1. INTRODUCTION

1.1 Purpose

The purpose of this project was to conduct a biomass resource and bioenergy technology assessment for Baker, Union and Wallowa Counties in Northeast Oregon. This assessment covers both forest biomass and agricultural residues. The federal, state and private forests in the area are at high risk for wildfire, and the development of a bioenergy facility would provide a market outlet for un-merchantable biomass and provide much needed jobs and tax revenues in the local economy. This assessment provides information that can help support the future development of biomass energy facilities in the three-county area. The assessment includes information regarding optimal locations for development of energy facilities in those counties, taking into account proximity to feedstocks and existence of supporting infrastructure.

1.2 Study Area

The project area includes Baker, Union and Wallowa Counties in Northeast Oregon (Figure 1-1).

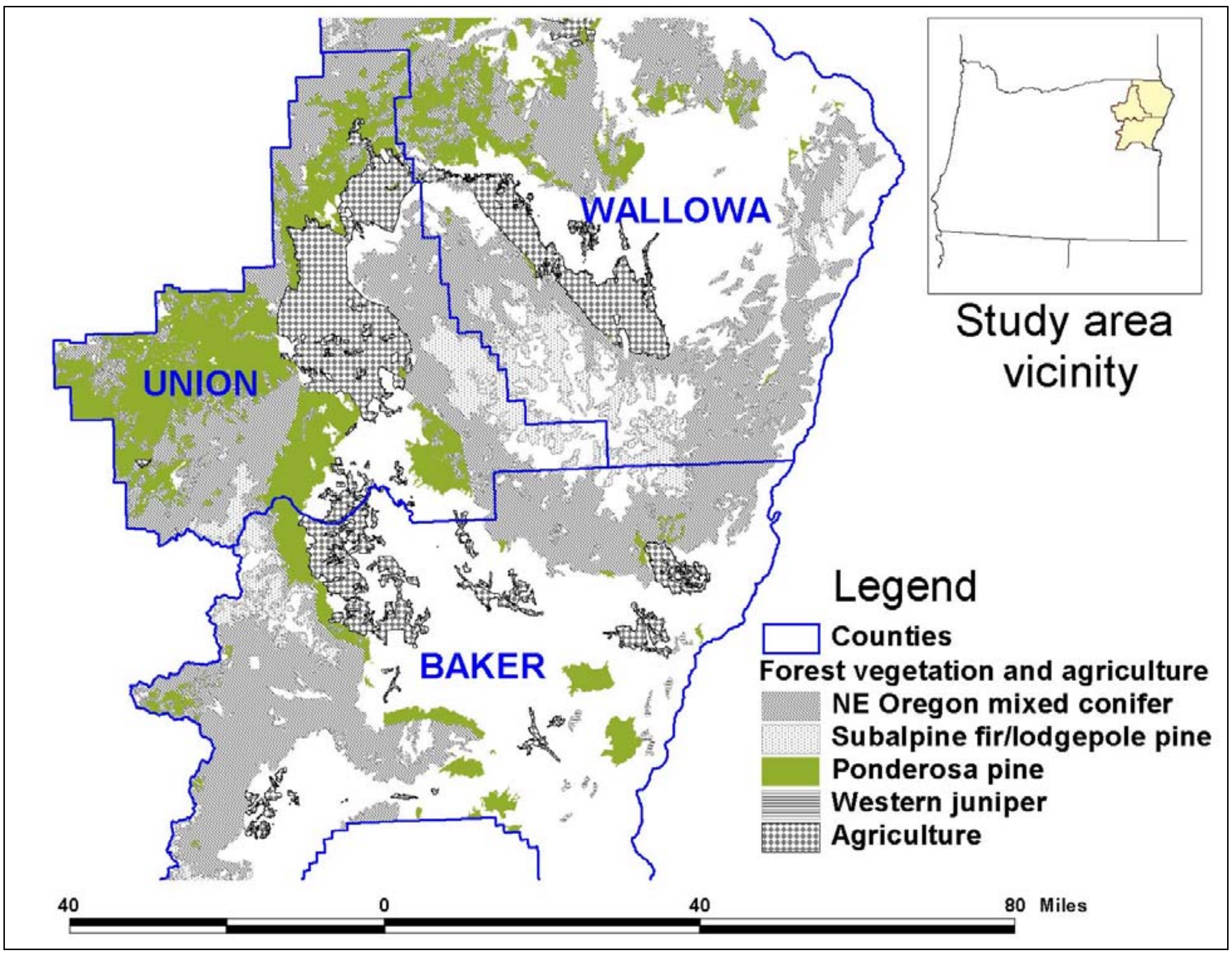

Figure 1-1. Project study area

Public land makes up 52% of total land ownership in the study area, with U.S. Forest Service (USFS) lands representing 45% of the total land area (Table 1-1).

Table 1-1. Land ownership in the study area

Landowner	Baker	Union	Wallowa	Total
Bureau of Land Mgmt [acres][14]	369,120	6,452	16,213	391,785
USFS Wallowa-Whitman[15]	598,553	514,789	1,020,293	2,133,635
USFS Umatilla[16]	3	102,268	123,550	225,821
State land [acres][17]	5,497	1,300	2,212	9,009
Total federal & state [acres]	973,173	624,809	1,162,268	2,760,250
Total area [acres][18]	1,976,960	1,304,320	2,017,920	5,299,200
Federal & state land [% of total area]	49	48	58	52

Table 1-2 shows summary statistics for population, housing, income, unemployment and precipitation for the three counties.

Table 1-2. Summary statistics for the study area[19]

Metric	Baker	Union	Wallowa
Population	16,700	24,550	7,100
Population density (Persons/mi^2, 2000)	5.5	12.0	2.3
Area [mi^2]	3,089	2,038	3,153
Housing units, 2000	8,402	10,603	3,900
Median household value (owner-occupied), 2000[$]	84,700	93,600	111,300
Median household income, 1999 [$]	30,367	33,738	32,129
Labor force, 2001	7,306	12,352	3,359
Unemployment rate, 2001 [%]	8.8	5.8	10.8
Local government employment (full-time equivalent), 1997	599	896	414
Annual precipitation [in]	10.63	18.79	13.08

1.3 Project Need

A significant amount of biomass that is not merchantable in traditional small-wood industries or for the manufacture of new wood products is available from forests in the three-county study area in Northeast Oregon. Biomass energy facilities (either stand-alone or integrated with an existing industrial facility) could provide a potential economic use for this material. Feasibility depends on locating an energy facility close to the source of the material and sizing the facility appropriate to the volume of material available on a long-term, sustained basis.

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14 Bureau of Land Management Oregon Office, *BLM Facts – Oregon and Washington 2001,* accessed September 22, 2003 (http://www.or.blm.gov/BLMFacts/2002BLMFacts.pdf).

15 U.S. Department of Agriculture Forest Service, Wallowa-Whitman National Forest, *Forest Facts,* accessed September 22, 2003 (http://www.fs.fed.us/r6/w-w/forest_facts.htm).

16 Umatilla National Forest, *Total Forest Acres,* accessed September 22, 2003 (http://www.fs.fed.us/r6/uma/acres.htm).

17 Oregon Division of State Lands, *DSL Land Ownership Acreage*, accessed November 11, 2003 (http://statelands.dsl.state.or.us/acreage_map.htm).

18 U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).

19 U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).

Using current and near-term technology, biomass energy facilities could convert surplus forest biomass into electricity, industrial steam energy and fuel ethanol. A barrier to private sector investment in biomass energy facilities is the lack of specific information about the amount of biomass feedstock available, the cost of feedstock delivered to the plant site and the best locations for proposed facilities relative to both feedstock supply and markets for energy products. There is a critical need for this information in view of both high-fire risk in the forest and the need for economic stimulus in rural communities.

The National Fire Plan is a collaborative effort between the U.S. Department of Agriculture's U.S. Forest Service (USFS) and the U.S. Department of Interior (DOI) to reduce wildfire risks to communities, natural resources, firefighters and the public through hazardous fuels reduction, forest rehabilitation and restoration, community support and research. This project addresses the goals of the National Fire Plan by supporting the development of a locally-based biomass energy industry that would provide a long-term market for utilization of biomass material resulting from fuels treatment projects on public lands. Information developed through this project is needed to assess the economic feasibility of biomass energy development. Locally based facilities would benefit rural communities through on-site and in-forest job creation, local tax revenue potential and local economic activity associated with construction and operation.

The Oregon Department of Energy supports the development of clean, reliable and affordable energy resources. This mission extends to the use of renewable energy resources, including biomass. The Oregon Department of Energy pursued this project because it promotes utilization of sustainable, clean biomass resources and protection of Oregon's natural resources.

1.4 Project Team

The Oregon Department of Energy assembled the project team that conducted this work. McNeil Technologies, Inc. (McNeil) conducted the primary work on the project. At McNeil, Scott Haase was the project manager, Tim Rooney was the principal investigator and Jack Whittier provided technical support and analysis. Dr. James Kerstetter provided technical assistance and conducted the assessment of agricultural residues. It is also important to acknowledge the many federal, state and local project participants, without whom this project could not have been completed. These include, but are not limited to: the Oregon Department of Forestry, the Grande Ronde Model Watershed Program, USFS staff at Wallowa-Whitman National Forest, the Pacific Northwest Research Station (USFS), Wallowa Resources, Oregon State University's Department of Forest Science and Oregon State University Extension Service staff in Baker, Union and Wallowa Counties.

1.5 Project Goals and Objectives

The overall project goal was to promote cost-effective, sustainable biomass use for power and liquid fuel manufacturing in Baker, Union and Wallowa Counties. An additional goal of the project was to identify potential sites in the area where a long-term, sustainable supply of biomass feedstock is available economically within a reasonable transportation distance from a potential plant.

The objectives of the project were to:

- conduct a review of previous related studies and assessments,
- evaluate the quantity of biomass produced in the region,

- conduct a preliminary siting analysis and identify potential facility sites
- determine biomass availability and costs for delivery to potential sites in the counties,
- develop biomass supply curves for each county,
- identify issues associated with the sustainable use of biomass,
- describe social, economic and environmental impacts of biomass energy use, and
- discuss biomass facility characteristics and quantify feedstock requirements for hypothetical biomass power and cellulose ethanol plants to be developed in the region.

1.6 Summary of Activities Performed

The primary analysis provided biomass supply curves for the study area and identified candidate facility sites in each county. The secondary phase of the project identified issues associated with the sustainable use for biomass, identified applicable biomass technologies for the study area and described the environmental, economic and social costs and benefits of biomass utilization.

This report contains supply curves for forest biomass and agricultural residues from all sources in the study area, including public and private lands. Forest biomass is further segmented to include logging residues and urban wood residues in addition to surplus biomass resulting from fuels reduction treatments on forests in high-fire threat zones. The assessment in this report also includes locally available agricultural residues as a supplemental or alternate feedstock source.

2. REVIEW OF PREVIOUS STUDIES

This section identifies and reviews seven studies that evaluate biomass resources in or near the study area. These studies provided background information for the present work. In this section we provide a brief overview of each study. Additional information on three of the studies is provided in Appendix A. Additional studies that have some relevance to the project area are identified and categorized in Appendix B.

2.1 Blue Mountains Vegetation Assessment

In November 2002, the USFS, Pacific Northwest Research Station released the results of the Blue Mountains Vegetation Assessment, a joint project by the USFS, the Oregon Department of Forestry (ODF), Oregon State University, and the Malheur, Wallowa-Whitman and Umatilla National Forests. The primary purpose of the study was to evaluate the availability of timber based on land suitability, vegetation conditions and harvest economics. The assessment includes Baker, Grant, Harney, Morrow, Umatilla, Union and Wallowa Counties of Oregon. Lands in Crook and Wheeler Counties managed by the Malheur National Forest were also analyzed. Appendix A provides additional information on the resource assessment and other findings of this study.

The study determined that a majority of the National Forest land in the study area (71%) is unavailable for substantial or sustained timber harvest due to Congressional designations, forest planning allocations or non-forested conditions. The remaining 29% (1,616,000 acres) of National Forest land is designated as "active forestry" land and could be available for substantial and sustainable timber harvest. The definition of "active forestry" includes land where timber harvest may occur, where significant and sustainable timber supplies are anticipated and where the resource direction is compatible with mechanical treatment. Up to 32% of these acres have experienced timber harvest or non-commercial thinning since 1988. Non-commercial thinning includes forest management that removes material that cannot be used in conventional wood products, and it is done for the purpose of guiding forest development to meet forest management objectives.

