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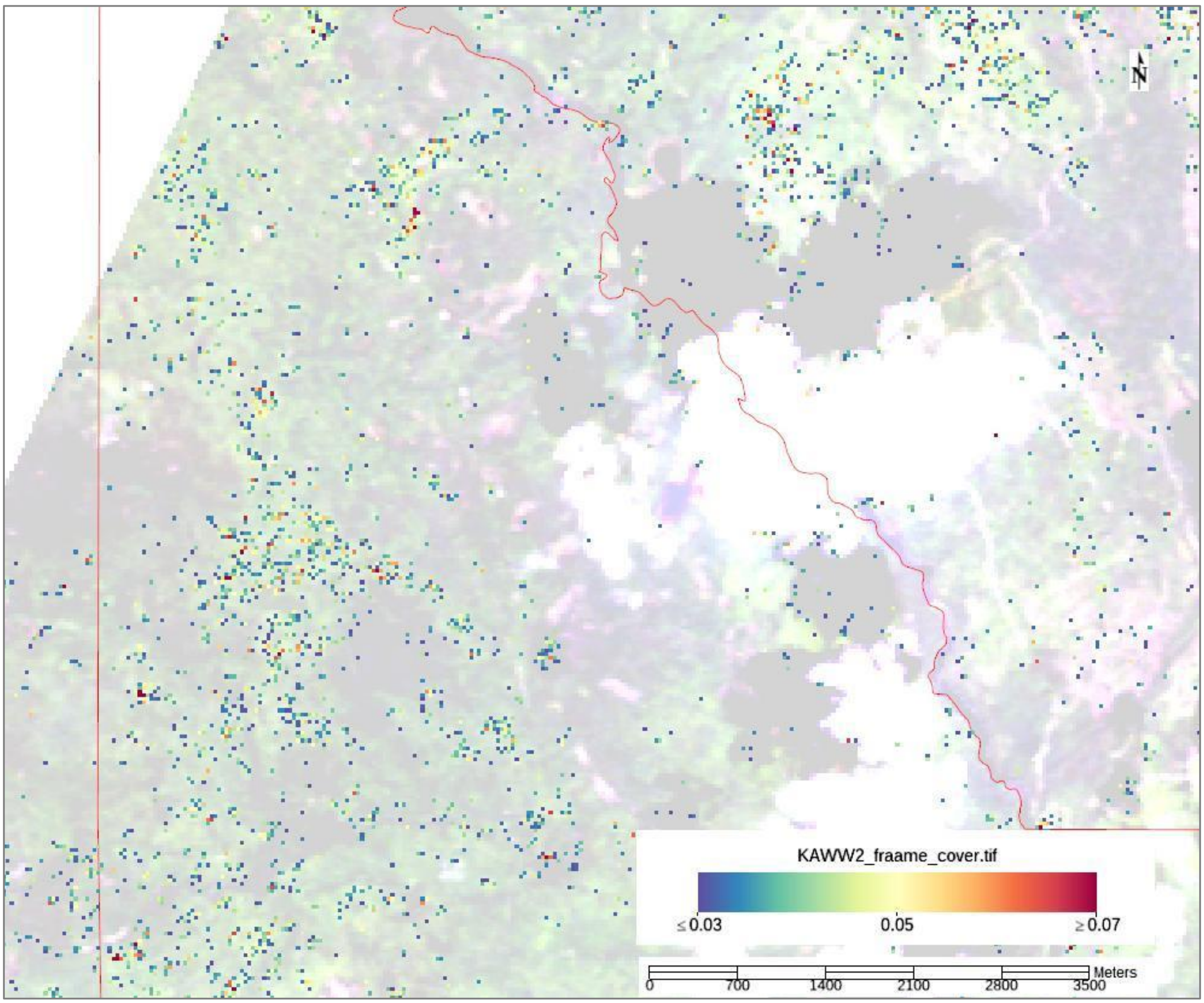
Forest Resource Mapping Products for Acadia National Park and Katahdin Woods and Waters National Monument



Data derived from remote sensing depicting distribution of white ash (*Fraxinus americana*) in a portion of Katahdin Woods and Waters National Monument. Includes copyrighted material of Teledyne Brown Engineering, Inc., All Rights Reserved.

