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Riparian Forests in Minnesota: A Report to the Legislature on Harvest in 2002

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PROJECT PERSONNEL

Project Management, GIS Analysis
Tim Aunan

Statistical Design, Estimation
George Deegan

Satellite Image Analysis
Tim Aunan
Jim Rack
Sam Rajasekhar

Aerial Photo Acquisition, Interpretation
Bill Befort
Bonnie Delare
Steve Flackey
Steve Gallay

Report Preparation
Bill Befort

Project Support
Peggy Nelson

Project Oversight
David Heinzen

Minnesota Department of Natural Resources
Division of Forestry, Resource Assessment
413 SE 13th Street
Grand Rapids, MN 55744

Report Preparation, Contact for more information
Clarence Turner
Division of Forestry
Department of Natural Resources
500 Lafayette Road, Box 33
St. Paul, MN 55155-4044
651-297-3357
651-296-5459 (fax)
clarence.turner@dnr.state.mn.us

Riparian Forests in Minnesota: A Report to the Legislature on Harvest in 2002

This report summarizes the results of DNR efforts in 2002 to estimate the extent of timber harvesting in riparian areas in Minnesota and is in response to the charge from the Legislature to the Department of Natural Resources in the Sustainable Forest Resources Act (SFRA). The SFRA states:

> 89A. 05, Subd. 4. ***Monitoring riparian forests.*** *The commissioner, with program advice from the council, shall accelerate monitoring the extent and condition of riparian forest, the extent to which harvesting occurs within riparian management zones and seasonal ponds, and the use and effectiveness of timber harvesting and forest management guidelines applied in riparian management zones and seasonal ponds.*

Introduction

Riparian areas are those areas where the transition from aquatic to terrestrial ecosystems occurs. Along streams, lakes, and wetlands, soils often are wetter than in adjacent uplands and usually support rich assemblages of plants and animals unlike those of adjacent upland and aquatic systems. Riparian areas strongly influence water quality and aquatic habitat because they help regulate the flow of materials (e.g., water, soil, leaves, woody debris, anthropogenic chemicals) from terrestrial to aquatic ecosystems. The width of riparian zones (i.e., the distance from the edge of a water body to the point where the vegetation no longer reflects the influence of enhanced soil water) varies widely from place to place in response to many factors including topography and geologic history, hydrologic regime, climate and precipitation, and management activities.

Although we often use the terms "riparian areas" and "riparian management zones" interchangeably, they seldom are equivalent. Riparian management zones (RMZs) are arbitrarily defined areas adjacent to rivers, streams, lakes and wetlands, the width of which we determine to suit management objectives, such as enforcement of shoreline regulations and protection of water quality. In RMZs we often modify typical management actions to accommodate and protect the unique features and functions of riparian areas. The Minnesota Forest Resource Council's site level forest management guidelines define RMZs as "that portion of the riparian area where site conditions and landowner objectives are used to determine management activities that address riparian resource needs" (MFRC 1999). In the guidelines, recommended widths for RMZs vary primarily with water body type and size and the adjacent forest management method (e.g., even-aged vs. uneven-aged harvesting). For the purpose of estimating timber harvest in this study, we defined riparian management zones as the area within 200 feet of the shoreline of lakes, wetlands, and large rivers and within 200 feet of the centerline of small streams. Forested riparian management zones are those RMZs in the areas where forest cover is the dominant cover type as determined by the Minnesota Gap Analysis Program.[1]

Surface water is abundant in Minnesota and riparian areas occur throughout the state (Table 1). The characteristics of riparian areas generally reflect the state's broad geographic patterns of land cover and use. Nearly 50 percent of the state's riparian areas occur in agricultural areas of the western and

1 Minnesota GAP protocols for satellite image processing and vegetation classification are available at http://www.umesc.usgs.gov/umgaphome.html. Minnesota GAP vegetation maps and metadata are available to DNR users at http://maps.dnr.state.mn.us:8080/gis/dp_list.jsp?tier=1.

southwestern parts of the state while about 35 percent occur in forested portions of the northeast and southeast. The vegetative cover of a riparian area, however, depends in large part on past land use decisions, current land use, and location.

Table 1. Riparian management zones in Minnesota and the general land covers and uses in which they occur (DNR Resource Assessment 2000). Data on land cover were derived from National Land Cover Data (http://landcover.usgs.gov/natllandcover.html) maps based on 1990s satellite images.

