W.G. VII/2 Vegetation Damage

PUTTING REMOTE SENSING TECHNOLOGY TO WORK IN FOREST DAMAGE EVALUATION

By

William M. Ciesla
USDA Forest Service
Forest Insect and Disease Management
Methods Application Group
Davis, CA 95616

ABSTRACT

Photographic sensors are valuable aids for data acquisition on status of certain destructive forest pests. In order for sensor-based data acquisition systems to be adopted as operational tools, they must provide data responsive to clearly defined user requirements. A nucleus of trained professionals and technicians committed to operational use of remote sensing technology is needed to ensure system implementation.

Use of high-resolution panoramic color infrared photography for forest damage evaluation is described as an example of how new technology is developed and transferred to users.

INTRODUCTION

Damage caused to forest vegetation by many forest insects and diseases is visible from remote distances. Most forest insect and disease management programs across the North American continent rely on data obtained by aerial observers mapping locations of tree mortality and foliar injury from low flying aircraft as the first step in detection of damage.

Remote sensing technology, particularly color and color infrared (IR) aerial photographs, offers promise for data acquisition for forest pest management decision making. It offers the advantage of data acquisition with increased accuracy and precision with less field time, and provides a permanent record of damage.

OBJECTIVES OF FOREST INSECT AND DISEASE MANAGEMENT

Simply stated, the overall purpose of Forest Insect and Disease Management in USDA Forest Service is to reduce losses caused by destructive forest pests relative to land management objectives with a minimum of adverse environmental effects.

In recent years, the concept of integrated pest management has received considerable attention in North American agriculture and forestry. As defined in the planning regulations of the National Forest Management Act of 1976, integrated pest management is:

A process in which all aspects of a pest-host system are studied and weighed to provide the resource manager with information for decision making. Integrated pest management is, therefore, a part of forest or resource management. The information provided includes the impact of the unregulated pest population on various resource values, alternative regulatory tactics and strategies, and benefit cost estimates for these alternative strategies. Regulatory strategies are based on sound silvicultural practices and the ecology of the pest-host system. Strategies consist of a combination of tactics such as stand improvement, and may include selective use of pesticides. The overriding principle in the choice of strategy is that it is ecologically compatible or acceptable.

Integrated pest management, therefore, consists of two parts: a decision-making process, and a series of ecologically compatible management alternatives that the resource manager may use to maximize resource outputs by regulating pest populations. Management alternatives designed to regulate pest populations may take one of two basic forms. Campbell (1977) describes these as responding to an outbreak (crisis response), and reducing the probability of future outbreaks through environmental manipulation (crisis prevention).

WHERE DOES REMOTE SENSING TECHNOLOGY FIT?

Color and color IR aerial photographs have been used successfully for data acquisition on status and trend of a variety of pests for pest management decision making. Wert and Roettgering (1968) used color aerial photos in combination with aerial sketch mapping and ground sampling to estimate losses caused by the Douglas-fir beetle, *Dendroctonus pseudotsugae*, in northern California. These data were used to help plan salvage operations. On a more extensive scale, color photos have been used effectively as an intermediate sampling stage to estimate annual mortality caused by mountain pine beetle, *D. ponderosae*, over large areas in both ponderosa and lodgepole pine in the Rocky Mountains (Klein et al. 1979; Hostetler and Young 1979a,b; Bennett and Bousfield 1980). These data are helpful in setting priorities at Regional and National planning levels, and for integration of insect and disease loss information into periodic resource assessments.

Color and color IR aerial photographs have been shown to be effective tools for evaluation of the effectiveness of certain pest management tactics. Ciesla et al. (1971), working with forest tent caterpillar, *Malacosoma disstria*, in southern Alabama demonstrated that foliage protected by aerial application of chemical and biological insecticides could be mapped on large- and medium-scale color and color IR photos. This proved to be particularly valuable in areas of limited access where conventional pre- and post-spray assessment methods could not be made to evaluate treatment effects.

In integrated pest management there is increased emphasis on prevention of outbreaks (crisis prevention) through cultural manipulation. This adds a new dimension to forest pest management planning and decision making, and provides an opportunity to integrate pest management with land management planning. In-place physical attribute data including stand composition, age, stocking, soil, aspect, and elevation may be used to determine the relative susceptibility of stands to certain pest or pest complexes so that management action may be planned and executed years before an outbreak actually occurs. Heller and Miller (1977) demonstrated that such data can be taken from aerial photographs to determine susceptibility of stands to periodic outbreaks of the Douglas-fir tussock moth, *Orgyia pseudotsugata*, a destructive defoliator of Douglas-fir and true fir stands throughout much of the Western United States.

