 65%	High intensity 20%
Suitable	12,250	1,837	7,962	2,450
Unsuitable	7,650	1,148	4,973	1,530
Wilderness	2,600	390	1,690	520
Total:	22,500	3,375	14,625	4,500

FVS keyword sets were written to describe each of these facets. Activity Group Policy Labels were assigned within conditionally scheduled events (If … Then … EndIf keyword sequences) to link grouping of stands with their associated treatment/disturbance activity. Refer to figure 2 for an example.

Yield Forecast

Stand projections were performed using the Forest Vegetation Simulator for a 100-year time horizon. Yield estimates were compared and calibrated to measured data as observed from the Flathead FIA data set.

Management Direction

The essence of the Senate Appropriations Committee's request was that given a specified level of harvest based upon current production output, what would be the resultant condition of the forest in terms of growing stock and mortality rates over the next 50 years. An inference of the current harvest activity needed to be made.

Sale Quantity—The most recent Forest Plan for the Flathead National Forest cited an allowable sale quantity of 54 million board feet per year from *suitable* lands. However, due to market constraints, pending litigation, threatened and endanger species considerations, and other unforeseen issues, the programmed financed sell had been 23 MMBF during the period from 1995 to 1999. This was the harvest level used for the analysis.

Implementation Strategy—Intermediate harvests (commercial thinnings) were targeted for the younger merchantable size classes of the *maintain* and *restore* condition classes (target 5.0 MMBF). Regeneration harvests were targeted for the older merchantable size classes of the *convert* condition class (target 18.0 MMBF). Also, high bark beetle hazard plots were prioritized for regeneration treatment. Stand improvement treatments (such as precommercial thinnings) were restricted to 10 percent of the potential area to aid in metering out the acres treated.

Resource Allocation

The Parallel Processing Extension was used to solve the forest trend inquiry. For resource supply analysis, PPE is easy to implement.

PPE Set up—The Suppose interface distinguishes FVS keywords for PPE as one of three component types: top, bottom, and report. Relevant keywords used for resource allocation were as follows:

Top Components

Exact - Instructs PPE to use partial stands to meet target objectives.

Bottom Components

MsPolicy - Signals that a multistand policy will be entered.

LabWts - Request that labels and weights be written to an auxiliary file. Used for post processing of stand structure statistics.

Report Components

Yields - Prints composite yield statistics table.

The MsPolicy keyword establishes the parameters associated with the *Multistand Policy* (fig. 3). This label is used to link groups of stands (Stand Policy) and their proposed silvicultural treatment (Activity Group Policy). For example, within the *suitable* forest land class on the Flathead, there were 29 Douglas-fir stands (fig. 1). The *convert* condition class was comprised of a subset of 12 stands (fig. 4). Regeneration harvest can only be applied to the *suitable_convert* activity group (fig. 2). The overall multistand-ASQ target for the *suitable_convert* forest land class was 18.0 MMBF (fig. 3). The priority for stand selection to meet target objectives was to harvest the oldest stands first. Their contribution to meeting the target goal was a factor of the stands' removal board foot volume and its size in acres. Therefore, if Douglas-fir stand within the *suitable_convert* forestland class was the oldest stand available at that point in the projection, it would be selected for regeneration harvest to meet the target ASQ objective of 18.0 MMBF.

PPE Reports—Within the main output report of FVS, two important PPE tables related to resource supply analysis are generated. The first, the *Targeted Resources Table* (fig. 6), displays a listing of stands selected to meet the

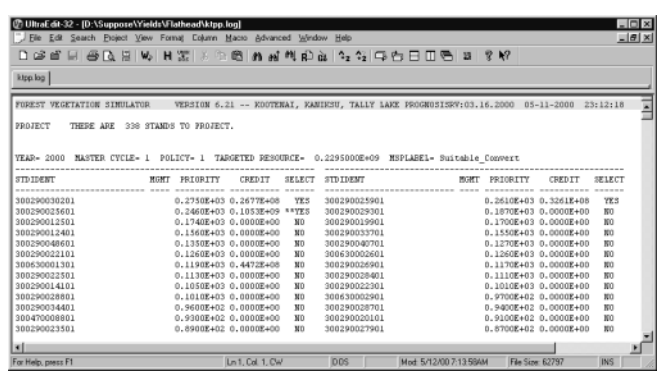
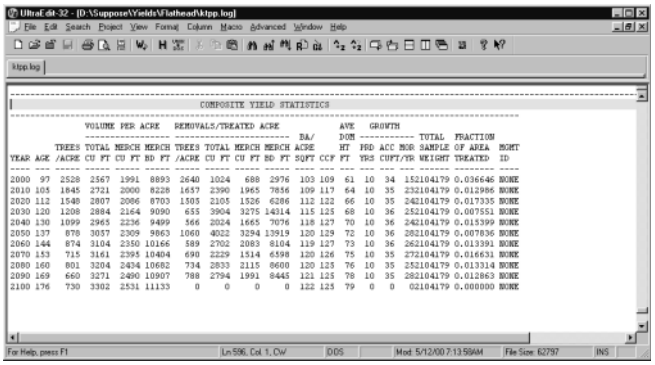