	Riparian Lands	
General Land Cover	**Acres**	**% of total**
Agriculture	3,823,300	49.5
Forest	2,668,200	34.6
Deciduous Forest	1,401,500	18.2
Lowland Forest	860,100	11.1
Mixed Forest	225,400	2.9
Evergreen Forest	181,200	2.3
Marsh	854,400	11.1
Water	168,300	2.2
Developed	148,700	1.0
Shrub-Grassland	28,500	0.4
Barren	27,800	0.4
TOTAL	7,719,200	

Annual harvest estimates

Based on information for the period beginning in July 1999 and ending in August 2002, our estimate of statewide annual forest harvest in RMZs is 9,542 acres. This is approximately seven percent of the 133,082 acres harvested during that period and approximately 0.4 percent of the forested RMZs in the state. These estimates are similar to estimates made in 2001 (Table 2). Because we based these estimates on a sample of harvest sites rather than a complete census of harvest sites, using additional information (i.e., by increasing the sample size or obtaining data from other sources) could reduce the potential for error and improve our estimate.

Table 2. Comparison of 2001 and 2002 timber harvest monitoring results.

	2001	2002
Remote sensing observations		
Forest disturbance sites detected	5,238	12,676
Smallest harvest site (acres)	5	2
Largest harvest site (acres)	1015	750
Mean harvest site (acres)		
Satellite-based	21.8	15.9
Aerial photo-based	29.9	22.4
Forest disturbance acreage detected	114,188	201,548
Statewide estimates		
Statewide harvest (acres)	157,212	133,082
Percent of Minnesota forest land[1] harvested	1.1	0.9
Statewide harvest in RMZs (acres)	10,145	9,542
Percent of statewide harvest in RMZs	6.6	7.2
Percent of forested RMZs harvested	0.4	0.4

[1]The estimate of Minnesota forest land used in this calculation excludes forested lands in the Boundary Waters Canoe Wilderness Area and Voyagers National Park

Methods

The following discussion is a brief review of our methods for estimating annual statewide forest harvest and harvest of forests in RMZs. Aside from minor modifications identified below, we used the same methods in 2001 and 2002. (For more information on the methods used in 2001, see DNR 2002. For more information on methods used in 2002 see Appendix A.)

The work proceeded in four broad steps: 1) mapping forested riparian management zones; 2) selecting a representative sample of forest harvest sites; 3) quantifying the relationship between satellite-derived data and photo-interpreted data on harvest; and 4) calculating statewide harvest estimates.

Mapping forested riparian management zones - The task of creating a statewide map of RMZs and describing patterns of ownership and land use in them was completed in 2000. (See DNR Resource Assessment 2000 for details.) Briefly, we combined separate GIS data sets that characterize different types of surface water bodies to form a single integrated data set that better characterizes the physical connections between them at a well-known and widely accepted level of detail. The data sets described intermittent and perennial streams, drainage ditches, ponds, lakes, and wetlands. The metadata describing this GIS data layer are available at http://dnrnet.state.mn.us/mis/gis/gisdata.html. See Table 3 for a description of the water bodies included in the RMZ data set.

Table 3. Geographic information used to construct the Minnesota DNR 200-Foot Riparian Zone map and GIS coverage. This coverage was completed in December 2000 using versions of the input datasets that were available at that time. Revisions to the input datasets made after that date have not been incorporated into the riparian zone coverage.

Type of water body and DNR dataset name	**Source of data for DNR dataset**	**Minimum size mapped by source**	**Additional information**
Lakes *DNR Lakes (1:24K)*	National Wetlands Inventory (NWI)	Generally 2.5 acres	The NWI digitized lakes using 1980s-vintage aerial photographs and USGS quadrangle maps primarily from the 1970s and 1980s. Large rivers and streams in the NWI were included in *DNR Lakes (1:24K)*. The 200-Foot Riparian Zone GIS coverage does not include riparian buffers around islands.
Wetlands *National Wetlands Inventory Polygons*	National Wetlands Inventory	Generally 2.5 acres; in treeless areas wetlands as small as 0.10 acre may be mapped	The NWI included all wetlands mapped by the U.S. Fish and Wildlife Service during field surveys and via photo-interpretation. Actively farmed wetlands were not mapped. In areas of coniferous forest, wetlands smaller than 3 acres may not be mapped. Only wetlands classified as inland shallow fresh marshes, inland deep fresh marshes, and inland open fresh water in NWI were included in the 200-Foot Riparian Zone GIS coverage.
Rivers and Streams *DNR 24K Stream Types*	USGS 7.5-minute quadrangle maps	Unknown; it is likely that many small headwater streams in forested areas were not included in the USGS maps.	Rivers and steams were digitized from the most recent versions of USGS printed maps available in the late 1990s by a consortium of state agencies, universities, and private contractors. Additional information from aerial photographs and local sources was used to improve map accuracy where available. Efforts to improve the dataset are currently underway.

