

East Central Landscape Timberland Growing Stock Mortality

**A support document to the
2nd Generation MFRC East Central Landscape Plan**

January 2019



Minnesota Forest Resources Council (MFRC)

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Please cite this document as:

Minnesota Forest Resource Council. 2019. *East Central Landscape Timberland Growing Stock*. Minnesota Forest Resource Council, St. Paul, Minnesota. Available online at www.frc.state.mn.us.



Timberland Growing Stock Mortality

MFRC staff compiled the following white paper on timberland growing stock mortality to develop a structure for informed dialog during the East Central Landscape Plan revision. This information was used by the Planning Committee when developing the goals and objectives in the revised East Central Landscape Forest Resources Plan.

Data source

The primary source for mortality data is the Forest Inventory and Analysis (FIA) dataset coordinated by the US Forest Service (www.fia.fs.fed.us). FIA is a continuous forest census designed to provide reliable estimates on the type, extent, growth, mortality, and removals of forestland. Results are based on remote sensing and field sample plots. FIA data is often reported for a single year (as we do here); however, the actual data represents a five year running average. For example data reported as 2015 is an annual average over the 2011, 2012, 2013, 2014 and 2015 period. This is important when comparing between consecutive years because four of the years leading to the estimate are the same. In other words the 2013 and 2014 data sets both include data from 2010, 2011, 2012, and 2013. This is done because it takes five years to accumulate one complete set of data; in each of those five years a different set of plots is measured. For this analysis we are focusing on mortality in Timberlands (see definitions below).

Forest Inventory and Analysis definitions:

- Timberland. Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included, but these likely are a very small number of acres.)
- Growing stock. All live trees of commercial species that meet minimum merchantability standards (at least 5 inches d.b.h.). In general, these trees have at least one solid 8-foot section, are reasonably free from defect on the merchantable bole, and at least 34% or more of the volume is merchantable. Excludes rough or rotten cull trees.
- Net cubic-foot volume. For timber species, this is the net volume of wood in the central stem of a sample tree ≥ 5.0 inches in diameter, from a 1-foot stump to a minimum 4-inch top diameter, or to where the central stem breaks into limbs all of which are <4.0 inches in diameter.
- Average annual net growth. The average annual change in the volume of trees during the period between inventories. Components include the change in volume of trees that have met the minimum size requirements over the inventory period, plus the volume of trees reaching the minimum size (≥ 5.0 inches dbh) during the period (ingrowth), minus the volume of trees that died during the period, minus the volume of cull during the period. Mortality removals (trees killed in the harvesting process and left on site) and diversion removals (trees removed from the forest-land base due to a change from forest to non-forest land) are not included.
- Average annual removals of growing stock. Trees that were growing-stock trees on timberland at the time of the previous inventory and were removed from timberland by the

time of the current inventory. Removals are cut and utilized trees, trees killed as a result of harvest operations but not utilized and live trees associated with land-use reclassifications.

- Average annual mortality of growing stock. Volume of growing stock trees that were alive at the time of the previous inventory and are dead in the current inventory. Tree death associated with insects, disease, fire, animals, weather, and other factors are included.
- Sampling error percent. Equals 100 multiplied by the square root of the variance divided by the sample estimate. Since sampling error is given in percent of the estimate, a large sampling error indicates that there is considerable uncertainty associated with the estimate.

Data analysis summary

There were 1.35 billion cubic feet (17.1 million cords) of growing stock on timberland in the East Central Landscape in the 2016 FIA survey dataset (Table 1). Average annual net growth in this dataset was over 28.7 million cubic feet. Quaking aspen and northern red oak had both the highest net volumes and average annual net growth rates; together they made up about 31.5% of the total growing stock volume and 41.7% of the total average annual net growth.

Average annual removals according to the 2016 FIA data was over 11.2 million cubic feet and mortality was about 21.7 million cubic feet. In both of these measures quaking aspen had the highest values, making up 51.8% of the removals in the region and about 34.0% of the mortality.

Between 2003 and 2016, net volume increased 6.2% but average annual net growth decreased by 54.2% (Table 2). Annual removals decreased by 6.1% and mortality increased by 61.8%. Notable standouts among individual species include Eastern white pine which increased growth by 220.2% and decreased mortality by 49.2%, both which helped to increase its overall volume by 65.6%. Other species did not do as well and during the same period black ash, northern pin oak, and American elm growth rates were reduced between 90% and 101% while their mortality increased between 395% and 932%.

Overall relative mortality rates increased from 0.9% of growing stock volume in 1977 to 1.6% in 2016 (Table 3). Mortality rate increases were much higher among American elm and jack pine which increased 17- and 41-fold, respectively. Data collection methods changed significantly over this period and we do not know how much those changes may have influenced the estimates.

More recent trends can be detected by comparing FIA data from 2003 to 2016. Relative mortality rates increased between 2003 and 2016 for American elm, jack pine, northern pin oak, black ash, quaking aspen, American basswood and northern red oak, decreased for red pine, eastern white pine, paper birch, black spruce, and did not change for bigtooth aspen. No data was available for the other major tree species.

Mortality is related to age class structure. Overall, mortality volume is higher in the 41-60 and 61-80 age classes, but relative mortality rates were fairly constant across age classes (Table 4). One notable exception to this trend was northern red oak, whose mortality volume is highest in the 81-100 age class.

