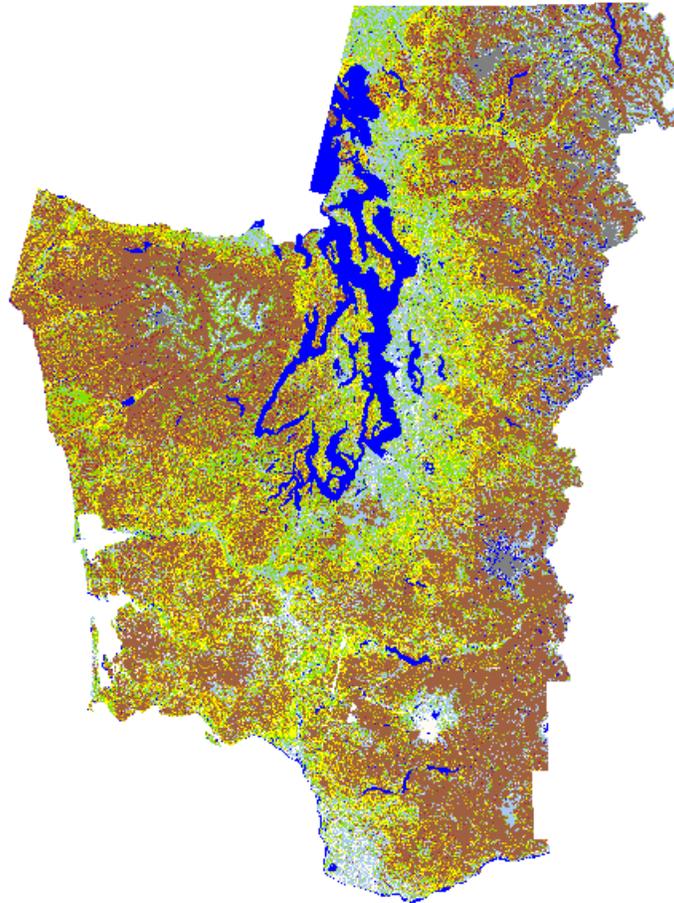


The Washington Hardwoods Commission

Presents:

A Hardwood Resource Assessment for Western Washington



June, 2002

Abstract

This project used Landsat TM images for mapping current forest distribution across western Washington. The classification of forest land was by forest type and age class. Estimates of available hardwood volume were derived by first reducing the timberlands base for ownership, regulatory, and physical constraints and secondly by applying volume estimates to that remaining acres base.

There are 12.5 million timberland acres in western Washington. This timberland base was reduced by the following criteria:

- Areas with elevation above 600 meters. The assertion was that hardwood above this elevation is of poor quality.
- Areas within riparian zones.
- All federal lands were assumed to be unavailable.

As a result, there are estimated to be 3.7 million acres available for commercial harvesting.

Total harvestable hardwood volume is estimated at 14.3 billion board feet in 2001 on timberland with elevation under 600 meters. Based on area stratification, 19% (2.7 billion BF) of that total harvestable hardwood volume is in riparian zones. Based on owner classification, 19% (2.7 billion BF) of the total volumes is on federal lands.

Available hardwood volume is estimated at 9.0 billion board feet after all reductions. Ownership of that volume is as follows:

- 31% - large industrial group
- 38% - state & local government group
- 31% - small private group

The species mix of that same volume is as follows:

- 84% - Red Alder
- 10% - Big Leaf Maple
- 6% - Black Cottonwood

The estimates were based on the available ownership files compiled in 1995, current available hydrography data from the WADNR, and available forest inventory data for both public and private groups. Some of these data were obsolete and need to be updated. The use of this study should be qualified by considering these conditions.

Project Overview

This project was a result of a joint agreement between the Washington Hardwoods Commission (WHC) and the Washington Department of Natural Resources (WDNR) to provide an assessment of Western Washington's hardwood inventory.

The WDNR provided the following data:

- Ownership of major public lands (MPL)
- Public ownership by county (POCA)
- Forest Resource Inventory System (FRIS) plot data
- WDNR clearcut harvest data from 1983-2000
- Latest available hydrography and stream type data

The WHC with the WDNR data and 2001 imagery would produce the following results:

- Ortho-rectified images
- Classified digital images for all commercial hardwoods in Western Washington
- Classified digital images by major age groups for all commercial hardwoods
- Summarized acreage for major land owners: small private, large private and public non-federal lands
- Assessment of commercial hardwood volume available for harvest by major age group and ownership class.

Weyerhaeuser Company, serving as contractor for the WHC, performed GIS analysis and data compilation.