Forest Resource Mapping Products for Acadia National Park and Katahdin Woods and Waters National Monument

Science Report NPS—2026

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Abstract

The purpose of this project is to develop and deliver new maps of tree species composition and tree health in Acadia National Park (ACAD) and Katahdin Woods and Waters National Monument (KAWW) and to describe the condition of a range of forest types across both parks. In particular, we examine the utility of the maps for managing tree species under threat via case studies of eastern hemlock (*Tsuga canadensis*)—threatened by hemlock woolly adelgid (*Adelges tsugae*)—and ash (*Fraxinus* spp.)—threatened by the emerald ash borer (*Agrilus planipennis*). This work produces three products to assist in this process.

The first product is a map layer of dominant canopy tree species over a land area including and beyond the borders of ACAD and KAWW, based on US Forest Service (USFS) data and built by the USFS Forest Health Technology Enterprise Team (FHTET). The dominant species layer does well at mapping common species, but those that are less common or less concentrated are likely underrepresented in this dataset. In addition, there are two different map layers that describe tree canopy health. The first is based on USFS data and depicts areas of damage; this product was also built by FHTET. These data are reasonably accurate but several years out of date due to lack of available, high quality satellite imagery, so conditions on the ground today certainly differ from those mapped in 2018. The second uses DESIS and other satellite data along with reflectance signatures to identify areas of canopy stress and map species. This dataset has not been ground-truthed but is likely best at mapping relatively common species and less accurate for rarer or lower density species.

In the context of known or soon-to-arrive insect pests, specifically emerald ash borer and hemlock woolly adelgid, these map layers do not successfully identify the locations or severity of infestations. While tree health layers may successfully identify zones of high tree stress, overlaying them with the dominant species layer does not help to identify stressed ash or hemlock stands, as both ash and hemlock are usually too sparsely distributed to be mapped accurately by these products. Here we describe the resulting maps and the methods by which data were obtained, provide metadata and supporting documentation, and outline their applications and limitations.

Keywords: Acadia National Park, canopy health, forest health, forest pest, invasive insect, Katahdin Woods and Waters National Monument, species distribution, remote sensing

List of Terms or Acronyms

ACAD: Acadia National Park

EAB: Emerald Ash Borer

FHTET: Forest Health Technology Enterprise Team

FIA: Forest Inventory and Analysis

HWA: Hemlock Woolly Adelgid

KAWW: Katahdin Woods and Waters National Monument

NAIP: National Agriculture Inventory Program

USFS: United States Forest Service

VNIR: visible and near infrared

Introduction

Forests comprise most of Acadia National Park (ACAD) and Katahdin Woods and Waters National Monument (KAWW). Research has identified forests in ACAD and KAWW as among the healthiest forests in the Northeast, and a source of biodiversity for surrounding areas. ACAD's foundational document identifies healthy forests as a central part of the park's significance and as a fundamental resource. Forests were named in the founding legislation of both ACAD and KAWW as a major part of the rationale for their protection. Today, biological and ecological forces are causing significant changes to these important ecosystems.

Pathogens, invasive insects, stress, and herbivory are accelerating the rates of change in forest composition in Maine. An outbreak of red pine scale (*Matsucoccus matsumurae*) recently killed nearly all the red pine (*Pinus resinosa*) in ACAD, and more recently several other insect pests have expanded to Maine and are expected to cause large-scale mortality. In 2022 hemlock woolly adelgid (HWA), a predator of the eastern hemlock (*Tsuga canadensis*), was detected inside ACAD park boundaries and have expanded since. In 2025 emerald ash borer (EAB), a predator of ash trees (*Fraxinus* spp.), was detected just outside of ACAD as well. A slow response to these and future outbreaks could lead to irreversible loss of species and damage to otherwise healthy forests. For now, neither of these insects have been detected in KAWW.

