Forest Biomass of Living, Merchantable Trees In Nova Scotia

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Report FOR 2008 - 9

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INTRODUCTION

How much biomass is contained in the forests of Nova Scotia? In 1995, Canada accepted both an international and a Canadian set of Criteria and Indicators for Sustainable Forest Management, which suggested that measures of biomass were useful. More recently, the increase in the price of oil has people and businesses looking for energy alternatives, and bioenergy can be generated from our renewable forests. Defining biomass is a good first step in describing this resource. There are many sources of biomass in the forest such as 1) the above ground biomass of all living merchantable trees 2) the roots of these trees 3) non-merchantable trees (smaller than 9.1 cm DBH), 4) deadwood - either standing or on the forest floor 5) woody vegetation, vascular plants and even forest wildlife. The intent of this report is to estimate a value for the first item on this list. The biomass for the above ground, living, merchantable sized, tree species, accounts for the largest portion of living biomass in the forests of Nova Scotia today. In this report, the term "biomass" will be used to describe this specific source.

While there are many sources of forest biomass, very few of them are widely used as forest products today. The exception would be the merchantable tree component for which biomass is estimated in this report. Products from merchantable sized trees are widely used in the forest industry and the co-generation/energy industry in Nova Scotia. The majority of the biomass that this report describes, is currently utilized by the forest products industry.

METHODS

Biomass is computed using equations that require tree mensurational data. Many trials were undertaken in the 1970s to measure and then estimate biomass from these measurements. These trials were a response to the energy crises in the 1970s, many were sponsored by the Federal ENFOR program. In 2005, Lambert et al, collected all the relevant tree biomass information in order to re-look at the data by major forest species and ensure most of the natural ranges of height and diameter were available. An additional objective was to develop equations that were additive. This simply means that the new equations could be applied to components of the tree, which, when added together, would give the total biomass for the tree. This report uses these new equations[1] to estimate biomass in Nova Scotia.

[1]For this report, equation [3] from Lambert et al (2005) was used.

The biomass values for each tree are comprised of 4 additive values. The stem is the sum of wood and bark, while the crown is the sum of limbs and foliage. Adding the stem and crown together gives the complete above ground tree biomass.

Biomass is reported as oven dry mass in metric tonnes. Weighing forest products has become the most common method for defining volume in Nova Scotia. Nova Scotia Department of Natural Resources (NSDNR) has estimated the volume of wood in this province for many years. Volume is reported in cords (cds), foot board measure (fbm), or cubic metres (m^3). The comparison of volume versus
biomass values is reviewed with respect to their impact on the relative amounts of softwood and hardwood in Nova Scotia's forests.

Data for this report comes from 3,252 NSDNR Permanent Sample Plots (PSPs). These plots are randomly located throughout the forested stands of Nova Scotia, with more than half of these plots established over 40 years ago between 1965 and 1970. The plot data comes from the most recent measurements of these plots over the 5 year period between 2002 and 2006 (650 plots are re-measured every year). NSDNR permanent sample plots are established primarily to report on growth and mortality in the forests of Nova Scotia. The PSP database is statistically large enough to generate estimates such as merchantable volume and biomass. Each plot is representative of a small sample of Nova Scotia forest, (1/10 ac ~1/25 ha), so a simple roll-up of the plot values can give an estimate of total provincial merchantable volume or biomass.

Individual tree values are aggregated to the plot level and then averaged with other plots for each defined classification (like covertype or age). Spatial classifications such as eco-region, come from the NSDNR's Forestry GIS system. To estimate provincial volume, forest area is from "Forest Resources Inventory Report" (NSDNR 1999).

Biomass values reported here are based on a one time picture of the forests of Nova Scotia. They are a result of compiling numbers over the most recent 5 year period. The values will vary over time, so extrapolation to another time or area is not recommended. Biomass currently exists as everything from wildlife habitat to future primary forest products, and occurs on all land types from private to protected Wilderness areas. The availability of this biomass is not estimated.

