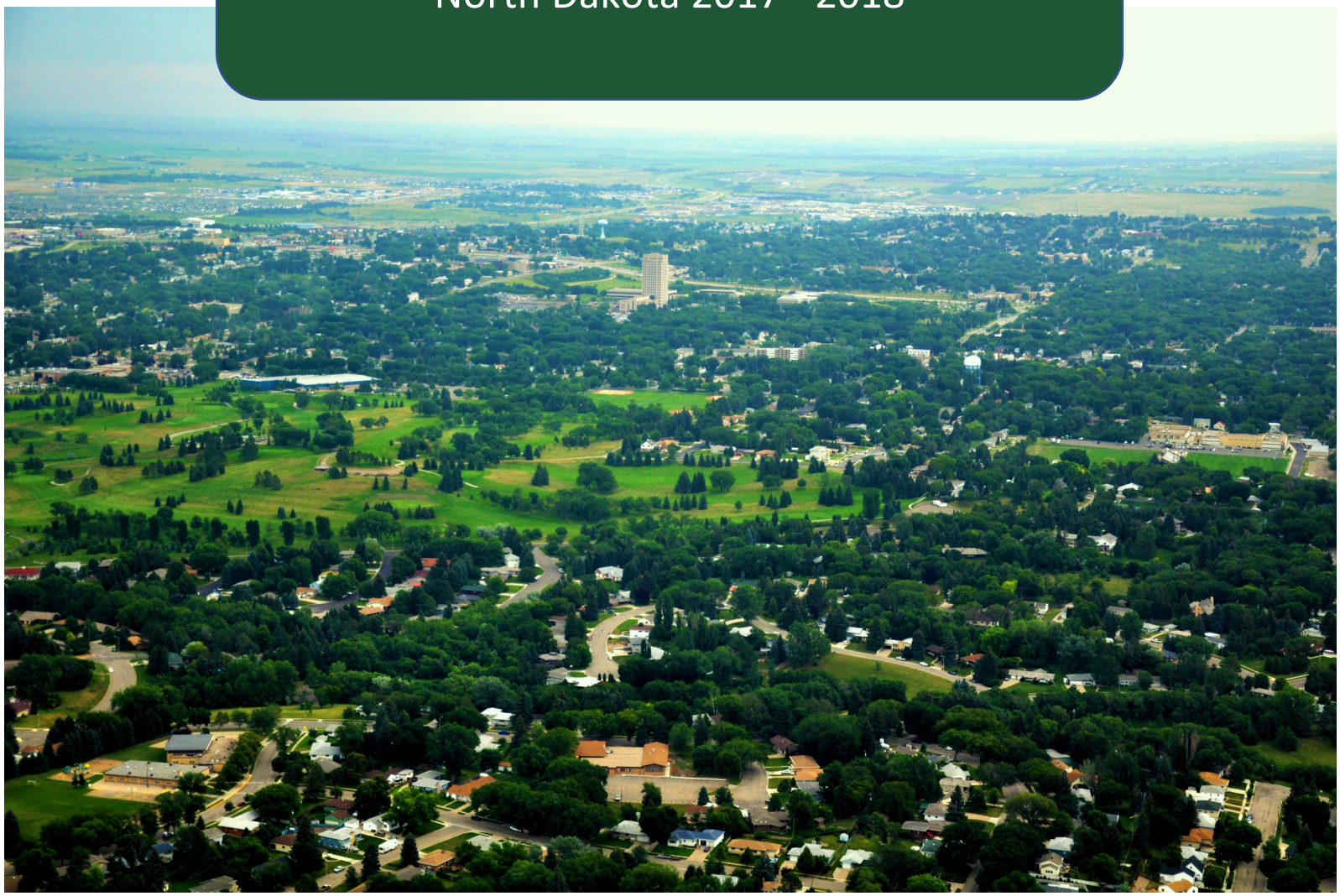
Biennial Forest Health Report

North Dakota 2017 - 2018



North Dakota Forest Service

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Overview

This report summarizes forest health conditions observed in 2017 and 2018 and describes emerging issues in relation to their effect on the sustainability and societal value of North Dakota's forested resources.

The term "forest health" does not denote the presence or absence of insect pests and diseases in the forest, nor is it equivalent to an arbitrary estimate of tree mortality. Forest health is more accurately understood as a depiction of forest sustainability, or the robustness of the forest's ability to provide social, economic, and cultural benefits while maintaining its ecological functions.

All forests undergo succession, a natural change in vegetation through time. Forest succession is driven by abiotic and biotic factors that influence the species composition of the forest and facilitate the death of weakened and less-fit individual trees and groups of trees. Abiotic factors include drought, flooding, temperature, soil properties, nutrient availability, fire, wind, sun, precipitation, and various human-caused injuries. Biotic factors include native or introduced insects, disease, fungi, invasive plants, animals, bacteria, phytoplasmas and nematodes that coincide with trees.

Abiotic and biotic factors are natural components of any site where trees grow, and the damage they cause should not be viewed as an imbalance of nature but rather a normal cycling and recycling of the forest. At times, however, the damage imposed by abiotic and biotic factors may exceed our perception of what is normal or conflict with our management objectives. Additionally, factors resulting from human activity and the introduction of non-native insects and pathogens may impair the long-term sustainability of trees and forests.

This report was compiled using NDFS documents by Peter Gag, Forest Health Manager, for the North Dakota Forest Service.

