Aerial detection surveys in the United States

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Summary

Aerial detection survey, also known as aerial sketchmapping, involves observing forest change events from an aircraft and documenting them manually onto a map. Data from aerial surveys have become an important component of the Forest Health Monitoring program, a national program designed to determine the status, changes and trends in indicators of forest condition. Aerial surveys are an effective and economical means of monitoring and mapping common forest disturbances such as tree damage and tree mortality caused by insects and disease. Information from aerial surveys can be considered the first stage in a multi-stage or multi-phase sampling design. Aerial sketchmap surveys have been used in the United States since the 1940s. Today, the United States Department of Agriculture (USDA) Forest Service, State and Private Forestry, Forest Health Protection, together with other federal, state and county cooperators conducts annual sketchmap surveys across all land ownerships. Between 2002 and 2006 an annual average of 1 800 000 km^2 of forested lands were aerially surveyed within the United States alone. Traditionally, forest damage has been sketchmapped on United States Geological Survey paper-base maps. Recently, the USDA Forest Service's Forest Health Technology Enterprise Team (FHTET) developed a digital aerial sketchmapping system that automates this process, allowing users to digitise polygons directly onto a touch-screen linked to a global positioning system (GPS) unit and computer or onto a tablet PC with an integrated GPS.

Keywords: aerial surveys; mapping; surveillance; detection; forest damage; forest health; monitoring; pest management; forest management; United States of America

Introduction

In the United States (US) forest health has gained popular attention in recent years because of environmental concerns about air pollution, acid rain, global climate change, population growth and long-term resource management. In response to these environmental concerns and to legislative and policy direction, federal and state agencies have been working together to develop a program for forest monitoring and reporting on the status and trends of forest health. The national Forest Health Monitoring (FHM) program has been established to accomplish this objective (USDA Forest Service 2008a). To the extent possible the FHM program uses existing federal and state programs and or infrastructure to accomplish its mission.

The FHM program consists of three interrelated monitoring activities:

- Detection monitoring (plot and survey components)
- Evaluation monitoring
- Intensive site ecosystem monitoring (USDA Forest Service 2008a).

A fourth related activity is research on monitoring techniques. Each monitoring activity provides a different level of information and each has specific, complementary goals.

Detection monitoring consists of two components: the plot component and the survey component (USDA Forest Service 2007a). The plot component of detection monitoring employs a set of plots systematically distributed across the entire US providing data on forest mensuration, tree crown condition, tree damage, ozone injury to vegetation, soil chemistry and erosion, vegetation diversity, lichen diversity, coarse woody debris and fuel loading. The survey component of detection monitoring makes use of both ground surveys and aerial surveys to collect data on the occurrence of forest insects, disease, weather-related damage and other forest health stressors. Monitoring for invasive plants, insects and diseases is fast becoming a large part of detection monitoring efforts. Both plot component and survey component information, in combination with data on weather and climate change, fire incidence and damage, and observations on shifts in land use, are required to interpret forest condition. This paper describes aerial surveys, how aerial survey data are collected, and how aerial survey programs are managed.

What are aerial detection surveys?

Aerial survey, also known as aerial sketchmapping, is a remote sensing technique of observing forest change events from an aircraft and documenting them manually onto a map (McConnell *et al.* 2000). The observer views a particular forest change event, such as mortality caused by bark beetles or defoliation caused by gypsy moths, and delineates the affected area on a map to record its size, shape and location as accurately as possible. Attributes such as host, causal agent, symptom and an estimate of intensity or number of trees affected may also be recorded. Together with ground intelligence, trained observers have learned to recognise and associate damage patterns, discoloration, tree species and other subtle clues to distinguish a particular type of forest damage from surrounding, healthier forest areas. This is known as a damage 'signature' and in most cases is pest specific. Aerial sketchmapping could perhaps be considered 'real time photo interpretation', with the added challenge of transferring the spatial information from a remote landscape view to a map or base image (USDA Forest Service 2007d).