Selecting a representative sample of forest harvest sites - Satellite images capture the patterns of light reflected from vegetation and other land covers on large areas of the earth's surface. Comparing images of the same area at different times highlights many types of disturbance during the intervening period, including forest harvest, that change the amount or quality of light reflected back into space. We compared images obtained in 1999 or 2000 (Time 1) with images of the same areas obtained in 2002

(Time 2) to identify sites that may have been harvested during the interim. In 2001, only sites that were 5 acres or larger were included in our analysis. This year at the request of the Minnesota Forest Resources Council we included sites as small as 2 acres.

We used images from several dates within each time frame in order to minimize the area obscured by clouds. Thus Time 1 included images from July 1999 to July 2000 and Time 2 included images from July and August 2002. All harvest estimates, however, are estimates for a one-year period. The 20 images (10 for each time period) we used provided data for approximately 70 percent of the state's forested area.

Significant changes in the tree canopy from all causes (forest harvest and non-forest harvest activities) between Time 1 and Time 2 occurred at 12,676 sites within the area depicted by satellite images. Sites ranged in size from 2 acres to 750 acres with an average size of about 16 acres. From these sites we drew samples for more detailed examination to verify harvest and more accurately measure the harvested area.

Quantifying the relationship between harvest area estimates from satellite images and from aerial photographs - We randomly selected 300 sites (up from 200 in 2001) from the larger pool of satellite-identified disturbances to be photographed from the air in October and early November 2002. Of these 300 sites, we obtained large-scale photographs with sufficient visual detail for accurate interpretation of 280. Of the 280 photographed sites, 247 included tree removals. On 33 sites no tree removal or other disturbance was visible. Most (79 percent) of these 33 "no change" sites were 5 acres or smaller in size. "No change" sites amounted to 23 percent of all 2-5 acre sites but only 4 percent of the sites greater than 5 acres.

Using standard photointerpretation and GIS procedures we measured the total acres harvested and acres of harvest within RMZs for all harvest sites. Sites where tree removals or other disturbances were not the result of standard forest management activities (e.g., land clearing for building construction) were assigned a value of 0 acres of harvest. Paired data on harvested acres measured on aerial photographs and disturbance acres on corresponding satellite images (for 280 sites) were used to calculate a quantitative (linear) relationship. We used this equation to estimate acres of harvest in the area covered by satellite imagery. In addition, we used the proportion of total harvest that occurred in RMZs on aerial photographs as an estimate of the proportion of total harvest that occurred in RMZs in satellite images.

As in 2001, we conducted an independent test of the effectiveness of the satellite-based disturbance detection procedure. We selected 80 1x6-mile blocks distributed statewide in proportion to the occurrence of forest cover (i.e., with forested areas more likely to be selected than areas without forest). Using the same cameras and procedures, we obtained aerial photographs of 33 of these blocks and delineated all apparent recent tree removals. For the remaining 47 blocks, we identified recent removals visually from the air. During this test, we used no information derived from the satellite image analysis to identify harvest sites. Results of this test support the 2001 finding that satellite change detection procedures are adequate for identifying forest harvests:

- We found no harvest sites that had not also been identified by satellite (aside from one that had been obscured by clouds at the time of the satellite overpass).
- Several sites of 5 acres or less that had been detected by satellite were missed by photointerpreters.