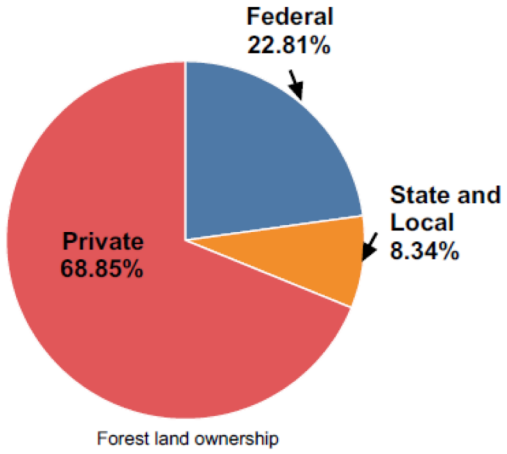
Cover Photo of the community forest surrounding the state capitol in Bismarck, NDFS

Forestland Ownership Distribution

Forests are an important part of North Dakota's natural resource heritage and make up just under two percent of the state's landcover. They provide access to outdoor educational and recreational opportunities and managed wildlife habitat, while playing an important role in protecting watersheds.

Roughly 69 percent (564,000 acres) of forestland in North Dakota is categorized as privately owned (Figure 1). The federal government, primarily the U.S. Forest Service, is responsible for the management of roughly 188,000 acres of North Dakota's forestland, or approximately 23 percent, while state and local entities manage approximately 68,000 acres, or roughly 8 percent (USDA Forest Service, 2019).

Figure 1: Estimated forestland ownership in North Dakota based on field data collected using the USDA Forest Service Forest Inventory and Analysis (FIA).
USDA Forest Service, 2020



Conditions of North Dakota's Forest Resources

North Dakota's forest resources can be separated into three categories: native forests, conservation plantings, and community forests. These resources provide numerous ecological, social and economic benefits to North Dakota residents. The following summaries describe the general conditions of each category of the state's forest resources. These narratives do not necessarily depict specific causal agents of tree or forest decline, but rather describe the factors that frequently influence their current condition.

Native Forests
Native forests are distributed sparsely across the state and cover 815,000 acres, or approximately 1.8 percent of North Dakota's total area. These native forests are comprised of eastern deciduous and western coniferous forest types with a myriad of associated flora and fauna. The distribution of North Dakota's native forests creates ecologically diverse and unique zones of transition across the state.

Deciduous forest types account for 98 percent of North Dakota's forests. Common deciduous forest types in North Dakota include elm/ash/cottonwood, aspen/birch, and bur oak. These forest types are categorized by the dominance of one or up to a few tree species, although numerous species may be included in each forest type. Native forests provide wildlife habitat, recreational opportunities, and wood products; stabilize river banks; filter water runoff from adjacent agricultural lands; serve as seed sources for conservation tree production; and increase the botanical diversity of the state.

The elm/ash/cottonwood forest type is the most abundant and occurs along rivers, lakes, and streams throughout the state. Bur oak and aspen/birch forests are common in the Turtle Mountains (north-central), Devils Lake Hills (center of northeastern quarter), and Pembina Gorge (northeastern corner). Isolated stands consisting of ponderosa pine and Rocky Mountain juniper are in the southwestern counties of the state, making up only two percent of the state's forestland.

Forests are generally resilient to damage imposed by endemic insects and diseases. However, damage caused by these agents, coupled with other underlying factors, may threaten the long-term sustainability of the state's forests. These factors include:

- Reduced species diversity due to damage caused by non-native forest pests.
- Over-maturity of existing stands and the absence of disturbances essential to regenerate forests.
- Lack of forest regeneration due to heavy deer browsing pressure and alteration of natural flood plains along rivers.

Nearly one-fifth of North Dakota's forests occur within 200 feet of a stream or lake (Haugen et al. 2011). The majority of these forests consist of ash, elm, and cottonwood. The health and sustainability of these plant communities have important implications for water quality, flood control, wildlife habitat, and recreational opportunities.

The elm/ash forest type is the most abundant of all native riparian forestland in the state. These forests have experienced significant alterations during the past several decades due to damage caused by Dutch elm disease (*Ophiostoma ulmi* and *O. nova-ulmi*), overgrazing, altered water flows, and conversion to non-forestland. The threat of the emerald ash borer is another significant issue with the potential to drastically affect the elm/ash forest type along riparian areas due to the overall abundance of ash. Emerald ash borer has not been detected in North Dakota.

The cottonwood (*Populus deltoides*) forests that occur within the Missouri River flood plain are in poor condition, which has resulted from progressive mortality of mature trees and the absence of natural regeneration to replace this mortality. Prior to flood mitigation, the Missouri River flood plain experienced periodic inundation as high spring water flows scoured and deposited sand in low-lying areas. These moist sandbars served as seedbeds for cottonwood and were critical for natural regeneration of the species.

In the absence of flooding and subsequent sandbar formation, riparian cottonwood forest acres continue to decline because no young cottonwoods will be available to replace the over-mature trees that have succumbed to old age and senescence. While historic flooding along the Missouri and Souris rivers during the 2011 growing season have re-created a situation that would benefit the regeneration of cottonwood, the extent of regeneration is yet to be seen. Due to the infrequency of flooding events such as in 2011, sustainability of cottonwood regeneration on the Missouri River is not likely without direct management.

Nearly 20 percent of North Dakota's forestland is classified as the aspen/birch forest type. The majority of this forest type is in the Turtle Mountains, where the state's largest concentration of forestland is represented. Lack of fire disturbance and/or harvesting has resulted in older stands with minimal natural regeneration within these forests. The current condition of many stands is characterized by extensive stem decay caused by Phellinus tremulae and large stem mortality caused by hypoxylon canker (*Hypoxylon mammatum*).

In addition, the Turtle Mountains are prone to periodic defoliation caused by the forest tent caterpillar (FTC) (*Malacosoma disstria*) and more recently, large aspen tortrix (LAT) (*Choristoneura conflictana*). Defoliation reduces growth, predisposes trees to other damaging agents, and exacerbates the senescence of aging aspen stands. The declining aspen overstory may succeed to hazel (*Corylus spp*.) shrub land, in part due to the absence of shade-tolerant conifers in North Dakota.