- The project focus was to provide a volume assessment of the hardwood inventory likely to be available for harvest by the three major ownership groups inclusive of the current forest practice code and adjusted for a minimum operational unit size.

Five Landsat TM images acquired in year 2001 were used for mapping distribution of the hardwood resource. Current available hydrology layer from WDNR was used to derive the riparian model, using a simple buffer model (Marshall et. al., 1995) and a slope related riparian model (Ma and Righter, 1995). An ownership file collected by the contractor was used to derive the major timberland ownership groups.

Area available for harvest was defined by excluding the following strata layers:

- areas with elevation above 600 meters (non commercial for hardwoods)
- riparian zones for water types 1, 2, 3 (buffer model to simulate forest practice rules)
- riparian zone for water type 4 (removed 50% of hardwoods for forest practice rules not for commercial harvest)
- non-harvest ownership and all federal lands

Hardwood volume calculation was derived for two ownership groupings. For the small and public owners volume per acre coefficients were developed from WDNR's plot data. The large private owners volumes were based from the contractor's hardwood inventory data. Volume data was only established for the major commercial hardwood species: alder, maple, and cottonwood.

Classifying the Hardwood Resource

Seventeen counties in western Washington were mapped using year 2001 Landsat 5 TM and Landsat 7 ETM images. Landsat image values were developed to classify land cover types and age groups for the major forest cover types.

Timberlands were defined based on the ownership file collected in 1995. The major forest cover types included conifers, hardwoods, and mixed forests. Pixels identified with more than 75% conifers were labeled as pure conifers. Pixels identified with more than 75% hardwoods were identified as pure hardwoods. All other pixels, identified as forest but did not meet above two thresholds, were labeled as mixed forests.

The age groups were derived using the best estimates from interpretation of image pixel values. The age classification was based on changes in forest canopy that strongly correlated with forest ages from seedling stage up to maturity. The actual age for a forest pixel could vary by plus or minus 5 years.

By comparing various available resources, the image classification of forest cover types and age groups met the generally accepted criterion of 85% classification accuracy for mapping land covers types across large geographic areas.

Table 1. Classified hardwoods and mixed types for western Washington (acres)*

Type / Age	< 26 Years	26-34 Years	35+ Years	Grand Total
Hardwoods	354,819	113,357	578,449	1,046,625
Mixed Forests	137,217	41,719	336,761	515,697
Grand Total	492,036	155,076	915,210	1,562,322

* Areas with elevation under 600 meter.

Land Owner Groups

Coverage for 17 counties in western Washington was divided into private and public timberlands. Timberland owners were defined from available ownership file. Private lands were divided into Small Private and Large Industrial using 500 acres of timberlands as the split between the two groups. Public lands were also divided into two major groups, based on harvest feasibility. Table 2 lists public owners and re-groups for western Washington. Available ownership file excluded any parks owned by state and local governments.

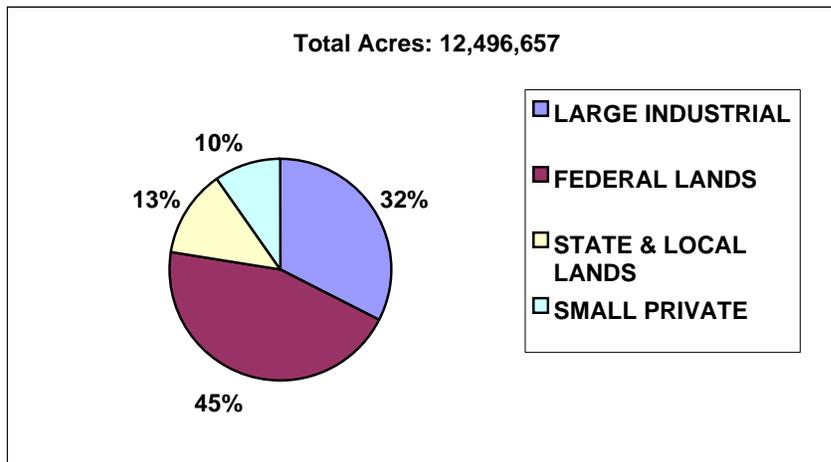
There were small percentage of unidentified timberland owners classified due to lack of urban boundaries, 50% of these areas were considered as available for harvesting.

Table 2. List of public owners regrouped into two major groups

BLM	FEDERAL LANDS
County	STATE & LOCAL LANDS
Indian Reservation	STATE & LOCAL LANDS*
Military	FEDERAL LANDS
Municipal Watersheds	STATE & LOCAL LANDS
National Forest	FEDERAL LANDS
National/Parks	FEDERAL LANDS
National Wildlife Refuge	FEDERAL LANDS
Nature Conservancy	FEDERAL LANDS
State of WA	STATE & LOCAL LANDS
Univ. of Washington	STATE & LOCAL LANDS
Wilderness Area	FEDERAL LANDS

* included in this group for harvest availability.