RESULTS

The results of this report are presented several ways, first by ownership, species, land capability, age class and covertype, then by ecoregion and ecosection. However, the cumulative average of 73.16 oven dry tonnes per hectare will always be the same for each result, as each are plot averages of the 3252 PSP's in the province. To get an estimate of the provincial biomass, this number can be multiplied by the total forested hectares in the province which is 4,226,563 hectares.

$$V_t = V_a * A$$

where: V_t = Volume in million tonnes of ovendry biomass
V_a = Average volume in ovendry tonnes per hectare
A = Total provincial forested area in hectares.

V_t = 73.16 t/ha (biomass) X 4.2 (million ha)
V_t = 309.2 million tonnes of oven dry biomass

Total provincial biomass is calculated to be 309,215,349 oven dried tonnes. biomass. This estimate is for all above ground biomass of living, merchantable trees located over all of Nova Scotia, including National Parks and protected Wilderness areas. The total value of 309 million tonnes should not be considered as currently available for bio-energy. While some of this biomass exists on protected lands, much of the remaining biomass is already used in the forest industry to produce lumber, flooring, hardboard, pulp etc. A significant portion (limbs and foliage) is also left on site where it serves as shelter and fertilizer for the next generation of forests.

Biomass By Owner

An estimate of biomass by ownership appears in Table 1. The highest biomass average, 81.66 t/ha, appears on Crown land classified as IRM 3. These are forested areas which are specifically allocated to special uses (such as wilderness areas) and where other resource activities may be limited, modified, or denied. The largest total source of biomass, 147 million oven-dry tonnes, resides on small private lands.

Table 1. Average oven dry biomass in tonnes for softwood and hardwood by landownership in Nova Scotia.

Owner	Plots	Biomass (t/ha)			Total Biomass (million tonnes)			Biomass
		Softwood	Hardwood	Total	Softwood	Hardwood	Total	Percent
Federal	74	37.26	39.72	76.98	3.6	3.8	7.4	2.4
Crown (IRM 3)	171	42.26	39.39	81.66	9.4	8.8	18.1	5.9
Crown (remainder)	813	38.25	28.96	67.21	40.4	30.6	71.0	23.0
Large Private	678	45.37	28.96	74.33	40.0	25.5	65.5	21.2
Small Private	1516	38.30	36.39	74.69	75.5	71.7	147.2	47.6
Total	3252	39.94	33.22	73.16	168.8	140.4	309.2	100.0

Biomass by Species

Biomass was computed for each individual tree, and compiled by species. The following Table 2 presents biomass by each tree component for each of the 7 major softwood and 6 major hardwood species in Nova Scotia. Individual species are sorted by average biomass content in descending order. In addition, the tree components of wood, bark, limbs and foliage are displayed in percent in Table 2. It is interesting to note that softwood tree biomass is comprised of 61% wood, 10% bark, 17% limbs and 13% foliage, whereas hardwood tree biomass is comprised of 64% wood, 10% bark, 22% limbs and only 4% foliage. Other softwood and other hardwood species are defined in Appendix I.

Table 2. Average oven dry biomass in tonnes per hectare for major softwood and hardwood species in Nova Scotia.

Species	Wood	Bark	Stem (Wood + Bark)	Limbs	Foliage	Crown (Limbs + Foliage)	Total
Balsam Fir	6.64	1.28	7.92	2.36	2.19	4.54	12.46
Red Spruce	7.92	1.20	9.12	1.43	1.02	2.45	11.58
White Pine	2.80	0.44	3.24	0.99	0.38	1.36	4.61
White Spruce	2.58	0.38	2.97	0.68	0.60	1.28	4.25
Black Spruce	2.08	0.33	2.41	0.61	0.56	1.16	3.57
E. Hemlock	1.13	0.22	1.35	0.33	0.16	0.49	1.83
Larch	0.77	0.08	0.85	0.21	0.08	0.29	1.14
Other SW	0.31	0.05	0.34	0.09	0.05	0.17	0.50
Total SW	24.23	3.98	28.20	6.70	5.04	11.74	39.94
Red Maple	9.36	1.40	10.76	2.97	0.47	3.44	14.19
Sugar Maple	3.24	3.24	3.67	1.18	0.23	1.41	5.08
Yellow Birch	3.00	3.00	3.45	1.42	0.18	1.61	5.06
White Birch	2.18	2.18	2.55	0.71	0.20	0.91	3.46
Trem Aspen	0.90	0.90	1.10	0.17	0.03	0.20	1.30
LT Aspen	0.54	0.54	0.69	0.12	0.02	0.14	0.84
Other HW	2.11	2.11	2.41	0.78	0.11	0.88	3.29
Total HW	21.33	3.30	24.63	7.35	1.24	8.59	33.22
Grand Total	45.56	7.28	52.83	14.05	6.28	20.33	73.16
Percent of SW	61	10	71	17	13	29	100
Percent of HW	64	10	74	22	4	26	100
Percent	62	10	72	19	9	28	100