Forestland owners have not actively pursued the harvest of aspen in the past several years. The vigorous regeneration of aspen that follows harvesting is important for the long-term perpetuation of this unique forested resource. Unfortunately, future opportunities to harvest North Dakota's timber will likely decrease due to the scarcity of sawmills, increasing mill production costs, and decreasing demand for aspen wood products from local sources.

Figure 2: Native aspen/birch forest of the Turtle Mountains.

Conservation Plantings

North Dakota is largely a rural state with an economy that is deeply rooted in agriculture. Conservation plantings are an important component of many agricultural systems and improve the quality of rural living in the Northern Plains. Conservation plantings are generally referred to as field windbreaks, farmstead shelterbelts, living snow fences, wildlife plantings, etc. Conservation plantings are designed to achieve conservation, economic, and societal goals. For example, field windbreaks reduce soil erosion during years of drought, reduce water evaporation from adjacent cropland, and increase crop yields.

Similarly, some plantings are designed to stabilize riverbanks, filter water runoff from adjacent agricultural lands, provide wildlife habitat, protect stretches of highways prone to severe snow accumulation, provide wind protection and increased gains for livestock, or protect farmsteads and rural homes from snow and wind, therefore saving energy while creating aesthetic value surrounding a homestead.

Although many conservation tree plantings occur in areas where the historical vegetation type was prairie, these resources are critical for the needs of rural residents who live in the current agricultural landscape.

Tree plantings of the northern Plains are exposed to numerous pests and environmental conditions that reduce their effectiveness, hinder planting success, and limit long-term survival. Deterioration of tree plantings is often incited by drought, flooding, wildland fire, early or late frosts, inadequate spacing, weed competition, herbicide exposure, defoliating insects, and foliar diseases. As trees become weakened, canker diseases and wood-boring insects may cause further damage to these plantings.

Preventing the deterioration of conservation plantings is more effective than treating the outcomes after the fact. Maintaining the availability of water, light, and nutrients to trees by incorporating various management techniques is fundamental. Using best practices for weed-control, planting density and arrangement, and species diversity will help prevent many

underlying factors that cause the decline of conservation plantings. Plantings composed of one or few species often experience episodes of elevated tree mortality simply because all trees are commonly vulnerable to the same damaging agents.

Some examples of planting failures associated with limited species diversity include the decline of single-row Siberian elm or green ash field windbreaks due to herbicide exposure, marginal cold hardiness, and canker diseases. The decline of Colorado blue spruce plantings is primarily due to yellowheaded spruce sawfly (*Pikonema alaskensis*) (predominantly in the western half of the state). Some spruce decline diseases are Stigmina needlecast (*Stigmina lautii*) and, less commonly, Rhizosphaera needlecast (*Rhizosphaera kalkhoffii*) (both predominantly in the eastern half of the state), and Valsa canker (*Valsa kunzei*), which commonly occurs statewide. The impacts of these damaging factors can be reduced by incorporating additional species into these or future plantings.

Figure 3: Conservation plantings in north eastern North Dakota, near the Pembina Gorge.

Community Forests

Community forests include boulevard trees, trees planted in city parks, and trees that naturally occur within city limits or public rights of way. As a whole, these tree resources provide many benefits to the community's residents, including reduced heating and cooling costs, wind and snow protection, beautification, recreational opportunities, and enhanced quality of life. Because of the need to address the relationships of neighboring trees, community forests must include trees that are growing on both public and private property. The management of such tree resources may fall under the responsibility of city foresters, public works departments, and/or community tree boards.

Trees planted in residential areas are exposed to numerous insects and diseases. The frequency and severity of pest damage often reflects the composition and abundance of host species in the community's forest. In addition, trees growing in residential areas are exposed to many environmental stressors, such as compacted soils, herbicides, variable watering, nutrient deficiency, and mechanical injuries. Such stresses compound the damage caused by insects and disease.

Additionally, Dutch elm disease continues to be a predominant tree health issue in our community forests. This disease has eliminated many of the stately elms that once graced North Dakota communities. Several larger communities have developed management programs to combat Dutch elm disease with notable success. However, many smaller communities that lack the financial resources and forestry staff, continue to be impacted by this disease.

Ash species and cultivated ash varieties have been the most common replacements for elm trees killed by Dutch elm disease. As a result, many community forests now have an overabundance of ash. Although ash performs well on a variety of sites and conditions, the overreliance on this species has made emerald ash borer (*Agrilus planipennis*) a considerable concern. This exotic ash-killing beetle has been detected as close as Winnipeg, Manitoba and Sauk Center, MN. Many North Dakota communities have realized the vulnerability of their community tree resource and are embracing tree species diversification. In 2015, ash trees still made up about 48% of municipal tree populations (Johnson, 2015).

Figure 4: One example of the many community forests that can be found encompassing all of our North Dakota communities.

Section 1 - Weather and Related Issues

The winter of 2016-2017 was the 6th wettest winter since records have been kept, starting in 1895. Winter precipitation recharged soil moisture, effectively eliminating drought conditions throughout the state. Despite having adequate soil moisture through the beginning of March, spring precipitation conditions declined through June 1st, leading to the 9th driest spring on record (Figure 5). Spring temperatures were very close to the 1981-2010 average, except for a small portion of the southeast corner of the state, where temperatures were 3 degrees warmer. Drought conditions persisted through the summer of 2017 with below average precipitation and a slightly warmer than average temperature throughout the growing season. Drought level precipitation totals continued through the autumn and in to the winter.