Figure 1. Distribution of timberland acreage for major ownership



Harvestable Area Stratification

To produce the net available harvest area from the gross timberland acres, stratification layers were developed to remove non-commercial areas and riparian area lost to forest practices. These strata were defined as follows:

- Stratum 1: areas with elevation above 600 meter
- Stratum 2: riparian zones for water types 1, 2, and 3
- Stratum 3: 50 foot wide riparian zones for water type 4
- Stratum 4: harvestable areas for commercial harvest.

The image pixels of hardwoods in Strata 3 and 4 were further adjusted to maintain a minimum five operable acres.

Figure 2. Total timberlands by stratification reductions

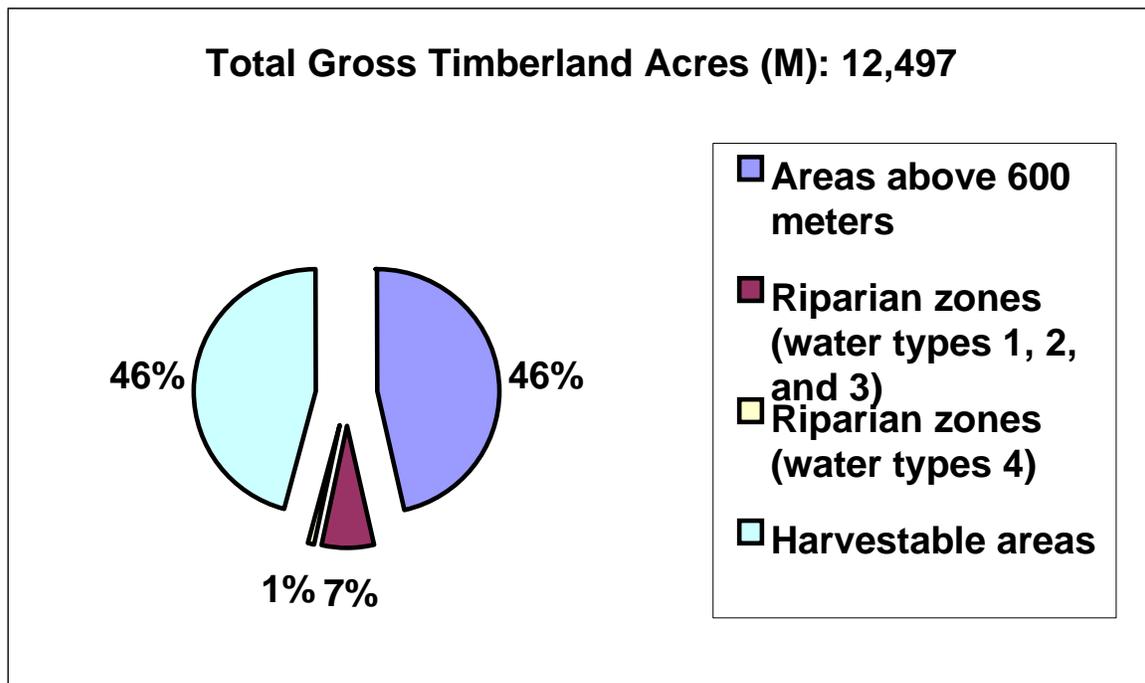


Table 3. Total timberland acres (M) by stratification reductions

Areas above 600 meters	Riparian (water types 1, 2, and 3)	Riparian (water type 4)	Harvestable Areas	Total
5,808	870	82	5,737	12,497

Available Timberland Acres

Not all-harvestable areas (5.737 million acres) are available for commercial hardwood harvesting. Ownership, regulation, and physical constraints determined the final available timberland acres for hardwood volume assessment.

A minimum 5-acres unit was considered as not operable, any continuous areas less than 5-acres were not used for hardwood volume calculation.

