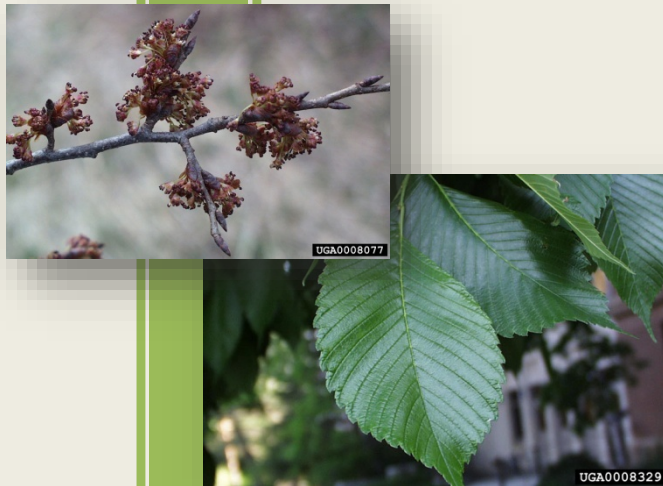
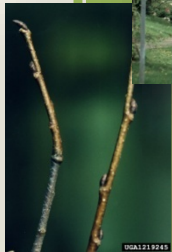


Elm

American elm: *Ulmus americana*

Slippery elm: *Ulmus rubra*

Rock elm: *Ulmus thomasii*



American elm has been decimated by Dutch elm disease which was brought from Europe in the 1930s. The volume of elm showed some signs of recovery after 1996 with increased growth rates and increased numbers of trees, but most recently, increased mortality rates are again decreasing the volume of elm.

Unfortunately, mortality remains quite high and has increased in the last since 1996. Elm accounts for 1.3% of all volume of trees in Wisconsin but almost 9.9% of total mortality. As of 2018, net growth is negative.

Elm is not an important timber species. Its prevalence in southern Wisconsin may make it a valuable species for biofuel production.

- [How has the elm resource changed?](#)
Growing stock volume and diameter class distribution
- [Where is elm found in Wisconsin?](#)
Growing stock volume by region with map
- [What kind of sites does elm grow on?](#)
Habitat type and site index distribution
- [How fast is elm growing?](#)
Average annual net growth: trends and ratio of growth to volume
- [How healthy is elm in Wisconsin?](#)
Average annual mortality: trends and ratio of mortality to volume
- [How much elm do we harvest?](#)
Roundwood production by product and ratio of growth to removals
- [How much elm biomass do we have?](#)
Aboveground biomass by region of the state
- [Does elm have any major disease or pest issues?](#)
Dutch elm disease: biology, symptoms and impact
- [Can we predict the future of elm?](#)
Modelling future volumes

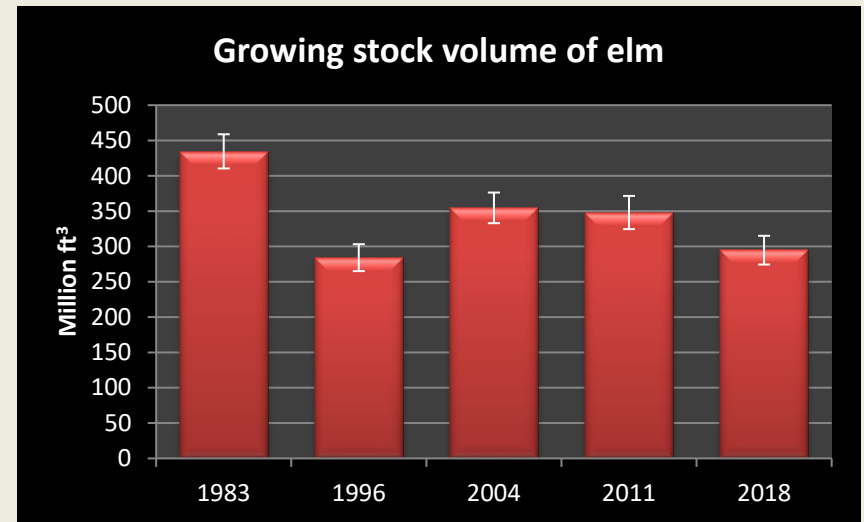
"How has the elm resource changed?"