Relative mortality rates were generally similar across ownerships (Table 5), although they were particularly high for jack pine on private timberlands.

Total relative removal rates were highest from state and county timberlands and lower from private timberlands, although the relative removal rate of individual species varied (Table 6). The most obvious differences were the high removal rates of quaking aspen, red maple, paper birch, and sugar maple on county timberlands.

Over the period from 2006 to 2016, average annual growing stock mortality in absolute terms held steady or rose slightly for most species (Figure 1). The most noticeable occurrence was a spike in aspen mortality in 2012, which was a year known for damaging windstorms across Minnesota. The relative mortality rates of most species have also increased since 2006 (Figure 2). The largest increases occurred in American elm and jack pine whose relative mortality rates more than quadrupled over the past 10 years.

Table 1. Net volume, average annual net growth, average annual removals, and average annual mortality of growing stock trees, in cubic feet, on timberlands in the East Central Landscape, 2016.

Species	Net Volume			Average Annual Net Growth			Average Annual Removals			Average Annual Mortality		
	Volume (ft ³)	Sampling error %	% of total volume	Growth (ft ³)	Sampling error %	% of total growth	Removals (ft ³)	Sampling error %	% of total removals	Mortality (ft ³)	Sampling error %	% of total mortality
Quaking aspen	260,259,760	9.0	19.3	7,774,293	17.3	27.0	5,814,982	29.7	51.8	7,190,578	14.6	34.0
Northern red oak	164,399,106	13.0	12.2	4,224,056	34.4	14.7	754,443	78.9	6.7	1,397,354	50.7	6.6
American basswood	126,428,204	13.1	9.4	2,040,918	28.9	7.1	965,159	52.1	8.6	1,040,258	33.7	4.9
Bur oak	106,888,716	14.7	7.9	2,107,292	13.7	7.3	397,149	52.9	3.5	262,257	39.5	1.2
Red pine	99,832,392	25.9	7.4	3,170,045	30.1	11.0	347,583	73.0	3.1	547,781	50.3	2.6
Red maple	87,761,079	10.5	6.5	2,452,470	10.5	8.5	435,095	71.8	3.9	422,091	25.6	2.0
Black ash	85,773,439	14.5	6.3	-23,585	-1,849.6	-0.1	295,350	80.4	2.6	1,816,600	26.9	8.6
Green ash	62,588,026	16.1	4.6	1,742,536	19.6	6.1	165,667	85.2	1.5	413,464	45.3	2.0
Paper birch	53,221,756	13.4	3.9	164,405	236.2	0.6	358,574	69.0	3.2	1,583,755	25.2	7.5
Bigtooth aspen	51,594,736	24.9	3.8	973,331	52.6	3.4	370,746	94.6	3.3	777,180	48.6	3.7
Silver maple	40,516,962	45.1	3.0	555,085	54.4	1.9	9,974	102.1	0.1	198,305	102.1	0.9
Eastern white pine	34,089,142	57.8	2.5	1,523,572	35.7	5.3	87,487	87.5	0.8	61,935	67.4	0.3
Sugar maple	33,244,067	21.9	2.5	921,290	30.9	3.2	653,641	59.4	5.8	106,305	75.1	0.5
Northern pin oak	31,104,681	27.2	2.3	99,446	530.4	0.3	403,219	77.5	3.6	977,982	51.4	4.6
American elm	17,320,979	14.3	1.3	7,508	3,514.5	0.0	--	--	--	1,199,507	25.5	5.7
Black spruce	16,459,803	33.8	1.2	159,023	73.5	0.6	--	--	--	247,502	45.6	1.2
Tamarack (native)	13,766,652	29.3	1.0	251,273	45.4	0.9	--	--	--	161,158	74.4	0.8
Balsam fir	9,457,921	25.8	0.7	300,519	60.4	1.0	--	--	--	341,127	34.6	1.6
White oak	8,935,566	37.0	0.7	179,071	35.9	0.6	--	--	--	--	--	--
Jack pine	7,351,310	44.3	0.5	-387,788	-69.8	-1.3	--	--	--	630,396	52.6	3.0
White spruce	7,035,350	35.1	0.5	627,615	42.5	2.2	--	--	--	--	--	--
Balsam poplar	6,223,663	55.8	0.5	-729,236	-104.4	-2.5	146,795	74.6	1.3	928,840	86.1	4.4
Eastern redcedar	3,891,498	43.5	0.3	135,761	46.6	0.5	--	--	--	--	--	--
Scotch pine	3,877,634	57.4	0.3	276,643	45.8	1.0	--	--	--	--	--	--
Eastern cottonwood	3,432,270	91.7	0.3	-245,471	-77.9	-0.9	--	--	--	432,878	77.6	2.0
Boxelder	3,108,062	28.1	0.2	178,677	37.0	0.6	--	--	--	21,318	102.1	0.1
Bitternut hickory	3,028,043	54.0	0.2	134,101	45.1	0.5	--	--	--	--	--	--
Black willow	2,190,882	101.5	0.2	54,380	102.1	0.2	--	--	--	--	--	--
Black cherry	1,674,258	25.2	0.1	111,997	27.6	0.4	20,257	106.1	0.2	--	--	--
Slippery elm	1,504,942	44.7	0.1	117,552	40.7	0.4	--	--	--	--	--	--
Siberian elm	1,396,074	69.1	0.1	77,937	64.4	0.3	--	--	--	--	--	--
Butternut	1,086,219	40.0	0.1	-56,546	-159.0	-0.2	--	--	--	142,669	69.2	0.7
Yellow birch	630,868	65.0	0.0	-23,725	-185.7	-0.1	--	--	--	48,400	100.2	0.2
Black walnut	332,891	90.4	0.0	19,792	73.0	0.1	--	--	--	--	--	--
Blue spruce	240,284	95.3	0.0	23,581	94.3	0.1	--	--	--	--	--	--
Hackberry	122,694	77.1	0.0	-199,004	-111.5	-0.7	--	--	--	220,681	106.1	1.0
White ash	37,692	96.5	0.0	8,147	94.6	0.0	--	--	--	--	--	--
Northern white-cedar	34,531	101.5	0.0	7,066	102.1	0.0	--	--	--	--	--	--
Other	70,374	96.9	0.0	14,704	94.7	0.1	--	--	--	--	--	--
Total	1,350,912,527	5.5	100.0	28,768,733	11.4	100.0	11,226,121	22.7	100.0	21,170,321	10.4	100.0