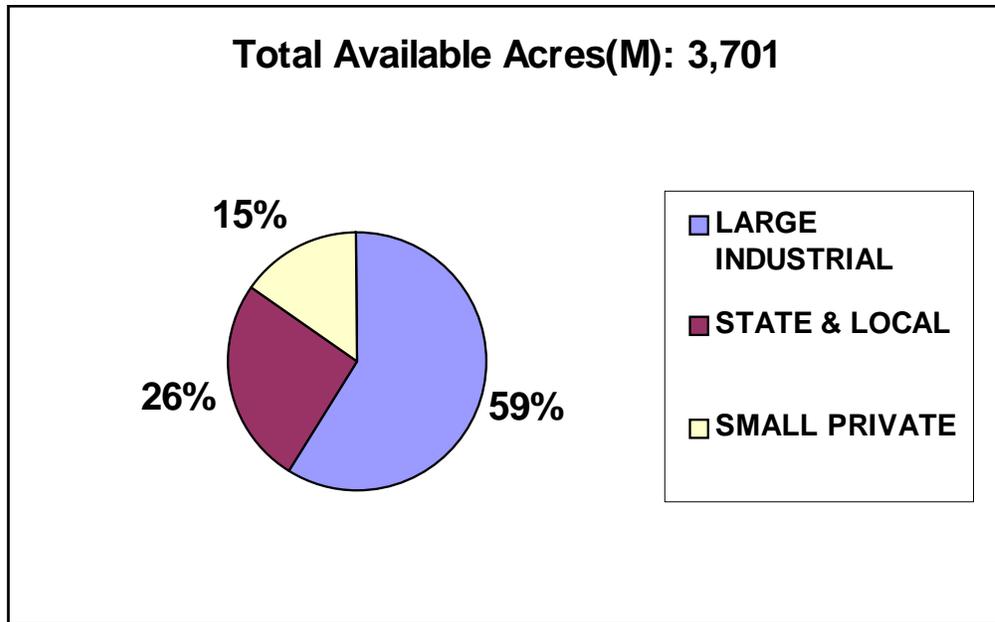
In the unidentified owner group, 50% of timberland acres was assumed from urban areas and removed from the total harvestable timberland acres. Timberlands owned by Federal government were not considered available and excluded from the final total available timberland acres.

Table 4. Reduction on total timberland acres for western Washington

Impact	Reduction Acres (M)	Remaining Acres (M)
Gross total		12,497
Above 600 meter (all owners)	(5,808)	6,689
Riparian (water types 1,2,3)	(870)	5,819
Non forest, non stocked & 5 acre operable*	(1,201)	4,618
50% riparian (water type 4)	(33)	4,585
Federal Lands	(850)	3,735
50% unknown owner	(34)	3,701

* Continuous area less than 5 acres was excluded

Figure 3. Total available timberland acres after reduction



Riparian Zones

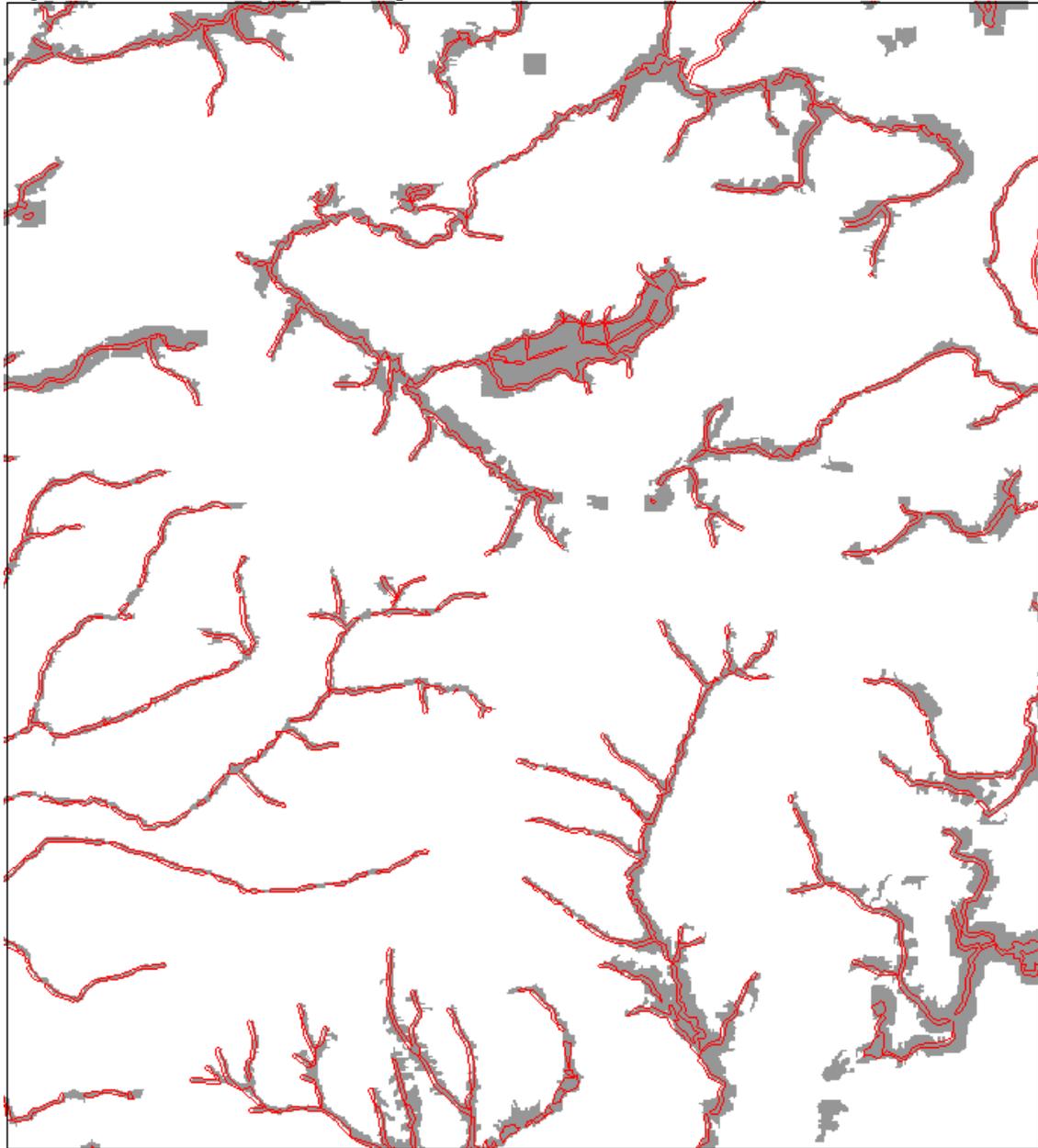
The hydrology layer was delivered by Washington DNR in 2001, and 10 meter Digital Elevation Model (DEM) was used for defining riparian buffer zone. The riparian model developed at Wildlife Spatial Analysis Lab, University of Montana (Ma and Righter, 1995) was used to build a variable width of riparian zone along the water types 1, 2, and 3. This model used slope (DEM) and stream locations to define the width of riparian area that is a better representation of riparian zone in the real world than a simple equal width buffer. As long as the DEM is accurate, the model takes care of the width of a big river very well from a single line feature of stream file.