Aerial surveys have been recognised for over 50 years as an efficient and economical method of detecting and monitoring forest change events over large forested areas (Wear and Buckhorn 1955). It is a relatively low-cost remote sensing method that provides a coarse, landscape-level overview of forest conditions. Today, USDA Forest Service, State and Private Forestry, and Forest Health Protection (FHP), together with other federal, state and county cooperators conducts annual sketchmap surveys across all land ownerships. In 2004, the total cost for the US annual aerial survey was about US$5 million or roughly \$.025 ha^{-1} surveyed (USDA Forest Service 2004). Between 2002 and 2006 an annual average of 1 800 000 km^2 of forested lands were aerially surveyed within the US (USDA Forest Service 2006). States are granted federal funding for monitoring activities and in many cases surveys are conducted cooperatively with federal personnel. Agency policy facilitates a cooperative spirit among various levels of government:

> <u>DETECTION SURVEYS.</u> Regional[1] and Area Forest Health Management staffs shall conduct detection surveys on Federal Land, and if necessary, on non-Federal land as often as necessary to provide insect and disease status information. Upon request and under mutual agreement, Forest Service personnel may conduct detection surveys on State and private lands, or conversely, State personnel may conduct surveys on National Forest System Land.
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> (USDA Forest Service 1990).

Aerial surveys can be used as the first step of a multi-tiered process of detection, monitoring and evaluation, using other remote sensing and ground sampling techniques to gather additional data on significant forest changes (Heller and Wear 1969; Wulder *et al.* 2006). As with all remotely derived data, some amount of ground-truthing is required before the data can be considered reliable.

How is aerial survey data collected?

In order to collect aerial survey data, the following elements are needed:

- a high-winged aircraft providing good visibility and capable of flying at relatively slow speeds
- a pilot who has a sincere interest in safety and is motivated to perform at a high level
- a sketchmapper who has the ability to relate forest damage observed on the ground to features on a map without experiencing the debilitating effects of motion sickness (McConnell *et al.* 2000).

The map base onto which the sketchmapped information is recorded varies from sketchmapper to sketchmapper and from program to program. For the more general 'overview' surveys, the map base will often be 1 : 100 000 scale topographic base maps or medium-resolution satellite imagery. For more intensive 'special' surveys, 1 : 24 000 scale topographic base maps and digital orthophotography are common (McConnell *et al.* 2000). Resulting data are entered in a national geographic information system (GIS) database using common standards that are required for forest health monitoring reporting efforts (USDA Forest Service 2005, 2008b).

> Since forest pests and the damage they cause are dynamic and highly variable, the resulting data will also be highly variable. No two sketchmappers will or can be expected to record the same outbreak in exactly the same way. For this reason, sketchmapping should be regarded more as an art than an exact science. It is important at the outset that this be understood, not only by conscientious sketchmappers who find that their data may not be in close agreement with their peers or with a subsequent statistically reliable aerial photo survey, but also by the forest manager, who may want to put the information to use. Sketchmapping is highly subjective, and the resulting data can be no more accurate than the competence of the sketchmapper and the conditions under which the data was obtained.
>
> (Klein *et al.* 1983).

As the preceding passage implies, there are certain limitations as to how the data obtained from aerial sketchmap surveys can be used. During a typical aerial survey mission, the plane speed is about 100 nautical miles per hour (185 km h^{-1}) flown at an altitude of 300–900 m above ground level (McConnell *et al.* 2000). Observers on average are evaluating a swath-width of about 2.5 km at any one time, which gives them only about 20 seconds per kilometre to recognise, classify and record all of the activity they see. Because of these circumstances, aerial sketchmap data should be regarded only as a coarse 'snapshot' of landscape-level forest health condition. Spatially, the data is best displayed at smaller scales such as 1 : 100 000, 1 : 250 000 or 1 : 500 000. The data are better used for demonstrating trends rather than exacting precise measurements.

How are aerial survey programs managed?

At the federal level, agency policy provides direction regarding scope, timeliness and responsibility for surveillance and detection surveys:

> <u>REGIONAL OR AREA STAFF DIRECTOR HAVING FOREST HEALTH MANAGEMENT RESPONSIBILITIES.</u> Within the Region or Area, the Director assigned pest management responsibilities shall ... 2. Conduct surveillance and detection surveys to ensure prompt discovery of potentially threatening pest populations and/or damage to forest vegetation.
>
> (USDA Forest Service 1990).