Source: Forest Inventory and Analysis estimates.

Table 2. Net volume, average annual net growth, average annual removals, and average annual mortality of growing stock trees, in cubic feet, on timberlands in the East Central Landscape, 2003.

Species	Net Volume			Average Annual Net Growth			Average Annual Removals			Average Annual Mortality		
	Volume (ft ³)	Sampling error %	% of total volume	Growth (ft ³)	Sampling error %	% of total growth	Removals (ft ³)	Sampling error %	% of total removals	Mortality (ft ³)	Sampling error %	% of total mortality
Quaking aspen	249,113,932	9.0	19.6	10,466,966	19.2	16.7	6,440,506	37.5	53.9	5,494,925	25.2	42.0
Northern red oak	158,856,864	12.7	12.5	6,400,199	27.4	10.2	1,849,188	78.2	15.5	921,285	45.0	7.0
American basswood	120,476,067	13.9	9.5	3,148,118	29.8	5.0	293,371	58.5	2.5	581,802	61.2	4.4
Red maple	104,521,315	11.0	8.2	5,986,080	23.0	9.5	208,386	70.7	1.7	--	--	--
Bur oak	98,986,764	15.5	7.8	5,674,063	23.8	9.0	802,345	59.0	6.7	--	--	--
Black ash	82,996,539	15.7	6.5	1,876,921	42.0	3.0	981,906	73.5	8.2	367,329	52.9	2.8
Red pine	66,396,736	29.9	5.2	5,816,858	46.9	9.3	--	--	--	484,317	51.2	3.7
Paper birch	58,471,355	13.4	4.6	1,618,709	74.6	2.6	421,518	60.5	3.5	2,161,423	35.4	16.5
Sugar maple	53,960,947	22.4	4.2	3,396,882	36.1	5.4	--	--	--	--	--	--
Green ash	47,452,978	18.6	3.7	2,863,940	31.0	4.6	251,753	70.6	2.1	--	--	--
Bigtooth aspen	34,051,406	23.8	2.7	4,375,480	39.2	7.0	--	--	--	726,070	56.7	5.6
Silver maple	25,179,437	43.1	2.0	4,816,740	52.2	7.7	--	--	--	--	--	--
Northern pin oak	23,554,209	38.9	1.9	919,116	54.0	1.5	--	--	--	121,880	100.1	0.9
Eastern white pine	20,590,065	70.1	1.6	475,769	60.1	0.8	--	--	--	121,942	95.5	0.9
White oak	18,802,308	34.5	1.5	1,165,207	62.7	1.9	274,338	99.5	2.3	--	--	--
American elm	16,686,255	14.5	1.3	748,466	49.9	1.2	--	--	--	116,210	69.7	0.9
Tamarack (native)	16,071,572	36.4	1.3	807,805	69.6	1.3	--	--	--	--	--	--
Balsam poplar	11,965,241	58.9	0.9	-248,985	-175.3	-0.4	--	--	--	549,790	90.8	4.2
Black spruce	10,297,469	44.2	0.8	-125,992	-117.8	-0.2	--	--	--	276,926	59.7	2.1
Jack pine	8,471,396	48.0	0.7	-359,962	-214.9	-0.6	--	--	--	751,537	72.7	5.7
Balsam fir	7,964,429	27.0	0.6	196,424	111.7	0.3	49,343	104.8	0.4	--	--	--
Eastern redcedar	5,605,703	60.7	0.4	497,044	70.0	0.8	--	--	--	--	--	--
Black willow	5,379,565	62.8	0.4	1,089,040	75.5	1.7	--	--	--	--	--	--
White spruce	4,657,574	40.0	0.4	374,686	59.3	0.6	--	--	--	--	--	--
Butternut	3,325,562	38.5	0.3	76,702	95.5	0.1	--	--	--	--	--	--
Eastern cottonwood	3,305,007	94.9	0.3	36,222	95.5	0.1	260,365	95.5	2.2	--	--	--
Scotch pine	3,123,063	83.3	0.2	46,119	104.8	0.1	--	--	--	--	--	--
Siberian elm	2,436,891	73.3	0.2	--	--	--	--	--	--	--	--	--
Black cherry	2,198,903	31.4	0.2	70,704	324.2	0.1	118,627	102.4	1.0	345511.448	66.5	2.6
Boxelder	1,967,147	34.2	0.2	15,529	459.6	0.0	--	--	--	60742.317	104.8	0.5
Yellow birch	1,431,646	58.0	0.1	--	--	--	--	--	--	--	--	--
Bitternut hickory	994,329	46.7	0.1	73,429	102.4	0.1	--	--	--	--	--	--
Slippery elm	843,982	47.8	0.1	367,290	80.4	0.6	--	--	--	--	--	--
Black locust	476,614	94.9	0.0	--	--	--	--	--	--	--	--	--
Hackberry	400,446	62.2	0.0	153,756	99.5	0.2	--	--	--	--	--	--
Blue spruce	45,324	99.9	0.0	--	--	--	--	--	--	--	--	--
White ash	39,735	101.0	0.0	35,900	102.4	0.1	--	--	--	--	--	--
Other	351,586	102.0	0.0	--	--	--	--	--	--	--	--	--
Total	1,271,450,363	5.1	100.0	62,855,227	11.6	100.0	11,951,648	26.8	100.0	13,081,691	15.8	100.0