The average volume by tree species was multiplied by provincial forest area to estimate the total value of biomass by species in the province. These numbers appear in Table 3 and are sorted from highest to lowest. The stem column is comprised of both the wood and bark, while the crown column is comprised of both the limbs and foliage. The top 3 softwood trees are balsam fir, red spruce and white pine, while the top 3 hardwood trees are red maple, sugar maple, and yellow birch. Red maple, balsam fir and red spruce alone, comprise over half of the entire biomass in Nova Scotia forests.

Table 3. Total biomass in millions of ovendry tonnes, for common species in Nova Scotia

Species	Stem	Crown	Total
Red Maple	45.5	14.5	60.0
Balsam Fir	33.5	19.2	52.7
Red Spruce	38.5	10.4	48.9
Sugar Maple	15.5	6.0	21.5
Yellow Birch	14.6	6.8	21.4
White Pine	13.7	5.7	19.5
White Spruce	12.6	5.4	18.0
Black Spruce	10.2	4.9	15.1
White Birch	10.8	3.8	14.6
Other HW	10.2	3.7	13.9
Eastern Hemlock	5.7	2.1	7.7
Trembling Aspen	4.6	0.8	5.5
Larch	3.6	1.2	4.8
Large tooth Aspen	2.9	0.6	3.6
Other SW	1.4	0.7	2.1
Total SW	119.2	49.6	168.8
Total HW	104.1	36.3	140.4
Grand Total	223.3	85.9	309.2

Land Capability

Oven dry biomass for merchantable softwood and hardwood trees by land capability class (LC) is now presented. Land capability is an estimate of the potential of fully stocked forest lands to produce merchantable volume for unmanaged stands. The most common LC class is 5 (761 plots) and implies potential growth of 5 m^3/ha/yr. The higher the number, the more productive the land. Table 4 shows that this is also the case for biomass, with increasing biomass values from LC < 0.5 up to LC 7. For LC 8 and higher, biomass values decrease. A review of these stands revealed that the majority of these plots with a high LC contain young trees which contain less biomass. Some of these younger stands are also plantations, which may achieve higher productivity than LC estimates.

Table 4. Average, oven dry biomass in tonnes per hectare for softwood and hardwood species in Nova Scotia, by land capability class.

Land Capability (m^3/ha/yr)	Plots	Softwood	Hardwood	Total
< 0.5	50	17.0	1.1	18.1
1	136	28.5	11.8	40.3
2	241	38.0	22.6	60.6
3	394	40.1	32.4	72.5
4	571	40.8	38.6	79.3
5	761	40.2	34.4	74.7
6	489	43.4	36.9	80.3
7	288	44.4	39.2	83.6
8	167	47.0	33.7	80.7
9	74	32.8	31.7	64.5
10	48	28.7	36.6	65.3
11	18	32.7	34.7	67.4
12	7	11.3	9.9	21.2
13	2	11.7	6.1	17.8
+13.5	6	1.8	32.5	34.3
Total	3252	40.0	33.2	73.2

Regional Biomass

Compiling biomass by each region shows that the highest biomass loads per hectare occur in the western section of the province with 80.9 t/ha of ovendry biomass. The provincial total average biomass for softwood is 40 t/ha (55%) and hardwood 33.2 t/ha (45%) (Table 5).