Among the species at risk from these insect pests and other threats are plants traditionally used by Wabanaki tribes in ACAD and KAWW. These species include black ash (*Fraxinus nigra*), which is threatened by EAB. Loss of ash to EAB (and losses of other culturally significant tree species to other threats) will lead to major and irreversible losses of crucial cultural resources.

We aimed to map select species of trees and tree health for all forested lands in ACAD and KAWW using ground, airborne, and satellite imagery. We then tested whether these data were effective at locating infested stands of focal tree species, chosen based on ACAD and KAWW priorities and available data. For example, ACAD has a higher risk of HWA while KAWW has relatively more ash and potential exposure to EAB, so we tested mapping success in terms of their ability to map eastern hemlock and ash species accurately. These maps can be paired with external products to improve understanding locally such as the National Insect and Disease Risk Map.

ACAD and KAWW currently lack maps accurately representing tree species occurrence and tree health at fine spatial resolution. The maps created by this project will provide a valuable resource for a number of management and resource applications. Three immediate applications include:

1. Management of invasive insect pests and diseases: Most insects and diseases, such as EAB and HWA, affect particular species of trees. Thus, species-level maps are needed to plan early-detection monitoring and management. Rapid management responses, such as targeted spraying or harvesting, will only be effective if park managers know where they are needed. The lack of maps of tree species contributed to the recent spread of red pine scale in ACAD, which has killed nearly all the red pine in the park over the past six years. ACAD and KAWW will use maps resulting from this project to directly inform monitoring and management actions.
2. Tribal plant gathering: Species-level maps are necessary to assist park managers with tribal plant gathering agreements. The Wabanaki have utilized tree species in Maine for building canoes, basket making, and much more for thousands of years. Park managers need to under-

stand where key species, such as ash, exist and how abundant they are in order to provide opportunities for sustainable harvesting and traditional use and to protect these species from insect pests and diseases.

3. Managing species declines: Park managers are using scenario planning to prepare management responses to declines in the abundance of many trees that will likely occur over the next few decades because of changes in climate. For example, it is likely that drought (possibly in combination with insect pests) will lead to significant decline in red spruce abundance in ACAD over the coming decades. Managers will use maps of tree species and health to determine areas to concentrate monitoring and management responses in the case of mass mortality of certain species.

Dominant Species Maps

Introduction

Dominant species maps are provided by the US Forest Service Forest Health Technology Enterprise Team (FHTET, Ellenwood et al. 2015). The dominant species layer indicates the dominant canopy tree species in each 30 m pixel. Pixels are assigned to the species that had the highest basal area. There are 32 species included in this product for ACAD and KAWW, and a list of those species can be found in Table 2.

Methods

Pixels in the dominant species layers are 30x30m, and each was assigned to the species that has the highest basal area within the pixel based on modeled basal area values representing c. 2011-12 conditions. Species identity was classified using preexisting US Forest Service models (Ellenwood et al. 2015), which were developed for the conterminous US using Forest Inventory and Analysis (FIA) data and environmental predictors (e.g., soils, topography, climate, etc.).

Results

The resulting product maps dominant canopy species to 30m resolution across about 10,300 square kilometers of coastal Maine from Warren to Calais and inland about five kilometers (plus the Penobscot Valley up to Old Town), along with an area of about 11,000 square kilometers centered on the Katahdin region and including Katahdin Woods and Waters National Monument.

Limitations

The data used to create these species maps represent c. 2011-2012 conditions, so it is possible that canopy species dominance has changed in the intervening years due to processes such as growth, storm damage, or timber harvest (outside of the parks). The pixel size of this dataset, as well as inherent limitations of FIA and the corresponding basal area models, also favor species that are distributed in a more concentrated way, as they are more likely to dominate any given 30m square. As a result, the dominant species layer likely underrepresents the commonness and distributions of species that are patchier in their distributions, including the focal taxa eastern hemlock (*Tsuga canadensis*) and ash (*Fraxinus* spp.).