Source: Forest Inventory and Analysis estimates.

Table 3. Average annual growing stock mortality, in percent of growing stock volume, on timberlands in the East Central Landscape, 1977, 1990, 2006, and 2016.

Tree species	1977		1990		2003		2016	
	% of volume	Sampling error %	% of volume	Sampling error %	% of volume	Sampling error %	% of volume	Sampling error %
Quaking aspen	2.0	2.4	2.0	5.2	2.2	23.9	2.8	13.4
Northern red oak	0.5	0.7	0.8	12.6	0.6	46.1	0.9	51.5
American basswood	0.4	2.0	0.5	29.6	0.5	56.9	0.9	31.7
Bur oak	0.2	8.4	0.1	30.4	--	--	0.2	39.4
Red pine	0.0	32.1	0.0	91.2	0.6	33.3	0.5	48.6
Red maple	0.2	2.6	0.4	25.3	--	--	0.5	22.3
Black ash	0.9	0.4	0.5	20.4	0.5	56.8	2.1	22.4
Green ash	0.9	0.7	0.2	36.7	--	--	0.7	47.7
Paper birch	0.2	20.9	2.4	9.3	3.8	38.2	2.9	21.7
Bigtooth aspen	1.4	2.6	1.1	20.7	1.5	55.4	1.5	46.0
Silver maple	0.2	15.9	1.2	60.4	--	--	0.8	101.1
Eastern white pine	0.1	15.4	0.8	33.1	0.4	40.4	0.2	38.7
Sugar maple	0.4	1.8	0.3	33.2	--	--	0.3	60.9
Northern pin oak	0.5	6.9	1.0	24.2	0.6	106.7	3.1	52.3
American elm	0.4	2.3	13.0	16.5	0.8	69.8	7.3	24.9
Black spruce	0.4	17.4	2.2	24.3	3.7	59.9	1.5	35.1
Tamarack (native)	2.2	1.8	0.9	36.0	--	--	1.1	63.5
Balsam fir	0.6	7.0	1.5	36.6	--	--	3.6	37.7
White oak	0.2	11.2	0.1	87.4	--	--	--	--
Jack pine	0.2	3.6	1.3	29.0	4.8	65.6	8.3	33.1
Total	0.9	2.8	1.4	4.3	1.0	14.8	1.6	10.0

Source: Forest Inventory and Analysis.

Note: Data collection procedures and plot design have changed over the course of the Forest Inventory Analysis program history which may lead to issues comparing between years. FIA data collected in 1977 and 1990 (*) were collected as a periodic survey while 2006 and 2016 are part of the annual survey (5 year running average). Comparisons between similarly collected survey data are stronger than between the two methods.

Table 4. Average annual growing stock mortality by age class on timberlands in the East Central Landscape, 2016.

Stand age class	All species				Quaking aspen				Northern red oak			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	57,523,215	965,226	1.7	22.5	11,348,192	317,832	2.8	46.4	9,704,136	--	--	--
21 to 40 years	178,395,818	2,073,198	1.2	21.3	76,425,205	1,118,392	1.5	19.1	5,177,959	7,966	0.2	78.5
41 to 60 years	318,490,077	5,049,823	1.6	14.3	90,308,553	2,399,223	2.7	15.7	17,641,186	--	--	--
61 to 80 years	455,502,687	8,067,133	1.8	17.6	62,736,986	2,891,592	4.6	27.3	75,441,090	153,217	0.2	58.9
81 to 100 years	230,403,374	4,059,669	1.8	29.1	17,333,892	302,288	1.7	43.2	32,241,025	1,131,205	3.5	69.5
101 to 150 years	71,908,150	864,622	1.2	56.4	2,452,641	143,423	5.8	0.0	11,932,239	73,961	0.6	73.9
Not collected	--	90,650	--	--	--	17,829	--	--	--	31,004	--	--
Total	1,312,223,321	21,170,321	1.6	10.0	260,605,469	7,190,578	2.8	13.4	152,137,635	1,397,354	0.9	51.5