A simple buffer was also used to build a 100 foot wide riparian buffer zone for water types 1, 2, and 3 as well as a 50 foot wide riparian buffer zone for water type 4. This simple model produced an equal width riparian buffer zone using a single center line regardless of the stream width.

These two riparian models were used concurrently, but only accepted the model that provided the greatest riparian width. This method allowed for the best estimate for stream migration and other wetlands protected under the forest practice laws.

Figure 4 shows difference between these two riparian models and indicates boundaries of combined riparian zones. The red lines indicate the riparian zones derived from a simple equal-width buffer model and black areas are riparian zones derived using a model developed by Ma and Righter*.

Figure 4. Illustration of the two riparian models

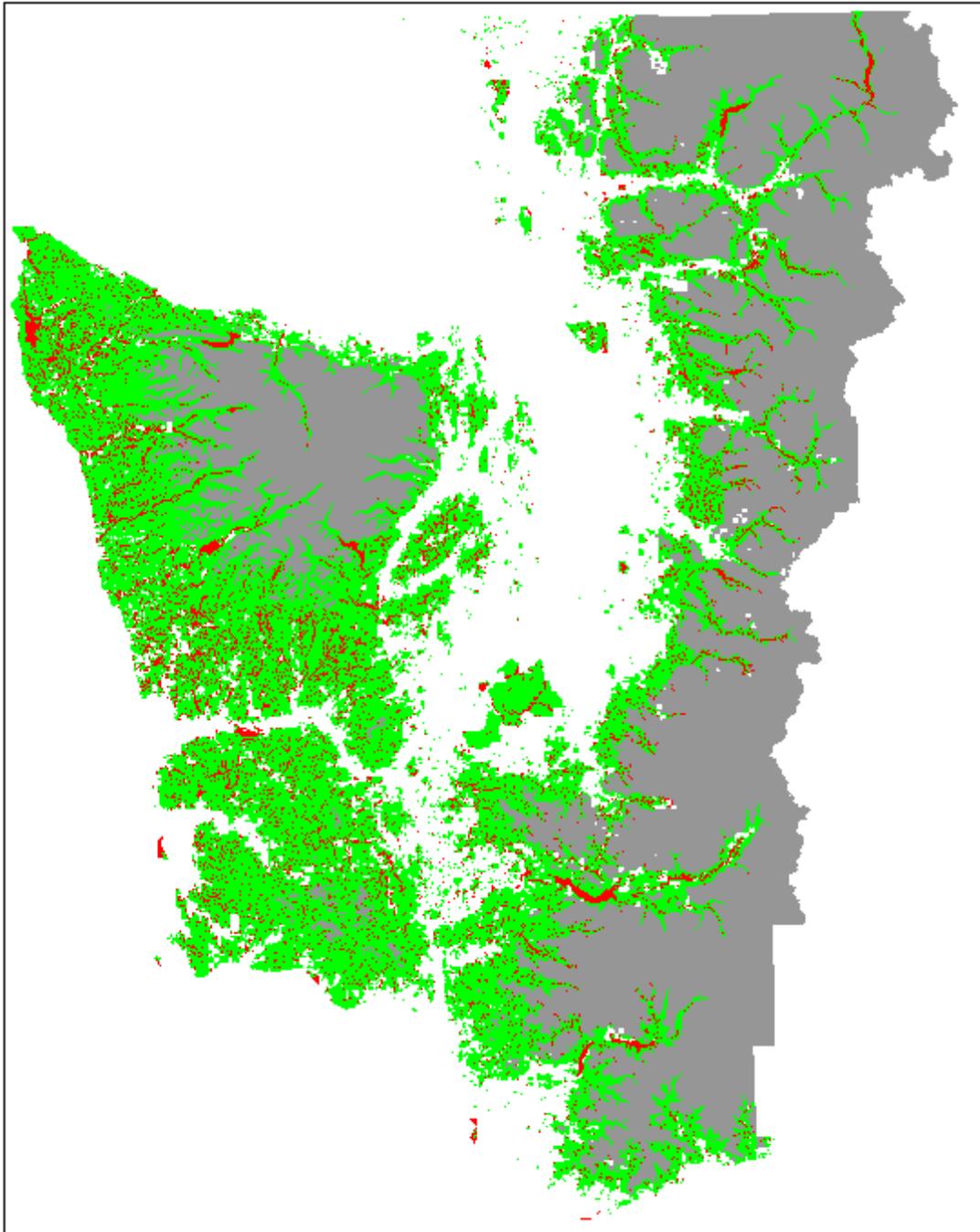


*Ma, Zhenkui and Ron Righter, 1995. *A method for modeling Riparian Distribution in Mountainous Terrain*, **Ninth Annual Symposium on Geographic Information System**, Vancouver, BC, Canada.

Total Reduction Strata

Figure 5 shows the geographic distribution of the strata reduction layers. The black lines are county boundaries, red color indicates the riparian zone, gray color indicates areas with elevation above 600 meters, and green color indicates the harvestable areas (not adjusted for timberland ownership availability).

Figure 5. Area stratification for timberlands in western Washington



Acres to Volume Relationship

WDNR Resources Inventory Units (RIU) and Weyerhaeuser Inventory Database were used to derive two sets of coefficients for relationship of hardwood volumes and forest acres for public and private lands, respectively.

The coefficients were made county by county, as forest site index indicated differences among counties in western Washington. The coefficient was a ratio of known forest volumes over certain forest areas, stratified by age groups from image classification. These two sets of coefficients were later adjusted based on site index and professional knowledge of the area to get an acceptable estimation of total hardwood volumes.