The results indicated that an estimated 943,000 acres of forested National Forest land classified as "active forestry lands" are overstocked, or 58% of the total area in that planning allocation. The criteria for overstocking was determined for specific groups of plant associations based on methods developed by Cochran, et al.[20], using analysis of aerial photographs and existing vegetation data. For this assessment, a stand was considered overstocked if its stand density index (SDI) exceeded 45% or if the number of trees per acre between 0.1 and seven inches in diameter at breast height (DBH) exceeded 300. The SDI is a measure of competition between trees for available site resources (water, sun and soil nutrients) and individual tree growth. Generally, stands with an SDI greater than 50% can be said to have greater competition between trees and lower tree resilience to environmental change, disease and pest infestation.[21]

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[20] Cochran, Geist, Clemens, Clausnitzer and Powell, *Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington* (Research Note RN-513, Pacific Northwest Research Station, 1994).
[21] D. Wilson and D. Maguire, *Draft: Potential Small-Diameter Timber Resource from Restoration Treatments in Overstocked Stands on National Forests in Eastern Oregon* (Oregon State University Department of Forest Sciences, 2002).

Thinning on 39,900 acres had a positive net value based upon the economic assumptions used. These treatments harvested 167 million board feet (MMBF) of timber with an error margin of plus or minus 36 MMBF.

The study also determined that an estimated 581,000 acres of private land were overstocked in the Blue Mountains region, although analysis of potential timber volume and economics was not complete at the time of the current study.

The results provide an indication of the potential for economically viable timber harvesting to contribute to fuels reduction goals and a sustainable biomass supply. The results of the assessment can also be used to validate estimates of long-term biomass availability from timber harvesting residuals on National Forest land.

The estimates of overstocked acres and potential timber harvest volumes do not take into account many significant site-specific variables. Analysis of these variables is best done on a project-by-project basis. Some of the information on overstocked stands was as much as 20-years-old. However, validation of the mapping with USFS ranger district personnel indicated that the identification of overstocked stands was correct about 80% of the time. County-level estimates are limited in accuracy because of the small number of plots. However, 95% confidence interval data make it possible to estimate an upper and lower boundary for overstocked acres and potential timber volumes in some counties. For these reasons, the analysis is only a starting point for project level planning.

2.2 Dry Forest Mechanized Fuels Treatment Trials Project

The Central Oregon Intergovernmental Council administered a study that evaluated the effects of forest biomass harvest projects at four locations in three states. The study investigated costs, productivity and impacts of biomass harvesting at each project location. The project was funded through a National Fire Plan grant from the USFS, Pacific Northwest and Intermountain Regions. In all, 15 different fuels treatment systems were demonstrated.[22] Field trials were conducted at locations near Idaho City, Idaho; Leavenworth, Washington; and Sisters, Ore. during the winter of 2001 and spring of 2002. Each location was representative of wildland urban interface sites that are likely to be treated in the next decade. Appendix A provides additional information on the resource assessment and other findings of this study. The study results can also be obtained on-line at: http://www.theyankeegroup.com/mechfuels/.

The results indicate that no single equipment configuration or treatment is appropriate for all forest stands. Rather, the results present information about the performance of many equipment configurations under a variety of conditions.

The cost and productivity data collected during the study are by no means comprehensive. Rather, the data are intended to show the broad range of performance that can be obtained using various equipment configurations at different sites. For all the project trial sites, production costs ranged from a low of $330/acre to a high of $2,187/acre. However, for most extraction systems, which remove trees from the forest, costs ranged from $500 to $1,000/acre. For mastication

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[22] E. Coulter, K. Coulter, T. Mason, J. Szymoniak and L. Swan, *Dry Forest Mechanized Fuels Treatment Trials Project* (http://www.theyankeegroup.com/mechfuels/, Central Oregon Intergovernmental Council, October 24, 2002).

systems, which grind material and leave it on-site, costs range from $400 to $850/acre. Administrative and follow-up treatment costs were not included.

2.3 Oregon Cellulose-Ethanol Study

In a study issued in June 2000, the Oregon Department of Energy evaluated the potential to manufacture biomass ethanol in Oregon. Major findings included:

- There are no ethanol plants in Oregon;
- Approximately 30 million gallons of ethanol are used each year in Oregon;
- In 1998, more than 8.5 million bone-dry tons (BDT) of biomass were generated;
- The biomass supply consists of 49% agricultural residue, 35% forest residue and 16% municipal solid waste (MSW);
- Based on estimated biomass availability from wheat straw and forest thinnings, 280 million gallons of ethanol per year (million gallon/year) could be manufactured in Oregon; and
- National Renewable Energy Laboratory economic modeling of hypothetical production plant scenarios showed potential internal rates of return of 19% for a 29-million-gallon/year plant using forest biomass and 18.3% for a 54-million gallon/year plant using and wheat straw, assuming delivered feedstock cost of $28/BDT for forest biomass and $30/BDT for wheat straw and assuming a natural gas boiler for process heat.[23]

Appendix A provides more information on the resource assessment and other findings of this study. Agricultural residues comprise the largest biomass resource in Oregon. Agricultural residue generation in Oregon was greater than four million BDT in 1998. Not all residues generated would be available due to restraints on residue removal for soil agronomic concerns and competing markets for grass straw, much of which is shipped to Japan for animal feed.

Biomass from forest thinning is the second largest biomass supply source in Oregon. However, a lack of a consensus of forest policymakers on the type of treatment needed and the extent to which forests should be managed actively contributes to a forest biomass supply that is difficult to quantify. This study estimated that more than 2.9 million BDT of biomass could potentially be available from forest management annually in Oregon. Estimates of forest residue availability are based on an estimate of acres requiring treatment for forest health reasons, assuming conservatively that 2% of the land area is treated annually with a biomass yield of 21 BDT/acre.

Municipalities generate an estimated 6,184 BDT/year in clean biomass residues in Baker, Union and Wallowa Counties. This estimate does not include wood waste from industrial sources.

The total potential ethanol yield in Oregon if all biomass generated were used for ethanol manufacturing exceeds 500 million gallons/year. As not all residues could be converted, analysis of biomass availability from wheat straw and forest biomass suggest that a more realistic estimate of annual biomass ethanol potential in Oregon is closer to 280 million gallons.

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[23] A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000).

2.4 Markets and Processing Options for Small Diameter Trees

The Central Oregon Intergovernmental Council (COIC) commissioned a study in May 2002 that evaluated available biomass supply infrastructure, processing technologies and markets.[24] The COIC study focused on the Deschutes, Ochoco and Winema-Fremont National Forests and the Prineville Bureau of Land Management (BLM) region. While the focus of this study was not energy, it did offer insights on supply challenges that are similar for Northeastern Oregon.
Key observations include that supply reliability and predictability needs to be improved to encourage new investment. Timber contracting and National Fire Plan planning procedures do not necessarily make this easy in all cases. Multi-year planning, coordination between fuels reduction and timber programs, collection of biomass removal volume data and coordination between National Forests at the regional level to coordinate annual biomass material offerings could help create a sustainable biomass supply.

2.5 Oregon Department of Forestry Private Land Resource Assessment

The Oregon Department of Forestry (ODF) conducted an assessment of overstocked stands on private land in the study region. ODF's criterion for overstocking was different than that used in the Blue Mountains Vegetation Assessment. The ODF study considered forested areas to be overstocked if the canopy closure rate was greater than 80% based on satellite imagery analysis. The treatable acreage would most certainly be lower than the overstocked acreage shown in Table 2-1 because of site-specific conditions that preclude thinning or suggest other management options, landowner preference and other factors.

Table 2-1. ODF estimates of overstocked acres on private land

County	Overstocked acres
Union	7,637
Wallowa	7,134
Baker	1,597
Subtotal – study area	***16,368***
Umatilla	16,436
Total with Umatilla County	***32,804***

Table 2-1 shows acreage in Umatilla County because the estimates resulted in significant areas of overstocked forestland in this adjacent county to the study area. Notably, the overall acreage of private land considered overstocked in this study was significantly smaller than the estimates conducted for the Blue Mountains Vegetation Assessment (Section 2.1).

2.6 Western Forest Health and Biomass Energy Potential

In April 2001, the Oregon Department of Energy issued a broad-level evaluation of biomass resources and policy initiatives in the Western U.S., with a special focus on Northeastern Oregon.[25] The study assessed potential forest biomass availability in Grant and Wallowa

[24] Mater Engineering, Ltd., *Markets and Processing Options for Small Diameter Trees* (Central Oregon Intergovernmental Council, June 2002).
[25] N. Sampson, M. Smith and S. Gann, *Western Forest Health and Biomass Energy Potential* (Oregon Department of Energy, April 2001).

Counties. There are an estimated 1.36 million acres of National Forest lands in Wallowa County. Of this, 56% is protected in wilderness areas, 7% is unsuitable for management or is reserved land and 29% is in the Hell's Canyon National Recreation Area. This leaves 8%, or 115,000 acres, available for forest management. There are 150,000 acres of private industrial forestland and 130,000 acres of non-industrial private forestland. The results of the assessment indicated that between 395,000 and 593,000 BDT of forest biomass could be available annually from Wallowa County forests if half of the available forestland were thinned over a 10-year period (5% of the available land each year). This assumes yields of 10 to 15 BDT/acre.

2.7 Agricultural Residue Supply Curves

In January 2001, the Washington State University Energy Program, under contract to the U. S. Department of Energy (DOE), developed supply curves for logging residue and agricultural field residue for Idaho, Montana, Oregon and Washington. Only logging residue in Western Oregon counties were included in the assessment, so those results are not reported here. Agricultural residue was limited to the straw residue from wheat and barley production. Agricultural quantities from Baker, Union and Wallowa Counties were included in this study.

Table 2-2 shows the average residue generation and delivered costs from each of these three counties to Pendleton, Ore. The residue generation estimates assume that 1.5 field dry tons/acre would be left on the field after straw removal. Field dry residue typically contains between 10% and 20% moisture content (MC). Estimated residue collection costs were $32/acre and transportation costs were calculated assuming a fixed cost of $5.50/ton, plus variable costs of $0.088/mile.

Table 2-2. Quantity and costs for agricultural field residue

County	**Quantity** (tons[a]/year)	**Yield** (tons/acre)	**Travel distance** (miles)	**Harvest cost** ($/ton)	**Fertilizer & storage cost** ($/ton)	**Hauling cost** ($/ton)	**Total cost** ($/ton)
Union	75,241	1.61	47	20	10	10	39.61
Baker	14,703	1.83	90	17	10	13	40.93
Wallowa	29,977	1.14	89	28	10	13	51.38
Total/ *weighted average*	119,921	1.52	63	22	10	11	42.71

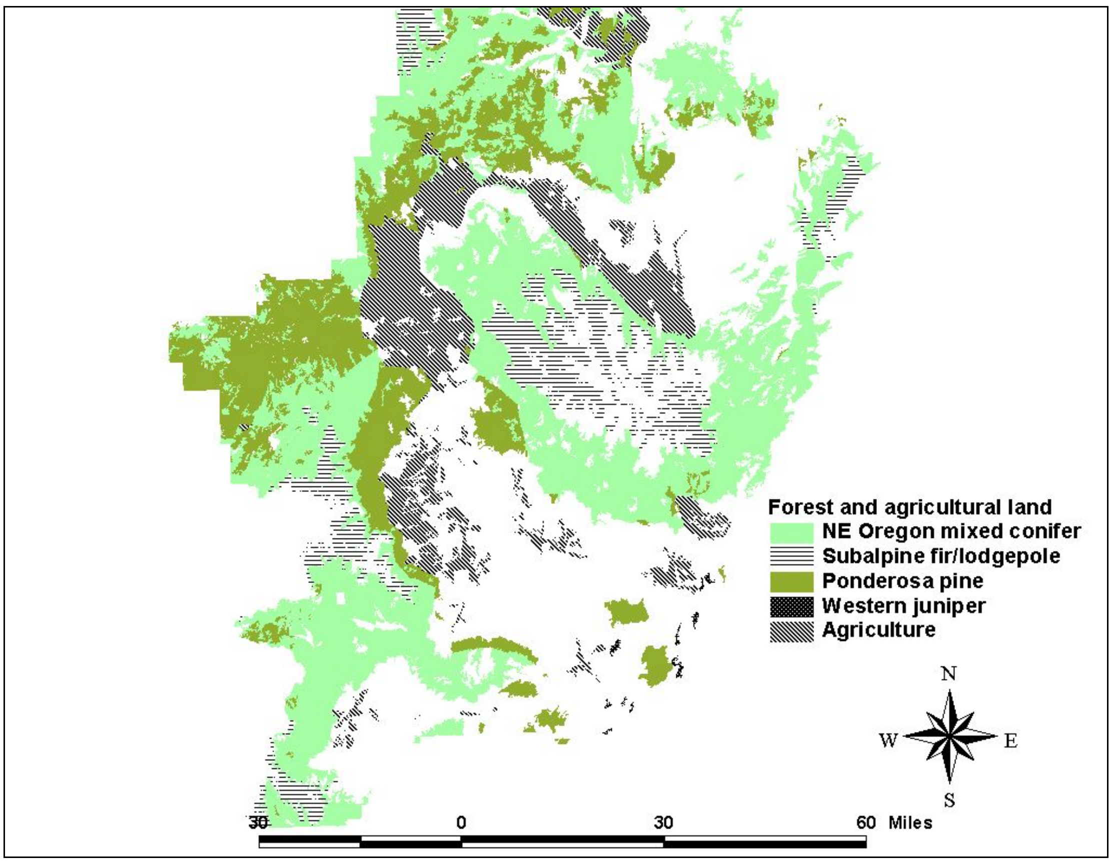
[a] Field dry tons.