Growing stock volume and diameter class distribution by year

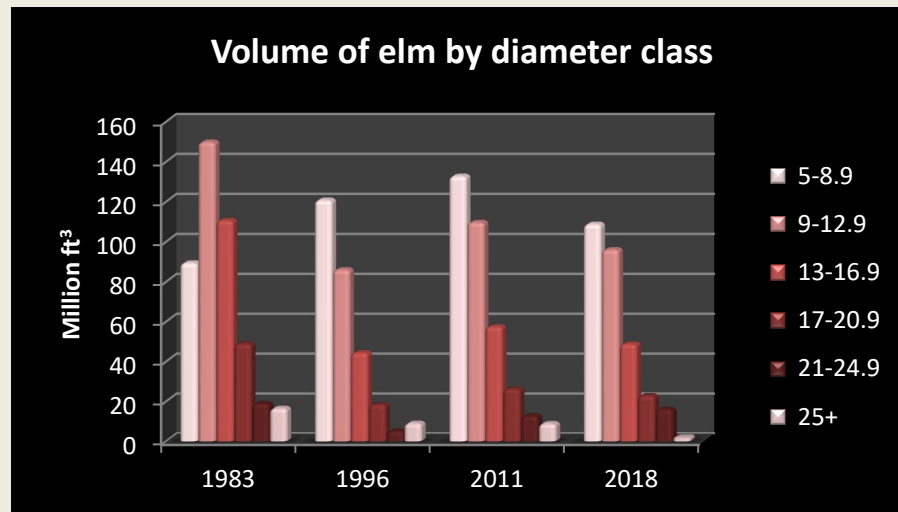
The volume of elm in Wisconsin in 2018 was about 295 million cubic feet or 1.3% of total [growing stock volume](#) (chart on right). Volume has decreased significantly since 2011.

The decrease in volume between 1983 and 1996 (charts on right and lower left) was mainly due to mortality related to Dutch elm disease. Volume in large size trees (over 13 inches) has decreased 54% since 1983 but has increased for both small and large trees since 1996.

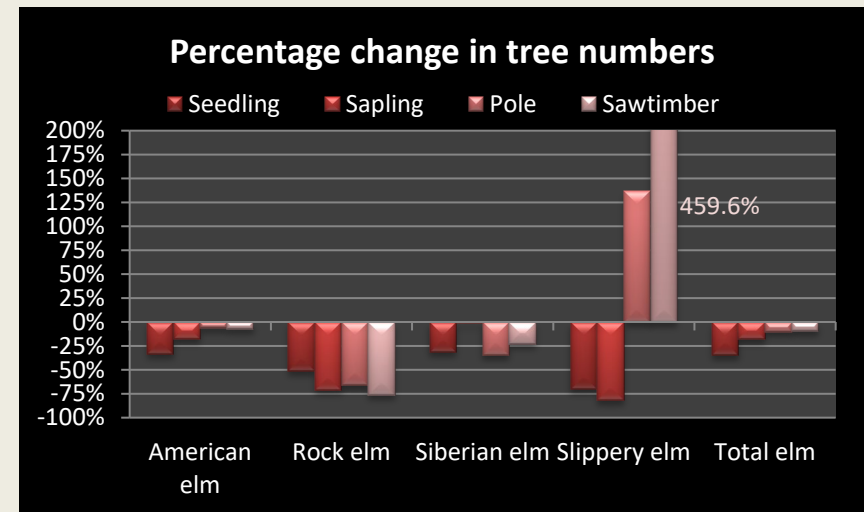
Slippery elm is the only elm species that experienced an increase in pole or sawtimber-sized trees between 2004 and 2018. For elm overall, strong decreases in seedlings and saplings since 2004 don't suggest a positive future.