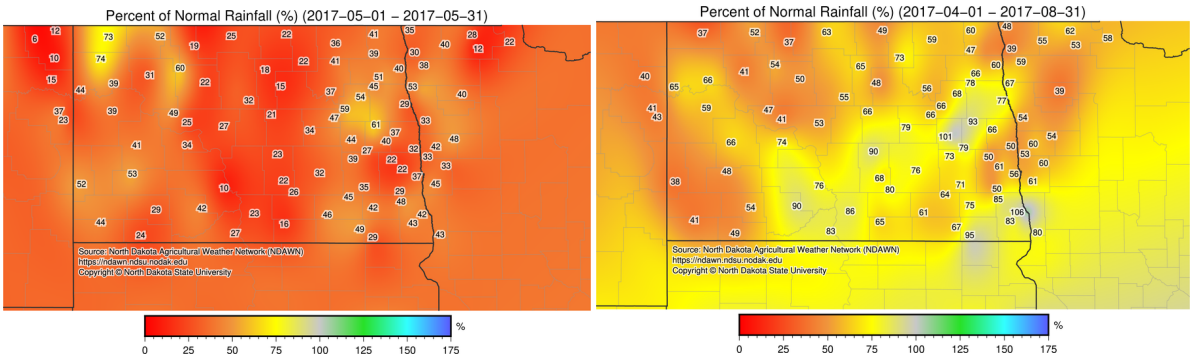


Figure 5: May 2017 percent of normal rainfall (left) and total growing season percent of rainfall (right).

Winter precipitation conditions for the 2017-2018 season continued drought conditions from the autumn and in to late winter. Spring of 2018 proceeded to be another of the driest on record, but much less so than the previous spring and also two degrees Fahrenheit colder than the 1981-2010 average (Figure 6). The precipitation trend further moved most of the state into more intense drought conditions as the growing season started. The growing season continued with slightly higher precipitation and temperatures than average. Drought conditions persisted with a slight decrease into the autumn.

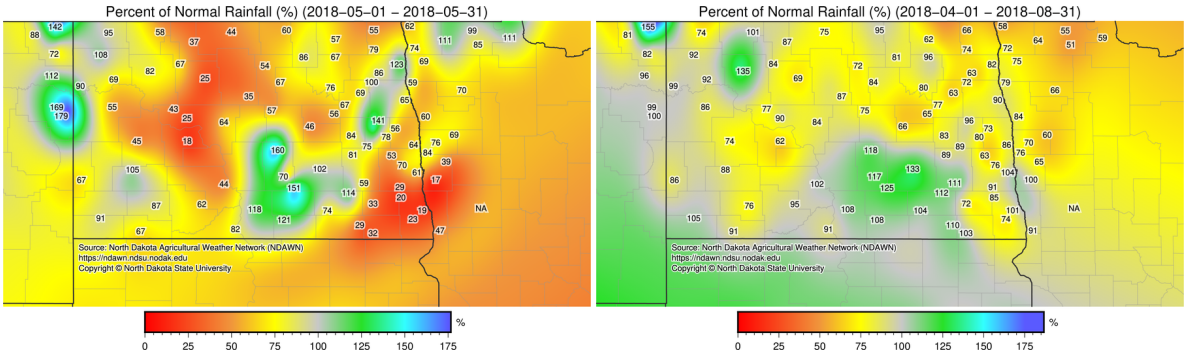


Figure 6: May 2018 percent of normal rainfall (left) and total growing season percent of rainfall (right).

Drought stress fundamentally causes stress in vegetation. This stress generally reduces vigor and opens the door for insect predation, because many defensive mechanisms become secondary to maintaining baseline functions. Insect pests are almost always a secondary response to other stresses related to the location and context where the vegetation is growing.

Drought conditions during the growing season of 2017 and 2018 created ample opportunity for insect pests to more successfully reproduce and caused elevated levels of infection and mortality.

Section 2 – Forest Health Surveys

Invasive Insect trapping – Cooperative Surveys

Wood-Borer Surveys: The North Dakota Department of Agriculture (NDDA) annually conducts wood-borer surveys at several locations throughout the state to look for exotic species of state and national concern. In 2017 and 2018, high traffic locations in cities and potential entry sites, were surveyed for the presence of species that have spread from counties where they were already established. Several species of conifer beetles from the families Scolytidae, Cerambycidae and Curculionidae were identified and recorded in both years. New species were collected at most survey locations, demonstrating an increasing distribution. As of 2018, none of the species of concern have been detected in North Dakota.

There were six notable conifer beetle species found during the 2017 and 2018 exotic wood-borer surveying. Three of the species found in 2017 are commonly found farther south and to the east in the United States. One of these species, the Ips beetle, infests stressed spruce and pine trees, preferentially breeding in freshly cut wood. *Hylesinus pruinosus* is a bark beetle of ash and *Phloeotribus dentifrons* reproduces in hackberry. In late May of 2018, the NDFS placed Lindgren funnel traps in ponderosa pine stands in Slope County as an attempt to detect mountain pine beetle (*Dendroctonus ponderosae*). Traps yielded three more conifer beetles that are new to the state and county.

Notable finds from the 2017 exotic wood-borer survey:

- A male and female six-spined ips (*Ips calligraphus*) were collected in Adams County. The only previous record is from Jamestown.
- *Hylesinus pruinosus* was recorded in Richland County. This is the third record of this species in the state.
- *Phloeotribus dentifrons* was recorded in Grand Forks County. This is the fourth record in the state.

Notable finds from the 2018 exotic wood-borer survey:

- *Dendroctonus rufipennis* (Kirby) was collected in Pembina and Cass Counties for the first time in North Dakota. The species feeds on Spruce (*Picea*), usually on slash or damaged trees but will attack healthy trees when population numbers are high.
- *Neospondylis upiformis* (Mannerheim) was collected in Slope County. This longhorn beetle occurs in coniferous forests throughout the western U.S. and southwestern Canada.
- *Hylastes tenuis* (Eichhoff) was collected in Slope County. This bark beetle occurs from central Mexico north throughout temperate North America reaching southwestern British Columbia and southern Ontario. Its life history is unknown.