Calculating statewide harvest estimates - We calculated our statewide estimates of harvest using the quantitative relationship obtained in the previous step and an expansion factor based on the proportion of the state's forested area covered by satellite imagery. The linear relationship allowed us to adjust for differences between satellite-delineated harvest areas and photo-interpreted harvest areas and to account for disturbances not related to forest harvest. The expansion factor allowed us to extrapolate data obtained from a portion of the state to an estimate for the entire state. See Appendix A for more detail on how these adjustments were made.

Additional Observations

This year's effort to estimate riparian harvest provided additional evidence that combining dual-date satellite imagery and aerial photography is an effective means of estimating forest harvest. As we gain experience with these methods under a wider range of conditions (e.g., more extensive insect defoliation, harvest practices that leave significant amounts of canopy intact) accuracy will improve, other data needs will can be fulfilled, and the cost will decline.

Decreasing the minimum size of disturbance to be considered (from 5 acres in 2001 to 2 acres in 2002) likely resulted in more detection errors, especially in smaller-acreage sites. These errors involve a relatively small number of acres and are a minor source of error in estimates of harvest acreage. A smaller minimum disturbance size, however, likely increased our ability to detect harvested areas that have accumulated significant amounts of regrowth. When there is a long time between harvest and the Time 2 satellite images (i.e., harvest occurs soon after the Time 1 image), vegetative regrowth may make it appear on satellite images that no harvest has occurred. The site then may be identified only by the presence of small patches, typically landings, where regrowth was slower.

References

DNR Division of Forestry. 2002. Harvest of Riparian Forests in Minnesota: A Report to the Legislature. DNR Document MP-0602.

DNR Division of Forestry. 1999. Minnesota's Forest Resources. St. Paul, Minnesota: Minnesota Department of Natural Resources.

DNR Resource Assessment. 2000. Minnesota's Riparian Lands Map. Grand Rapids, Minnesota: Minnesota Department of Natural Resources.

MFRC. 1999. Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. St. Paul, Minnesota: Minnesota Forest Resources Council.

Satellite-Based Forest Harvest Monitoring: 2002 Report

Wm. Befort, Timothy Aunan, George Deegan
Resource Assessment, Division of Forestry
Minnesota Department of Natural Resources
413 SE 13th Street, Grand Rapids MN 55744

Abstract

The second consecutive year of regular satellite monitoring of Minnesota forest harvests is described. Annual statewide removal acreage estimates and riparian harvest acreage estimates are reported.

Introduction

In 2001 the Resource Assessment Unit, Minnesota Department of Natural Resources (DNR) began continuous monitoring of forest harvests on all land ownerships by satellite image analysis. The project was an attempt to satisfy simultaneously, through a unified approach based on large-area remote sensing and geographic information systems (GIS), three independent data requirements earlier addressed separately by disparate means:

- to estimate total timber removal acreage statewide,
- to estimate total riparian acres affected by timber removals statewide, and
- to identify recent harvest sites suitable for field visits in the Guideline Implementation Monitoring (GIM) program, testing compliance with forest practices guidelines.

Procedures and outcomes of the first year's installment of work were reported in detail by Befort and Deegan (2002). Briefly:

1. Two sets of Landsat 7 multispectral images, summer 1999 and summer 2001, were purchased. These scenes covered about 70 percent of the state.
2. Forested areas were separated from nonforest in the images. Within the former, between-date image differencing was used to detect removals and estimate their acreage.
3. From the thousands of sites detected, a subsample of 200 was randomly selected and photographed from the air. Those with actual harvests became GIM field sites.
4. Harvest measurements from the photographs were used to adjust the acreage estimates made from satellite data. The adjusted acreages, converted to an annual basis and expanded to include the remaining 30 percent of the state, became the statewide total timber removal estimate.
5. The satellite harvest images were overlaid on statewide riparian zone maps in a GIS to derive the estimate of harvested riparian acres.
6. A separate set of aerial photos was taken and interpreted to test reliability of satellite harvest detection.

2002 Operational Plan

The 2001 project was planned as the initial installment of a continuing survey covering the entire state every two years, and 2002 work followed its general outlines. The biennial scheme was heavily influenced by the anticipated workload and the midwinter reporting deadline for some of the output data. Work could not begin before acceptable current summer satellite imagery was available, approximately in September; harvest detection would have to be complete on all satellite scenes before sampling flights could be made, and site photointerpretation would be unreliable after appreciable snow accumulation, which could easily occur in November. Of the 20 satellite scene pairs necessary to cover the whole state, it had been calculated that only half could be processed under this time constraint with existing personnel and facilities.