Growing stock volume (million cubic feet) by inventory year.
Source: USDA Forest Inventory and Analysis data



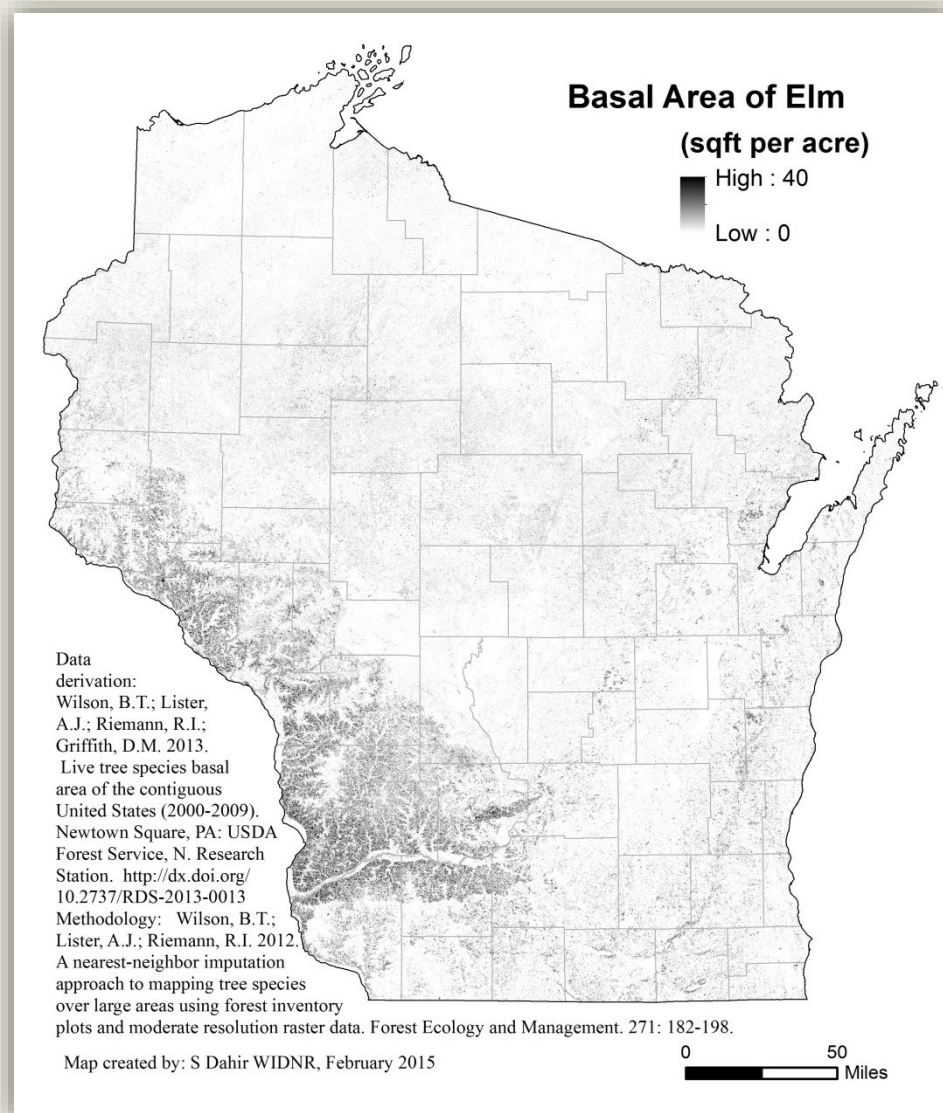
Growing stock volume (million cubic feet) in.
Source: USDA Forest Inventory and Analysis data



Percentage change in the number of live trees by size class between 2004 and 2018.
Source: USDA Forest Inventory and Analysis data 2004 and 2018.

"Where does elm grow in Wisconsin?"

Growing stock volume by region with map



Elm is a southern species with almost $\frac{2}{3}$ of volume located in southern Wisconsin and another 14% in the central part of the state. The vast majority (82%) is American elm (Table 1) with 16% slippery elm, 2% Siberian elm, and <1% rock elm.