There is more to aerial sketchmapping, however, than looking for damaged trees from an aircraft; a great deal of preliminary work must be done before anyone is sent up in the air to do this type of work. Some of this work includes developing an aviation

[1] The US is divided into nine Forest Service 'Regions', each covering a large geographical area that may consist of multiple states.

management plan and an aviation safety awareness program; providing for suitable, safe, cost-effective aircraft; and ensuring the availability of trained, qualified personnel to do the work, including experienced qualified pilots.

The regional aerial survey program manager (federal) manages the operational component of aerial surveys while the safety component is managed by the unit aviation officer (UAO): frequently these two roles are fulfilled by a single position. The UAO coordinates aviation safety activities with regional and national aviation safety managers; these include providing safety and training programs for field units (USDA Forest Service 2007b). Operationally, state aerial survey programs cooperate with and are often patterned after their respective regional (federal) aerial survey programs. As an example, the 2007 aerial survey program in the Rocky Mountain Region, which consists of five states (Colorado, Wyoming, South Dakota, Nebraska and Kansas), surveyed nearly 17.5 million ha, used ten surveyors from three different agencies and four different aircraft, and required over 600 hours of aircraft time.

The Aerial Survey Working Group, a federal and state entity, was formed to ensure aerial survey quality and safety (USDA Forest Service 2007b). In the 1990s a nationally recognised set of aerial survey standards was created which established data definitions, metadata guidelines and data quality expectations (USDA Forest Service 1999). Additionally, aerial survey program quality control components were determined including sketchmapper training and certification (USDA Forest Service 1999).

Information collected from aerial detection surveys is shared and distributed at local, county, state, regional and national levels. For example, direct control of southern pine beetle (*Dendroctonus frontalis*) infestations is at times initiated the very afternoon following the morning survey flight. Survey personnel often produce specialised products and interact directly with customers at local levels, while annual summary reports are produced regionally and nationally for broader audiences. Aerial survey data are compiled regionally and managed nationally by the Forest Health Technology Enterprise Team (FHTET) which maintains a central repository for national data and data products (Fig. 1) (USDA Forest Service 2008b).

Aviation management plans

An aviation safety and management plan provides all of the program participants with information about the nature and intent of the mission and the program (USDA Forest Service 2007c). It includes a description of the program along with its purpose and scope; the personnel involved and their responsibilities; and a definition of all of the pertinent policies, procedures, operations, safety plans and documents that apply to the program. By reading the aviation management plan, anyone unfamiliar with the program should be able to quickly grasp the intent, authority and extent of the program.

Aviation safety awareness program

The purpose of an aviation safety awareness program is to ensure that all participants understand the importance of conducting an aerial survey program safely. It is the responsibility of management to provide adequate safety awareness training. It is the responsibility of all participants to be aware of the safety implications in an aviation program. Proper training includes formal aviation safety and management courses which should be repeated every few years. Approaching and solving problems through continual training ensures a high standard of job performance where instilled safety practices are an integral part.

Suitable aircraft

Having the right tool for the right job also applies to aerial surveys. Aircraft specifications can vary depending on many factors including terrain, number of observers, flying altitude, flight speeds, flight patterns, size of survey area, ferry distance to the survey area and expected accuracy levels. Greater horsepower comes at an increased cost. A mission should never be flown with an under-powered airplane. Finding