3. FOREST BIOMASS GENERATION AND AVAILABILITY

This section provides estimates of annual generation and availability of forest biomass from commercial timber harvesting, timber stand improvement (TSI), fuels treatment and non-commercial thinning on federal, state, county, private and municipal land. Timber stand improvement can result in removal of some commercially valuable trees, but it is conducted primarily as a means of manipulating stand composition and maximizing stand productivity and timber stand value. Non-commercial thinning activities have the objective of maximizing timber value or meeting other resource management goals but generally do not result in removal of commercially valuable trees.

3.1 Forest Biomass Generation

Figure 3-1 shows the distribution of forest types that are the focus of most active management within the study area. Agricultural land is also shown.



Source: Eber, Ron, Rural Lands Database, *Gap Analysis Program (GAP) Vegetation Cover Database*, Oregon Department of Land Conservation and Development.

Figure 3-1. Distribution of forest vegetation and agricultural land

Forests covers 48.3% of the land area in the study area, based on Gap Analysis Program data for vegetation cover.[26] This supply analysis focuses, however, on biomass availability from active forest management on only the portion of this area that is managed annually, a small percentage of the total forested area.

A wide range of forest management activities generate biomass in the form of tops, branches, dead and dying trees and trees being removed to help meet the goals of a forest management prescription. This section describes the methods and results used to estimate forest biomass generation in Baker, Union and Wallowa Counties. Later, Section 3.2 discusses how much of this forest biomass is potentially available to generate power and or ethanol.

3.1.1 Methods

Forest biomass generation estimates relied on historical timber harvest data and estimated overstocked acreage on public and private timberland. Forest biomass quantities are reported in green tons (GT) in this report. Table 3-1 summarizes the data sources used to estimate forest biomass generation.

Table 3-1. Data sources used to estimate forest biomass generation

Biomass source	Data source			
	USFS	ODF Timber harvest database	National Fire Plan	ODF Private land assessment
Timber harvest	yes[a]	yes[b]		
TSI	yes[a]			
Fuels treatment			yes[c]	yes[d]
Non-commercial thinning	yes[a]			

[a] USFS Umatilla National Forest Planning, *Tri-forest Planning for Malheur, Umatilla and Wallowa-Whitman National Forest* (http://www.fs.fed.us/r6/uma/nepa/planning.htm).
[b] ODF Forest Resources Planning Program, *Complete Harvest Database: 1962 – 2001* (http://www.odf.state.or.us/DIVISIONS/resource_policy/resource_planning/,ODF, 2002).
[c] USFS, *GEOMAC National Fire Plan Maps: 2000-2001 National Fire Plan Fuels Reduction Project data for Congressional District*, accessed March 19, 2003 (http://wildfire.geomac.gov/NFPmaps/viewer.htm?extent=Oregon).
[d] A. Johnson, *Unpublished report: Overstocked Private Land Assessment for Baker, Union, Wallowa and Umatilla Counties* (ODF, 2002).

USFS planning and monitoring data were used to estimate biomass generation from timber harvest, TSI and non-commercial thinning on USFS land. A 30-year ODF timber harvest database was used to estimate timber harvesting residue generation from private, tribal, state, county and municipal land. National Fire Plan data for USFS projects were used to estimate biomass generated from fuels reduction on federal land. National Fire Plan project data for other federal land management agencies (U.S. Fish & Wildlife Service and BLM) were collected, but these projects are frequently prescribed fire or fuels reduction activities on Pinyon/juniper stands that yield little biomass. These projects could serve as a supplemental source of biomass for a power or ethanol manufacturing facility, but they should not be considered as available for

[26] R. Eber, *Rural Lands Database: GAP Vegetation Cover Database for Union, Baker and Wallowa Counties* (http://geography.uoregon.edu/infographics/rldatabase/, Oregon Department of Land Conservation and Development).

planning purposes. The results of an ODF analysis of overstocked acreage were used to estimate biomass generation from private land.

Different biomass yields were used to estimate biomass generation from timber harvesting and three other silvicultural treatments: (1) TSI, (2) non-commercial thinning and (3) fuels treatment projects. Different values were used because timber harvesting residues consist mainly of tops and branches that are a byproduct of commercial timber removal. TSI results in removal of a limited volume of commercially valuable trees, and non-commercial thinning and fuels treatment involve both pruning and removal of whole trees that are mostly too small or not of sufficient quality to use for wood product manufacturing.

The generation of timber harvest residue was estimated from harvest volumes as shown in Table 3-2. This method was adapted from one used by USFS at the Black Hills National Forest.[27]

Table 3-2. Description of method used to estimate timber harvesting residues

Variable	Description	Value
A	Total residue weight/square foot basal area of 12-inch DBH tree to a 6-inch top diameter (GT)[a]	0.20
B	Basal area per 12-inch DBH tree (square feet)	0.785
A*B	Estimated residue weight per tree harvested (GT)	0.157
C	Trees/MMBF of timber (assuming 80 board feet/tree [b])	13,333
A*B*C	Estimated residue weight/MMBF of timber harvested (GT/MMBF)	2,099

[a] Brown, Snell and Bunnell, *Handbook for Predicting Slash Weight of Western Conifers* (USFS Intermountain Forest and Range Experiment Station GTR INT-37, 1977).
[b] Colorado State Forest Service, *Forest Products Utilization Handbook, 1980*. Based on top diameter inside bark of eight inches, two sawlogs/tree and 40 board feet/log (International rule).

Biomass yields from non-commercial thinning, TSI and fuels reduction depend on the degree to which current forest stand density exceeds optimal levels for forest productivity, wildlife habitat, fuel loading and fire risks. Yields range from as little as two GT/acre for pruning and trimming projects to 40 GT/acre or more for sites with heavy accumulation of ground fuels. For this study, yields of 5, 10 and 15 GT/acre were used to estimate biomass generation from fuels reduction projects.

The assumption of 15 GT/acre is consistent with yields from the Starkey Fuels Reduction project. This project was conducted on 1,782 acres of the Wallowa-Whitman National Forest during 2001 and 2002. The Starkey project contract specified the removal of 12,025 hundred cubic feet (CCF) of White fir and Douglas-fir biomass.[28] Assuming 2.13 GT/CCF of biomass (average of 2.35 GT for White fir and 1.9 GT/CCF for Douglas-fir[29]), the resulting yield for that project was 14.3 GT/acre.

The estimates of forest biomass generation are based on planning and monitoring data for USFS land, on a conservative estimate of forest management on overstocked private land and on actual

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[27] B. Cook, *Internal Report – Black Hills Annual Timber Management Program: Annual Estimated Biomass Availability - FY 1998* (U.S. Forest Service Black Hills National Forest, 2002).
[28] USFS, *Starkey Fuels Reduction Costing White Paper* (http://www.fs.fed.us/bluemountains/docs/starkey-final-tsc-portion.pdf, May 1, 2001).
[29] J. Morrison Corona and W. Wilcox, *Forest Products Utilization Handbook* (Colorado State Forest Service, January 1979).

past timber harvest practices from other landowners. Other studies have focused on what the potential biomass supply would be if all overstocked stands were managed. It is valuable to compare estimates of biomass generation based on current management practices with what potential biomass generation could be under a more aggressive management scenario. To do this, the authors calculated potential biomass yields from estimated overstocked acreage from the Blue Mountains Vegetation assessment. Appendix A discusses this study in more detail.

Quantities are reported in green tons (GT) for forest biomass because that is the typical fuel characteristic of biomass received at a biomass conversion facility. Similarly, agricultural residue quantities are reported in field dry tons, which includes approximately 10% to 20% moisture content (MC). Biomass power and biomass fuel production facilities use GT quantities as the basis for fuel supply planning. Differences in moisture content between biomass types (i.e., agricultural residue, mill residue and forest biomass) will affect the efficiency of combustion processes and fuel yields. Section 8 provides more information on typical moisture content values for various biomass types.

3.1.2 Results

Figure 3-2 shows estimated annual forest biomass generation in the study region assuming yields of 5, 10 and 15 GT/acre. Total estimated forest biomass generation varies from 463,000 to 636,000 GT/year (37% difference) using different yield assumptions. The quantity of timber harvesting residues shown in Figure 3-2 remains the same for the 5, 10 and 15 GT/acre yield scenarios because timber harvesting residues were estimated assuming 2,099 GT/MMBF of timber harvested, as described in Table 3-2.

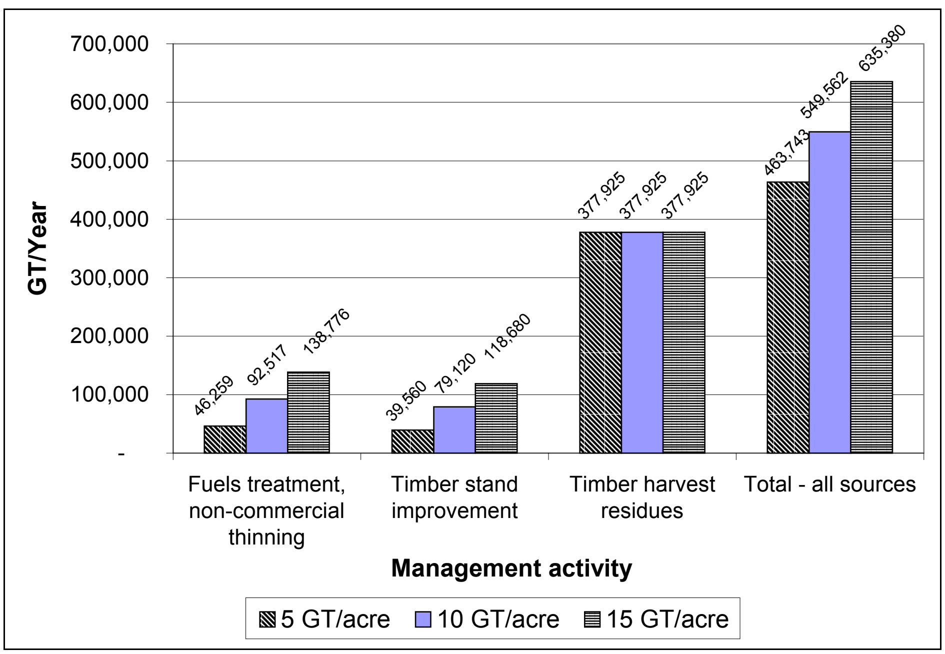
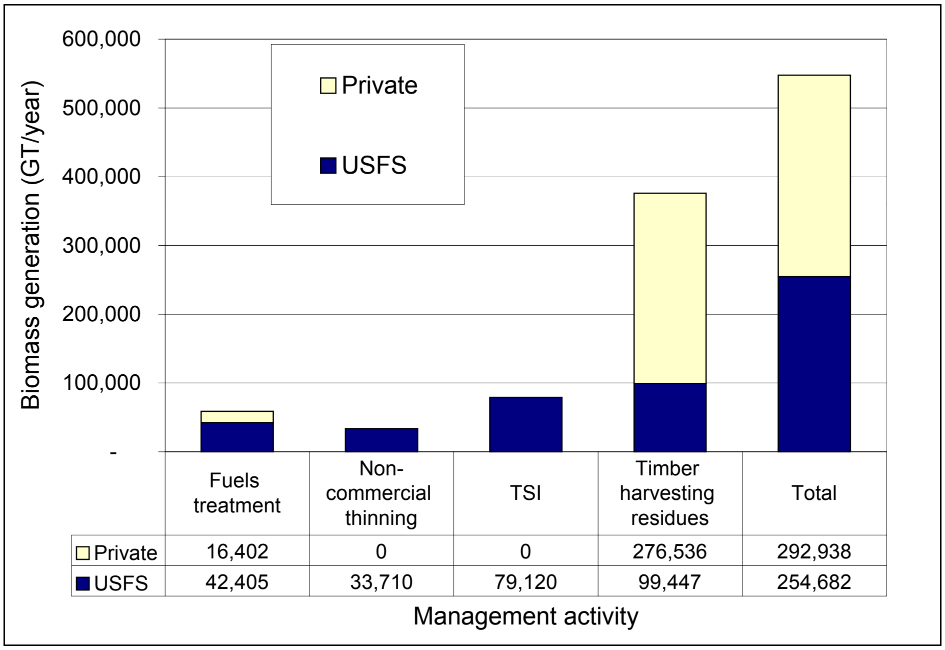


Figure 3-2. Estimated forest biomass generation, with different yield scenarios

Based on the quantities shown in Figure 3-3, 53.3% of the total forest biomass generated comes from private land, and 46.3% comes from federal land. This assumes a yield of 10 GT/acre for fuels treatment, non-commercial thinning and TSI. The remaining 0.4% comes from state, county and municipal land.



