Supplementing the Forest Health National Aerial Survey Program with Remote Sensing during the COVID-19 Pandemic: Lessons Learned from a Collaborative Approach

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Abstract

The COVID-19 pandemic has created unprecedented challenges in the way the USDA Forest Service conducts business. Standard data collection methods were immediately challenged due to travel restrictions and due to uncertainty regarding when it would be safe to return to a “business as usual” approach. These challenges were met with an inspiring collaboration between forest health specialists directly involved in the annual Aerial Detection Survey (ADS) program and remote sensing specialists from the Forest Service and academia. This group worked together to generate informative training materials, new workflows, and weekly help sessions to directly address problems that arose during this capacity building exercise. Small ad hoc teams were created to identify regionally specific program resources to enhance remote sensing utilization while supplementing information gaps where aerial detection surveys were either limited or not possible. The lessons learned from this challenge provide an opportunity to continue the exploration of combining ADS, remote sensing, and field data to deliver comprehensive information for managing the nation's forests, while applying what is working and learning and growing from both successes and limitations.

Study Implications: The 2020 USDA Forest Service’s (USFS) Aerial Detection Survey (ADS) program faced unprecedented challenges resulting from the COVID-19 pandemic, which limited surveys across nearly all USFS regions. However, this pandemic created an unexpected positive outcome through an ongoing and wide-reaching collaboration between federal, state, academic, and private sectors that has allowed for a strong and lasting collaboration across USFS regions. Moreover, this collaboration has provided a unique opportunity to optimize a combination of ADS, remote sensing, and field visits to deliver a comprehensive, robust, and near-real-time assessment of the health of our nation’s forests.
Monitoring the health of America’s forests is a collaborative effort that forges partnerships across all lands, regardless of ownership. A variety of invasive and native insects and diseases affect these forests, causing significant economic, environmental, and human health impacts. To help mitigate these problems, there is a growing need for adaptive, near-real-time, and accurate information. The US Forest Service (USFS) and state partners conduct annual Aerial Detection Surveys (ADS) to monitor current forest health conditions across federal, state, and privately-owned lands. These data are used by the USFS Forest Health Monitoring program (FHM) to document the status and trends of insect and disease activity and to inform land managers, the general public, and government officials (Bennett and Tkacz 2008, Potter and Conkling 2020; Figure 1). Although coarse resolution (e.g., ForWarn II, Real Time Forest Disturbance Monitor; 240 m) remote sensing products have been available to FHP in the past, recently there has been more interest in and use of high-resolution imagery (e.g., WorldView 2, NAIP; less than 1 m), high-resolution change detection products (e.g., DeltaViewer; 10 m), and other ancillary data (e.g., ground verification and field plots) to better inform ADS efforts and supplement where ADS data is not collected.

Traditionally, ADS are conducted using fixed-wing aircraft and a three-person crew consisting of a pilot and two aerial surveyors looking out of either side of the aircraft. Surveys occur during the growing season at times of peak pest signatures (Ciesla 2006) and have been ongoing in some USFS regions since the 1930s, with the first documented aerial survey conducted over Yellowstone National Park (Furniss 2007). Flights occur at speeds of 100–140 nautical miles per hour and at approximately 1,000–2,000 feet above ground level with surveyors visually recording damage onto tablets where the data is stored into national databases (Billings and Ward 1984, McConnell et al. 2020).

**COVID-19 Challenges and Support**

The ADS program faced unprecedented challenges in 2020 resulting from the COVID-19 pandemic, which limited surveys across nearly all USFS regions for the first time. As COVID-19 cases rose nationally, the USFS implemented an agency-wide extended telework plan in March 2020, resulting in all nonessential employees working from home full-time. As uncertainty loomed, it quickly became apparent that 2020 would not be business as usual and that the ADS program and associated field work would require supplemental approaches to data collection and reporting.

In response, FHM coordinators, USFS Forest Health Protection (FHP) subject matter experts, USFS Forest Health Assessment and Applied Sciences Team (FHAAST) members, and remote sensing specialists from the USFS Geospatial Technology and Applications Center (GTAC) and RedCastle Resources (RCR; government contractors) worked together to quickly develop innovative remote sensing workflows and build capacity across USFS regions to supplement limited ADS missions. This small ad hoc team identified program resources to enhance geospatial and remote sensing utilization and supplemented information gaps with training resources and technical workflows to produce spatial damage products for areas where ADS could not be flown.

Building remote sensing capacity within the Forest Health program became a primary focus for the ad hoc team, with GTAC and RCR developing two virtual webinars as ADS plans continued to change with the stark rise in COVID-19 cases. The first webinar, “Forest Health Survey Options and Opportunities During the COVID-19 Pandemic” was focused on introducing remote sensing concepts and workflows to determine future training needs, and over two hundred participants from federal and state agencies participated. This webinar was kicked off by the National ADS Program Manager with a risk assessment of the 2020 survey season and was followed by an introduction to available change detection tools and high-resolution imagery (e.g., submeter satellite and aerial imagery). It concluded with a demonstration of conducting “scan-and-sketch” with high-resolution imagery (Figure 2) on the same Digital Mobile Sketch Mapper (DMSM) tablets that are used in aerial surveys, and a discussion on data consistency and validation.