Fortunately, Landsat orbital paths intersect the state in such manner that an annual purchase of 10 scenes from alternate paths covers 70 per cent of the state's area every year. Figure 1 shows the arrangement of satellite scenes with respect to the state, and gives dates of images for the 2001 and 2002 iterations of the project.

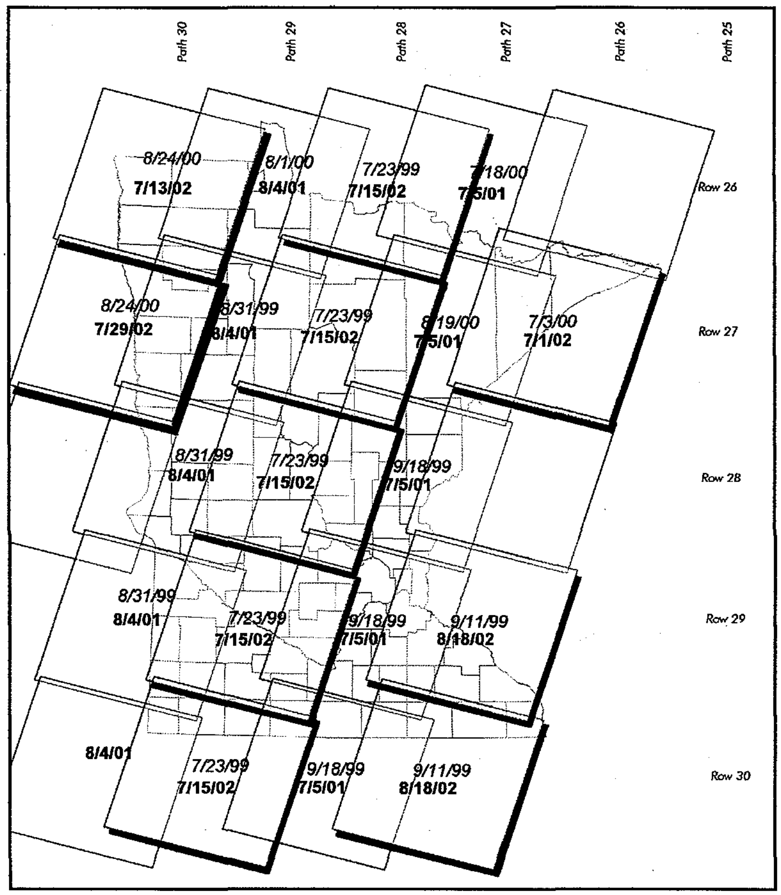

Figure 1: Landsat 7 image acquisitions. Drop-shadow scenes were processed in the 2002 iteration. Upper dates are Time 1 images, lower are Time 2.

The 2002 workplan differed from that of 2001 in some respects:

- Because of a scheduled hiatus in GIM field survey, identifying GIM candidate harvests was not a requirement for 2002.
- As the 2001 tests provided strong evidence that between-date Landsat image differencing was as reliable a tool for removal detection as single-date aerial photography, the testing phase received less emphasis in 2002.
- However, the number of detected sites to be photographically sampled for acreage adjustment was raised was raised from 200 to 300.
- The most significant change, arising out of a request from the Minnesota Forest Resources Council, was a lowering of the detection threshold for forest removals from the 2001 5-acre minimum to 2 acres.

A 2-acre harvest minimum might be expected to press the limits of possibility in Landsat-based disturbance detection. A Landsat 7 Enhanced Thematic Mapper (ETM) multispectral scene (Figure 2) consists of a rectangular array of approximately 6000 x 6000 picture elements (pixels) covering an area of 180 x 180 kilometers (110 x 110 miles). Each pixel measures 30 x 30 meters in ground dimensions – about 100 x 100 feet, or roughly ¼ acre. A 2-acre harvest may thus involve as few as 8 of the 36 million pixels in the scene. This is near the level of random "noise" likely to arise in any between-date satellite image comparison through geometric misregistration, atmospheric interference and other inexactitudes.