Metadata

ACAD consists of two LiDAR missions: ME_Midcoast_1_2021 and ME_MidCoast_2_2021; KAWW is one LiDAR mission named: ME_Eastern_B1_2017 (Table 1). Species codes are defined in Table 2.

Table 1. Metadata for the GIS data describing dominant canopy species distribution at 30m resolution. These data resulted from three LiDAR missions flown over Katahdin Woods and Waters National Monument (2017) and Acadia National Park (2021).

Metadata field	**ME_Eastern_B1_2017**	**ME_Midcoast_1_2021**	**ME_MidCoast_2_2021**
Area	KAWW	ACAD (part 1)	ACAD (part 2)
Workunit ID	66486	220045	300071
Project	ME_EasternME_2017_A17	ME_MidCoast_2021_B21	ME_MidCoast_2021_B21
Project ID	66488	220048	220048
Collection Start	4/30/2017 00:00:00 UTC	5/9/2021 00:00:00 UTC	5/13/2021 00:00:00 UTC
Collection end	12/4/2017 00:00:00 UTC	5/27/2021 00:00:00 UTC	5/11/2022 00:00:00 UTC
QL	QL2	QL2	QL2
Spec	USGS Lidar Base Specification 1.2	USGS Lidar Base Specification 2020 Revision A	USGS Lidar Base Specification 2020 Revision A
P method	linear-mode lidar	linear-mode lidar	linear-mode lidar
Dem gsd meters	1	1	1
Horizontal CRS	6348	6348	6348
Vertical CRS	5703	5703	5703
Geoid	GEOID12B	GEOID18	GEOID18
LPC pub date	5/1/2019 00:00:00 UTC	2/14/2023 00:00:00 UTC	3/1/2023 00:00:00 UTC
LPC update	(null)	(null)	(null)
LPC reason	Meets 3DEP LPC requirements	Meets 3DEP LPC requirements	Meets 3DEP LPC requirements

Metadata field	ME_Eastern_B1_2017	ME_Midcoast_1_2021	ME_MidCoast_2_2021
Sourcedem pub date	5/1/2019 00:00:00 UTC	2/14/2023 00:00:00 UTC	2/28/23 00:00:00 UTC
Sourcedem update	(null)	(null)	(null)
Sourcedem category	Meets	Meets	Meets
Sourcedem reason	Meets 3DEP source DEM requirements	Meets 3DEP source DEM requirements	Meets 3DEP source DEM requirements
Onemeter category	Meets	Meets	Meets
Onemeter reason	Meets 3DEP 1-m DEM requirements	Meets 3DEP 1-m DEM requirements	Meets 3DEP 1-m DEM requirements
Seamless category	Meets	Meets	Meets
Seamless reason	Meets 3DEP seamless DEM requirements	Meets 3DEP seamless DEM requirements	Meets 3DEP seamless DEM requirements
LPC link	https://rockyweb.usgs.gov/vdelivery/Datasets/Staged/Elevation/LPC/Projects/USGS_LPC_ME_Eastern_B1_2017_LAS_2019	https://rockyweb.usgs.gov/vdelivery/Datasets/Staged/Elevation/LPC/Projects/ME_MidCoast_2021_B21/ME_MidCoast_1_2021	https://rockyweb.usgs.gov/vdelivery/Datasets/Staged/Elevation/LPC/Projects/ME_MidCoast_2021_B21/ME_MidCoast_2_2021
Sourcedem link	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/OPR/Projects/ME_EasternME_2017_A17/ME_Eastern_B1_2017	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/OPR/Projects/ME_MidCoast_2021_B21/ME_MidCoast_1_2021	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/OPR/Projects/ME_MidCoast_2021_B21/ME_MidCoast_2_2021
Metadata link	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/metadata/ME_EasternME_2017_A17/ME_Eastern_B1_2017	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/metadata/ME_MidCoast_2021_B21/ME_MidCoast_1_2021	http://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Elevation/metadata/ME_MidCoast_2021_B21/ME_MidCoast_2_2021