Note: Biomass generated from state and county/municipal land is not shown, but these sources make up less than 1% of the total. Quantities from fuels treatment, non-commercial thinning and TSI assume that 10 GT of biomass is generated per acre of land treated.

Figure 3-3. Forest biomass generation by landowner and management activity

The vast majority (94%) of the supply from private land is from timber harvesting residue. On federal land, 155,035 GT, or 61%, of the biomass supply is generated from fuels treatment, non-commercial thinning or TSI. The remainder of the supply from USFS is from timber harvesting residue. Appendix C provides the data that underlie Figure 3-3.

In order to provide a basis for comparison of the results in Figure 3-2 and Figure 3-3, the authors developed estimates of biomass generation based on the analysis of overstocked lands provided in the Blue Mountains Vegetation Assessment (see Section 2.1 for more information). Section 3.1.3 describes the results of this effort and its implications for the reliability of the estimates in this section.

3.1.3 Comparison of Blue Mountains Results with Current Analysis

This section provides a comparison of the volume of small-diameter material generation estimated in Section 3.1.2 with estimates derived from the Blue Mountains Vegetation Assessment evaluation of overstocked forest acreage and potential timber harvest yields.

Table 3-3 shows estimated annual biomass generation based on the Blue Mountains assessment. The Blue Mountains assessment identified a total of 251,000 overstocked acres on USFS active forestland. The Blue Mountains economic analysis showed that timber harvesting on 16,100 acres of this area could result in a positive net value, yielding an estimated 84 MMBF of sawlogs with an error margin of plus or minus 24 MMBF. The estimates in Table 3-3 assume that the remaining 234,900 acres of overstocked land would be treated using a combination of fuels reduction, TSI or non-commercial thinning treatments.

Timber harvesting residue generation was estimated using the method in Table 3-2. The volume of small-diameter biomass that could be removed on overstocked land was also estimated.

These estimates employed several assumptions:

- Commercial timber harvest would occur on overstocked land identified as yielding economically viable timber,
- Remaining overstocked land would be treated via combination of fuels treatment, TSI and non-commercial thinning, and
- Timber harvest and fuels treatment would occur over a 20-year timeframe.

This method provides an approximation of biomass generation, because it is really not known how much of the overstocked acreage will be treated, or over what time frame. The total biomass generated annually would double if treatment were done over 10 years; likewise if overstocked land is treated over a 40-year timeframe, the annual total generated would be cut in half.

Table 3-3. Estimates of annual biomass generation from overstocked land[30]

Biomass source	Total overstocked area (acres)	Annual treated area (acres)	Total biomass generated (GT)	Annual biomass generation over a 20-year time frame (GT/year)
Timber harvest on economically viable forest land	16,100	850	176,316	8,816
Thinning overstocked forest land (assumes 10 GT/year yield)	234,900	11,745	2,349,000	117,450
Total	251,000	12,595	2,525,316	126,266

The Blue Mountains study focused on the potential for removals from overstocked land, rather than focusing on residue available from all timberland in the study area. Because of that, total biomass generation from this study is perhaps best compared to the estimates of biomass generation from fuels treatment, non-commercial thinning and TSI on USFS land shown in Figure 3-3, based on USFS planning and monitoring data for the Umatilla and Wallowa-Whitman National Forests. Those estimates totalled 155,235 GT/year, which is similar to the estimate of 126,266 GT derived from the results of the Blue Mountains study.

In Baker, Union, and Wallowa Counties, the Blue Mountains Vegetation assessment determined that there are an estimated 213,000 acres of overstocked stands in active forestry areas on privately owned land. However, timber volumes from private stands had not been assessed by the time the current study was completed.

It is worth comparing the Blue Mountains assessment estimate of overstocked private forestland to a recent ODF analysis, which showed only 16,368 acres of overstocked private forestland in Baker, Union and Wallowa Counties. The Blue Mountains study used a criterion to determine

[30] Oregon Office of the Governor and Oregon Department of Agriculture, *Assessment Of Timber Availability From Forest Restoration Within The Blue Mountains Of Oregon* (http://www.fs.fed.us/bluemountains/pubs.htm, Blue Mountains Demonstration Area, November 14, 2002) [Hereafter, Blue Mountains Demonstration Area Assessment.]

overstocking based on stocking guides developed by Cochran et al., described further in Appendix A. The ODF study defined overstocked acres using a criterion of 80% crown closure and estimated overstocked acres through analysis of satellite imagery. Nearby Umatilla County had 16,436 acres of overstocked land, bringing a regional total to 32,804 acres. The ODF method is a more conservative means of determining the extent of overstocking and probably underestimates the forested area that could benefit from forest management, whereas the USFS estimate probably overestimates this area because it does not incorporate sufficient site-specific data on tree distribution, canopy cover and other factors.

3.2 Forest Biomass Availability

Forest biomass availability is affected by a variety of factors. Some biomass must be left on-site to reduce soil erosion and compaction, conserve soil nutrients and retain dead standing and fallen trees for wildlife habitat. Slope constraints also limit forest biomass recoverability.

Yield assumptions used to estimate forest biomass generation in Section 3.1 are consistent with actual biomass removals from fuels reduction and thinning projects after the projects have satisfied all planning requirements, management practice guidelines and laws related to soil conservation, wildlife habitat and forest productivity. It should also be recognized that biomass availability is ultimately site-specific. High, mid-range and low biomass yield assumptions were used to reflect this variability. Therefore, the analysis of forest biomass generation in Section 3.1 already accounts for the quantities required to maintain soil productivity and wildlife habitat.

Some percentage of slash will technically not be removable, due to slope considerations and because some biomass will be heavily contaminated with soil and other debris. These constraints were applied to forest biomass generation estimates to provide a more realistic portrayal of forest biomass availability in the study area.

This section discusses biomass requirements for prevention of soil erosion and compaction, conservation of wildlife habitat and maintenance of soil productivity. It also provides estimates of forest biomass availability in the study area, adjusting for slope and technical barriers.

3.2.1 Prevention of Soil Erosion and Compaction

Some degree of soil compaction can take place on as much as 10% to 40% of land harvested using tractors, but compaction can be reduced to as little as 5% with careful planning.[31] Designating skid trails is one major way to reduce the potential for soil compaction. Skid trails are paths used to move harvested trees to a central location in the forest or by the road for further processing or hauling to a conversion site. Leaving slash in mats or distributed on the forest floor, especially in areas such as skid trails where equipment will make multiple passes, is another way to help reduce the potential for soil compaction. Leaving slash in place on landing sites after use can also guard against future soil movement.

On USFS land, the Wallowa-Whitman National Forest Land & Resource Management Plan specifies the following standards and guidelines to maintain and enhance soil productivity: "...Minimize detrimental soil conditions with total acreage detrimentally impacted not to exceed 20% of the total acreage within the activity area including landings and system roads. Where

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[31] K. Birch, *First Approximation Report: Criterion 4, Indicator 22*, (http://www.odf.state.or.us/DIVISIONS/resource_policy/resource_planning/far/FAR/crt4ind22.asp, ODF, April 2000).

detrimental conditions affect 20% or more of the activity area, restoration treatments will be considered."[32] On private land, the Oregon Forest Practice Rules require projects to cause soil deterioration on less than 20% of the soils in a management unit. They also require that operators place slash in a landing site to prevent soil movement.[33]

Forestry professionals working on projects in the Wallowa-Whitman National Forest use several methods to reduce compaction and displacement during mechanized harvesting. Ground-based harvest systems are normally limited to slopes of 30% or less. Cable-yarding systems are typically used for slopes greater than 30%. When feller-buncher/harvester/forwarder systems are operating in areas where compaction is a concern, the equipment will lay slash down in front of itself on the skid trails as it operates and then "walks over" that slash to reduce impacts to soils. In addition, equipment is often operated on frozen ground or over snow to avoid compaction. Many landings and skid trails are used over and over and are dedicated for that purpose. Others are mitigated by tilling soil followed by planting or seeding to reduce erosion risks, to prevent noxious weed invasion and to put these areas back into forage or tree production.[34]

The quantity of slash required to reduce soil compaction on skid trails varies from site to site. In most cases, slash will only be used on a small percentage of skid trails, if at all. Figure 3-4 provides a graphic showing how skid trail spacing and percentage of skid trail coverage affect the quantity of slash on skid trails.

Timing of operations and careful skid trail design and layout can minimize the need to use biomass on skid trails to prevent soil erosion and compaction. If equipment is operated on frozen ground, over snow or on dry soils, no material may be required. In most cases, operators would have to use slash on less than 20% of the skid trail area. However, with close skid trail coverage or wet soils, operators may need to use a significant quantity of material on skid trails to reduce the potential for soil compaction. In such operating conditions, the amount of biomass required to prevent soil compaction could be substantial.

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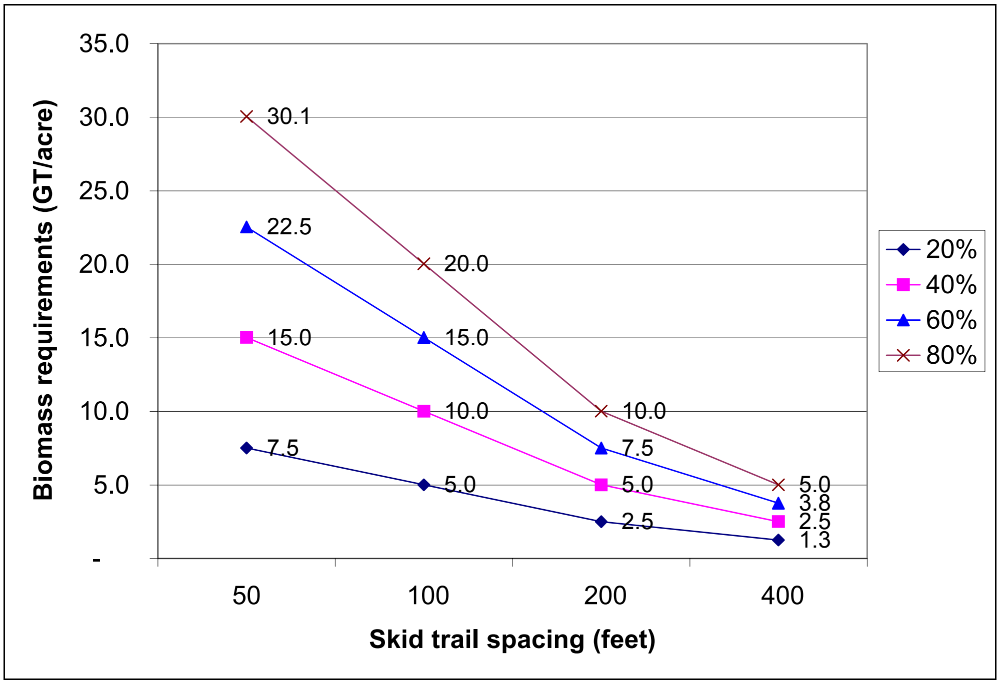
[32] USFS, *Wallowa-Whitman National Forest Land & Resource Management Plan* (Wallowa-Whitman National Forest).
[33] ODF, *Oregon Forest Practice Rules – Guidance – Skidding and Yarding Practices OAR-629-630-300* (http://159.121.125.11/FP/RefLibrary/RuleLawGuidance/Administrative%20Rules%20and%20Guidance/RuleGuidanceTableContents1200.htm).
[34] Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).



Note: Assumes slash depth of one foot and 12 foot skid trail width.

Figure 3-4. Biomass requirements for prevention of soil compaction based on skid trail spacing and percentage of skid trail coverage

3.2.2 Retention of Coarse Woody Material

Forestry professionals are required to retain standing and downed trees in management areas to provide for wildlife habitat considerations. Some of this wildlife requirement can contribute to the long-term soil productivity needs as well.

The Oregon Forest Practice Rules specify that forest operators leave standing and downed woody materials in forestry operations that are larger than 25 acres and that require wildlife leave trees (Harvest Type 2 and 3). The rules require two snags or green trees at least 30 feet in height and 11 inches DBH or larger, at least 50% of which are conifers, and two downed logs or downed trees, at least 50% of which are conifers that each comprise at least 10 cubic feet gross volume to be left on-site.[35] The estimated weight of biomass an operator must leave on-site to meet these requirements is 1.2 GT/acre (Table 3-4).

[35] Oregon Revised Statutes 527.676.