Japanese Beetle Surveys: The NDDA conducts Japanese beetle (*Popillia japonica*) surveys in North Dakota. Japanese beetle is a highly destructive insect with a strong feeding preference for basswood (*Tilia Americana*) and littleleaf linden (*Tilia cordata*). Both trees are important in community forests, with basswood also being an important component of native forests and conservation plantings.

In 2012, 139 Japanese beetles were trapped, mainly near nurseries. Since then, they have appeared in traps on an annual basis. In 2017, after discovering that infested nursery stock had been distributed statewide, NDDA intensified trapping efforts, collecting 1,467 beetles in 22 counties, again, mainly near nurseries. The survey continued in 2018 with 412 beetles captured, in 12 counties, half from infested nurseries. Surveying, outreach, and education will continue in the future to prevent the spread of *Popillia japonica*.

Gypsy Moth Surveys: The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) conducts Asian gypsy moth (*Lymantria dispar*) surveys in North Dakota. A single adult male gypsy moth, the first since 2000, was trapped at Sully Creek State Park near Medora in 2017. In 2018 another single adult male gypsy moth was trapped at Sertoma Park in Grand Forks. Under both circumstances, it is customary for the APHIS to conduct a delimiting survey during the early summer to determine the potential extent of the population. Nothing further was found in 2018 when delimiting the Medora survey detection. In 2019 the Grand Forks detection will be delimited. In most situations the finding of an individual adult male is not indicative of a larger population, which seems to be the case in this situation.

Emerald Ash Borer Surveys: Emerald ash borer (EAB) (*Agrilus planipennis*) has not been discovered in North Dakota; however, it is one of the greatest threats to North Dakota forest health. EAB feeds on and kills green ash (*Fraxinus pennsylvanica*), the most abundant tree species in the state. In 2017, 748 traps where established with the guidance of the USDA-APHIS and maintained throughout the state during the growing season.

For 2018 the USDA-APHIS discontinued trapping efforts and instead supported surveying efforts by providing purple prism traps and the necessary lures. NDFS staff, interns, and contractors continued to assist the NDDA in conducting the annual statewide EAB survey. Other partners included city foresters and NDSU Extension. For 2018, trap numbers were reduced by nearly half. EAB has yet to be detected in North Dakota.

Section 3 - Recent and Common Forest Insects, Disease, and Abiotic Issues

The following section represents the most commonly encountered pests, pathogens, and abiotic issues encountered during 2017 and 2018. Many of these issues can be attributed to a particular species, forest category, or combination of the two. The conditions of North Dakota's forest resources are challenged by a changing climate, a reduced variety of disturbance mechanisms, and the challenges of "off-site" planting. Trees that are considered off-site are not native to the site and its conditions, and are often influenced by common planting mistakes.

Planting creates a variety of situations that are uncommon to naturally regenerating trees that have originated from seed. The first of these are errors in placing the bare root or container-grown root systems in the ground. Many times these seedlings are planted too deep, causing roots to grow towards the more limited space nearer the soil surface. In other cases, older planting stock have been imprinted, following the shape of the container. Both of these mistakes tend to allow roots to grow over and around one another, girdling themselves and restricting water, nutrient, and carbohydrate transport. These circumstances often cause poor resource acquisition and structurally unsound root systems, leading to an increased level of stress that makes way for secondary mechanisms of tree decline, such as wood-boring insects.

Forest Insect Issues

There were several conifer wood-boring and bark beetles encountered during the 2017 and 2018 seasons that are not common to North Dakota. These beetles were mentioned as "Notable finds" listed above and detected through the exotic wood-borer surveys. All of these notable conifer beetles are of particular interest as they are symbionts of the popular conifer species that are found in conservation plantings and our native conifer forests. Future effort will be necessary to monitor the effects of these species on coniferous trees, as neighboring states are struggling with large population outbreaks.

Other native bark beetles are ever present and generally pose a consistent threat to tree species found in North Dakota. These bark beetles will cause a steady level of decline and loss in populations of trees that are stressed by the myriad of other biological and non-biological stresses that trees are experiencing.

Defoliators

Changes in tree crown and forest canopy leaf area directly relates to photosynthesis and the production of carbohydrates, influencing growth and the ability to deal with variation in biological and non-biological stresses. It is common for insects to forage the leaves of conifer and deciduous trees, but successive seasons of defoliated leaf area will weaken a tree. In 2017 and 2018, forest tent caterpillar (FTC) (*Malacosoma disstria*) was periodically found defoliating deciduous trees in North Dakota's landscape. An extensive FTC outbreak has not occurred since the early 2000's, but small dispersed populations have remained present.

A defoliator of spruce (*Picea spp.*), the yellow-headed spruce sawfly (*Pikonema alaskensis*), was also found in landscape trees in the eastern half of the state. This sawfly overwinters in the duff as prepupae with the adults emerging in the spring. Eggs are then laid on the developing foliage where larvae will feed, moving into the older foliage as the need arises. Damage to new growth is the loss of the current year's needles on infested branches. The degree to which a tree is affected depends on the overall extent of new foliage lost.

Other Forest Insects

There are other forms of feeding on foliage that can influence the effectiveness of a tree's ability to photosynthetically produce carbohydrates. Besides directly consuming the foliage, insects can alter a leaf by penetrating the leaf's outer surface. The spruce spider mite (*Oligonychus ununguis*) sucks chlorophyll from the needles of conifers, reducing the photosynthetic capacity of the leaf. Others like the Cottony ash psyllid (*Psyllopsis discrepans*) have been found to feed on black and mancana ash (*Fraxinus nigra* and *F. mandschurica*) causing leaf rolling, not only reducing chlorophyll in the leaf, but reducing the effective leaf area of the leaves that were fed upon.