Metadata field	ME_Eastern_B1_2017	ME_Midcoast_1_2021	ME_MidCoast_2_2021
Dem gsd ft	3.281	3.281	3.281
Vertical unit	Meter	Meter	Meter
Square KM	11035.072754624436	3595.199157259942	6687.527332381235
Shape length	1096073.1603582618	818291.4186306078	1150748.3524861273
Shape area	11035072754.624435	3595199157.2599416	6687527332.381235
Projection	Albers Equal Area	Albers Equal Area	Albers Equal Area
Coordinate System	EPSG:5070	EPSG:5070	EPSG:5070
Datum	NAD83	NAD83	NAD83
Horizontal Accuracy	1 meter	1 meter	1 meter
Vertical accuracy	19.6 cm (nonvegetated) and 30cm (vegetated) at the 95-percent confidence level	19.6 cm (nonvegetated) and 30cm (vegetated) at the 95-percent confidence level	19.6 cm (nonvegetated) and 30cm (vegetated) at the 95-percent confidence level

Table 2. Common and Latin name definitions of species codes used in dominant canopy species mapping files.

Code	Common Name	Latin Name
0	NA	–
1	Other	–
2	Balsam fir	*Abies balsamea*
4	tamarack (native)	*Larix laricina*
6	white spruce	*Picea glauca*
7	black spruce	*Picea mariana*
8	red spruce	*Picea rubens*
9	jack pine	*Pinus banksiana*
10	red pine	*Pinus resinosa*
11	pitch pine	*Pinus rigida*
12	eastern white pine	*Pinus strobus*
14	northern white-cedar	*Thuja occidentalis*
15	eastern hemlock	*Tsuga canadensis*
16	striped maple	*Acer pensylvanicum*
17	red maple	*Acer rubrum*
19	sugar maple	*Acer saccharum*
21	serviceberry	*Amelanchier spp.*
22	yellow birch	*Betula alleghaniensis*
24	paper birch	*Betula papyrifera*
25	gray birch	*Betula populifolia*
30	American beech	*Fagus grandifolia*
31	white ash	*Fraxinus americana*
33	green ash	*Fraxinus pennsylvanica*
37	balsam poplar	*Populus balsamifera*
39	bigtooth aspen	*Populus grandidentata*
40	quaking aspen	*Populus tremuloides*
41	pin cherry	*Prunus pensylvanica*
42	black cherry	*Prunus serotina*
43	chokecherry	*Prunus virginiana*
47	northern red oak	*Quercus rubra*
49	black willow	*Salix nigra*
50	American mountain-ash	*Sorbus americana*
51	American basswood	*Tilia americana*
52	American elm	*Ulmus americana*

Tree Crown Health Maps

Introduction

The goal of this product is to create a data layer depicting the distribution of Tree Crown Health (Monahan et al. 2022) across the landscape, especially in the context of damage-causing forest insects and pathogens. In combination with the dominant species layer described above and additional aerial detection surveys completed for this portion of the project, the intention is for these layers to be used to identify unhealthy stands and the causal agents of the damage, and to use that information to prioritize areas for early detection, monitoring, and management.

Methods

This layer is based on 2018 NAIP (National Agriculture Inventory Program) aerial photographs at a 60cm resolution, as well as aerial surveys performed by trained US Forest Service aerial surveyors who identified and mapped tree canopy damage from the air in 2018. The two data sources were combined to highlight hotspots of tree stress and death at a 60cm resolution. During this period, red pine scale was especially active, and thus these datasets are especially useful for mapping and characterizing recent red pine mortality.

These layers were then masked with a tree/non-tree raster that was created from LiDAR-based canopy height data collected in 2017 or 2021 to remove all objects or areas that were not classified as trees (e.g., poles, buildings, shrubs, rocks). To increase the likelihood that all mapped areas are indeed canopy trees, all pixels with height values less than 4m were removed from the dataset. Canopy heights were field checked in 2024.