American and slippery elm are found primarily in the oak-hickory [forest type](#) and, to a lesser extent, in bottomland hardwoods. Rock elm is largely found on the maple-basswood forest type.

Table 1. Growing stock volume (million ft³) by species and region of the state.

| Species | Central | North east | North west | South east | South west | Total | Percent of total |
|------------------|---------|------------|------------|------------|------------|-------|------------------|
| American Elm | 35 | 27 | 40 | 43 | 97 | 241 | 82% |
| Rock Elm | 0 | 1 | 0 | 0 | 0 | 1 | 0% |
| Siberian Elm | 0 | 0 | 1 | 3 | 2 | 6 | 2% |
| Slippery Elm | 4 | 0 | 1 | 6 | 35 | 46 | 16% |
| Total elm | 39 | 28 | 41 | 52 | 134 | 295 | 100% |
| Percent of total | 13% | 10% | 14% | 18% | 45% | 100% | |

Source: USDA Forest Service, Forest Inventory and Analysis 2018 data

For a table on **Volume by County** go to:

<http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/VolumeCountySpecies.pdf>



"How fast is elm growing?"

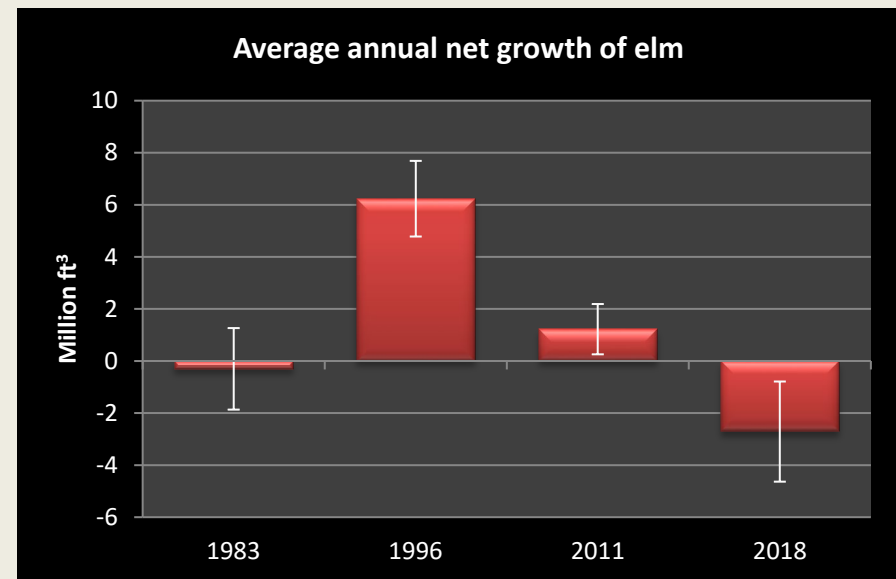
Average annual net growth: trends and ratio of growth to volume

Average annual net growth of elm has decreased significantly since 1996. From 2012 to 2018, net growth was about -2.7 million cubic feet per year (chart 4). Elm had the lowest net growth rate out of all major species in Wisconsin.

Table 2. Average annual net growth (million ft³/year) of growing stock and the ratio of growth to volume by region of the state.

| Region | Net growth | Percent of Total | Ratio of growth to volume |
|-----------|------------|------------------|---------------------------|
| Northeast | 0.0 | - | 0.1% |
| Northwest | 0.8 | - | 2.0% |
| Central | -0.8 | - | -2.1% |
| Southwest | -0.3 | - | -0.2% |
| Southeast | -2.5 | - | -1.3% |
| Statewide | -2.7 | - | -0.9% |

Source: USDA Forest Inventory and Analysis 2018



Average annual net growth (million cubic feet).
Source: USDA Forest Inventory & Analysis data

In southern and central Wisconsin, the ratio of growth to volume is less than zero, which means that mortality exceeds growth (Table 2). The ratio of growth to volume for elm is -0.9%, much lower than the 2.6% for all species in the state.