Stand age class	American basswood				Bur oak				Red pine			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	6,383,691	115,975	1.8	35.6	5,098,783	--	--	--	132,691	--	--	--
21 to 40 years	5,941,353	--	--	--	14,309,693	33,107	0.2	121.7	24,471,188	--	--	--
41 to 60 years	13,796,122	203,719	1.5	90.1	10,045,664	--	--	--	69,764,748	366,730	0.5	51.6
61 to 80 years	42,126,802	353,019	0.8	52.9	40,976,307	127,898	0.3	44.3	1,923,448	--	--	--
81 to 100 years	40,902,748	367,545	0.9	48.2	23,051,244	101,252	0.4	69.3	6,002,089	181,051	3.0	132.9
101 to 150 years	8,789,934	--	--	--	12,068,815	--	--	--	--	--	--	--
Not collected	--	--	--	--	--	--	--	--	--	--	--	--
Total	117,940,649	1,040,258	0.9	31.7	105,550,506	262,257	0.2	39.4	102,294,163	547,781	0.5	48.6

Stand age class	Red maple				Black ash				Green ash			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	6,907,551	49,705	0.7	44.2	2,032,595	129,834	6.4	83.8	929,885	11,529	1.2	101.7
21 to 40 years	3,338,907	--	--	--	2,081,937	--	--	--	5,061,422	--	--	--
41 to 60 years	14,787,158	66,404	0.4	71.0	14,568,169	264,783	1.8	51.5	12,133,188	--	--	--
61 to 80 years	41,174,694	255,592	0.6	27.7	49,077,801	882,420	1.8	35.0	30,658,613	160,961	0.5	63.2
81 to 100 years	14,476,201	50,390	0.3	62.2	19,300,472	509,262	2.6	38.2	14,482,074	240,975	1.7	78.5
101 to 150 years	697,265	--	--	--	49,388	--	--	--	208,215	--	--	--
Not collected	--	--	--	--	--	30,299	--	--	--	--	--	--
Total	81,381,777	422,091	0.5	22.3	87,110,362	1,816,600	2.1	22.4	63,473,397	413,464	0.7	47.7

Stand age class	Paper birch				Bigtooth aspen				Silver maple			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	3,311,146	248,915	7.5	46.7	--	--	--	--	--	--	--	--
21 to 40 years	6,993,745	147,512	2.1	58.6	3,066,351	--	--	--	1,634,855	--	--	--
41 to 60 years	16,252,596	333,008	2.0	52.1	19,411,492	135,452	0.7	33.7	8,927,589	198,305	2.2	87.2
61 to 80 years	24,066,863	620,533	2.6	32.6	18,142,339	517,960	2.9	61.6	5,189,631	--	--	--
81 to 100 years	2,347,255	233,787	10.0	71.5	10,869,543	123,769	1.1	89.9	1,327,929	--	--	--
101 to 150 years	1,158,581	--	--	--	--	--	--	--	7,656,780	--	--	--
Not collected	--	--	--	--	--	--	--	--	--	--	--	--
Total	54,130,185	1,583,755	2.9	21.7	51,489,725	777,180	1.5	46.0	24,736,783	198,305	0.8	101.1

Stand age class	Eastern white pine				Sugar maple				Northern pin oak			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	2,613,227	--	--	--	2,362,299	--	--	--	444,332	--	--	--
21 to 40 years	7,314,570	27,033	0.4	82.5	2,021,299	--	--	--	5,133,396	89,593	1.7	43.2
41 to 60 years	442,276	--	--	--	704,123	--	--	--	1,405,447	84,368	6.0	40.3
61 to 80 years	3,243,879	--	--	--	7,207,631	--	--	--	11,634,162	202,230	1.7	76.0
81 to 100 years	1,098,119	--	--	--	17,695,351	106,305	0.6	52.2	11,775,925	119,330	1.0	42.9
101 to 150 years	21,114,260	34,902	0.2	0.0	412,140	--	--	--	800,460	482,462	60.3	134.1
Not collected	--	--	--	--	--	--	--	--	--	--	--	--
Total	35,826,330	61,935	0.2	38.7	30,402,842	106,305	0.3	60.9	31,193,721	977,982	3.1	52.3

Stand age class	American elm				Black spruce				Tamarack			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	619,042	24,422	3.9	49.8	2,245,530	67,013	3.0	0.0	360,766	--	--	--
21 to 40 years	2,100,795	74,154	3.5	52.3	72,846	--	--	--	941,950	41,620	4.4	73.1
41 to 60 years	5,394,257	620,958	11.5	44.9	5,812,930	22,118	0.4	83.0	394,060	--	--	--
61 to 80 years	4,029,666	187,666	4.7	33.0	5,479,984	59,108	1.1	67.1	9,709,982	119,538	1.2	76.4
81 to 100 years	3,702,859	150,916	4.1	52.1	3,321,365	99,262	3.0	1.6	1,887,910	--	--	--
101 to 150 years	669,622	129,874	19.4	102.0	--	--	--	--	932,171	--	--	--
Not collected	--	11,517	--	--	--	--	--	--	--	--	--	--
Total	16,516,242	1,199,507	7.3	24.9	16,932,654	247,502	1.5	35.1	14,226,840	161,158	1.1	63.5