Table 3-4. Weight of biomass required to be left on-site for wildlife habitat

Biomass Category	Number of trees/ acre	Tree length (feet)	Tree diameter (feet)	Total tree volume (cubic feet)	Estimated total weight (GT /acre)[a]
Standing snags or green trees	2	30	0.9	40	0.8
Downed trees	2	6	Not provided	20	0.4
Total	4	N/A	N/A	60	1.2

Source: Oregon Forest Practices Act, ORS 527.626; Oregon Department of Forestry (http://www.odf.state.or.us/divisions/protection/forest_practices/default.asp?id=403010601 Interpretive Guidance link).
Note: N/A means not applicable.
[a] Assumes 0.005 GT/cubic foot of solid wood

Other sources recommend that greater amounts of biomass be left on-site than the Oregon Forest Practice Rules require. Recommendations for amounts and sizes of large diameter standing live and dead wood need to be developed for local geoclimatic and vegetation types in the Blue Mountains. In the absence of local data, the interim amounts of coarse woody debris by forest type in Table 3-5 from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) have been recommended for on-site retention for wildlife habitat.

Table 3-5. Recommendations for leaving biomass for the Interior Columbia Basin

Forest type	Green tons per acre (GT/acre)
Dry Forest**:**	
ponderosa pine	4-8
Douglas-fir	5-9
lodgepole pine	4-8
Moist Forest:	
mixed conifer	10-20
Cold Forest:	
spruce/fir	8-12
whitebark pine	5-15

Source: Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).

Fuels planners at Wallowa-Whitman National Forest are comfortable with burn plans or piling contracts that specify no more than five to seven tons/acre remaining after treatment, whether treatments involve mechanical or underburning activities. This is the case mostly in warm/dry ponderosa pine or mixed conifer forest types, where most of the thinning and fuels reduction work has been occurring. Moist and cold forest types typically require that more biomass be left on-site in order to protect forest soils from disturbance.[36]

3.2.3 Slope as a Technical Barrier to Biomass Removal

Collecting and using biomass from projects on slopes greater than 30% presents challenges, because typically some form of cable-yarding is recommended to transport material from the

[36] Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).

point where it is felled to a landing site. Cable-yarding is practical for removal of trees that are of commercial size (approximately 10 inches DBH for sawlogs and five to 10 inches DBH for pulp wood). However, removal of tops, branches and small diameter trees (less than five inches DBH) can be difficult for both technical and economic reasons. Recent modeling of biomass availability in Oregon's Klamath region assumed that all materials less than five inches DBH would be left on-site in areas where the slope exceeds 30%.[37]

For this study, it is assumed that forest biomass would not be removed from project areas with a slope greater than or equal to 30%. However, slope data for current and future thinning and other forest management projects are not available. To provide a conservative estimate of biomass availability that takes into account slope constraints, USFS Forest Inventory & Analysis (FIA) estimates of forested acreage with slopes greater than or equal to 30% was divided by the total forested acreage by county. These values were then multiplied by total biomass generation from Section 3.1 to provide a revised estimate of biomass availability.

Table 3-6 shows total forested acreage and forested acreage with slopes less than 30% (excluding USFS land, which was not included in most recent FIA data) in the study area.

Table 3-6. Estimated forest land slope restrictions, excluding USFS land

County	**Landowner**				
	BLM	**Private**	**State**	**Local**	**Total/*weighted average***
Baker					
Total forested acres	23,325	242,914	-	-	266,239
Acres with slope less than or equal to 30%	11,213	154,939	-	-	166,152
Percent with slope less than or equal to 30%	48	64	NA	NA	*63*
Union					
Total forested acres	-	747,802	-	-	747,802
Acres with slope less than or equal to 30%	-	609,147	-	-	609,147
Percent with slope less than or equal to 30%	NA	81	NA	NA	*81*
Wallowa					
Total forested acres	23,368	667,388	23,441	7,351	721,549
Acres with slope less than or equal to 30%	-	540,555	23,441	7,351	571,348
Percent with slope less than or equal to 30%	-	81	100	100	*79*
All counties					
Total forested acres	46,693	1,658,104	23,441	7,351	1,735,590
Acres with slope less than or equal to 30%	11,213	1,304,642	23,441	7,351	1,346,646
Percent with slope less than or equal to 30%	48	79	100	100	*78*

Source: USFS, *FIA Database 1999 Cycle 4* (www.fia.fs.fed.us).

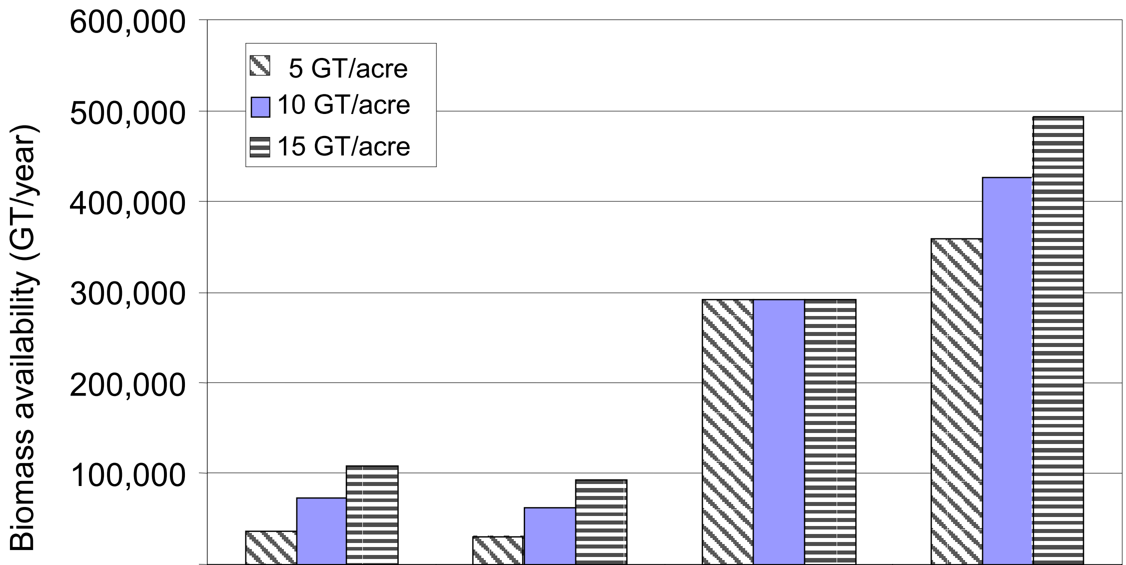
This approach provides a conservative estimate of biomass generation, because it assumes that the forestland being managed has topography similar to the region as a whole, when most likely project areas will have an average slope that is lower than the entire region. Estimates of total

[37] J. Fried, J. Barbour, R. Fight, G. Christensen and G. Pinjuv, *Small Diameter Timber Alchemy: Can Utilization Pay the Way Towards Fire Resistant Forests* (http://www.fs.fed.us/pnw/fia/ear/jfried/pubs/, USFS Pacific Northwest Research Station, 2000).

forested area in the region from the Oregon GAP analysis identified 2,539,669 acres.[38] The slope information in Table 3-6 therefore represents approximately 68% of the total forested area. This is one source of error in estimates of forest availability, since average slopes may be different on federal land than for other landowners.

3.2.4 Estimated Forest Biomass Availability

Figure 3-5 provides estimated forest biomass availability. The different columns in Figure 3-5 show biomass availability by treatment type and overall availability. In addition, the estimates show the effects of using 5, 10 and 15 GT/acre yield assumptions on biomass availability.



	Fuels treatment, non-commercial thinning	Timber stand improvement	Timber harvest residue	Total - all sources
5 GT/acre	36,166	30,929	291,745	358,840
10 GT/acre	72,331	61,857	291,745	425,934
15 GT/acre	108,497	92,786	291,745	493,028

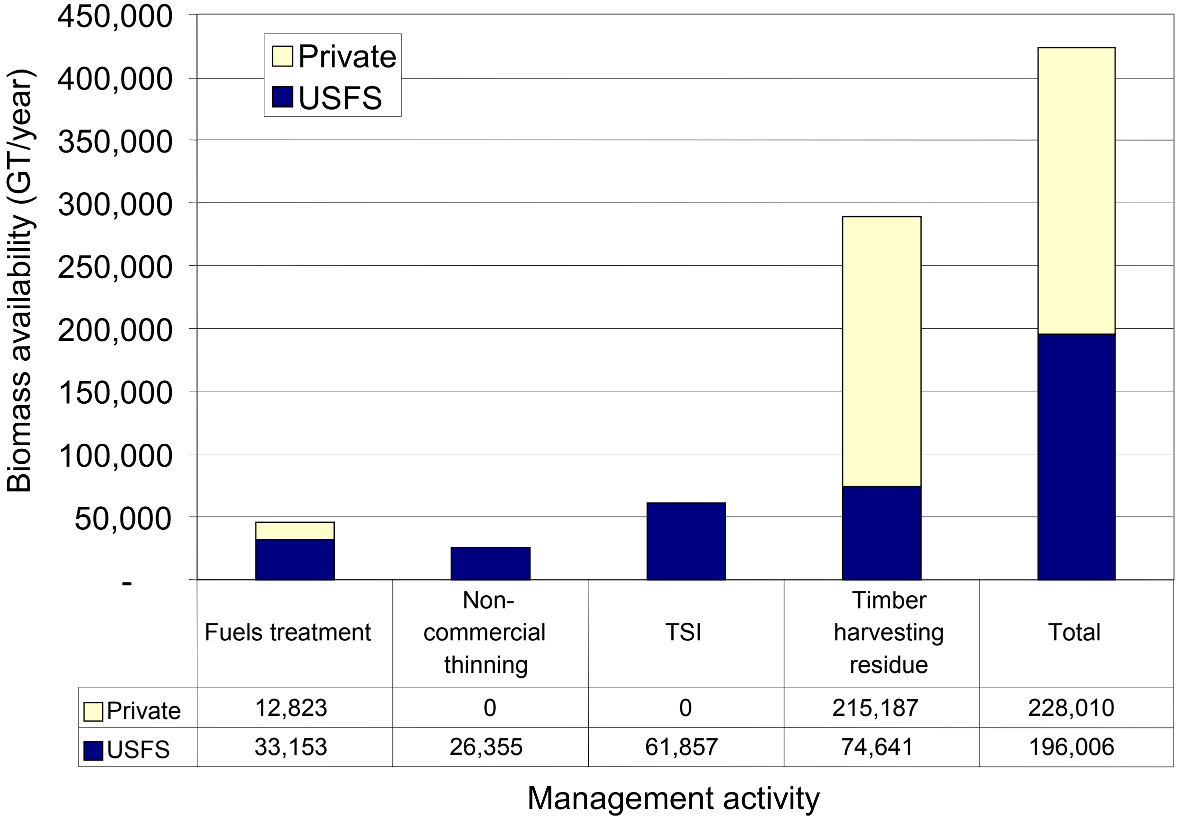
Management activity

Figure 3-5. Forest biomass availability with different yield scenarios for fuels treatment, non-commercial thinning and timber stand improvement

Figure 3-6 shows the distribution of forest biomass availability between private and USFS land, assuming a yield of 10 GT/acre for fuels reduction, TSI and noncommercial thinning. Timber harvesting residue from private land accounts for approximately 50% of the available supply.

[38] R. Eber, *Rural Lands Database: GAP Vegetation Cover Database for Union, Baker and Wallowa Counties* (http://geography.uoregon.edu/infographics/rldatabase/, Oregon Department of Land Conservation and Development).

Supply planning should take a conservative approach to how much biomass will be available from forest management due to the site-specific variability, annual variability from the different landowners and unknowns such as landowner interest in providing biomass from their forests.



	Fuels treatment	Non-commercial thinning	TSI	Timber harvesting residue	Total
Private	12,823	0	0	215,187	228,010
USFS	33,153	26,355	61,857	74,641	196,006

Note: Based on yields of 10 GT/acre for fuels treatment, non-commercial thinning and TSI. Timber harvesting residue availability does not change because estimate is based on a 10-year average of timber harvest volumes.

Figure 3-6. Forest biomass availability by landowner and management activity

4. WOOD PRODUCTS RESIDUE GENERATION AND AVAILABILITY

4.1 Wood Products Residue Generation

Residue generation, use and cost data were collected from manufacturers through personal interviews with the generators and with a fiber broker in the region. Boise Cascade is the primary residue generator. Boise Cascade operates sawmill and particleboard mills in La Grande and a stud and plywood mill in Elgin. The particleboard mill produces little residue, and uses a large quantity of residue from other Boise Cascade facilities. Nearby Pilot Rock, Ore., in Umatilla County is the site of a sawmill that generates residue from poplar logs produced on a Potlatch Corporation hybrid poplar plantation in Boardman, Ore. Some logs from this plantation are also sold to a Boise Cascade paper mill in Wallula Junction, Wash.[39]

This section summarizes residue generation for the region from the study area and the Wallula Junction and Pilot Rock mills. Quantities are shown in aggregate and prices are given as averages in Table 4-1 to protect confidentiality of individual residue generator information.

Chips and planer shavings are the most expensive residue sources; other residues are significantly less expensive.