Table 5. Average biomass for softwood and hardwood species in Nova Scotia, by Region.

Region	Plots	Biomass (t/ha)		
		Softwood	Hardwood	Total
East	966	30.4	37.5	68.0
Central	1203	39.9	30.5	70.4
West	1083	48.5	32.4	80.9
Total	3252	40.0	33.2	73.2
Percent (%)	100	54.6	45.4	100.0

Biomass vs Volume

While volume describes the space that contains a product, mass describes the density of the product within a given space. However, both are common terms, so a comparison is described and the following table presented. Wood density is important when you consider burning a piece of firewood. Burning a piece of sugar maple results in the production of a lot more heat than a similar sized piece of balsam fir. This is because the sugar maple has a higher wood density. To compare biomass with volume, the average wood component from the biomass calculation was compared with the average total volume[2] for all the PSPs. The results in Table 6 show that Nova Scotia's softwood comprises 63% of the total volume but only 53% of the total biomass.

Table 6. Average total volume versus average, oven dry biomass for the wood portion of the softwood and hardwood boles in Nova Scotia.

Specie Type	Average wood total volume		Average wood biomass	
	(m^3/ha)	(%)	(t/ha)	(%)
Softwood	66.7	63	24.2	53
Hardwood	39.7	37	21.3	47
Total	106.4	100	45.5	100

Age Class and Covertype

Average forest biomass is now shown by age class within forest covertype in Table 7. Covertype is a description of the dominant species type in a forest stand, and there are three covertypes; softwood (75%+ softwood), hardwood (+75% hardwood) and mixedwood (softwood and hardwood component are both less than 75%). As expected, biomass generally increases with age. The highest average biomass by covertype was located in mixedwood plots with 86.8 t/ha. The largest individual biomass value occurs in 81-100 year old hardwood stands with 133.9 t/ha.

[2]Total Volume includes the total above ground bole wood of every tree. The most common value presented in Nova Scotia Forest Inventory in recent years is merchantable volume, which is somewhat less than total volume as it removes a stump, with a height of 15 cm and the top of the tree with a diameter of 7.6 cm inside bark.

Table 7. Average forest biomass in tonnes/hectare by age class within covertype for softwood and hardwood in Nova Scotia.

Covertype	Age Class	Sample Size		Biomass (t/ha)		
Softwood	(years)	Plot s	Percent	Softwood	Hardwood	Total
	1-20	155	4.8	13.9	1.0	14.9
	21-40	274	8.4	46.1	4.8	50.9
	41-60	443	13.6	67.2	9.1	76.2
	61-80	360	11.1	72.0	9.8	81.8
	81-100	151	4.6	64.6	6.6	71.2
	100+	83	2.6	74.1	8.3	82.4
	Total/Average	1466	45.1	58.9	7.3	66.2
Hardwood	1-20	119	3.7	1.0	15.9	16.9
	21-40	77	2.4	3.5	44.3	47.7
	41-60	191	5.9	4.7	93.8	98.5
	61-80	157	4.8	5.9	107.7	113.6
	81-100	44	1.4	6.5	127.4	133.9
	100+	17	0.5	6.4	121.8	128.2
	Total/Average	605	18.6	4.3	79.0	83.3
Mixedwood	1-20	92	2.8	10.7	11.1	21.8
	21-40	185	5.7	28.7	30.7	59.4
	41-60	380	11.7	43.9	52.5	96.4
	61-80	265	8.1	43.4	57.6	100.9
	81-100	96	3.0	52.3	62.9	115.2
	100+	24	0.7	59.1	66.1	125.2
	Total/Average	1042	32.0	39.3	47.5	86.8
Regeneration	0 - 20	139	4.3	0.3	0.1	0.3
All	Total	3252	100.0	39.9	33.2	73.2

Ecological Land Classification Units

Nova Scotia's forests are located in the Acadian ecozone which is sometimes referred to as the Atlantic-Maritime ecozone. This ecozone has been stratified into 4 additional ecological units in Nova Scotia; Ecoregions, Ecodistricts, Ecosections and Ecosites. Biomass is computed for the top two stratifications, the ecoregions and ecodistricts. Ecoregions (Neily et al., 2003) are ecological land classifications units which delineate macro-climatic differences at a provincial scale as expressed through similar soils and vegetation. Ecodistricts rely on unique combinations of relief, geology, landform, soils and vegetation within the ecoregions. The following biomass volumes by ecological classification unit are given for general interest. Land capability, species composition and age structure would all impact these groupings. Most of all 'cultural history' will have impacted on the current biomass loads, as certain eco-district features are more likely to have attracted settlement, agriculture or frequent forest harvesting in the past.