OPERATIONAL IMPLEMENTATION: A CHALLENGE IN TECHNOLOGY TRANSFER

We have seen that aerial photography is a helpful tool for forest pest management planning, decision making, and evaluation of treatment tactics. One of the greatest challenges in forest insect and disease management is to implement sensor technology for routine data acquisition in a real-time operational mode for pest management decision making.

Data Requirements

Before any methodology can be made effective, there must be a clear understanding between resource manager and specialist as to what data is needed, by what ecological or political strata, the time frame within which the data must be made available, and the desired precision. Survey methodology must be selected based on these needs. Often this is not the case, and when inappropriate data is collected or not presented in a timely manner, the survey method may be faulted. This has on occasion been the case in Forest Insect and Disease Management when aerial photography has been used for data collection and the technology has lost favor with both resource manager and specialist. In the United States, data requirements for pest management decision making have been formalized at the National planning level, and a geographic information system for managing these data is being proposed (Ciesla and Yasinski 1980; Young 1977, 1979).

Data Collection

Forest pests, particularly insects, are dynamic. Outbreak boundaries may change significantly from year to year. With insects that have several generations a year, such as the southern pine beetle, *D. frontalis*, outbreak boundaries can change drastically several times during a single season. To further complicate matters, the period of maximum damage is very short, usually a matter of weeks or even days. Summer temperatures hasten foliage desiccation and discoloration, wind and rain strip the damaged foliage, and fall coloring causes confusion. In order for any sensor, whether it be the human eye or the most sophisticated camera system, to be effective for mapping forest insect and disease damage, data must be collected when peak symptoms occur. Timing of photo acquisition is therefore very critical. Add to this complications imposed by cloud cover, and it frequently becomes impossible to acquire the needed data.

Forest pest surveys are generally plot or strip sample surveys over relatively small acreages. This, coupled with the rigid timing requirements imposed by the pest's biology and ecology, makes contracting for acquisition of photographs not very attractive to prospective bidders.

Lack of interest by the commercial sector in forest insect and disease surveys has led the Forest Service, and at least one state agency, to develop an in-house aerial photo acquisition capability. Within the Forest Service, at least four aircraft are available to fly large- to medium-scale photo missions. These are used extensively by Forest Insect and Disease Management. In addition, a few contract aircraft equipped for aerial photography are available for photo missions by Forest Service specialists. This small fleet of aircraft is insufficient for operational data collection. Contracts must be made more attractive to prospective bidders, even if it is necessary to consolidate several surveys under a single contract.

Skills Required

If photographic and other remote sensors are to be fully implemented in forest pest management, a team of trained professionals committed to the use of sensor technology is needed. A minimum of at least one individual with this expertise is needed within each Regional Forest Insect and Disease Management staff. Ideally, he should be supported by at least one technician capable of planning surveys, image acquisition, and interpretation. With these skills, operational technology can be used more effectively, and new techniques can be incorporated more readily into existing programs.

PANORAMIC AERIAL PHOTOGRAPHY FOR MAPPING FOREST DAMAGE

The following example serves to illustrate how new sensor technology can be integrated into existing programs, provided that data requirements are clearly defined, and a proper mix of technical skills are available to evaluate, demonstrate, and implement the new technology.