Table 4-1. Mill residue generation and price, excluding transport costs

Residue type	Annual quantity (GT/year)	Average price ($/GT)
Planer shavings	64,603	$19.10
Chips	308,794	$15.93
Plywood trim	33,875	$7.14
Hog fuel (mixed bark, sawdust and chips)	190,160	$5.56
Sawdust	115,961	$4.31
Veneer cores	1,458	$3.00
Total/*weighted average*	714,852	$11.13

Sources: John Dick, Fiber Manager, Wallula Resources and Jared Rogers, Region Engineer, Boise Cascade (personal communication with Tim Rooney, McNeil Technologies, Inc., May 13 - 14, 2003).

4.2 Wood Products Residue Availability

In the study region, all of the residue generated is currently utilized. Chips are sold for pulp. Shavings, sawdust and planer trim produced by Boise Cascade facilities are used internally for particleboard. Boise also purchases residue from other mills for use in its facilities. Bark is converted to hog fuel and burned on-site for heating or sold to a nearby cogeneration facility. A small quantity of bark is processed, bagged and sold for mulch.

Because of the high degree of integration of the Boise Cascade facilities and existing markets and uses for other residue, it is likely that much of the residue supply would not be available for use in a new cogeneration facility. However, chips that are currently sold for pulp may be

[39]M. Sullivan, *Potlatch Poplar Farm Earns Forest Stewardship Council Certificate and Launches Cooperative Certified Lumber Marketing Effort* (http://www.potlatchcorp.com/company/newnews/news_story.asp?id=59, August 24, 2001).

available if the price offered is competitive. This should not affect the availability of residue used internally by regional facilities.

An increase in regional demand for wood fiber, caused by a diversion of chips normally sold for pulp being used for energy, is likely to drive up prices because the supply of residue is relatively inflexible. This is because residue is a co-product of lumber and veneer manufacturing in the region. The quantity of material harvested and processed is determined in part by factors other than pulp markets, including availability of material from public and private lands and markets for lumber and plywood.

The extent to which fiber prices would increase in response to a large regional demand shift is not known. However, current chip generation is approximately 309,000 GT/year. Using 10% to 20% of chips for energy that would otherwise be sold for pulp would not likely be a large driver for pulp supplies. A short-term price fluctuation is possible, but paper mills can respond to supply shifts by relying on other resources if the change is not too drastic. The 2003 chip prices were at a historically low level, however, and future escalating chip prices could make chips an uneconomical feedstock supply.

Because mill residue is currently fully utilized and the impacts of large regional demand shifts for residues could negatively impact other manufacturers in the region, it is recommended that only residue not currently used internally by local mills be considered as potentially available. In the region, this supply consists of 310,252 GT of sawmill chips and veneer cores. To avoid large shifts in regional resource utilization that could dramatically increase residue prices, it is recommended that only 20% of this quantity, or 62,050 GT/year, be considered available for energy purposes. This quantity could increase or decrease, depending on lumber, plywood and pulp markets, energy prices and other factors. It is likely that chip purchase prices will increase somewhat from its current levels due to the change in regional demand, at least in the short-term.

5. AGRICULTURAL RESIDUE GENERATION AND AVAILABILITY

5.1 Agricultural Residue Generation

Figure 5-1 shows the location of agricultural crop areas in the study area.

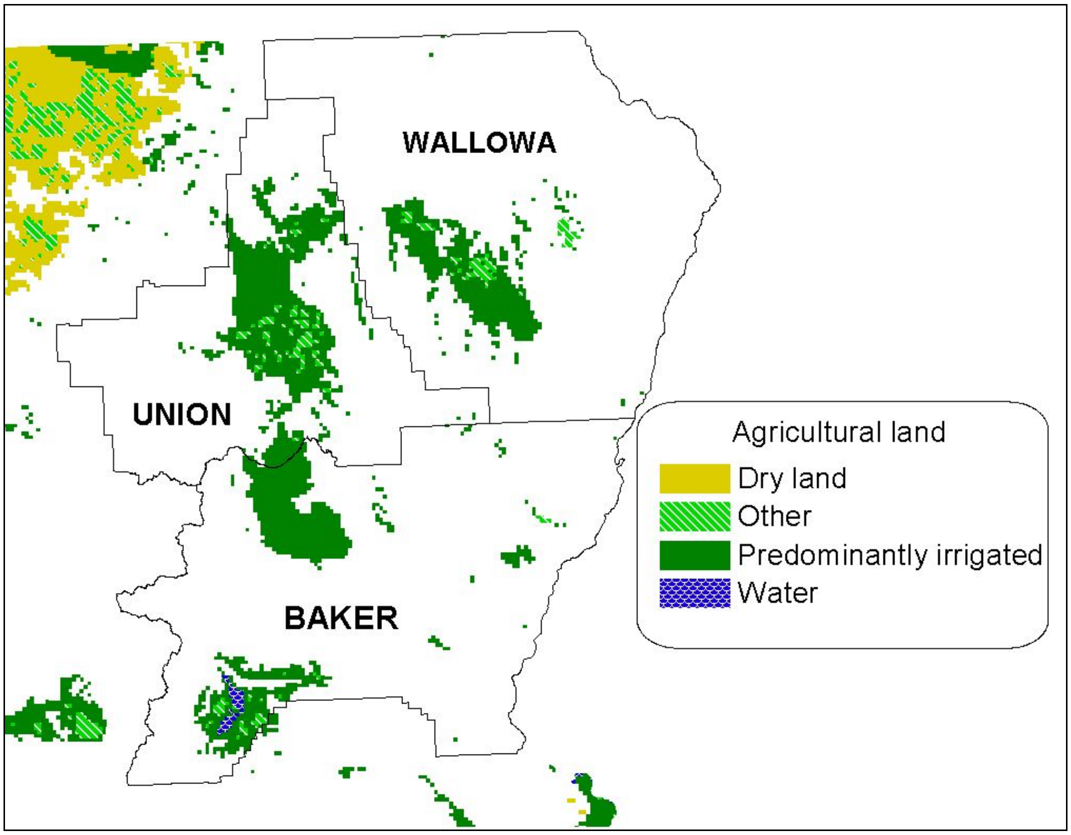
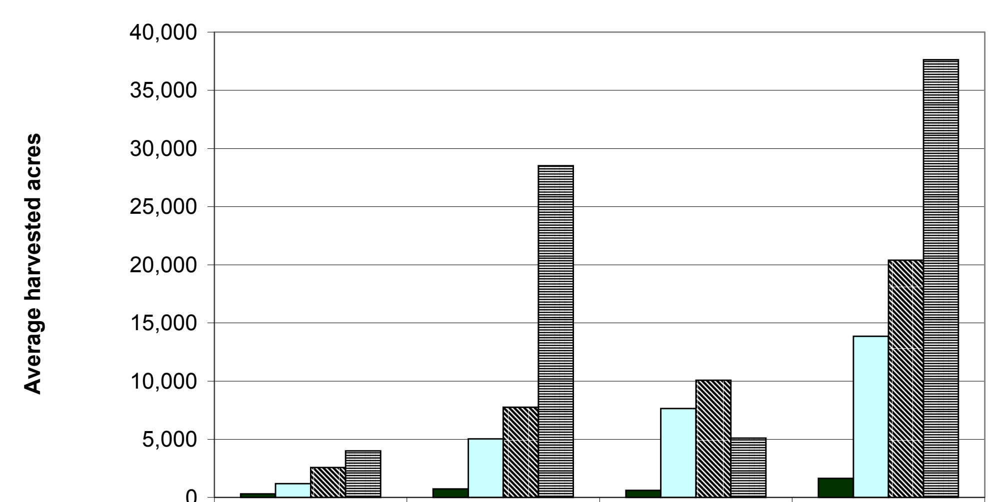


Figure 5-1. Location of agricultural land

The quantity of agricultural residues is directly related to crop production, which in turn depends on crop yield and acreage harvested. These quantities vary annually and are determined by weather conditions and the farmer's decisions on how many acres to plant. The relationships between crop yield and the quantity of residue produced are known. To account for annual variations, we use ten years of annual data (1992 - 2001) to determine the average and the range of values.

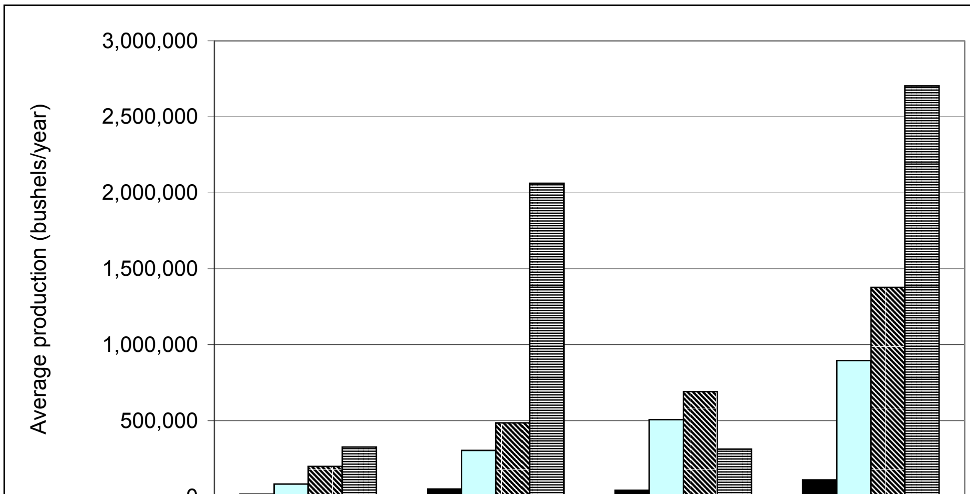
Figure 5-2 and Figure 5-3 show 1992 - 2001 average crop acres harvested and production, respectively, for major field crops in the study area. Grass seed, not shown, is also a major cash crop, though acreage and yield data are less readily available. Oat yields are significantly higher than for other crop types. Also, there is significant annual variability in both annual harvested acres and production, which is incorporated into estimates of biomass generation. The data in Figure 5-2 and Figure 5-3 reflect production from both irrigated and non-irrigated farmland; yields from irrigated farmland are often significantly higher than for non-irrigated land. This difference is also accounted for in biomass generation estimates.



	Baker	Union	Wallowa	Total
Oats	299	720	611	1,630
Spring wheat	1,180	5,020	7,650	13,850
Barley	2,580	7,750	10,070	20,400
Winter wheat	3,990	28,530	5,100	37,620

Source: USDA, National Agricultural Statistics Service, Annual Agriculture Survey. On-line at: http://www.nass.usda.gov:81/ipedb.

Figure 5-2. Acres harvested for major crop types (1992 - 2001)



	Baker	Union	Wallowa	Total
Oats	17,292	51,296	42,983	111,571
Spring wheat	83,698	305,631	507,119	896,447
Barley	200,384	485,577	690,985	1,376,945
Winter wheat	326,904	2,063,318	313,051	2,703,273

Source: USDA, National Agricultural Statistics Service, Annual Agriculture Survey. On-line at: http://www.nass.usda.gov:81/ipedb.

Figure 5-3. Average crop production for major crop types (1992 - 2001)

The major data source for field crop production is the annual survey conducted by the USDA, National Agricultural Statistics Service (NASS).[40] This survey is by county and focuses on grains and other commodity crops. The data of interest are: agricultural practice (irrigated or non-irrigated), acres planted, acres harvested, yield and total production. The grain crops of interest are wheat, barley and oats. The Oregon Agricultural Statistics Service[41] also collects data on grass seed production for each county, by year and seed type.

The USDA Census of Agriculture is conducted every five years, and all farms provide data.[42] It is not a statistical sample like the NASS survey and covers all agricultural production, not just grain crops. The data from census years 1992 and 1997 allows comparison between the survey data and census data to estimate the accuracy of the survey data. The Census also has information on the size and number of farms, which is of interest in determining how many different landowners may be involved.

Residue factors show the relationship between the quantity of residue generated and the quantity of grain produced. Residue factors were obtained from the database within the soil conditioning index (SCI) computer program documented in Part 508 of the Natural Resources Conservation Service (NRCS) National Agronomy Manual.[43] This database gives residue factors as a function of grain yield. For example, for winter wheat in the Pacific Northwest the residue factor is 1.75 pounds (lb) of residue per pound of grain harvested for a 30 bushel/acre crop yield and 1.32 lb of residue per pound of grain harvested for 100 bushel/acre yield. This gives a more realistic value than using a single value of 1.7 lb of residue per pound grain harvested that is typically used as a residue factor. The residue factors are given in Table 5-1.

Table 5-1. Residue factors

Crop	Relationship (lb of residue/lb grain) for yield in bushels/acre	R-squared fit
Barley	= 11.133*(yield(bu/acre)^-0.5248	0.999
Spring Wheat	= 9.3045*(yield(bu/acre)^-0.4775	0.998
Winter Wheat	= 3.9121*(yield(bu/acre)^-0.2371	0.997

The quantity of crop residues generated was computed for Baker, Union and Wallowa Counties for barley, spring wheat, winter wheat, oats and grass straw. Data over a 10-year period were used to develop average, minimum and maximum values for biomass generation. Total estimated agricultural residue generation in the study area is 202,772 dry tons (Table 5-2). Generation is reported in field dry tons. Field dry residues may contain 10% to 20% MC (wet basis).