In both iterations, satellite detection of harvests labored under a significant accidental handicap: in northern Minnesota, 2001 and 2002 were peak years for defoliation of hardwood species by the forest tent caterpillar (*Malacosoma disstria* Hubner). In both summers literally millions of acres were attacked. This created dilemmas. At 30-meter image resolution, defoliation mimics partial harvesting. Laborious analyst intervention may be necessary in order to minimize mistakes in the harvest-detection process; this extends the analysis period and reduces time available for flight and photointerpretation. As tent caterpillar defoliation occurs in early summer, its effects can be palliated by waiting till refoliation in late summer before acquiring imagery; however, delay in acquiring imagery similarly cuts the total time available for the entire process. And because more than half of satellite images are likely to be unusable in any case because of clouds, waiting 16 days for Landsat 7 to revisit a given location may result only in lost time, with no compensating advantage.

Other satellites are available and usable for change detection, some having better spatial resolution than Landsat. Their imagery generally costs much more than Landsat's 5 cents per square mile. Moreover, any change detection work over time requires the closest possible correspondence between datasets representing Time 1 and Time 2; heterogeneous imagery used as a stopgap would be likely to introduce more problems than it would remedy.

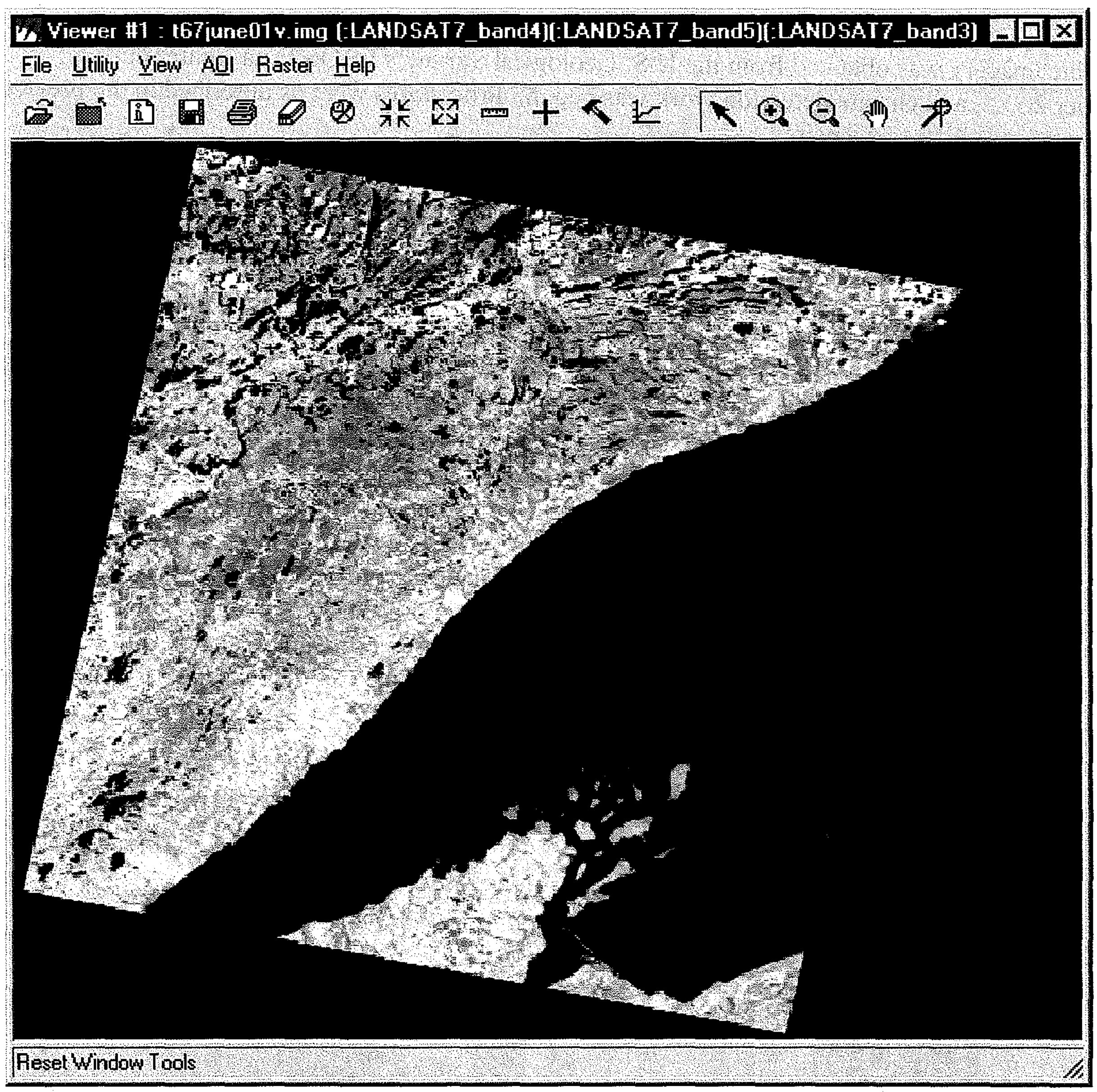

Figure 2: A single Landsat 7 ETM multispectral image covers 7.7 million acres. Each individual picture element covers a 100-foot square on the ground, and contains information from six bands in the visible, near-infrared and mid-infrared portions of the electromagnetic spectrum. Current purchase price is only $600.