The procedure for deriving coefficient of Alder volume per acre for public lands is described here.

- First, the average tree height and DBH from RIU were derived for the age groups made from image classification. Second, the average RIU information and age groups 30 (26 to 34) and 35+ from image classification were used to find the volume from a yield table published by USFS (Research paper 36, August, 1960).
- Since the average site index from RIU for each county measured for Douglas Fir (DF) stands was too high for Alder site index, an adjustment was based on the index relationship of DF to Alder. The factor (0.702) for the adjustment was derived from ratio of the average site index from all the counties for Alder at 85 to DF at 121. This factor was applied to each county DF site index to yield the Alder site index.

Because some of WDNR inventory data is 5 years old, estimates were made for average Alder height and DBH for current 30 and 35+ age groups of hardwoods (from image classification). The volume was found from the yield table, using adjusted Alder site index, average tree height, and average DBH. The coefficient of volume per acre was calculated by a ratio of summarized volumes to classified hardwood acres. These coefficients were applied at 100% for hardwood stand types, 44% for mixed hardwood/conifer stand types, and 14% for conifer stand types for each county in western Washington. The percentage by stand type was derived from WDNR inventory data.

Similar procedure was made for private lands (large industrial) using stand information from Weyerhaeuser inventory database. These coefficients were applied at 100% for hardwood stand types, 25% for mixed hardwood conifer stand types, and 6% for conifer types for each county in western Washington.

Harvestable Hardwood Volumes

The total harvestable hardwood volume was derived by applying the appropriate volume coefficient by owner group net of the reduction strata layers. No volume was calculated for elevations above 600 meters. Figure 6 below illustrates the volume calculated for each major ownership group. Figure 7 illustrates the volume impact for the riparian zones.