This scan-and-sketch approach is meant to mimic ADS surveys, where an ADS surveyor scans current-year high-resolution imagery at their desk and digitizes...
polygons of visible damage, much like they would in an aircraft, with the DMSM tablet. This data is created with the same data standards of a visual survey, which is particularly important when using alternative supplemental data sources, such as remote sensing, when adding to national databases (Bright et al. 2020a, 2020b). Because data consistency and validation are critical components of ADS data (Coleman et al. 2018; Hicke et al. 2020), additional training efforts went into standardizing the amount of time spent over one area, the amount of zoom used to mimic the distance from an aircraft to damage on the ground, and the best practices for attribution to meet national reporting standards.

The second webinar, “Geospatial Solutions for Supporting ADS FY20 Field Season” had a continued emphasis on capacity building, with similar attendance as the first webinar. Day 1 consisted of a proposed conceptual framework for using remote sensing at various scales to assess, detect, map, monitor, and report on insect and disease outbreaks (Figure 3). Day 2 entailed three tracks of targeted trainings based on the proposed workflow from day 1. Track 1, “Historic Perspective, Coarse and Quick Near Real-Time Assessments”, examined historic ADS data, outputs from the Landscape Change Monitoring System (LCMS; a Landsat-based [30 m spatial resolution]) system to map and monitor annual forest change.

Figure 1. 2019 National Insect and Disease Detection Survey map and highlights. Aerial Detection Survey (ADS) data is synthesized by the USFS Forest Health Assessment and Applied Sciences Team (FHAAST) for national reporting and outreach products on an annual basis. Image provided by FHAAST (https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/detection-surveys.shtml).
Remote Sensing Change Detection Workflow for Forest Health Monitoring

**Figure 2.** Scan-and-sketch survey completed by FHP aerial surveyors in Region 6. Polygons show fir engraver damage north of Enterprise, Oregon, in the Blue Mountains. Background imagery is from the 2020 NAIP collection.

**Figure 3.** Conceptual diagram outlining the proposed remote sensing workflow.

from 1985 to present; Healey et al. 2018), ForWarn II data (a MODIS-based [250 m spatial resolution] near-real-time change detection product; Norman et al. 2013), and LandTrendr (a spectral-temporal segmentation algorithm used to monitor change with Landsat data; Kennedy, Yang, and Cohen 2010). Track 2, “Confirming Change, Tasking Satellites, and Sharing Imagery”, focused on acquiring Sentinel-2 imagery (10 m spatial resolution) to confirm the presence of change and tasking satellites to collect high-resolution imagery through the US Government’s NextView license agreement. Track 3, “Mapping Infestations,” consisted of a tutorial on using different band combinations that focus on vegetation stress to map forest disturbance.
signatures and provided additional training on the scan-and-sketch method of directly mapping disturbances from high-resolution imagery.

Between the first and second webinars, small teams were formed across the nine USFS regions to organize available staff and identify resources and needs to supplement ADS with a wide variety of remote sensing tools. These small regional teams met with remote sensing specialists from GTAC to address local management issues and begin developing workflows based on available imagery and capacity. These regional teams became even more necessary as three USFS regions announced a complete stand-down of their ADS programs due to safety concerns and state restrictions, and four USFS regions developed hybrid plans to fly 30%–40% of normal ADS to limit overnight travel and crew sizes (Figure 4). However, one USFS region was able to fly almost complete ADS coverage based on state guidance at the time, using preseason planning information from available imagery, change detection products, and drought monitoring data.

In response to the increased demand for remote sensing support, a new change-detection method was developed, DeltaViewer, which provides simple, easy-to-interpret change products. Remote sensing specialists from GTAC and RCR created the DeltaViewer change detection method to rapidly respond to temporally discrete events in near-real time, such as storms or insect defoliation and mortality in near-real time (Figure 5). DeltaViewer operates in Google Earth Engine and uses two-date change detection with three commonly used indices related to vegetation greenness and vegetation water content (the normalized difference vegetation index, the normalized burn ratio, and the normalized difference moisture index) that are derived from the European Space Agency’s Sentinel-2 imagery at a 10 m spatial resolution. This method quickly became an important source of information among most of the regions, and DeltaViewer is supported and enhanced by a collaborative process between forest health experts and remote sensing specialists to rapidly hone the outputs to meet regional needs. This close collaboration has led to additional improvements to better serve the forest health community, and DeltaViewer is constantly undergoing benchmarking through its use. For additional information about DeltaViewer or for support opportunities, please reach out to Aaron Kamoske, GTAC remote sensing specialist (aaron.kamoske@usda.gov).