Image Analysis

All satellite imagery was obtained from the U.S. Geological Survey's EROS Data Center during September 2002 , and change detection work was begun. Procedures were as described in the previous year's report for all 10 scene pairs:

- Images were geometrically corrected and referenced to the DNR-standard NAD83 UTM extended Zone 15 projection. The Minnesota Department of Transportation statewide roads coverage served as the accuracy standard. Image-to-image registration was performed at each scene location.
- Original multispectral brightness values were converted to at-satellite reflectance. This radiometric calibration adjusts for differences in solar elevation, distance, and sensor differences over time between the two images.
- Clouds and cloud shadows were detected and excluded from consideration by Normalized-Difference Cloud Index techniques.
- The existing Gap Analysis Project vegetation map of Minnesota was used to restrict change detection to areas previously classified as forest.
- A multispectral differencing algorithm was used to detect forest disturbances likely to involve vegetation loss. These disturbances were visually edited scene by scene, and compiled into a statewide raster layer containing 12,676 change sites, representing a nominal 95,263 acres. Each site was given an identifying number. About 40 percent of the change sites appeared to be under 5 acres (Figure 3).

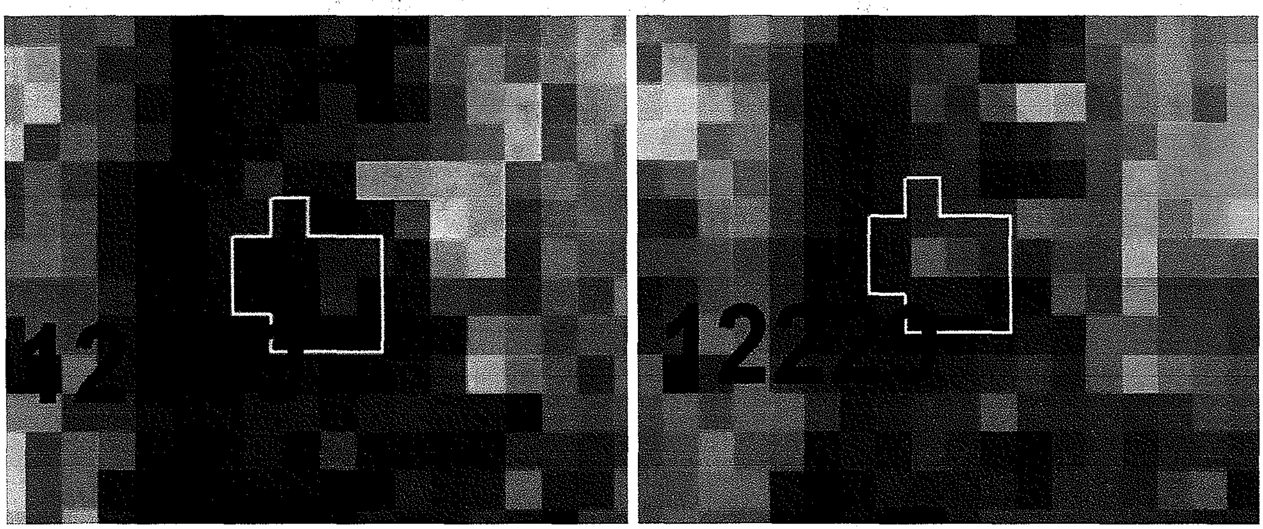

Figure 3: Matching portions of two Landsat 7 images, summer 1999 left and summer 2002 right. 30-meter picture elements are clearly evident. Yellow outline indicates a detected forest disturbance of about 3 acres.