Figure 6. Distribution of hardwood volumes by major ownership group

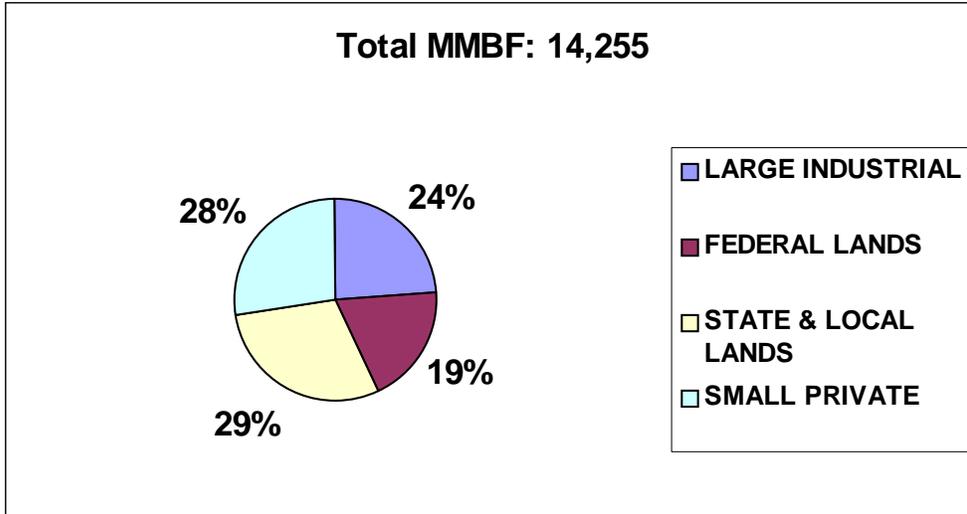


Figure 7. Riparian zone reduction

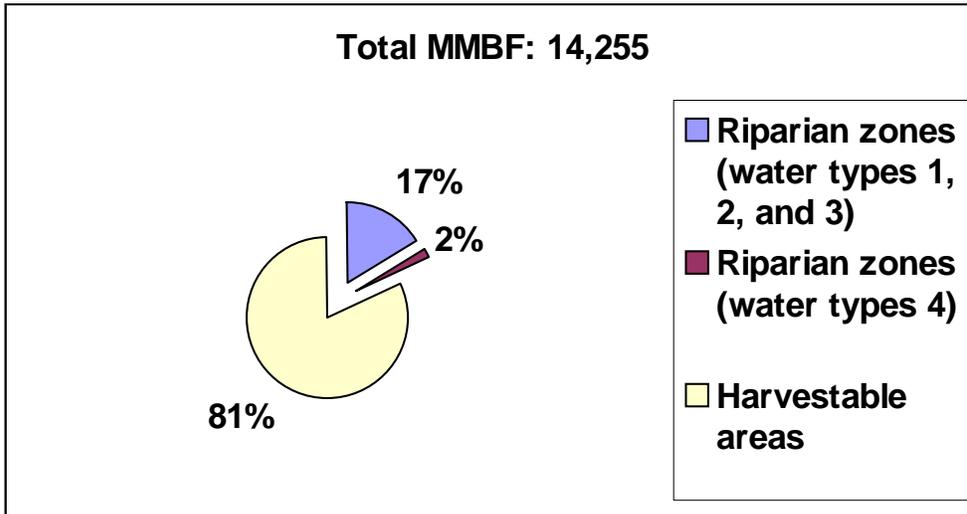


Table 5. Riparian zone reduction (MMBF)

Riparian (water types 1, 2, 3)	Riparian (water type 4)	Harvestable	Total
2,367	238	11,650	14,255

Available Hardwood Volumes

Ownership, regulation, and physical constraints determined the final available hardwood volume. In the unidentified owner group, 50% of hardwood volume was assumed from urban areas and removed from the total harvestable hardwood volumes. Hardwood volume owned by Federal government was not considered available and excluded from the final total volume.

Figure 8. Available hardwoods by major owners (minimum 5-acre operable unit)