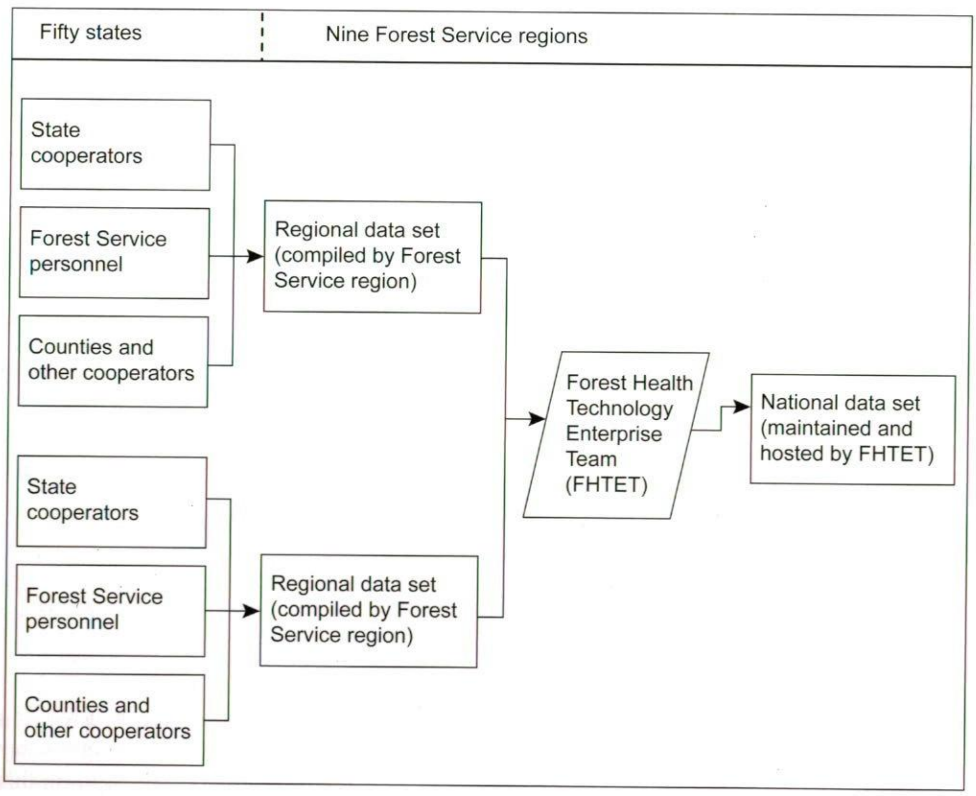

Figure 1. Aerial survey data synthesis in the United States

the appropriate aircraft is a matter of weighing the benefits and the costs without compromising safety (McConnell *et al.* 2000).

Personnel

The most critical element in aerial sketchmapping is also the most variable: the sketchmapper. Conducting an aerial survey with a trained, experienced sketchmapper is the best way to assure a quality aerial survey. Although it helps that a sketchmapper is good with maps, is able to endure riding in an aircraft without experiencing motion sickness, has a background in forestry or entomology and an interest in aviation, and has had some form of aerial sketchmapping training, there is no substitute for experience. An individual cannot be expected to collect quality aerial survey data without receiving months, perhaps even years, of on-the-job training (McConnell *et al.* 2000).

A good pilot contributes greatly to the safety and quality of the survey. A well-qualified pilot works as a team player to position the aircraft at the appropriate altitude, speed and location to give the observer the best view. An aerial survey program benefits greatly by having stringent requirements for pilot qualifications.

Along with personnel flying the aerial survey, the survey team includes personnel on the ground responsible for 'flight following'; that is, monitoring the location of the aircraft through regular radio contact. The flight follower, or dispatcher, maintains radio contact with the flight crew in case of an emergency or the need to pass along important information. A good dispatcher is diligent about constantly monitoring the aircraft's position and follows proper procedures in the event of an emergency.

New technologies

New technologies are constantly being sought and integrated into aerial surveys. The USDA Forest Service's Forest Health Technology Enterprise Team has recently developed a digital aerial sketchmap system (DASM) whereby observed forest damage polygons can be directly recorded onto a touch-screen linked to a global positioning system (GPS) unit and computer, or onto a tablet PC with an integrated GPS (Schrader-Patton 2002). This eliminates the need to use pencils to draw on paper maps and the ensuing lengthy process of post-processing the maps into a digital format. The DASM also helps the observer to stay on course via an aircraft icon linked to a GPS receiver that flashes on the screen across a moving map display.

Automated flight following systems have now been established in many aerial survey programs nationally. A GPS unit installed in the aircraft transmits position locations to a centralised dispatch center responsible for following the aircraft's route. In the event of an emergency, help can be immediately dispatched to the incident's exact location (British Columbia Forest Service 2002).

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