For a table of **Average annual growth, mortality and removals by region** go to:
<http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf>

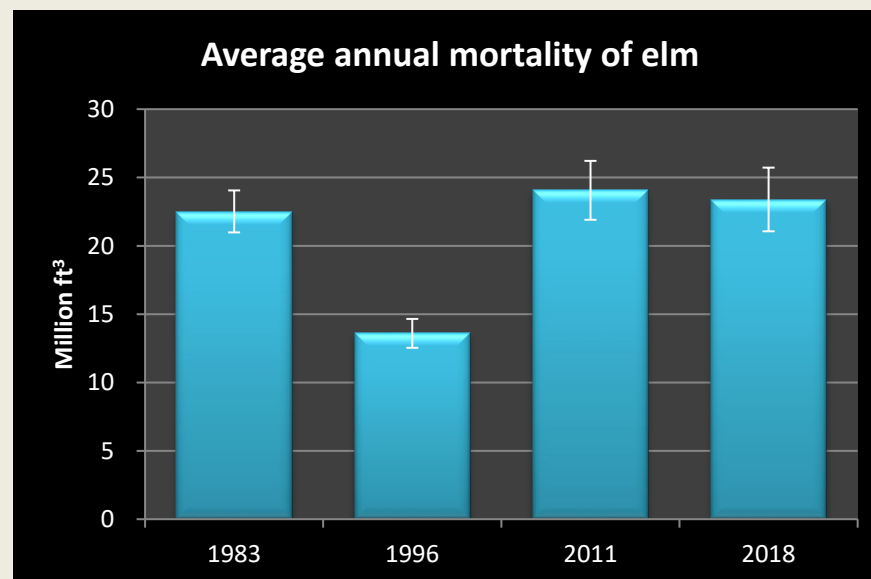


"How healthy is the elm resource in Wisconsin?"

Average annual mortality: trends and ratio of mortality to volume

Average annual mortality of elm, about 23.4 million cubic feet per year, has increased 72% since 1996 (chart 5).

The ratio of mortality to volume of growing stock is about 7.9% for elm (Table 3), the highest of all species groups. This ratio is much higher than the average for all species which is 1.1% and is nearly twice as high as the next highest major species.



Average annual mortality (million cubic feet) by inventory year.
Source: USDA Forest Inventory & Analysis data

Table 3. Mortality, volume and the ratio of mortality to volume

| Species | Average annual mortality (ft³) | Volume of growing stock (ft³) | Mortality / volume |
|------------------|--------------------------------|-------------------------------|--------------------|
| American Elm | 18,872,770 | 240,935,017 | 7.8% |
| Rock Elm | 47,021 | 1,406,427 | 3.3% |
| Slippery elm | 4,448,729 | 46,346,736 | 9.6% |
| Total elm | 23,394,320 | 294,753,832 | 7.9% |

Source: USDA Forest Inventory and Analysis data: 2018

Whereas elm accounts for 1.3% of volume, it has negative net growth and makes up 9.9% of total mortality statewide. This high mortality is probably due to the continuing effect of Dutch elm disease.

For a table of **Average annual growth, mortality and removals by region** go to:
<http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf>