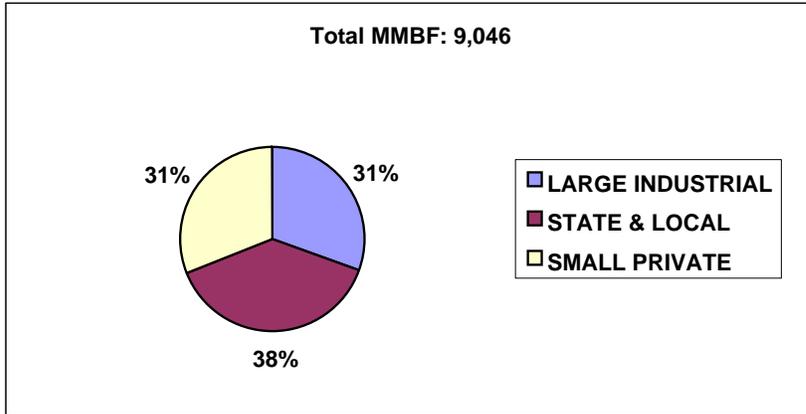


Figure 9. Available hardwoods by species

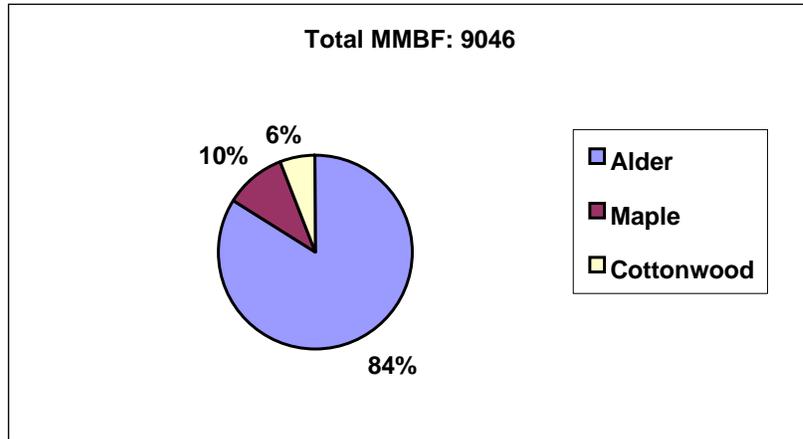


Table 6. Available hardwood volumes (mmbf) (minimum 5-acre operable unit)

Area/Owner	Large Industrial	State & Local	Small Private	Total
Red Alder	2314	2917	2352	7583
Big Leaf Maple	179	429	336	944
Black Cottonwood	95	234	189	518
Total	2588	3580	2877	9046

Table 7. Reduction on total Red Alder volumes for western Washington

Impact	Reduction Volume (M mbf)	Remaining Volume (M mbf)
Gross total*		11,993
Above 600 meter (all owners)**	(Not Applicable)	11,993
Riparian (water types 1,2,3)	(2,042)	9,951
Non forest, non stocked & 5 acre operable	(116)	9,835
50% riparian (water type 4)	(97)	9,738
Federal Lands	(1999)	7,739
50% unknown owner	(156)	7,583

* Excluded volume from areas with elevation above 600 meter.

** Volume was not calculated for this stratum.

Table 8. Reduction on total Big Leaf Maple volumes for western Washington

Impact	Reduction Volume (M mbf)	Remaining Volume (M mbf)
Gross total		1,451
Above 600 meter (all owners)	Not Applicable)	1,451
Riparian (water types 1,2,3)	(210)	1,241
Non forest, non stocked & 5 acre operable	(16)	1,225
50% riparian (water type 4)	(13)	1,212
Federal Lands	(247)	965
50% unknown owner	(21)	944

Table 9. Reduction on total Black Cottonwood volumes for western Washington

Impact	Reduction Volume (M mbf)	Remaining Volume (M mbf)
Gross total		811
Above 600 meter (all owners)	Not Applicable)	811
Riparian (water types 1,2,3)	(115)	696
Non forest, non stocked & 5 acre operable	(9)	687
50% riparian (water type 4)	(7)	680
Federal Lands	(149)	531
50% unknown owner	(13)	518

Summary and Data Qualifications

This project used currently available public information to assess available hardwood resources by major ownership groups and to demonstrate impact of forest practice laws.

All requirements of the project were met, however, overall use of this study should be qualified by the following observations:

- Imagery data used in this study was high quality products from both Landsat 5 TM and Landsat 7 ETM sensors. They were ortho-rectified using control points from WHC 1994 Landsat database. The accuracy of the image classification was considered at a 85% acceptable level.
- Hardwood volumes were estimated from dated inventory plot data, requiring some professional judgment to reflect current hardwood resources. More current inventory data would certainly improve the estimate.
- As mentioned, the hydrology data is the current available layer from WDNR and does not include new update work currently in progress. The riparian model, therefore, used against this layer is only as accurate as the stream typing data provided. This obviously had an impact on the accuracy of the assessment in defining the impact of the current forest practice rules. It is strongly recommended that when the new hydrology data is available it should be applied to this analysis.
- The ownership file was compiled in 1995. A new ownership layer would obviously improve the data but probably not materially as major changes usually occur within the same groups. More important may be the change in land status from timberlands to higher value applications; this would certainly impact the sustainability of hardwoods in the future.