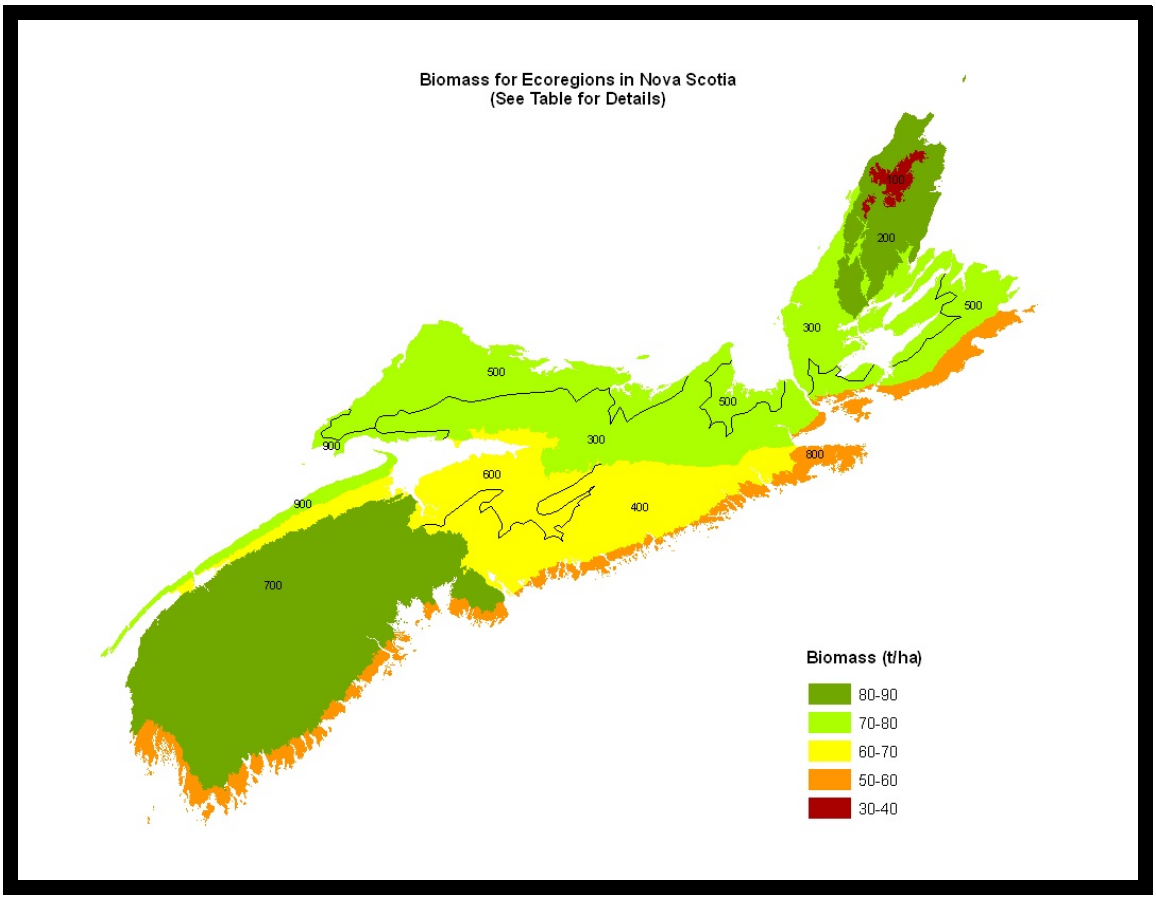
Ecoregion

The average forest biomass was computed for the forested lands of each ecoregion in Nova Scotia (Table 8, Figure 1). Ecoregions are sorted by descending biomass values. The most biomass (81.1 t/ha) was recorded in the "Western" ecoregion. The least biomass (34.2 t/ha) was recorded for the Cape Breton Taiga ecoregion. These average biomass values are divided into five value ranges of biomass for visual comparison in Figure 1.