Results

This product accurately identifies areas of crown health across the landscape and does so at a fine resolution. When paired with the dominant species layer, it can help determine which species are likely responsible for showing the decreased health. From this, managers can extrapolate to what might be causing the damage, identify areas of concern that require more focus, survey areas to determine which species and what causes might be leading to this damage, and plan management strategies. For non-dominant species (i.e., ash, eastern hemlock, red pine), this method may have low success at identifying swaths of poor health across the landscape.

Limitations

These data were collected in 2018. While aerial surveys did occur in 2024, we were unable to incorporate the newest data into these products because the 2024 data were not publicly available at the time of producing this report. Consequently, mapped canopy damage areas are several years out of date and may represent conservative estimates of canopy damage, as damage areas likely have shifted, grown, or increased in severity in the intervening years.

Metadata

The geodatabase "ACAD_Polygon_Boundaries.gdb" includes three files (Table 3). The first of these files contains 2018 aerial detection survey polygons for red pine scale within Acadia National Park.

1. "DMSM_Damage_Areas_ACAD_2018"
2. "ME_Midcoast_1_2018_Gray"
3. "ME_Midcoast_1_2018_Red"

Table 3. Metadata for tree crown health mapping files.

File	Projection	Coordinate System	Datum	Accuracy
DMSM_Damage_Areas _ACAD_2018	Albers Equal Area	ESRI:102039	USA_Contiguous_Albers_Equ al_Area_Conic_USGS_version	Unspecified
ME_Midcoast_1_2018 Gray	Mercator	EPSG:3857	WGS84	Based on World Geodetic System 1984 ensemble (EPSG:6326), which has a limited accuracy of at best 2 meters
ME_Midcoast_1_2018 Red	Mercator	EPSG:3857	WGS84	Based on World Geodetic System 1984 ensemble (EPSG:6326), which has a limited accuracy of at best 2 meters

Attribute Definitions: ME_Midcoast_1_2018_Gray and ME_Midcoast_1_2018_Red

- **OBJECTID:** Identifier assigned to each polygon
- **MEAN_Pct:** Contains the mean percentage of the boundary mapped (red or gray), can be used to identify hotspots of red pine scale damage
- **NEAR_FID:** Feature identifier of the nearest DMSM polygon OBJECTID
- **NEAR_DIST:** Calculated near distance in meters that defines physical proximity of a pixel to known red pine scale activity. In this field, values start at 0, which indicates a damage pixel residing within an aerial detection polygon
- **SHAPE_Length:** Length of the damage polygon in meters
- **SHAPE_Area:** Area of the damage polygon in square meters
- **PIXEL_Count**: The count of 30m pixels within the buffered polygon zone
- **PIXEL_AREA:** The area of 30m pixels within the buffered polygon zone in square me-ters