Figure 6—Targeted resources table.

management policy objective. Note that the *Priority* column is ordered sequentially from left to right then down in terms of descending stand age. The *Credit* column equates to the selected stands' harvested board foot volume multiplied by the number of acres within the stand. If only part of the stand was needed to meet the exact ASQ goal, then the remaining stand acres would be carried to the next time period. Split stands are denoted by a series of two asterisks in the *Select* column within the Targeted Resources table.

The second important PPE table to review is the *Composite Yield Statistics Table* (fig. 7). Average removal volume per acre is displayed. *Total Sample Weight* [acres] and *Fraction of Area Treated* are also presented. Multiplying these terms together will render the targeted volume goal.



COMPOSITE YIELD STATISTICS

YEAR	AGE	TREES /ACRE	VOLUME PER ACRE TOTAL CU FT	MERCH CU FT	MERCH BD FT	REMOVALS/TREATED ACRE TREES /ACRE	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA/ ACRE SQFT	CCF	AVE DOM HT FT	PRD YRS	GROWTH ACC CUFT/YR	MOR CUFT/YR	TOTAL WEIGHT	SAMPLE TREATED	FRACTION OF AREA	ID
2000	97	2528	2567	1991	8893	2640	1024	688	2976	103	109	61	10	34	152	104179	0.036646		NONE
2010	105	1845	2721	2000	8228	1657	2390	1965	7856	109	117	64	10	35	232	104179	0.012986		NONE
2020	112	1548	2807	2086	8703	1505	2105	1526	6286	112	122	66	10	35	242	104179	0.017335		NONE
2030	120	1208	2884	2164	9090	655	3904	3275	14314	115	125	68	10	36	252	104179	0.007551		NONE
2040	130	1099	2965	2236	9499	566	2024	1665	7076	118	127	70	10	36	242	104179	0.015399		NONE
2050	137	878	3057	2309	9863	1060	4022	3294	13919	120	129	72	10	36	282	104179	0.007836		NONE
2060	144	874	3104	2350	10166	589	2702	2083	8104	119	127	73	10	36	262	104179	0.013391		NONE
2070	153	715	3161	2395	10404	690	2229	1514	6598	120	126	75	10	35	272	104179	0.016631		NONE
2080	160	801	3204	2434	10682	734	2833	2115	8600	120	125	76	10	35	252	104179	0.013314		NONE
2090	169	660	3271	2490	10907	788	2794	1991	8445	121	125	78	10	35	282	104179	0.012863		NONE
2100	176	730	3302	2531	11133	0	0	0	0	122	125	79	0	0	02	104179	0.000000		NONE

Figure 7—Composite yield statistics table.

Summary

By using the labelling capabilities and Parallel Processing Extension of the Forest Vegetation Simulator, a comprehensive analysis of a resource supply problem was addressed. These tools were used to prepare reports showing trends in forest stocking as impacted by changes in growth, harvest, and mortality. Figure 8 displays the projected outcome relative to board foot volume over the next 50 years. Live tree stocking showed an ever-increasing accumulation as a result of forest growth outpacing harvest and mortality components.

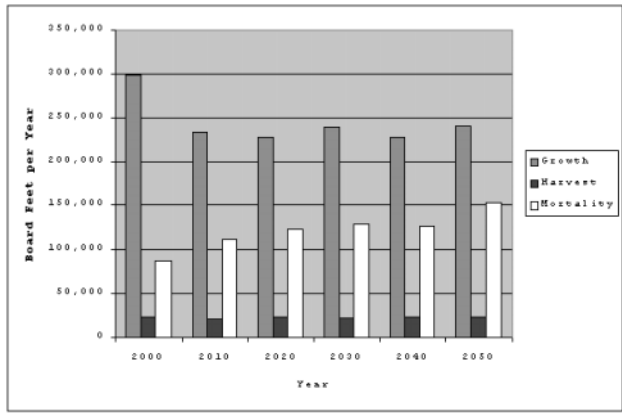


Figure 8—Flathead National Forest, board foot volume trends.

Acknowledgments

The complexities of the Flathead National Forest example could not have been fully developed without the input and oversight provided by Doug Berglund, Forest Silviculturist, Flathead National Forest. Doug's consummate knowledge of local history, ecology, and silviculture proved invaluable. Barry Bollenbacher, Northern Region Silviculturist, and George Lightner (retired), Northern Region Inventory Specialist, provided preliminary support data and direction.

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