Many assistance requests in 2017 and 2018 were associated with the presence of distortions, blisters, galls, and rusts that formed on the leaves or stems of conifers and deciduous trees. One common request was associated with the Cooley spruce gall adelgid (*Adelges cooleyi*), which forms a gall on the terminal growth of spruce. This small cucumber-shaped gall houses the aphid that produced it and causes the terminal tissues to die. The consequence of the gall and the sucking of sap by the foraging aphid rarely cause significant damage to the tree.

Eriophyid mites (*Eriophyid spp*.), a group of mites that can cause all of the potential formations listed above on leaves and stems, made up a significant portion of assistance requests in community forests during 2018. These are very small worm-like mites that have a head and two pair of legs, a unique identifier, located on one end of the body. The presence of this mite was concentrated in the north central part of the state, where they were causing distorted development of the new growth of Colorado blue spruce (*Picea pungens*).

Diseases

The prevalence of many disease issues is often driven by early growing season temperature and moisture conditions that promote fungal sporulation. With needlecasts, such as *Stigmina lautti* and *Rhizosphaera kalkoffi*, cool moist springs encourage their spread, since spores are released from infected dead needles in the duff under a tree. This is part of the reason why these two diseases usually originate at the bottom of the tree. These two diseases have been a consistent problem in the state since 2006, when *stigmina* was first detected and demonstrated to be the more virulent of the two. This was similar in 2017 and 2018, where *stigmina* made up the majority of spruce related assistance requests.

The next most prevalent spruce disease was Valsa canker caused by the fungus *Valsa kunzei*, which is synonymous with the fungus *Leucostoma kunzei*. This fungus is one of the most common found on all *Picea* species in North Dakota. *Valsa kunzei* infects wounds in the bark where it will infect the cambium, girdling a stem, and cutting off water, nutrient, and carbohydrate movement. Common symptoms are dead branches in the crown and a blueish-white sap excretion at the point of the canker. Annually, the symptoms of Vasla canker prompt a significant number of assistance requests throughout the state.

Ophiostoma ulmi and *O. novo-ulmi* are two closely related fungi that cause Dutch elm disease (DED). These fungi are transmitted through both root grafts and three species of bark beetles. During 2017 and 2018, assistance requests for DED made up a considerable number of the calls relating to our community forests. As an example of the continued presence of DED, the city of Fargo removes 1-2% of the approximately 6000 remaining elm trees annually. DED first arrived in North Dakota in 1969 and the infection continues to this day.

Diplodia pinea and *D. scorbiculata*, are fungi that infect the actively growing shoots of 2-3 needle pine. As of 2017 and 2018 the occurrence of Diplodia in North Dakota has been at low levels, often found in ponderosa pine (*Pinus ponderosa*) in conservation plantings. This fungus is a natural disturbance agent that exists asymptomatically on the cone scales, shed needles, and infected branch tips. As continued stress events weaken a tree, Diplodia can establish on the actively growing shoots, eventually forming cankers that kill the branches.

Ash (*Fraxinus spp.*) in the Northern Great Plains states are in a steady state of decline due to an abundance of mechanisms causing additive stresses. One of the increasingly common mechanisms is an ash heart rot (*Perenniporia fraxinophila*) that causes structural weakness in older trees that leads to breakage from things such as wind and ice events. This rot has increased in prevalence as many of our community and native forests age.

Anthracnos diseases cause foliar damage in the form of dead areas or blotches in many species of hardwood. A group of closely related fungi, they reproduce by spreading spores from one host to another, becoming more evident during wetter than average growing seasons. In North Dakota, ash anthracnose (*Gnomoniella fraxini*) is especially common and can be found in green ash (*Fraxinus pennsylvanica*). During 2017 and 2018, anthracnose was found in many hardwoods throughout the state, but was most noticeable in ash.

Abiotic Issues

There are many variables that influence the quality of a site and its ability to support a growing tree. To this point, the variables that have been addressed are associated with those that are biological in nature. Abiotic variables are those that stem from the climate and weather, such as temperature, precipitation, wind, or from the site, such as the soil conditions or characteristics. Another important abiotic variable is human cultural behaviors, or how we interact directly or indirectly with our trees.

Root Disturbance

Tree health issues are frequently challenged by poor planting behavior. Excessive depth drives fundamental root structure problems that become increasingly complicated through time. Machinery use causes compaction of the soil under the tree crown, often leading to damage to the roots and trunk. Digging around trees damages root structures and can hinder physical and functional processes necessary for tree growth. These are consistent issues encountered in our community forests and conservation plantings in North Dakota.

Herbicide damage

The application of herbicides is consistently seen as an agent of damage in trees of our community forests and conservation plantings. In most cases it is the indirect consequences of applications placed on surrounding competing vegetation that is translocated into the tree through the root system or inadvertently applied to the foliage through overspray or drift. The majority of these circumstance stem from misunderstood or careless selection or application of a product that was done with good intention. Fertilizer, herbicide, and pesticide use have direct influence on foliage, beneficial insects, and competing vegetation. 2017 and 2018 were consistent with other years, where a large portion of assistance requests were in one way or another complicated by the application of these chemicals.

Soil Conditions

Most of North Dakota's soils have high alkalinity, which hinders the solubility of the essential nutrients for plant growth. Because high pH creates a situation where nutrients cannot readily dissolve into a soil solution, they cannot be accessed by the vegetation. This is a fundamental issue that underlies the occurrence of health problems experienced by trees in North Dakota. Spruce (*Picea spp.*) and pine (*Pinus spp.*) are both species commonly planted in North Dakota that are intolerant of high pH soil, underscoring the initial stress of being planted in many places in the state.