Attribute Definitions: DMSM_Damage_Areas_ACAD_2018

- **OBJECTID:** Automatically assigned identifier for the polygon
- **DAMAGE_AREA_ID:** Identification code for the polygon
- **CREATED_DATE:** Date the polygon was created [MM/DD/YYYY HH:MM (24hr time) (time zone)]
- **MODIFIED_DATE:** Date the polygon was last modified [MM/DD/YYYY HH:MM (24hr time) (time zone)]
- **FEATURE_USER_ID:** User identifier of the person who created the feature
- **OBSERVATION_USER_ID:** User identifier of the person who made the observation
- **REGION_ID:** Numeric code defining the region in which the polygon is located
- **HOST_CODE:** USFS code number that identifies host tree species
- **HOST:** Host tree species common name
- **DCA_CODE:** USFS code for the damage causing agent affecting the polygon
- **DCA_COMMON_NAME:** Common name for the damage causing agent affecting the polygon
- **DAMAGE_TYPE_CODE:** USFS code defining the type of damage observed
- **DAMAGE_TYPE:** Plain language name of the type of damage observed
- **PERCENT_AFFECTED_CODE:** USFS code for percent category of polygon affected by the damage
- **PERCENT_AFFECTED:** Descriptive class and percentage range that defines the proportion of the polygon affected by the damage
- **PERCENT_MIN:** Minimum estimated percentage of polygon affected by the damage
- **PERCENT_MAX:** Maximum estimated percentage of polygon affected by the damage
- **PERCENT_MID:** Calculated midpoint between the minimum and maximum estimate
- **NOTES:** Any notes recorded by the observer
- **OBSERVATION_COUNT:** Single or multiple observations on a feature. Overlapping features can result in multiple observations if two different damage-causing agent observation polygons overlap each other.
- **COLLECTION_MODE:** Method of data collection in the field
- **AREA_TYPE:** Whether the polygon is a polygon or a grid shape, and what type
- **ACRES:** Acres covered by the polygon
- **STATUS:** Data status must be FINAL to be included in the national datasets, otherwise it will be excluded. 0 (or NULL) = No, 1 = Mid-season draft, 2 = Final.
- **SURVEY_YEAR:** Year data were collected
- **OBSERVATION_ID:** Unique code for the observation
- **IDS_DATA_SOURCE:** Data source identifier code
- **DATA_SOURCE_NAME:** File name of data source
- **US_AREA:** US mapping area in which the polygons fall
- **Shape_Length:** Length of polygon in meters
- **Shape_Area:** Area of polygon in meters

Reflectance-Based Tree Species and Health Maps

Introduction

This project's goal is to create high resolution maps depicting tree species distribution and health across the landscapes of Acadia National Park and Katahdin Woods and Waters National Monument using a combination of aerial and satellite data. The high spatial resolution of these data are meant to complement the satellite- and FIA-based maps described in previous sections, and the remote-sensed tree health data complements older data collected by aerial observers.

Methods

We mapped tree species and health (via near-infrared reflectance) using remote sensing products that cover large areas at fine spatial and spectral resolution. Specifically, we used visible and near infrared (VNIR) reflectance data from airborne and space-based (1m, 30m) sensors (i.e., DESIS). Using imagery with similar spectral properties but multiple spatial resolutions enabled us to use the finer grained (airborne) imagery to analyze within-pixel variation of the coarser grained images (satellite). We used pixels in the finer spatial resolution (airborne) images to estimate the presence or absence of each tree species and tree health, using the ground reference data as training. These results were then passed to satellite image processing, where we used the percentage of each satellite pixel covered by each tree species in the fine-scale airborne product to map percent cover of the target species in the coarser-scale satellite products. In this way, within-pixel variation of the satellite product could be verified with the airborne images while also greatly multiplying the sample size of training data available for the satellite mapping step.

Our species mapping approach is built on the fact that each tree species has a unique reflectance (aka "color" profile). Our project uses detailed reflectance profiles of trees in the visible and near infrared available from what are known as "hyperspectral" sensors on airplanes and new, space-based sensors. The reflectance measured in hundreds of narrow color channels in these cameras allows the detection and separation of tree species much better than previous types of sensors with only 5–10 bands. To estimate the probability of occurrence for each species, we used end members collected by the Nelson Lab in previous years and compiled into a tree spectral library.

Results

These maps produced stress and cover maps of 16 species in both ACAD and KAWW. These products are best treated as drafts because they were not ground-truthed and other checks for accuracy were not completed. Regardless, these maps are still helpful in understanding potential areas of canopy stress and locations of species across the landscape. Again, it's not as accurate for less common or non-dominant species but pairing this with the other products and managers' knowledge of the landscape can still provide beneficial information.

Limitations

These maps have not been ground-truthed, and their real-world performance is unknown. They should be treated as draft products, though can still be useful in planning for monitoring and management when combined with other products and data sources.

Metadata

- **Projection:** Mercator Auxiliary Sphere
- **Coordinate System:** WGS 84
- **Datum:** WGS 84
- **Accuracy**: Unspecified

Literature Cited

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