Stand age class	Balsam fir				White oak				Jack pine			
	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %	Volume (ft³)	Mortality (ft³)	% of volume	Sampling error %
0 to 20 years	1,456,781	--	--	--	541,225	--	--	--	--	--	--	--
21 to 40 years	1,248,759	--	--	--	--	--	--	--	1,808,724	79,626	4.4	16.6
41 to 60 years	3,334,120	137,872	4.1	68.9	1,747,457	--	--	--	1,259,052	126,014	10.0	17.4
61 to 80 years	1,974,499	81,603	4.1	91.0	3,779,781	--	--	--	4,420,039	424,756	9.6	47.2
81 to 100 years	1,507,606	121,652	8.1	34.2	833,969	--	--	--	64,224	--	--	--
101 to 150 years	--	--	--	--	2,360,760	--	--	--	--	--	--	--
Not collected	--	--	--	--	--	--	--	--	--	--	--	--
Total	9,521,765	341,127	3.6	37.7	9,263,192	--	--	--	7,552,040	630,396	8.3	33.1

Source: Forest Inventory and Analysis.

Table 5. Average annual growing stock mortality by timberland ownership in the East Central Landscape, 2016.

Species	State				County and Municipal				Private			
	Volume (ft³)	Mortality (ft³)	% of Volume	Sampling Error (%)	Volume (ft³)	Mortality (ft³)	% of Volume	Sampling Error (%)	Volume (ft³)	Mortality (ft³)	% of Volume	Sampling Error (%)
Quaking aspen	36,509,188	1,376,172	3.8	41.2	13,717,026	361,369	2.6	24.8	210,379,255	5,435,208	2.6	14.0
Northern red oak	28,610,280	674,428	2.4	93.1	9,740,531	22,293	0.2	73.1	113,786,824	669,628	0.6	53.2
American basswood	20,888,357	332,700	1.6	45.5	11,081,339	310,659	2.8	56.7	85,970,954	396,899	0.5	49.7
Bur oak	8,595,900	45,590	0.5	64.4	3,558,085	--	--	--	93,396,521	216,667	0.2	45.1
Red pine	17,367,918	220,032	1.3	90.9	--	--	--	--	84,926,245	327,750	0.4	59.7
Red maple	16,617,444	78,918	0.5	59.5	4,955,865	--	--	--	59,808,468	343,173	0.6	23.3
Black ash	16,672,835	333,247	2.0	57.8	2,038,821	--	--	--	68,398,706	1,453,053	2.1	24.4
Green ash	2,582,180	145,109	5.6	101.4	1,207,564	--	--	--	59,683,653	268,355	0.4	49.3
Paper birch	12,260,341	493,495	4.0	32.1	2,775,192	--	--	--	39,094,652	1,090,259	2.8	26.7
Bigtooth aspen	2,861,565	72,001	2.5	58.1	7,675,941	65,255	0.9	1.3	40,952,219	639,924	1.6	54.9
Silver maple	--	--	--	--	--	--	--	--	24,736,783	198,305	0.8	101.1
Eastern white pine	3,550,982	--	--	--	505,653	--	--	--	31,769,695	61,935	0.2	38.9
Sugar maple	12,657,934	106,305	0.8	40.9	2,912,980	--	--	--	14,831,927	--	--	--
Northern pin oak	1,032,492	--	--	--	3,249,355	182,073	5.6	23.6	26,911,875	795,909	3.0	62.4
American elm	1,732,193	39,866	2.3	61.7	387,020	--	--	--	14,397,029	1,148,124	8.0	26.2
Black spruce	7,017,453	111,476	1.6	44.8	195,780	6,045	3.1	0.0	9,719,422	129,980	1.3	52.4
Tamarack (native)	1,906,353	--	--	--	3,186,904	161,158	5.1	16.1	9,133,582	--	--	--
Balsam fir	4,218,151	138,527	3.3	52.7	--	--	--	--	5,303,613	202,601	3.8	51.4
White oak	592,504	--	--	--	--	--	--	--	8,670,688	--	--	--
Jack pine	--	--	--	--	2,090,506	72,372	3.5	0.0	5,461,534	558,024	10.2	30.4
Other	7,899,047	577,022	7.3	--	39,922	--	--	--	31,998,076	1,217,763	3.8	--
Total	203,573,116	4,744,889	2.3	27.2	69,318,483	1,181,224	1.7	23.2	1,039,331,722	15,153,557	1.5	10.9