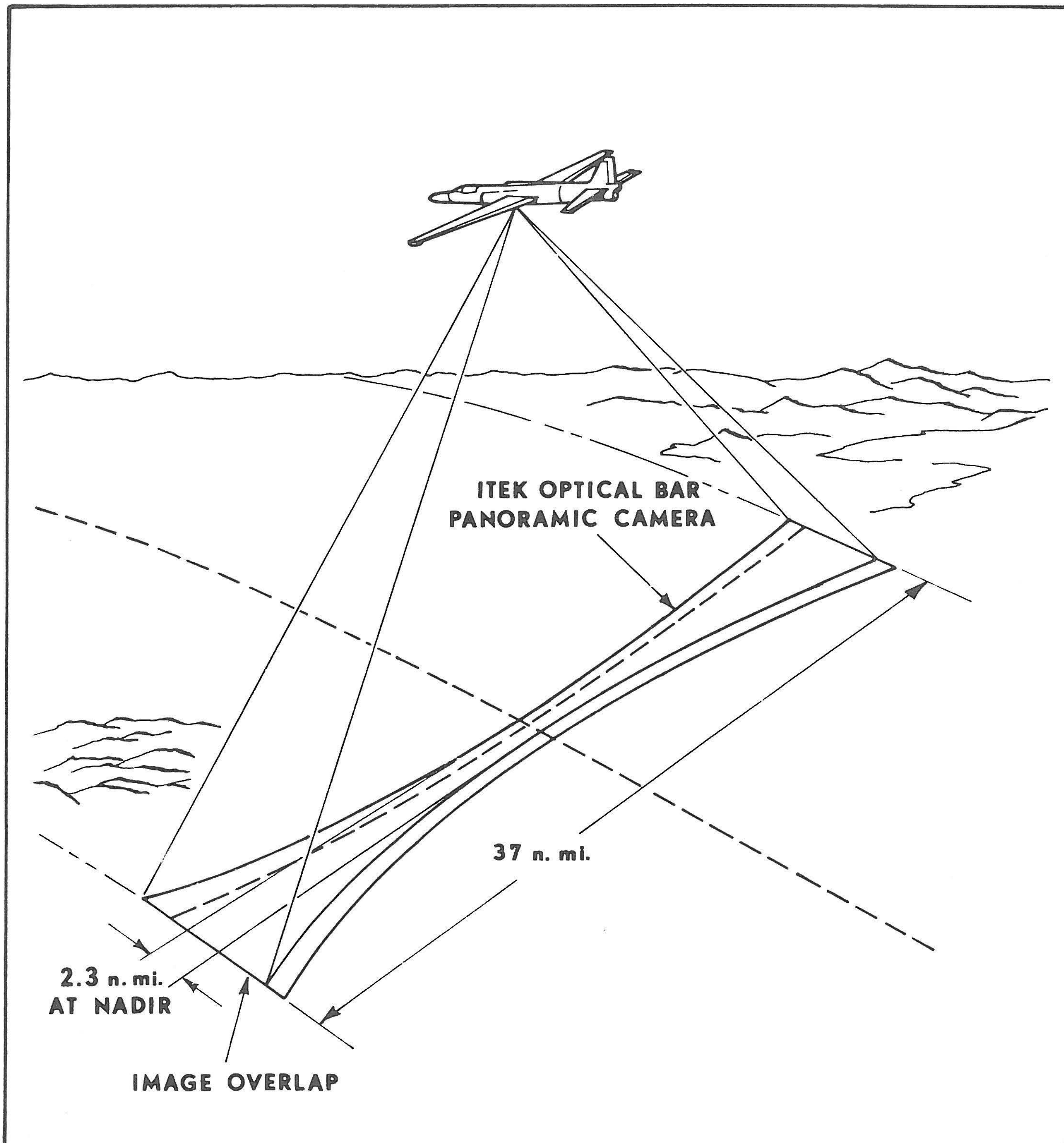
In 1977, work was begun to estimate statewide losses caused by major forest insect and disease pests in the Untied States. These surveys were designed to acquire loss data as defined by the Forest Service (Ciesla and Yasinski 1980). The mountain pine beetle, D ponderosae, a major bark beetle pest of western North America, was the first insect selected for which statewide loss data was obtained.

A multistage survey consisting of aerial sketch mapping, large-scale (1:6000) color aerial photography, and ground sampling was designed to estimate annual damage in terms of numbers of trees and volume lost. This technique was successfully used in lodgepole pine forests in Idaho and Montana, and ponderosa pine forests in South Dakota and Colorado (Klein et al. 1979; Hostetler and Young 1979a,b; Bennett and Bousfield 1980).

Shortly after this work was initiated, we were advised of the capabilities of the Itek KA80A optical bar panoramic aerial camera by the Forest Service Nationwide Forestry Applications Program, located at the Johnson Space Center in Houston, Texas. This camera is equipped with a 24-in. (61-cm.) focal length lens, and has a 4 1/2 x 50 in. film format. Mounted in a U-2 flying at 65,000 ft. (21,325 m) above sea level, this system acquires aerial photography at a nadir scale of approximately 1:30,000. Scale increases to 1:64,000 at the outer extremeties of the film. From nadir to 35°, the photographic image is near vertical; beyond 35°, the image tends toward obliquity. Ground coverage is approximately

2.3 x 37 nautical miles (4.3 x 69 km) per photo (figure 1). Photography is obtained by special request to the NASA Ames Research Center, Moffett Field, California.

Figure 1. Land area covered in a single frame of film taken with the Itek optical bar camera.