Table 8. Average biomass for softwood and hardwood species in Nova Scotia, by ecoregion.

Ecoregion	Map Code	Plots	Biomass (t/ha)			Biomass (t/ha)
			Softwood	Hardwood	Total	
Western	700	992	49.5	31.6	81.1	80+
Cape Breton Highlands	200	184	28.1	52.1	80.2	80+
Fundy Shore	900	86	45.2	33.5	78.7	70-80
Northumberland Bra D'or	500	432	38.5	35.0	73.5	70-80
Nova Scotia Uplands	300	659	30.6	42.4	73.0	70-80
Valley and Central Lowlands	600	200	39.3	28.4	67.7	60-70
Eastern	400	402	40.6	25.0	65.6	60-70
Atlantic Coastal	800	272	37.2	19.1	56.3	50-60
Cape Breton Taiga	100	25	27.7	06.4	34.2	<50
Total		3252	39.9	33.2	73.2	

Figure 1. Biomass of living, merchantable sized trees by Nova Scotia ecoregions.



Ecodistricts

The biomass values by ecodistrict are shown in Table 9 and Figure 2, sorted from highest to lowest. The highest, Victoria Lowlands, at 157.1 t/ha is much higher than the other ecodistricts, and this is probably due to the small area and sample size associated with the Victoria Lowlands. Because there are only 8 plots, confidence would be reduced when using the biomass value for this area. Biomass can exceed 300 t/ha in a mature, fully stocked stand of average land capability, so the high level is possible. Biomass, divided into ranges, is shown by ecodistrict in Figure 2. Again, it should be stressed that this is only a picture of biomass at this point in time.

Figure 2. Biomass of living, merchantable sized trees by Nova Scotia ecodistricts.