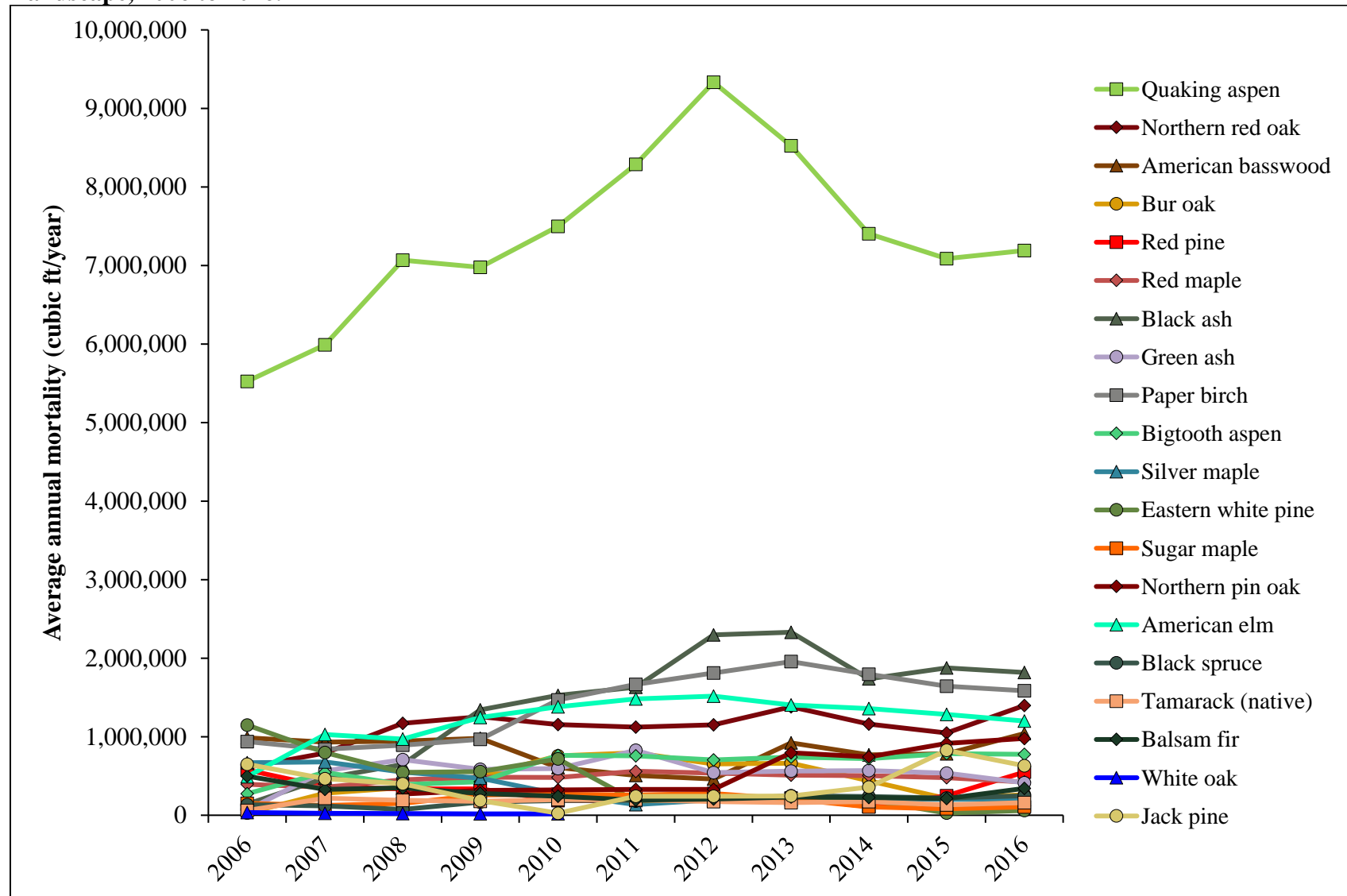
Source: Forest Inventory and Analysis.

Table 6. Average annual growing stock removals by timberland ownership in the East Central Landscape, 2016.

Species	State				County and Municipal				Private			
	Volume (ft³)	Removals (ft³)	% of Volume	Sampling Error (%)	Volume (ft³)	Removals (ft³)	% of Volume	Sampling Error (%)	Volume (ft³)	Removals (ft³)	% of Volume	Sampling Error (%)
Quaking aspen	36,509,188	1,022,347	2.8	56.1	13,717,026	631,126	4.6	116.6	210,379,255	3,915,208	1.9	39.7
Northern red oak	28,610,280	37,580	0.1	107.7	9,740,531	21,308	0.2	73.1	113,786,824	67,548	0.1	68.3
American basswood	20,888,357	554,874	2.7	82.3	11,081,339	213,862	1.9	95.6	85,970,954	196,423	0.2	74.4
Bur oak	8,595,900	74,781	0.9	96.5	3,558,085	--	--	--	93,396,521	322,368	0.3	63.9
Red pine	17,367,918	347,583	2.0	72.8	--	--	--	--	84,926,245	--	--	--
Red maple	16,617,444	79,018	0.5	63.9	4,955,865	289,186	5.8	113.5	59,808,468	66,891	0.1	64.4
Black ash	16,672,835	--	--	--	2,038,821	35,136	1.7	111.1	68,398,706	--	--	--
Green ash	2,582,180	--	--	--	1,207,564	--	--	--	59,683,653	165,667	0.3	86.2
Paper birch	12,260,341	160,304	1.3	96.3	2,775,192	189,799	6.8	124.5	39,094,652	--	--	--
Bigtooth aspen	2,861,565	--	--	--	7,675,941	--	--	--	40,952,219	370,746	0.9	98.5
Silver maple	--	--	--	--	--	--	--	--	24,736,783	--	--	--
Eastern white pine	3,550,982	--	--	--	505,653	--	--	--	31,769,695	80,467	0.3	111.4
Sugar maple	12,657,934	504,178	4.0	73.0	2,912,980	149,463	5.1	63.0	14,831,927	--	--	--
Northern pin oak	1,032,492	--	--	--	3,249,355	--	--	--	26,911,875	403,219	1.5	82.4
American elm	1,732,193	--	--	--	387,020	--	--	--	14,397,029	--	--	--
Black spruce	7,017,453	--	--	--	195,780	--	--	--	9,719,422	--	--	--
Tamarack (native)	1,906,353	--	--	--	3,186,904	--	--	--	9,133,582	--	--	--
Balsam fir	4,218,151	--	--	--	--	--	--	--	5,303,613	--	--	--
White oak	592,504	--	--	--	--	--	--	--	8,670,688	--	--	--
Jack pine	--	--	--	--	2,090,506	--	--	--	5,461,534	--	--	--
Other	7,899,047	129,169	1.6	--	39,922	--	--	--	31,998,076	--	--	--
Total	203,573,116	2,909,835	1.4	37.6	69,318,483	1,529,879	2.2	86.2	1,039,331,722	5,588,537	0.5	33.3