ITEK OPTICAL BAR
PANORAMIC CAMERA
37 n. mi.
2.3 n. mi.
AT NADIR
IMAGE OVERLAP

Initial use of this camera system by the Forest Service was a survey to measure cumulative tree mortality in northern Idaho (Duggan et al. 1977). As a result of participating in this survey, we recognized the potential of this camera system as a tool for estimating current levels of bark beetle mortality. High resolution panoramic photography might serve two purposes: (1) stratifying the infestation into intensity levels, thus eliminating need for aerial sketch mapping; and (2) making detailed counts of discolored crowns.

A special study in the central Sierra Nevada Mountains of California successfully demonstrated the capabilities of the Itek panoramic camera using color IR (SO-131 film) for mapping bark beetle mortality (Klein et al. 1978). Subsequent surveys conducted with this camera system in Montana and Colorado produced estimates of mountain pine beetle mortality roughly equivalent to those obtained by a combination of aerial sketch mapping and large-scale color aerial photographs (Klein et al. 1980, Dillman et al. 1980). Several innovations in specialized equipment for interpretation of this unconventional format photography were devised. An equal-area grid overlay, calibrated to compensate for scale variation (figure 2), was designed by the Forest Service Engineering Staff in Washington, D.C.. When interfaced with the Defense Mapping Agency topographic data, a grid corrected for variations in aircraft attitude, panoramic geometry, and elevational changes can be produced. A technique using microfiche viewers was devised for rapid viewing of individual grids for classification of the infestation into intensity strata (figure 3), and a field stereo viewer was designed for viewing transparencies in the field to locate and delimit ground plots (figure 4).

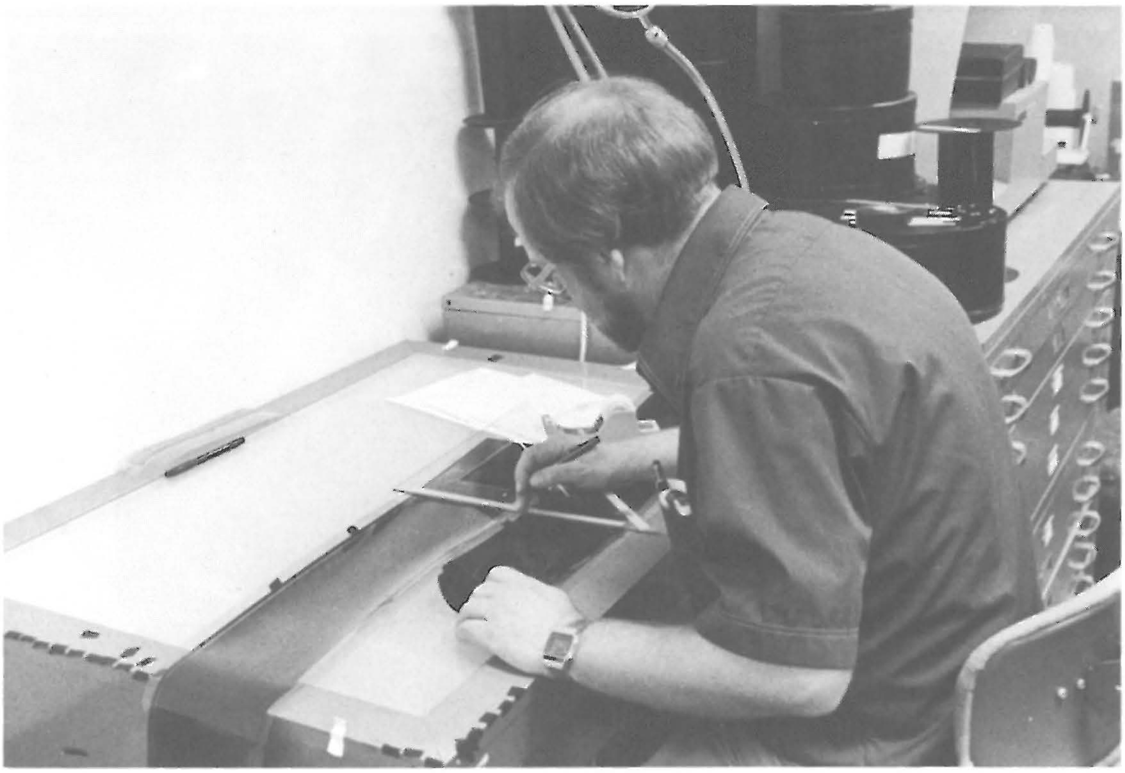


Figure 2. Placement of a grid overlay on a frame of optical bar film.