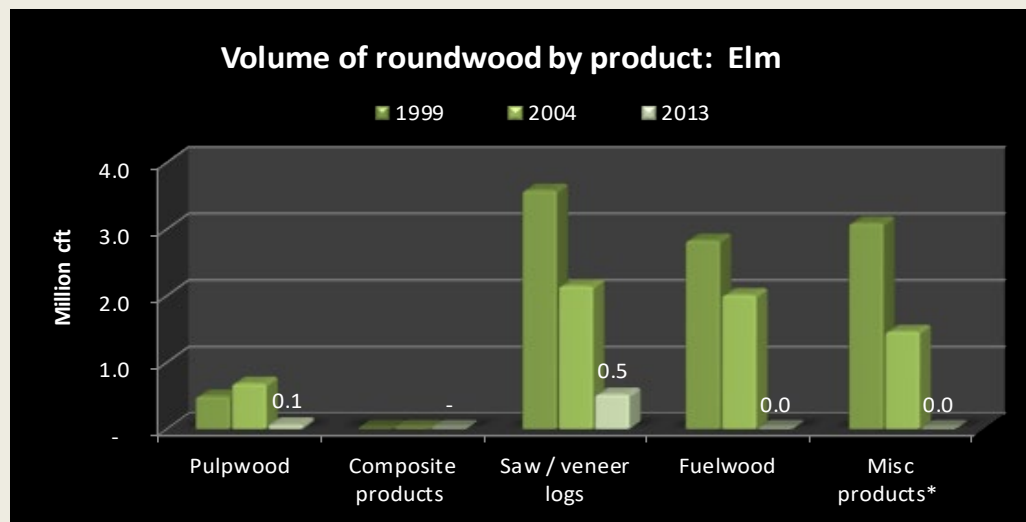


"How much elm do we harvest?"

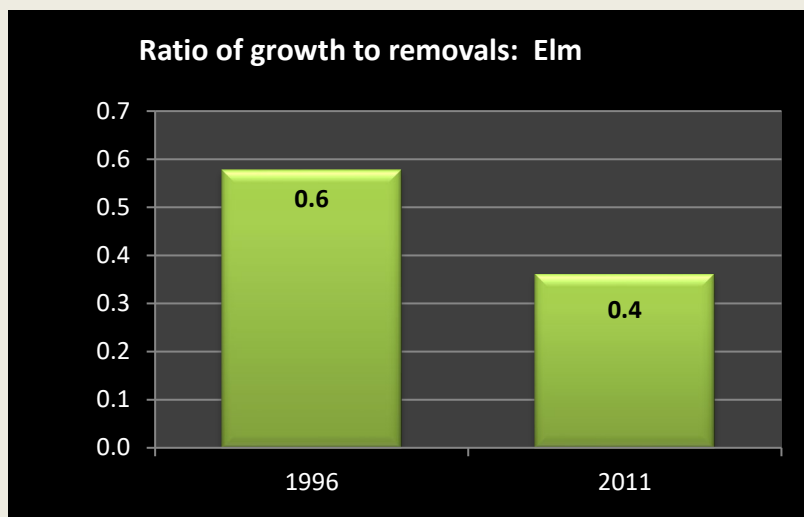
Roundwood production by product and ratio of growth to removals

In 2009-2012, Wisconsin produced about 587,000 cubic feet of elm roundwood or about 0.2% of total statewide product (chart on right). About 90% is for sawlogs.

Since 2004, elm pulpwood and sawlog production has decreased significantly, by more than 90%.



Volume of roundwood. * Miscellaneous products include poles, posts and pilings.
Source: Ronald Piva, USDA Forest Service, Northern Research Station, St. Paul MN



Source: USDA Forest Inventory & Analysis data

Removals of elm totaled 3.5 million cubic feet per year from 2012 to 2018. This is equal to 1.2% of total removals in the state.

The ratio of growth to removals has been either low or negative since 1983 (chart on left), mainly because net growth is very low. This is much lower than the average of 1.9 for all species statewide.

For a table of **Average annual growth, mortality and removals by region** go to:

<http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf>

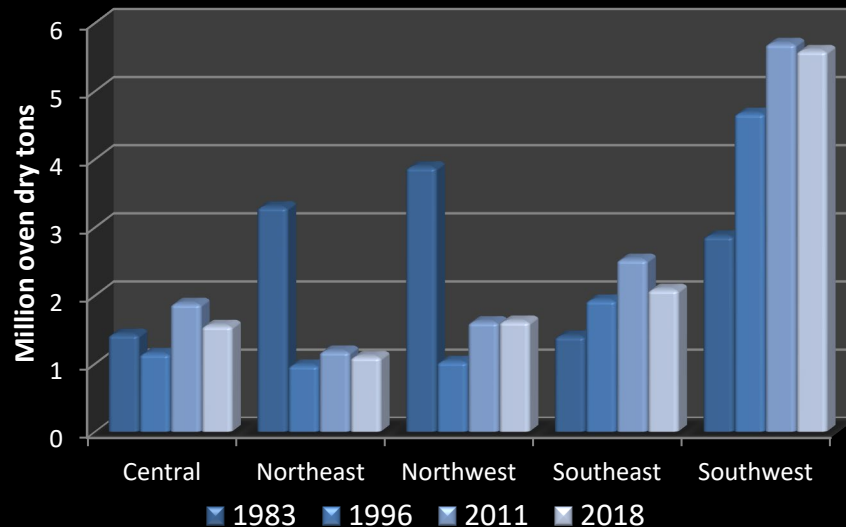


"How much elm biomass do we have?"