As ADS plans continued to evolve throughout the field season, remote sensing capacity building of the USFS regional teams became a key focus of the ad hoc team. Virtual team meetings and USFS file-sharing software created an opportunity for weekly video calls to share training documents and remotely sensed imagery and to develop and work through new training exercises as issues arose. In addition, a weekly technical assistance call (TA Office Hours) was established for information sharing, training, capacity building, and developing best practices. The recordings from these meetings were distributed across the forest health community and are stored for future reference in a location where both state and federal partners can access recordings and all training material generated from the weekly topics of interest. If you would like access to these materials, please contact Ryan Hanavan, FHM coordinator (ryan.hanavan@usda.gov). Weekly call participation ranged between 75 and 100 participants from USFS and state government cooperators during the monitoring and reporting...
season. Topics ranged from the process of submitting high-resolution imagery requests using the United States Geological Survey (USGS) Commercial Remote Sensing Space Policy Imagery-Derived Requirements tool, to generating Tile Packages from high-resolution images for scan-and-sketch operations on the DMSM tablets, and best practices for using automated change detection products such as DeltaViewer, ForWarn II, LCMS, and others. An invaluable source of imagery for these teams was the National Agricultural Imagery Program (NAIP), which acquires submeter aerial imagery at the state level on a rotating basis of every 2 to 3 years. Regions 5, 6, and 10 (Figure 4) relied heavily on 2020 NAIP and other newly acquired high-resolution imagery for scan-and-sketch activities for identifying insect and disease activity as their ADS programs halted completely due to COVID-19 concerns.

Where an ADS was not flown, scan-and-sketch and DeltaViewer products were used as a replacement. Regions identified specific areas of interest and GTAC worked closely with these forest health teams to provide support on both scan-and-sketch implementation (e.g., finding and downloading high-resolution imagery, digitizing best practices, etc.) and DeltaViewer products. Two examples of this collaboration included (1) mapping, refining, and validating whitebark pine mortality in the Ruby Mountains of

Figure 5. Lymantria dispar defoliation north of Grand Rapids, Michigan, in the summer of 2020. Orange clusters show DeltaViewer outputs and purple polygons show ADS data from the same defoliation event. Photo on right shows a severe L. dispar defoliation event for reference.
Nevada with USFS and Nevada State Forest health experts, with plans for field-based restoration treatments, and (2) documenting the extent of a large wind blowdown event in Colorado and Wyoming, with the USFS Region 2 FHP, which led to refinement of ADS survey routes in Colorado and a large, ongoing field campaign in Wyoming, where ADS was not available in 2020. In addition to these two examples, all regions used the trainings and available tools to supplement ADS, regardless of where they were able to fly complete or limited ADS coverage or were grounded completely, with data being submitted to national databases for yearly reporting.

Lessons Learned

One of the main takeaways from the COVID-19–reduced ADS survey in 2020 was a clear need to foster a stronger forest health remote sensing network and establish a comprehensive suite of tools to supplement ADS. To this end, the original group of specialists from FHP, FHAAST, FHM, GTAC, and RCR delivered several presentations on these 2020 efforts at the national SAF conference, Washington Office FHP Leadership and Regional Directors monthly meetings, the USFS Bark Beetle Technical Working Group annual meeting, and the USGS Management Oversight Group meeting.

This team also formed the Forest Health Remote Sensing Technical Working Group (RSTWG) to bring partners together from the federal, state, academic, and private sectors. Now chartered, RSTWG provides a formal mechanism to increase awareness about regional remote sensing activities and projects and discuss the ability of remote sensing to monitor forest health and supplement ADS. The RSTWG will continue to expand outreach to better engage with all those interested in forest health monitoring while building stronger collaboration, working towards a common goal, and reducing duplicative efforts. To this end, RSTWG held its inaugural virtual meeting, consisting of lightning talks and breakout sessions about remote sensing platforms, automated change detection, finding common ground between ADS and remote sensing, integrating remote sensing into forest health monitoring, and other topics. There were over 170 participants from state, federal, academic, and private institutions, providing representation spanning from Hawaii to Maine to Puerto Rico. To get involved in RSTWG, please contact Ryan Hanavan (ryan.hanavan@usda.gov) or Aaron Kamoske (aaron.kamoske@usda.gov).

Developing an on-the-fly triage effort to supplement ADS data with remote sensing has created an unexpected positive outcome in a postpandemic vision for the FHM detection monitoring program—the ability to remotely monitor the health of the nation’s forests as a supplement to ADS and a strong and lasting collaboration across regions. RSTWG and the broader forest health community will continue to explore the role of remote sensing in supporting the FHP mission by providing best practices, training, capacity building, remote sensing tools, and decision matrices. The lessons learned from 2020 provide a unique opportunity to optimize a combination of ADS, remote sensing, and field visits, and to deliver comprehensive, robust, and near-real-time information for managing and monitoring the nation’s forests. These remote sensing tools, collaborations, working groups, and capacity building workshops will continue into the future, allowing FHP to apply what worked, while learning and growing from both the successes and limitations.

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