One nutrient that is significantly affected by high pH soils is iron. The inability of many tree species to acquire sufficient iron from the soil is expressed through chlorosis in the leaves, where the leaf surface between the veins turns yellow. This symptom is a very common assistance request for a variety of species, but is most frequently seen in maples (*Acer spp.*).

Section 4 – Forest Health Assessments

Under-bark Temperature Monitoring of Green Ash

In 2010, Venette and Abrahamson published findings on the cold hardiness of Emerald ash borer that raised questions about its reproductive success in northern latitudes, including North Dakota. This work focused on the minimum temperatures that needed to reached in order to kill a certain percentage of the over wintering larvae. It was determined in this study that if the larvae reached a temperature of -30°F, 98% of those overwintering would die. So, what does this mean for EAB in North Dakota, a major pest of ash trees?

During three consecutive winters, starting in late 2014, Aaron Bergdahl (NDFS) installed temperature sensors under the bark of a selection of ash trees in three locations around the state. The intent was to investigate the discrepancy that may exist between ambient air temperature and that under the bark. It was anticipated that a differential between under-bark and ambient temperature would depend on the side of the tree being measured. Under-bark

locations with southern exposure were found to vary as much as ten degrees from ambient temperature when minimum larvae killing temperatures were reached.

North Dakota experiences a range of minimum winter temperatures that geographically define relative plant growth and survival, known as Plant Hardiness Zones. Primarily encompassing two of these zones, North Dakota vegetation and their related pests in the northern third of the state experience minimum temperatures of -35°F, while the southern two-thirds experience -30°F. Given the possible ten-degree difference between ambient and under-bark temperatures, findings supported the conclusion that EAB will survive the cold winters that are experienced in North Dakota.

In December of 2017, EAB was confirmed by the Canadian Food Inspection Agency (CFIA) in Winnipeg, Manitoba, 60 miles north of the North Dakota border. Winnipeg is considered Plant Hardiness Zone 3a, with minimum temperatures of -40°F. This finding further reinforces the conclusions drawn from the under-bark temperature project, that EAB can successfully reproduce in North Dakota. Importantly, it should be recognized that although the cold temperatures of North Dakota do not prevent the establishment of EAB, they can effectively reduce the portion of the tree where larvae can successfully develop. This understanding combined with the ability of cold temperatures to slow development, lengthening the lifecycle of EAB (Duan et al. 2013), creates the possibility that EAB will spread more slowly than has been experienced in latitudes further south.

Limber Pine Assessment

In 2017 Jim Walla, Northern Tree Specialties, spearheaded a sampling effort to conduct a health assessment of a population of limber pine (*Pinus flexilis*) in Slope County. This was the third season the effort was made to assess changes in needle characteristics for signs of an unknown needle blight. Originating during the 2015 growing season, needles presented chlorotic conditions that were indicative of a needle blight, similar to *Diplodia pinae*. The chlorotic conditions did not prove to be this blight and has since markedly declined in its presence on 2017 annual needle growth. This issue will continue to be monitored on a longer interval to assess any reoccurrence and to address any long-term effects it may have on the health of the stand.

Woodpecker Foraging of Oak

The downy woodpecker (*Picoides pubescens*) is the smallest of the bark foraging birds that can be found preying upon forest insects throughout the upper Midwest and Plains states. These birds are present throughout the year, adjusting their foraging behavior to fit the changing abundance of prey species populations. During the winter, downy woodpeckers can be found foraging for insect larvae that have bored into the bark of a variety of trees.

Since the winter of 2006, there has been consistent reports of damage to the stems of smaller Bur oak (*Quercus macrocarpa*) branches ranging from 1” to 8” where the outer bark had been

shredded. The shredding has been recognized to be caused by the foraging behavior of the downy woodpecker, preying on the larval stages of a particular gall forming wasp. The gall wasps (*Callirhytis flavipes*) overwinter in the bark as larvae, slowly developing until they pupate and emerge in the spring where they form galls on the midrib of newly formed leaves.

During the winter months these larvae become a valuable food resource for foraging woodpeckers, that can cause dieback by girdling the full circumference of tissues in the smaller diameter branches. On its own, *Callirhytis flavipes* would rarely cause damage sufficient to kill or severely injure a bur oak tree, but in some cases the subsequent woodpecker foraging does. There is currently no treatment for dealing with this issue other than pruning out dead branches for cosmetic purposes and to promote healing.

Since 2006, the interaction of *Picoides pubescens* and *Callirhytis flavipes* has led to periodic reports in several communities in North Dakota. In the winter of 2013-2014, the NDFS and the North Dakota State University (NDSU) Extension Forestry assessed 200 oak trees in eight neighborhoods in Fargo. During the winter of 2016-2017, Fargo, Cando, and Bismarck reported foraging damage. NDFS and NDSU Extension Forestry re-surveyed the original Fargo trees in 2017. Damage in the 2016-2017 winter was very light and occurred on very few trees in comparison to 2013-2014. Many of the trees that were damaged heavily in 2013-2014 displayed contorted growth or were missing in 2016-2017.