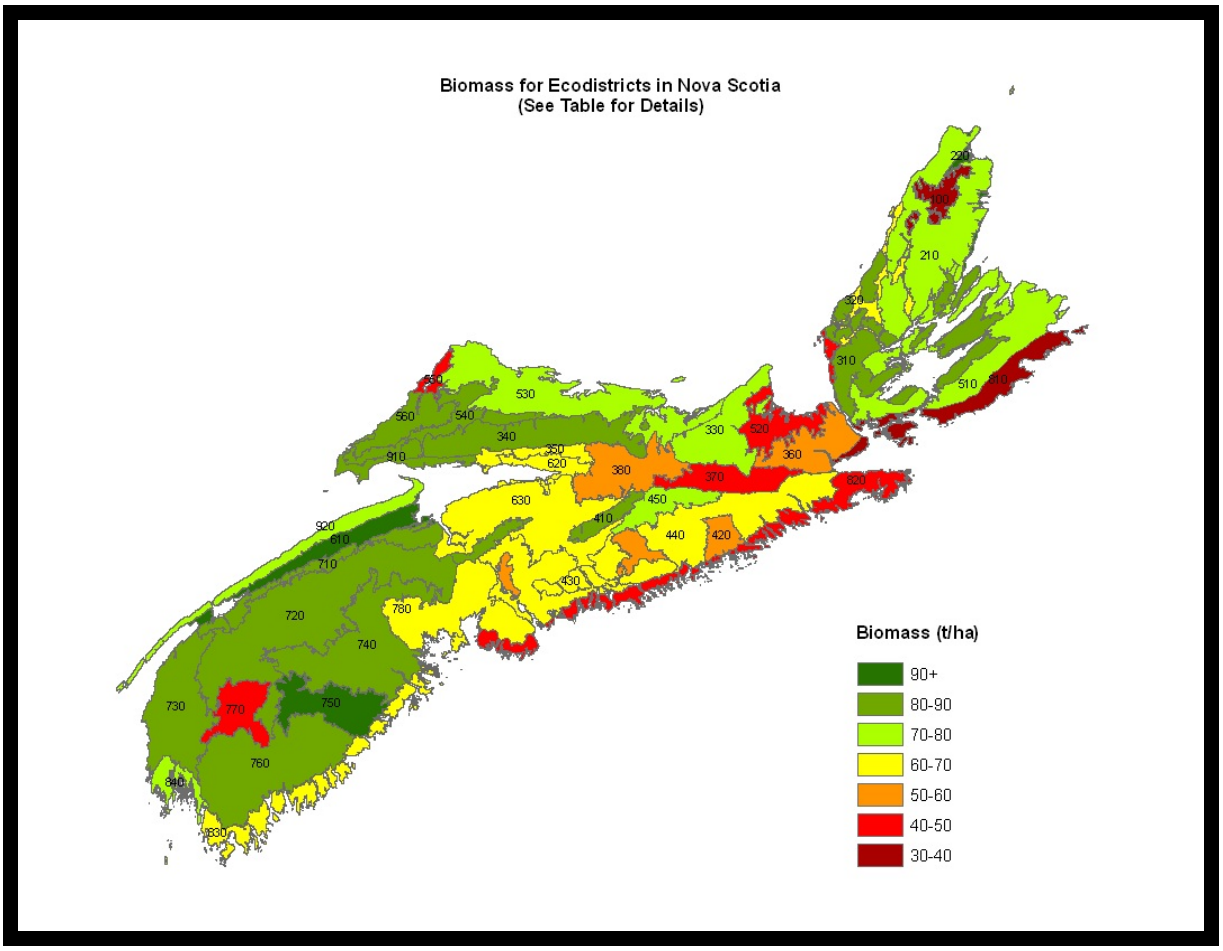


Table 9. Average biomass for softwood and hardwood species in Nova Scotia, by ecodistrict.

Ecodistrict	Map Code	Plots	Biomass (t/ha)			Relative Biomass
			Softwood	Hardwood	Total	
Victoria Lowlands	220	8	27.6	129.5	157.1	90+
Rossignol	750	68	66.9	31.1	98.1	90+
Annapolis Valley	610	27	47.1	44.8	92.0	90+
Cape Breton Hills	310	159	28.6	60.3	88.4	80-90
Parrsboro Shore	910	29	63.4	25.4	88.1	80-90
Cobequid Hills	340	132	34.7	53.0	87.8	80-90
Valley Slope	710	61	41.8	45.3	87.1	80-90
Sable	760	161	53.4	32.6	86.0	80-90
Rawdon \ Wittenburg Hills	410	35	43.6	41.1	84.7	80-90
South Mountain	720	282	50.1	33.4	83.4	80-90
Chignecto Ridges	560	50	53.9	29.5	83.4	80-90
Cumberland Hills	540	60	38.5	43.8	82.3	80-90
Clare	730	104	46.3	34.8	81.1	80-90
Lahave Drumlins	740	168	47.2	33.0	80.2	80-90
Govenor Lake	450	39	51.4	25.9	77.3	70-80
C.B. Highlands	210	189	27.4	49.6	77.0	70-80
Northumberland Lowlands	530	151	39.3	36.4	75.7	70-80
Tusket Islands	840	13	43.1	31.0	74.2	70-80
Bras D'or Lowlands	510	161	39.3	34.7	74.0	70-80
North Mountain	920	73	37.0	36.6	73.6	70-80
Pictou Antigonish Highlands	330	93	25.7	44.8	70.6	70-80
Minas Lowlands	620	13	53.1	16.0	69.1	60-70
St. Margaret's Bay	780	122	48.0	19.7	67.8	60-70
Eastern Interior	440	242	39.7	25.1	64.8	60-70
South Shore	830	78	42.1	21.9	64.0	60-70
Central Lowlands	630	156	37.0	26.9	63.9	60-70
Cobequid Slopes	350	31	41.5	22.2	63.7	60-70
Inverness Lowlands	320	33	36.5	25.9	62.4	60-70
Eastern Granite Uplands	430	31	43.7	16.7	60.4	60-70
Mulgrave Plateau	360	60	26.2	33.3	59.4	50-60
Eastern Drumlins	420	58	33.8	19.5	53.3	50-60
Central Uplands	380	81	31.2	21.4	52.6	50-60
Western Barrens	770	30	31.5	15.1	46.7	40-50
St. George's Bay	520	43	17.9	28.2	46.1	40-50
Eastern Shore	820	60	32.0	13.7	45.8	40-50
St. Mary's River	370	57	33.6	11.6	45.2	40-50
Cumberland Marshes	550	4	22.0	19.6	41.6	40-50
C.B. Coastal	810	66	27.9	9.3	37.3	30-40
C.B. Taiga	100	25	27.2	6.4	34.2	30-40
Total		**3252**	**39.9**	**33.2**	**73.2**	