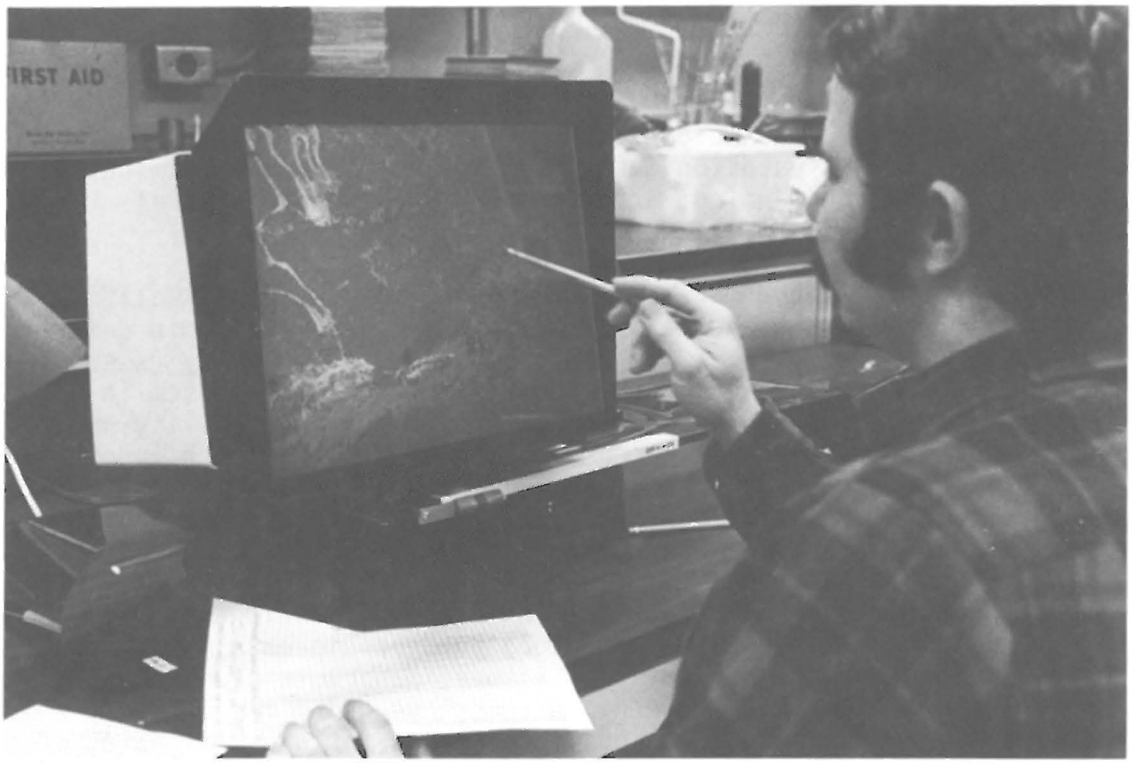


Figure 3. Using a microfiche viewer to stratify bark beetle infestation on optical bar film.

Figure 4. Viewer for examining optical bar photography in the field.

In addition, complete panoramic photo coverage of National Forest lands in northern California was obtained by the Pacific Southwest Region of the Forest Service during 1978-79. Film was distributed to individual Forests to aid in planning timber salvage sales in areas of concentrated bark beetle activity following two years of drought. A total of 1.4 million board ft. of dead and dying timber, approximately five times that sold in previous years, was removed from 13 National Forests in California during fiscal years 1978 and 1979 as a direct result of the availability of this photography (Bowlin 1979).

The panoramic camera system offers several distinct advantages in forest insect and disease management. It provides rapid, continuous coverage of large areas of forest land, as opposed to a series of sample strips or plots normally obtained with large-scale (23 cm or 70 mm) photography. This provides a permanent record of the damage over an entire outbreak area. It also permits classification of damage areas into intensity strata in a comfortable office environment, as opposed to attempting to locate and classify infested areas from low-flying aircraft, where hasty, subjective, and often inconsistent estimates are made. In addition, the photography may be of some use to other resource disciplines or cooperating agencies; therefore, cost of photo acquisition might be shared between functional staffs or cooperating agencies.

On the other hand, acquisition cost is high, perhaps as much as three times that of conventional photography, and presently there are no civilian class aircraft available to acquire photos from these altitudes. Continued availability of this service is questionable if NASA's workload should increase significantly in the future. In addition, its variable scale and unusual format makes photointerpretation and film handling more difficult.