Tons of aboveground biomass by region of the state

There were 12.0 million short tons of [biomass](#) in live elm trees in 2018, slightly less than 1983. This is equivalent to approximately 6.0 million tons of carbon and represents 1.8% of all aboveground carbon statewide. As with volume, most of the elm biomass is located in southwest Wisconsin (chart 9).

Biomass of all live trees: Elm



Biomass (above ground dry weight of live trees >1 in dbh, short tons) by year and region of the state.
Source: USDA Forest Inventory & Analysis data.

Elm wood has an average specific gravity and oven-dry weight. The specific gravity is 0.5 compared to 0.51 for all species and the oven-dry weight is 31.2 pounds per cubic foot compared to 31.4 lbs/cft for all species.

Approximately 59% of elm biomass is in the merchantable bole, 20% in saplings, 4% in stumps, and 18% in tops and limbs.

For a table of **Biomass by County** go to:

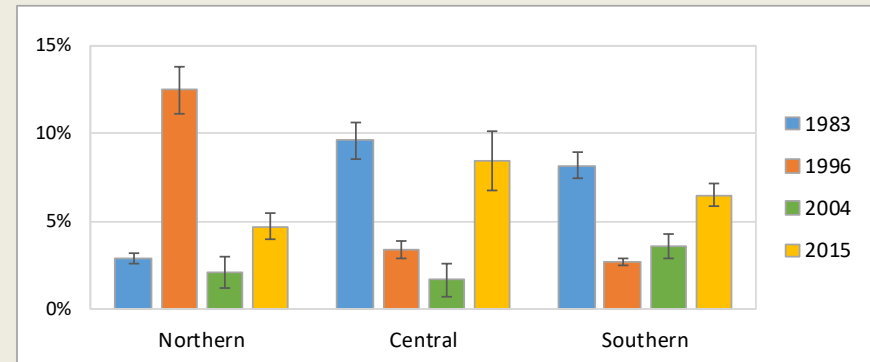
<http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/BiomassByCounty.pdf>

“Does elm have any major disease or pest issues in Wisconsin?”

Dutch elm disease: range, symptoms and impact

Dutch elm disease (DED) is the single greatest cause of elm mortality in Wisconsin. Introduced into North America in the 1930s, DED has been devastating Wisconsin's elms since the 1960s.

The mortality rate for elms in Wisconsin decreased significantly after 1983 to 1996 but has been on the upswing for the last decade (chart on right). Mortality has increased to a greater degree in areas with lower volume such as northern and central Wisconsin. From 2004 to 2015, the mortality rate quadrupled in central Wisconsin and more than doubled in the north.



Ratio of mortality to volume by region of the state and inventory year. Error bars represent the 68% confidence interval. Source: USDA Forest Inventory & Analysis data



Left: Browning leaves of DED infected tree. Top right: *Ophiostoma ulmi* fruiting bodies
Bottom right: Native elm bark beetle (*Hylurgopinus rufipes*)

Dutch elm disease symptoms are the result of a fungus, *Ophiostoma spp.* (figure on left) infecting the vascular system of the tree. Infection by the fungus results in clogging of vascular tissues, preventing water movement to the crown and causing visual symptoms as the tree wilts and dies. Symptoms of DED begin as wilting of leaves and proceed to yellowing and browning.