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[40] NASS, *Annual Agriculture Survey* (http://www.nass.usda.gov:81/ipedb).
[41] Oregon State University Extension Service, *Oregon Agricultural Information Network* (http://ludwig.arec.orst.edu/oain/SignIn.asp).
[42] NASS, *Census of Agriculture* (http://www.nass.usda.gov/census/).
[43] NRCS, *National Agronomy Manual* (ftp://ftp.nssc.nrcs.usda.gov/pub/agronomy/SCIfiles/Latest_revisions/Training%20Materials/NAM508.pdf).

Table 5-2. Estimated agricultural residue generation by crop (field-dry tons/year)

County	Barley straw	Spring wheat straw	Winter wheat straw	Oat straw	Grass straw	Total straw
Baker	5,539	2,353	13,244	419	0	21,555
Union	14,728	9,979	86,365	1,248	20,314	132,634
Wallowa	19,640	14,275	13,685	983	0	48,583
Total	39,907	26,608	113,294	2,649	20,314	202,772

Winter wheat straw makes up the largest component of agricultural residue generation (Figure 5-4). Union County is the largest source of winter wheat straw and agricultural residues overall.

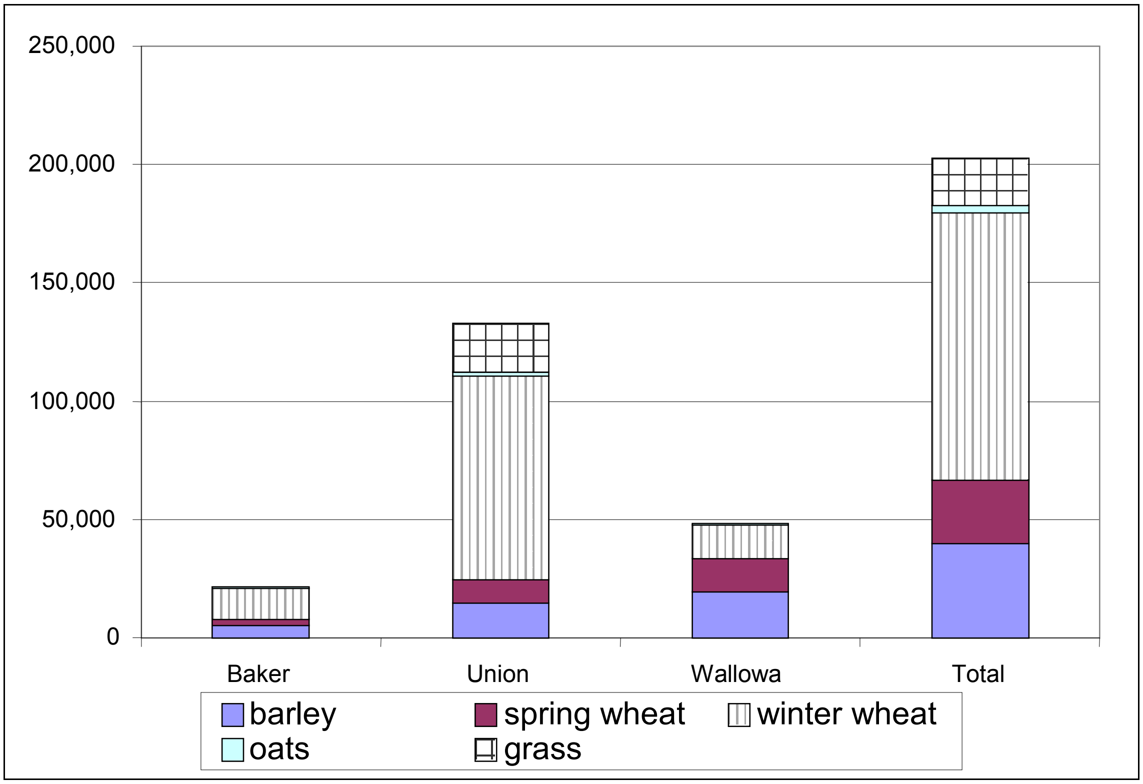

Figure 5-4. Average agricultural residue generation (field-dry tons/year)

Average agricultural residue generation does not reflect annual variation in residue generation (see Section 5.2). Figures 5-5 through 5-7 show the average, high and low values for annual residue generation for the counties in the study area.[44] Figure 5-6 includes grass straw generation for Union County. In Union County, grass straw is generated as a byproduct of the production of Kentucky bluegrass seed and other grass seed crops. Figure 5-6 shows total grass straw generation.

[44] Note, for Figure 5-5, Figure 5-6 and Figure 5-7, the column shows average residue generation, the superimposed line illustrates the range of annual values.

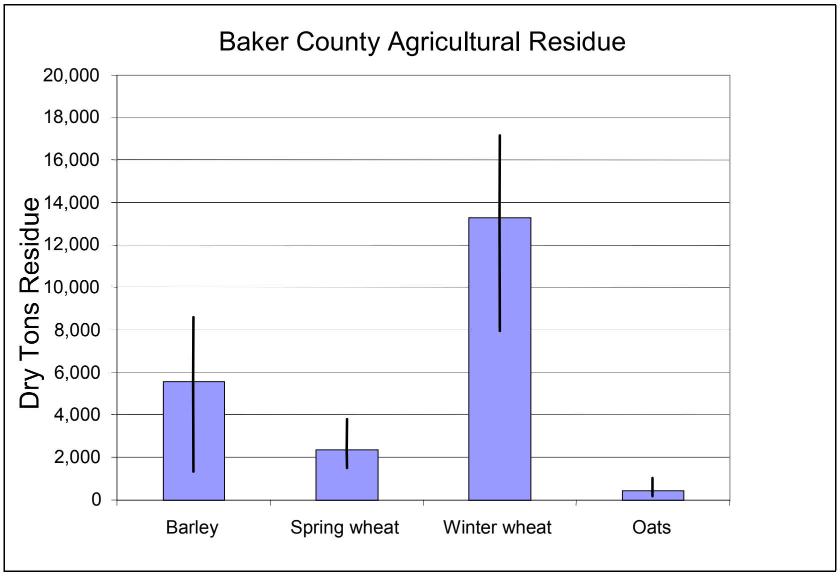

Figure 5-5. Agricultural residue generation in Baker County by crop (field dry tons/year)

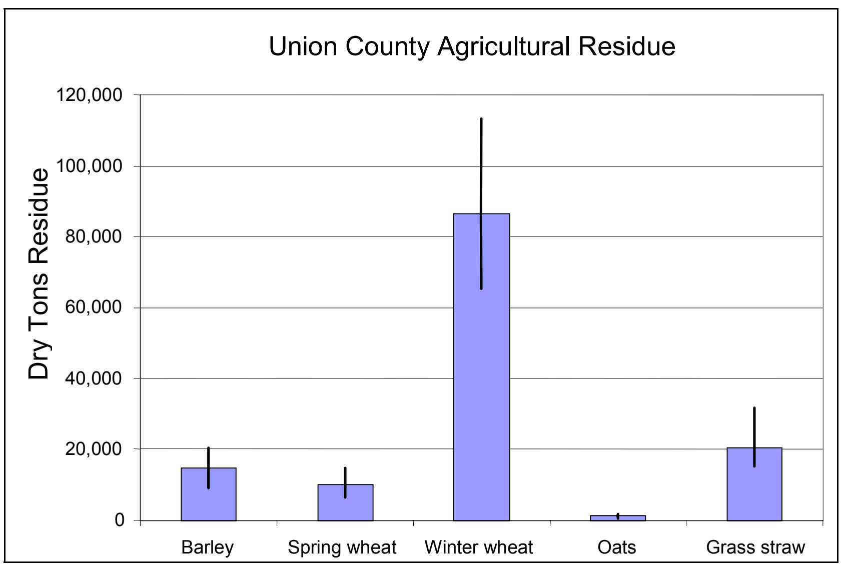

Figure 5-6. Agricultural residue generation in Union County by crop (field dry tons/year)

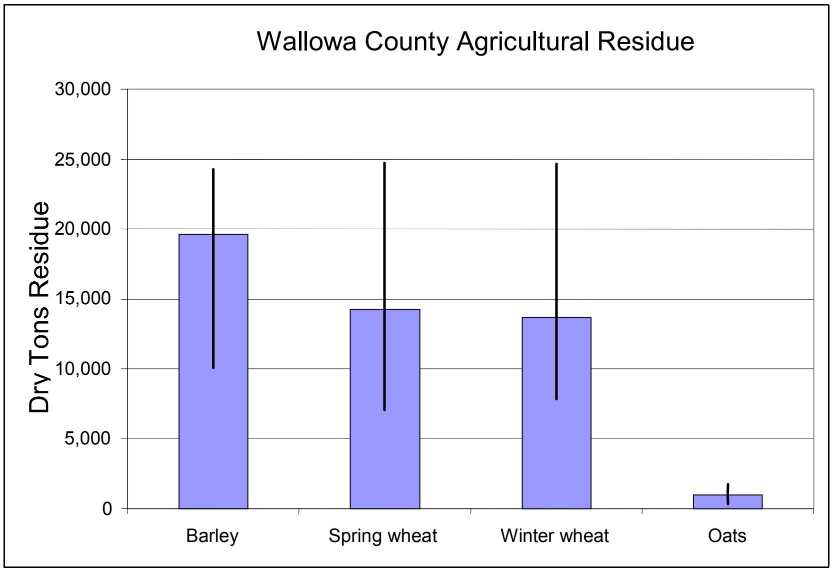

Figure 5-7. Agricultural residue generation in Wallowa County by crop (field dry tons/year)

5.2 Agricultural Residue Availability

The quantity of straw generated is a straightforward computation compared to determining the quantity of material available for recovery. We use the term "available" in a broad sense to mean the materials available after accounting for how much must be left to insure the long-term productivity of the land. This is not an easy number to quantify. The quantity that must be left depends on weather, crop rotation, existing soil fertility, slope of the land, wind patterns, rainfall patterns, historic farming culture and tillage practices. We talked to several agricultural and soil scientists about this issue.[45] They all acknowledged the difficulty of coming up with generalities that could be applied at the county level and still give a meaningful number. Some used rules of thumb such as, "don't take any straw off of lands with yield of less than 60-70 bushels/acre," "leave 8-10 inches of straw" and "leave 5,000 pounds of residue/acre."

The USDA has regulatory authority in addressing this question. Landowners who want to participate in federal commodity programs must prepare a soil conservation plan for their farms if the land is classified as highly erodible.[46] The 1997 Oregon National Resources Inventory estimated that only 10,100 acres (3%) out of the 291,100 acres in the Lower Snake hydrologic unit (Union and Wallowa Counties) had a water erosion rate of greater than the soil loss tolerance factor, T.[47] Baker County had less than 1% of its cropland, Conservation Reserve Program (CRP) land and pastureland with erosion rates greater than the tolerance factor. The USDA Soils Reports contain the soil tolerance factors (T-values) for each soil type in each

[45] Don McCool, Washington State University; Dennis Roe, Natural Resources Conservation Service, Pullman, Washington, and Valerie Oksendahl, Natural Resources Conservation Service, Spokane, Washington (personal communications with Jim Kerstetter).

[46] Highly erodible lands are those with a soil loss eight times greater than the soil loss tolerance factor, T. The soil loss tolerance factor is defined as the maximum rate of annual soil loss that will permit crop productivity to be sustained economically and indefinitely on a given soil.

[47] NRCS, *Oregon Natural Resources Inventory* (http://www.or.nrcs.usda.gov/nri/geoarea/huc6/orb6/usle/orb6uslett.PDF).

county.[48] The weighted average T-values for prime croplands in Baker and Union Counties are 3.75 and 4.48 tons/acre-year, respectively. The soil data for Wallowa County were not available. The use of water or wind erosion methods to determine residue availability suffers from the reliance on the soil loss tolerance used as the benchmark. T-values are not currently accepted by the scientific community as an adequate level of protection.[49]

Tillage practices also affect residue availability. The Conservation Technology Information Center (CTIC) surveys tillage practices in each county for spring and fall planted crops. CTIC is a branch of the National Association of Conservation Districts and promotes the adoption of conservation tillage and residue management.[50] The survey reports the number of acres with residue covers of 0% to 15%, 15% to 30%, and 30% or greater. Table 5-3 shows the tillage practices reported in 1997 for Baker, Union and Wallowa Counties. Greater than 80% of the land in Baker and Union Counties and 60% in Wallowa County do not meet the conservation tillage criteria.