SUMMARY

Biomass can be computed for many components in the forest. The biomass in this report is for the above ground, living, merchantable sized (≥9.1 cm diameter at breast height), tree species and is expressed in oven dry tonnes. While many other sources of biomass exist, this biomass estimate is probably the largest living component in the forest. The values in this report are a picture in time, from 3252 plots measured over five years ending in 2006. It is estimated that there are 309 million tonnes of oven dry biomass in the forested lands of Nova Scotia. Much of this biomass is already part of the wood supply for the forest industry or is protected on Federal or Provincial Crown land. Fifty-five percent of forest biomass is softwood and forty-five percent is hardwood. Fifty-two percent of forest biomass is contained in three species: red maple, balsam fir and red spruce. The highest average biomass by ownership is on Provincial IRM class 3 land, whereas the largest total source of biomass, 147 million oven-dry tonnes, resides on small private lands. Generally, biomass values increased as land capability and/or age increases. Looking at biomass by other categories, the largest biomass values by region, covertype, ecoregion and ecodistrict occurred in the western region, in mixedwood covertype, in the western ecoregion and the Victoria Lowlands ecodistrict respectively.

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APPENDIX I

Common Softwood

Balsam Fir	Abies balsamea (L.) Mill
Black Spruce	Picea mariana (Mill) B.S.P.
Eastern Hemlock	Tsuga canadensis(L.) Carr
Red Spruce	Picea rubens Sarg.
Tamarack Larch	Larix laricina (DuRoi)
White Spruce	Picea glauca (Moench)Voss
White Pine	Pinus strobus L.

Other Softwood

European/Japanese Larch	Larix sp
Jack Pine	Pinus banksiana Lamb.
Norway Spruce	Picea abies (L.) Karst.
Red Pine	Pinus resinosa Ait.
Scots Pine	Pinus sylvestris L.

Common Hardwood

Red Maple	Acer rubrum L.
Sugar Maple	Acer saccharum Marsh.
Trembling Aspen	Populus tremuloides Michx.
White Birch	Betula papyrifera Marsh.
Yellow Birch	Betula alleghaniensis Britton
Large Tooth Aspen	Populus grandidentata Michx.

Other Hardwood

Alder (speckled)	Alnus rugosa(DuRoi) Spreng.
Alder (green)	Alnus crispa (Ait.) Pursh
American Elm	Ulmus americana L.
Apple	Malus sp.
Beech	Fagus grandifolia Ehrh.
Black Ash	Fraxinus nigra Marsh.
Black Cherry	Prunus serotina Ehrh.
Choke Cherry	Prunus virginiana L.
English Oak	Quercus robur L.
Grey Birch	Betula populifolia Marsh.
Ironwood	Ostrya virginiana (Mill.)K.Koch
Manitoba Maple	Acer Nergundo L.
Mountain Ash	Sorbus americana Marsh.
Mountain Maple	Acer spicatum Lamb.
Pin Cherry	Prunus pensylvanica L.f.
Red Oak	Quercus rubra L.
Serviceberry	Amelanchier sp.
Staghorn Sumac	Rhus typhina L.
Striped Maple	Acer pennsylvanicum L.
White Ash	Fraxinus americana L.
Willow	Salix Sp.