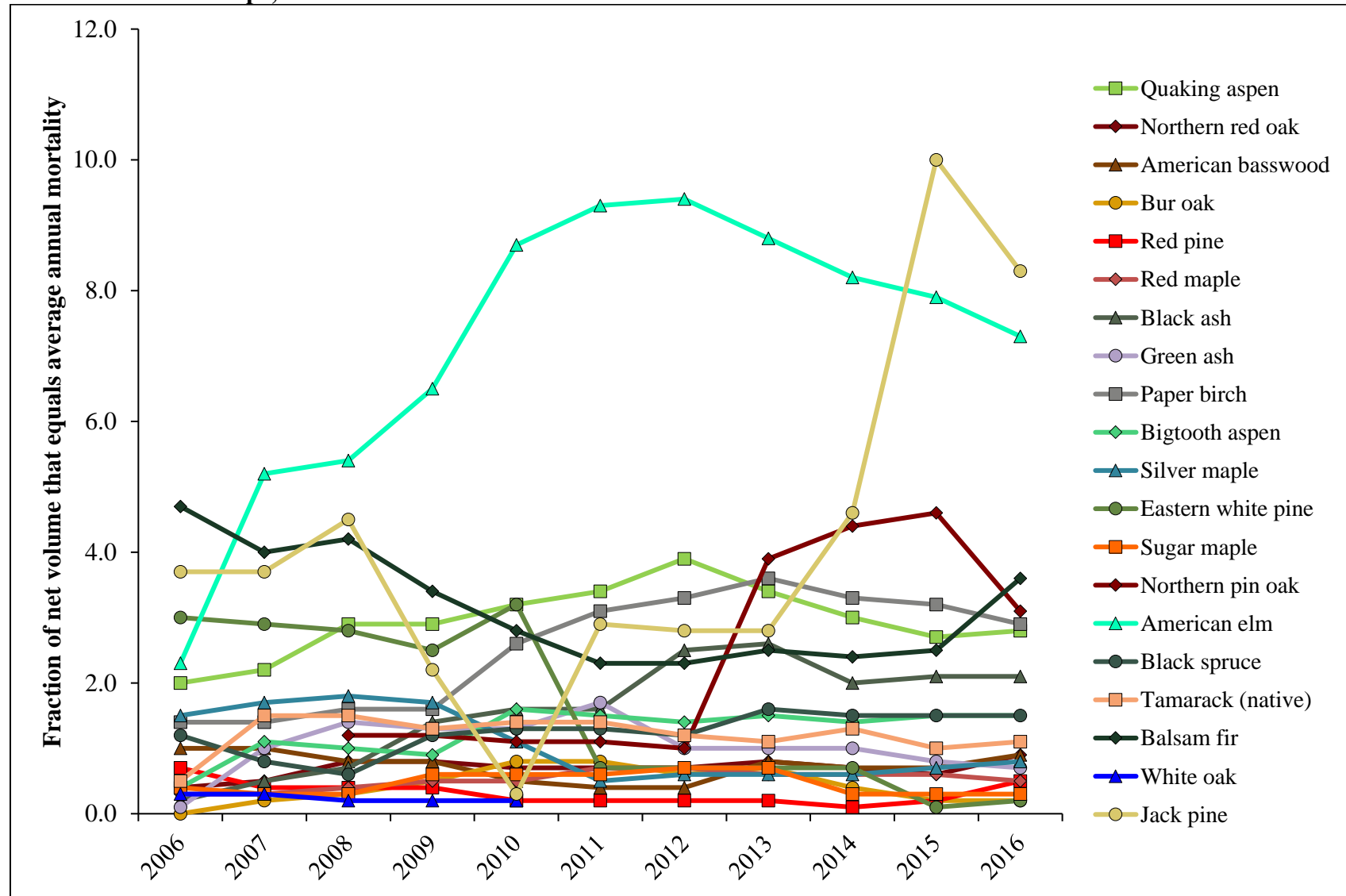
Source: Forest Inventory and Analysis.

Figure 1. Average annual growing stock mortality volume estimate of selected species on timberland in the East Central Landscape, 2006 to 2016.



Source: Forest Inventory Analysis.

Figure 2. Average annual growing stock mortality, in percent of growing stock volume, of selected species on timberland in the East Central Landscape, 2006 to 2016.



Source: Forest Inventory Analysis.