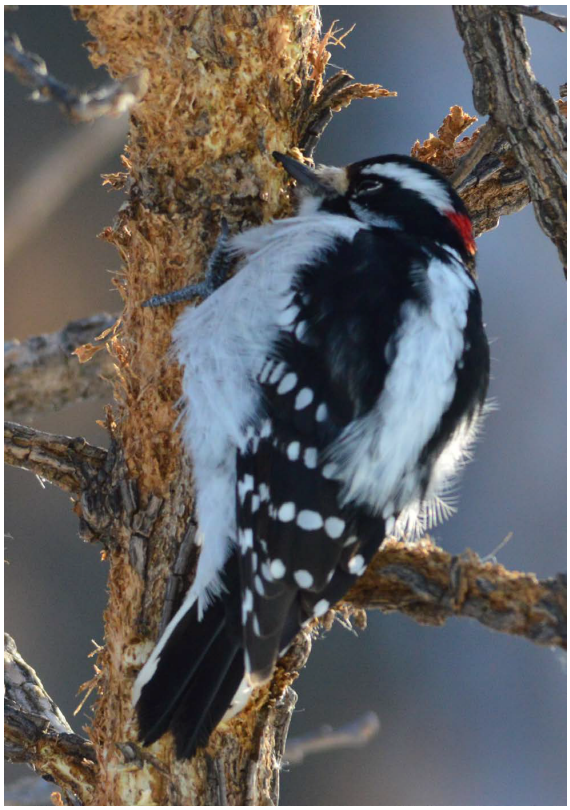


Figure 7: The downy woodpecker (*Picoides* pudescens) forages for (*Callirhytis flavipes*) larvae in the bark of a bur oak in Cando. (Photo courtesy of Rick Craig, Cando)

Section 5 – Aerial Surveys

Aerial detection surveys are conducted on a periodic basis in North Dakota to develop a broader scale perspective on forest-associated changes in the landscape. An aerial survey was conducted during the 2018 growing season that was specific to the western half of the state. Approximately 74 thousand square miles of land area in five southwestern counties in the corner of the state were observed during the end of June. Of the observable area flown, approximately 3700 acres were identified as having either a high, moderate, or low severity disturbance (Figure 7). Severity categories are determined by the percentage of impact that an area experiences based on the disturbance to the crown and canopy of the trees present.

Table 1: 2018 Aerial Detection Survey data (NDFS).

Disturbance Type	Severity	Acres
Drought		
	HIGH	3124.45
Flooding-High Water		
	HIGH	246.18
	LOW	6.17
	MODERATE	29.19
Ips Engraver Beetles		
	LOW	0.33
Mountain Pine Beetle		
	LOW	0.02
Pine Engraver		
	LOW	0.19
Unknown		
	HIGH	227.62
	LOW	4.46
	MODERATE	45.01
Unknown Defoliator		
	LOW	54.46
	Grand Tot.	3738.07

The types of disturbance distinguishable from the air included drought, which affects the greatest area, and three species of bark beetles (Table 1). In the western half of North Dakota, we continually monitor for the presence of particularly prominent forest pests that are a threat to our native pine forests in the southwestern corner of the state. The other disturbances help guide further monitoring as well as management direction.

Section 6 - Forest Health Program Activities

Emerald Ash Borer Awareness Week

For a week at the end of May in both 2017 and 2018, ash trees where marked throughout approximately 30 North Dakota communities. By attaching colorful marking flagging and a QR code, designed to allow access to information about ash trees and EAB, people had an opportunity to make themselves aware of the potential loss of trees when EAB arrives in North

Dakota. Information regarding the effort was disseminated to local media, and NDFS, NDDA, and NDSU Extension employees. NDFS, NDDA, and NDSU Extension personnel were responsible for the marking of community trees and hanging of signage, as well as, answering question from the public. Additional materials were made available through the NDInvasives.org website maintained through the NDFS Forest Health program. Awareness week activities were coordinated by the EAB Planning Team.

EAB Planning Team:

- Dr. Joe Zeleznik, NDSU Extension
- Charles Elhard, North Dakota Department of Agriculture
- Lezlee Johnson, North Dakota Forest Service

Training Sessions

EAB Detection and Response (streamlined): Soil Conservation District Employees Annual Conference and Tree Promotion meeting. EAB was an important topic for overall forest insect and disease presentation.

Natural Resource Conservation Service (NRCS)/Soil Conservation District (SCD) EAB annual March Detection and Management Training (intensive): 4-hour course. Materials were delivered by the EAB Planning team members in Devils Lake, Jamestown, and Dickinson. Training focused on USDA NRCS and Soil Conservation District staff. Dickinson has consistently had the greatest number of attendees due to the size of the community. Attendance for all three trainings brought in approximately 65 participants. The training has a field experience, consisting of branch sampling practice and larvae ID.

North Dakota Game and Fish (NDGF) biologists Annual meeting each August (streamlined): 1-hour presentation on EAB detection and management to approximately 60 NDGF employees.

NDUCFA EAB Annual Detection and Management Workshops (4-hour, intensive): Conducted annually during October in Bismarck and Grand Forks to approximately 40 attendees.

NDFS Forest Health continues to maintain the website NDInvasives.org as an outreach method focused on broadening the avenues for disseminating pertinent forest health related materials and information, while also creating another process for assisting with public inquiries.

Forest Health Internship Program

The Forest Health Internship/Technician program acquired fantastic summer student interns and early career professionals to help conduct collaborative tree health activities across the state. During both the 2017 and 2018 field seasons, three employees were involved in collaborative survey efforts for Animal Plant Health Inspection Service (APHIS) supported and North Dakota Department of Agriculture (NDDA) coordinated Emerald ash borer sampling across the state. They also worked in other aspects of the states EAB efforts to inventory community forests to collect the data used to guide EAB planning and conducted Lindgren trap surveys to monitor presence and absence of other non-target forest insects. This program

continues to be vital in assisting with the collection of the necessary data to help monitor health changes in North Dakota's trees and forests.

Forest Health Issues of Concern

The following issues remain significant management concerns.

- Absence of historical disturbance on the landscape poses a forest health concern by limiting the opportunity for natural regeneration, ultimately influencing sustainability.
- The threat of Emerald ash borer creates risk for all of the ash growing in North Dakota's plantings, and community and native forests.
- Variability in temperature and precipitation events poses a significant issue, creating complex growing season conditions.

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For more information, please contact the North Dakota Forest Service Forest Health Manager, Peter Gag peter.gag@ndsu.edu or visit the agency website: www.ag.ndsu.edu/ndfs

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