Table 5-3. Conservation tillage practice by percent of cropland

Crop type by county	Conservation Tillage (> 30% residue cover)			Conventional Tillage (< or = 30% residue cover)	
	No-till	Ridge-till	Mulch-till	15-30%	0-15%
Baker					
Spring seed	0	0	0	33.3	66.7
Fall seed	0	0	20	50	30
Union					
Spring seed	4	0	16	54	26
Fall seed	2.8	0	1.4	86.1	9.7
Wallowa					
Spring seed	9.6	0	33.7	33.7	23
Fall seed	3.4	0	34.1	37.5	25

The quantity remaining after replanting depends on the quantity generated and on the tillage method used. For example, disk plowing removes 80% to 90% of the straw from the surface. Other methods, such as use of a rodweeder (a cultivating implement equipped with rods that turn underground to flip weeds and distribute soil evenly across planting beds), are much less disruptive and only remove 10% to 20% of the straw from the surface.

CTIC developed a program called Conservation for Agriculture's Future (CORE4) that aims to protect and improve the land while addressing on-farm profits. They set the criteria for qualifying as conservation tillage at 30% residue cover for water erosion protection and 1,000 pounds/acre of small grain residue for wind erosion protection.[51] The NRCS supports the CTIC/CORE4 marketing plan.

Rather than use wind or water erosion methods or the CTIC residue standard to estimate agricultural residue availability, we used the USDA Soil Conservation Index (SCI) computer model to develop benchmarks to determine what levels of agricultural residues could be removed without negatively affecting soil productivity. The SCI model estimates the impacts of tillage

48 NRCS, *Soils Report* (http://www.or.nrcs.gov/soil/oregon/or_databases.htm).
49 L. Mann, V. Tolbert, and J. Cushman, *Agriculture, Ecosystems and Environment* 89 (2002) pp.149-166
50 Conservation Technology Information Center (http://www.ctic.purdue.edu/Core4/CT/CT.html).
51 NRCS, *Core4 Conservation Practices Training Guide* (August 1999).

and residue management practices on soil organic matter, another indicator of soil productivity. The SCI appears to be a more conservative tool to estimate the quantity of residues that can be removed and maintain soil productivity.

The SCI computes the effects of residue management and tillage practices on soil organic matter.[52] The result is an index and not an absolute value. The index predicts a qualitative change in organic matter. The organic matter declines if the SCI is less than zero, increases if the SCI is greater than zero, or is in equilibrium if it equals zero. The model calculates the SCI number by applying weighting factors of 40% to organic material subfactor, 40% to the field operations subfactor and 20% to the erosion subfactor.

The SCI program has default values for residue quantities related to crop yields, root mass adjustments and rate of crop residue decomposition. The model uses these values and model inputs to calculate the results for a particular combination of subfactors that are benchmarked to actual soil organic measurements made at a test plot in Texas. The model input variables are:

1. Location that contains default values for the initial maintenance amount of organic matter each year to maintain soil organic matter levels
2. Soil type that contains default values for a soil organic modifier factor used to compute the average maintenance amount
3. Number of years in crop rotation
4. Crop grown in the rotation
5. Quantity of residue removed, which is used to compute the organic material subfactor
6. Field operations, which account for the effects of the type and number of tillage operations on organic matter. Each operation is assigned a soil disturbance rating that accounts for the effects on soil aeration, lifting, shattering and compaction; and
7. Erosion factors, which are entered and then indexed to erosion at the Texas benchmark location. The benchmark erosion level in Renner, Texas, is four tons/acre-year.

We obtained typical tillage practices from the Oregon state conservation agronomist, Tom Gohlke, soil types from the soils data base, crop yields from NASS and soil erosion values from the 1997 National Resources Inventory (NRI). The tillage practices were used as input to the field operations module to compute subfactors. We chose a range of subfactors for irrigated and non-irrigated land to see their effect on the SCI. We chose rotations of winter wheat with either barley or spring wheat and used the average yields for each crop. We assumed the removal of residues ranging from zero to three tons per acre. This allows computation of the organic matter subfactor. Finally, we used NRI erosion values to compute the erosion subfactors.[53]

We looked at rotation combinations of winter wheat with both barley or spring wheat for irrigated and non-irrigated lands. The tillage practices for non-irrigated land included a rotation period of three years and a sequence of operation including one year of summer fallow. The more severe tillage operation included straight point chisel, sweep and coil spring harrow while the less severe operation included field cultivation, rodweeding and weed spray. The average soil disturbance ratings were 59.0 and 39.7 for barley and wheat, respectively. For irrigated lands, the

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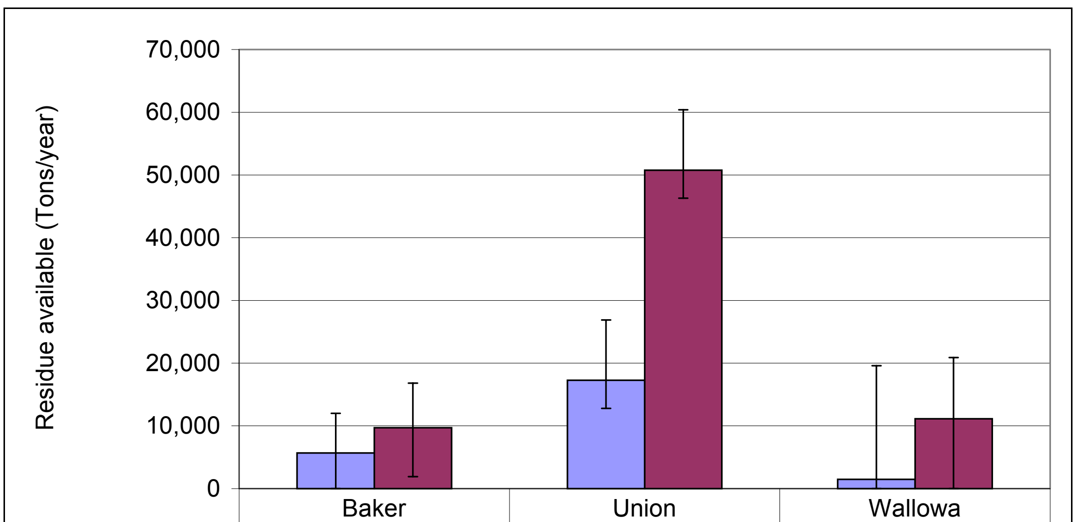
[52] USDA, *Soil Conditioning Index* (http://soils.usda.gov/sqi/sci.htm).
[53] Mark Tilton, Resource Inventory Specialist, NRCS Oregon Office.

two tillage practices considered were the more severe operation that included chisel disk, multiple field cultivations and harrow. The less severe practice included conservation moldboard plow and field cultivation. The average soil disturbance ratings were 107.0 and 93.5 for barley and wheat, respectively.

Those combinations of crop type, yield, soil, location, tillage practice, amount of residue removed and erosion that give a positive value of the index were chosen as the values for the allowable quantity of crop residues that could be removed. Removing both winter wheat straw and either spring wheat or barley straw resulted in index values less than zero. Therefore, we assumed that only winter wheat straw would be recovered with the rotation crop of barley or spring wheat providing the necessary organic matter. In general, only 1 to 1.5 tons of residues could be removed and still maintain a positive soil conditioning index (i.e., no decrease in soil organic matter). The total quantity of residues available for removal is then computed by multiplying the tons/acre available for removal by the acres harvested.

Figure 5-8 shows a range of estimated quantities of field crop residue available for removal from the field. The columns show the average quantities over a ten-year period, and the error bars are the range of values for the highest and lowest availability over the same period. The figure shows the two tillage practices used in the model. They represent a high and a low degree of tillage severity based on current tillage practices. The tillage practice used on a particular field will depend on the crops grown, the landowner's experience with different tillage practices and the amount of residue or weeds that have to be dealt with before planting the next crop.



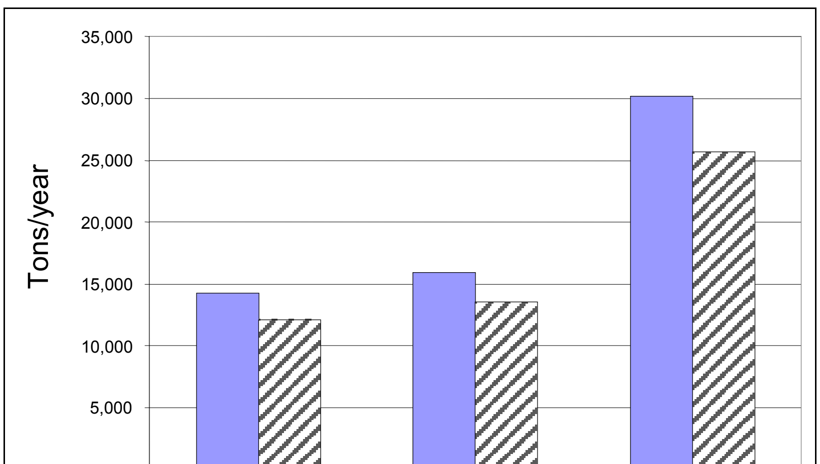
	Baker	Union	Wallowa
high severity	5,685	17,267	1,460
low severity	9,685	50,777	11,140

Figure 5-8. Availability of agricultural residue

Figure 5-8 shows the significant effect of tillage practice. For example, in Wallowa County, the annual availability varies between 1,460 and 11,140 tons depending on the tillage practice. In reality there would be a host of intermediate tillage practice, each indicating a different quantity of residue available. Low-till practices would tend to allow more residue to be removed but there are still the soil erosion constraints that must be met.

The computer models developed to determine water and wind erosion and soil organic matter are based on inputs for specific agricultural fields using a specific crop rotation and tillage practice. Their application at a county level represents a gross approximation of what may be expected using average input parameters. The quantities indicated by the SCI model are similar to those estimated from another report using different methodologies. Kerstetter and Lyons reported 65,000 tons of winter wheat residue available in Union County based on leaving 1.5 tons/acre on the field after harvest.[54] Graef and Koehler assumed that 1.7 tons/acre of wheat residue could be removed from wheat lands in Northeastern Oregon and still maintain soil fertility.[55] The SCI model gave an average value for the three counties of 1.3 tons/acre of residue available.

The SCI model allowed us to estimate agricultural residue availability from field crop residues. In addition, grass straw from the production of Kentucky bluegrass seed and other grass seed commodities may be available for biomass energy. Figure 5-9 summarizes grass straw generation and availability in the study area. Grass straws are traditionally burned or removed from the fields for agronomic purposes. We assumed that 85% of the grass straws generated could be recovered. This quantity represents the amount that is technically recoverable from land used for grass seed production. However, Kentucky bluegrass has an economic value as feed and would not be available for energy uses unless the project could afford the additional cost of $10/ton that is currently paid to the landowners. We considered straw from Kentucky bluegrass to be available, under the assumption that biomass energy could cover this additional cost.



	Kentucky bluegrass straw	Other grass straw	Total
Generated	14,287	15,917	30,204
Available	12,144	13,529	25,673

Figure 5-9. Grass straw generation and availability (all located in Union County)

Figure 5-10 summarizes overall agricultural residue availability in the study area. Field crop residue availability is based on 10-year annual average availability as shown in Figure 5-8. We assumed that low-severity tillage practices would be used on field crops, thus increasing agricultural residue availability from field crops. The rationale for this assumption is that

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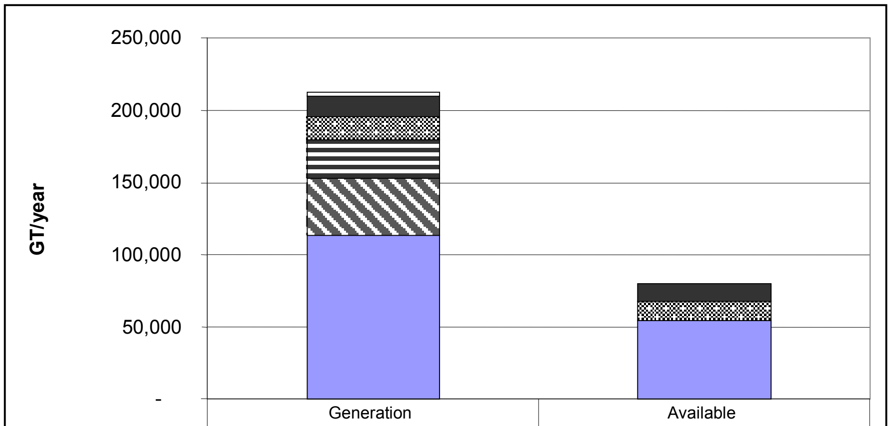
54 J. Kerstetter and K. Lyons, *Logging and Agricultural Residue Supply Curves for the Pacific Northwest* (Washington State University, January 2001).

55 A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000).

development of an outlet market for agricultural residue would increase adoption of low-severity tillage options. A total of 85% of straw from grass seed production is assumed to be available.



	Generation	Available
Oats	2,649	-
Kentucky bluegrass	14,287	12,144
Other grass	15,917	13,529
Spring wheat	26,608	-
Barley	39,907	-
Winter wheat	113,294	54,335

Figure 5-10. Overall agricultural residue generation and availability in the study area