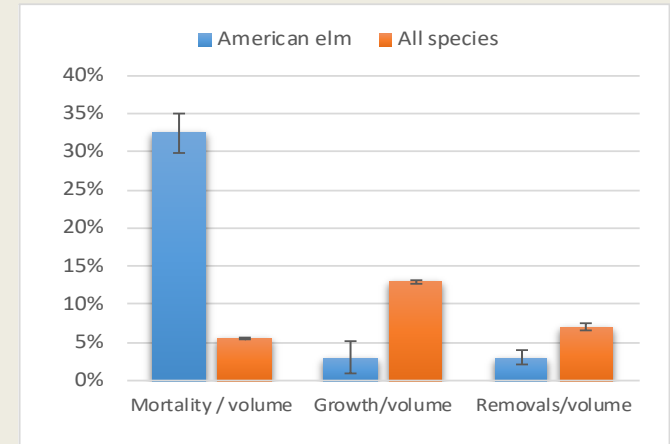
Overland spread of DED is thought to be related to both the native elm bark beetle and the European elm bark beetle. Both beetles are attracted to stressed, dying or dead elm wood to complete the breeding stage of their life cycle. The DED fungus can also move from infected trees to adjacent trees through grafted roots.

"Can we predict the future of elm?"

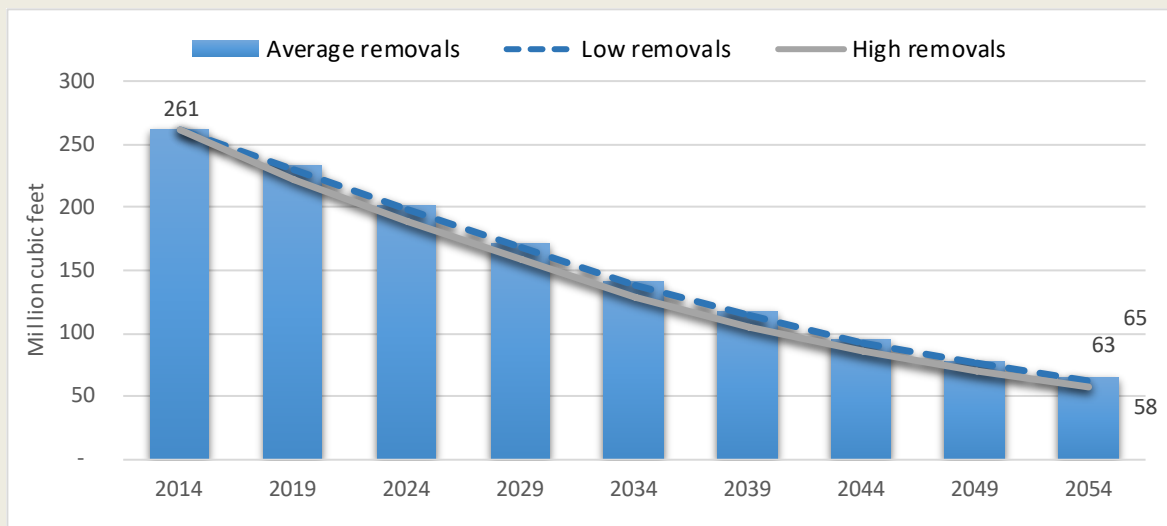
Predicted volumes based on current rates of mortality and harvest

Only the volume of American elm was modeled here as it represents almost 80% of elm volume. The 5-year ratio of mortality to volume for American elm is significantly higher compared to all species, while the ratios of growth and removals to volume are significantly lower for American elm compared to all species in the state (chart on right).

The Forest Vegetation Simulator (FVS¹) was used to predict future volumes of American elm through 2054. Three scenarios are forecast. One with current rates of mortality and removals (2010 to 2015). Another with current mortality rates and the lower 67% confidence interval for current removals and another with the upper 67% confidence interval for removals.



The five year ratio of mortality, growth and removals to volume of growing stock. Error bars represent the 67% confidence interval.



Predicted growing stock volume of American elm based on average mortality rates plus average removal rates, low removal rates and high removal rates.

Volume decreases dramatically in all three scenarios, between 76% and 78% by 2054. Since the projection is based on current mortality rates which are very high due to Dutch elm disease, a change in this parameter would greatly affect future volumes.