A demonstration of panoramic photography as an effective tool for obtaining statewide estimates of mountain pine beetle mortality is planned for Colorado in 1980, and is currently underway. Objectives of this demonstration are to determine if this technique is cost-effective, and if it is an effective tool for mapping, classifying, and evaluating losses caused by forest insect and disease pests over a large area such as a state.

LITERATURE CITED

Bennett, D.D. and W.E. Bousfield. 1980. Pilot survey to measure annual mortality of lodgepole pine caused by the mountain pine beetle on the Beaverhead and Gallatin National Forests. USDA For. Serv., Northern Region, Missoula, MT (in press).

Bowlin, H.L. 1979. Optical bar camera imagery and technology applications evaluation. Unpublished report. Timber Mgmt. Staff, USDA For. Serv., Pacific Southwest Region, San Francisco, CA. 5 pp.

Campbell, R.W. 1977. Integration of program outputs: Development of a pest management system. Proceedings, ESA Symposium. Douglas-fir Tussock Moth Research and Development Program. Bull. Entomol. Soc. of Amer., 23:179-180.

Ciesla, W.M., L.E. Drake, and D.H. Wilmore. 1971. Color photos, aerial sprays, and the forest tent caterpillar. Photogramm. Engr., 36:867-873.

Ciesla, W.M. and F.M. Yasinski. 1980. Forest insect and disease information system (FIDIS) implementation plan. USDA For. Serv., FI&DM/MAG, Davis, CA, Report 80-3. 10 pp.

Dillman, R.D., S.S. Chu, B.B. Eav, and J.C. Prill. 1979. Aerial photographic technology. Development and Application Support Project: Stage III Final Report. A pilot test of high altitude optical bar camera photography to estimate annual mortality of ponderosa pine by the mountain pine beetle in Colorado. USDA For. Serv., Nationwide Forestry Applications Program, Houston, TX.

Duggan, I.E., B.E. Edwards, R.F. Liston, and A.R. Stage. 1977. Western dead timber pilot study (phase II). Final Report. USDA For. Serv., Nationwide Forestry Applications Program, Houston, TX.

Heller, R.C., and W.A. Miller. 1977. Color infrared photos defined site conditions favorable for Douglas-fir tussock moth outbreaks. Proceedings, Sixth Biennial Workshop on Color Aerial Photography in the Plant Sciences, Colorado State University, Ft. Collins, CO, pp. 43-52.

Hostetler, B.B. and R.W. Young. 1979a. A pilot survey to measure annual mortality of ponderosa pine caused by the mountain pine beetle in the Black Hills of South Dakota and Wyoming. USDA For. Serv. Rocky Mtn. Region, Denver, CO, Tech. Report R-2-15.

Hostetler, B.B. and R.W. Young. 1979b. Estimation procedures for determining annual tree mortality caused by the mountain pine beetle, Dendroctonus ponderosae. USDA For. Serv. Rocky Mtn. Region, Denver, CO, Tech. Report R-2-20.

Klein, W.H., W.F. Bailey, E. Wilson, and I.E. Duggan. 1978. Efficiency of two high elevation camera systems for assessment of insect caused tree mortality. USDA For. Serv., FI&DM/MAG, Davis, CA, Report No. 78-3. 20 pp.

Klein, W.H., D.D. Bennett, and R.W. Young. 1979. A pilot survey to measure annual mortality of lodgepole pine caused by the mountain pine beetle. USDA For. Serv., Intermtn. Region and FI&DM/MAG, Ogden, UT, and Davis, CA, MAG Report No. 78-4. 15 pp.

Klein, W.H., D.D. Bennett, and R.W. Young. 1980. Evaluation of panoramic aerial photography for measuring annual mortality of lodgepole pine caused by the mountain pine beetle. USDA For. Serv., Northern Region and FI&DM/MAG, Missoula, MT, and Davis, CA, MAG Report No. 80-2 (in press).

Wert, S.L. and B. Roettgering. 1968. Douglas-fir beetle survey with color photos. Photogramm. Engr., 44:1385-1392.

Young, R.W. 1977. Comparison of two computerized mapping systems for analysis, storage and retrieval of forest insect and disease survey data. USDA For. Serv., FI&DM/MAG, Davis, CA, Report 77-4. 28 pp

Young, R.W. 1979. Evaluation of a commercial geographic data base system for storage and retrieval of forest insect and disease information. USDA For. Serv., FI&DM/MAG, Davis, CA, Report 79-4. 36 pp.