Sampling Photography and Interpretation

From the statewide list of forest disturbance sites, a sample of 300 was drawn randomly for aerial photography. The sample spanned the entire state (Figure 4). These sites were flown during October and November, using medium-format cameras and high-speed color film (Figure 5). Lenses, film and flying altitude were chosen to allow completion of the project in adverse weather and under overcast conditions. For each site flown, photographers were supplied with site images (Figure 6) extracted from the satellite imagery, showing the change polygon to be photographed and any neighboring polygons with which the target might be confused.

Of the 300 sites flown, 280 yielded interpretable photographs; the remainder were badly exposed or could not be accurately georeferenced. The 280 usable photographs were rectified against digital orthophoto quadrangles, and displayed for interpretation in the ESRI Arc/View 3.3 GIS (Figure 7), which also permitted viewing of the Landsat images and other ancillary datasets as overlays. Interpreters delineated the photographed harvests, and the system measured their acreage.

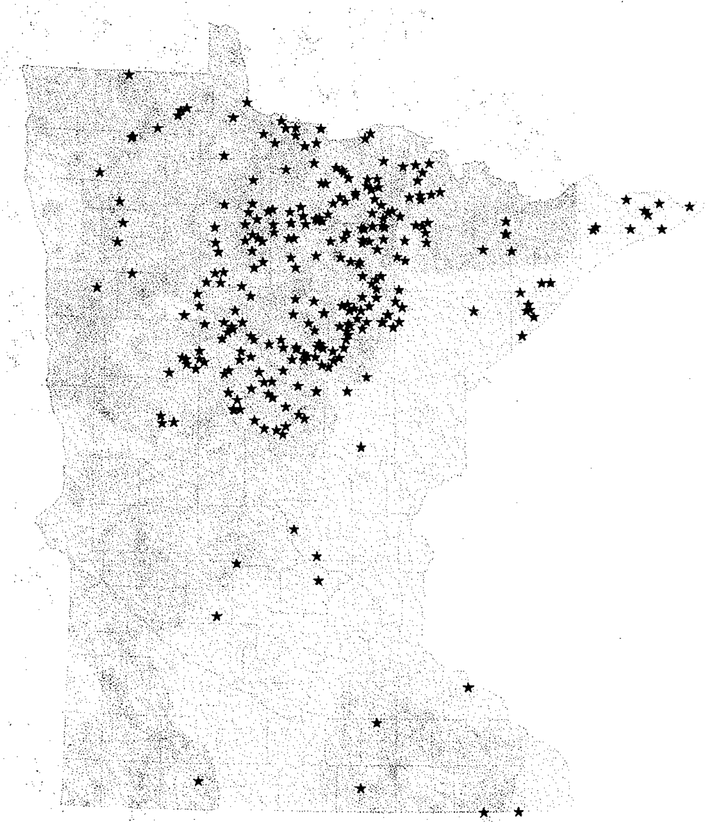

Figure 4: From over 12,500 satellite-detected forest disturbance sites, 300 were selected for photo sampling and acreage measurement.

As in the 2001 iteration, a separate aerial reconnaissance was conducted as a check on the reliability of satellite disturbance detection. A total of 80 1x6-mile (3840-acre) north-south strips within the satellite coverage area were selected with probability proportional to their mapped forest acreage. Of these, 33 were photographed and the rest examined visually from the air to identify any recent removals not detected by satellite image analysis. No previously undetected harvests were found, aside from a single instance in which cloud had concealed the site from the satellite's view. However, several sites in the 2-5 acre class detected by satellite were missed by photointerpreters in this phase. This exercise tended to confirm the 2001 finding that dual-date satellite change detection is at least as sensitive a detector of harvest activity as single-date aerial photography.

Figure 5: Resource Assessment photographers used Pentax 645-format cameras (shown above with aerial mount) and Kodak Portra 400VC color-negative film. The 41x56mm format size captures more detail than 35mm photography at equivalent scales. Photos were produced as nominal 1:6000 scale prints and scanned at 300ppi for interpretation.

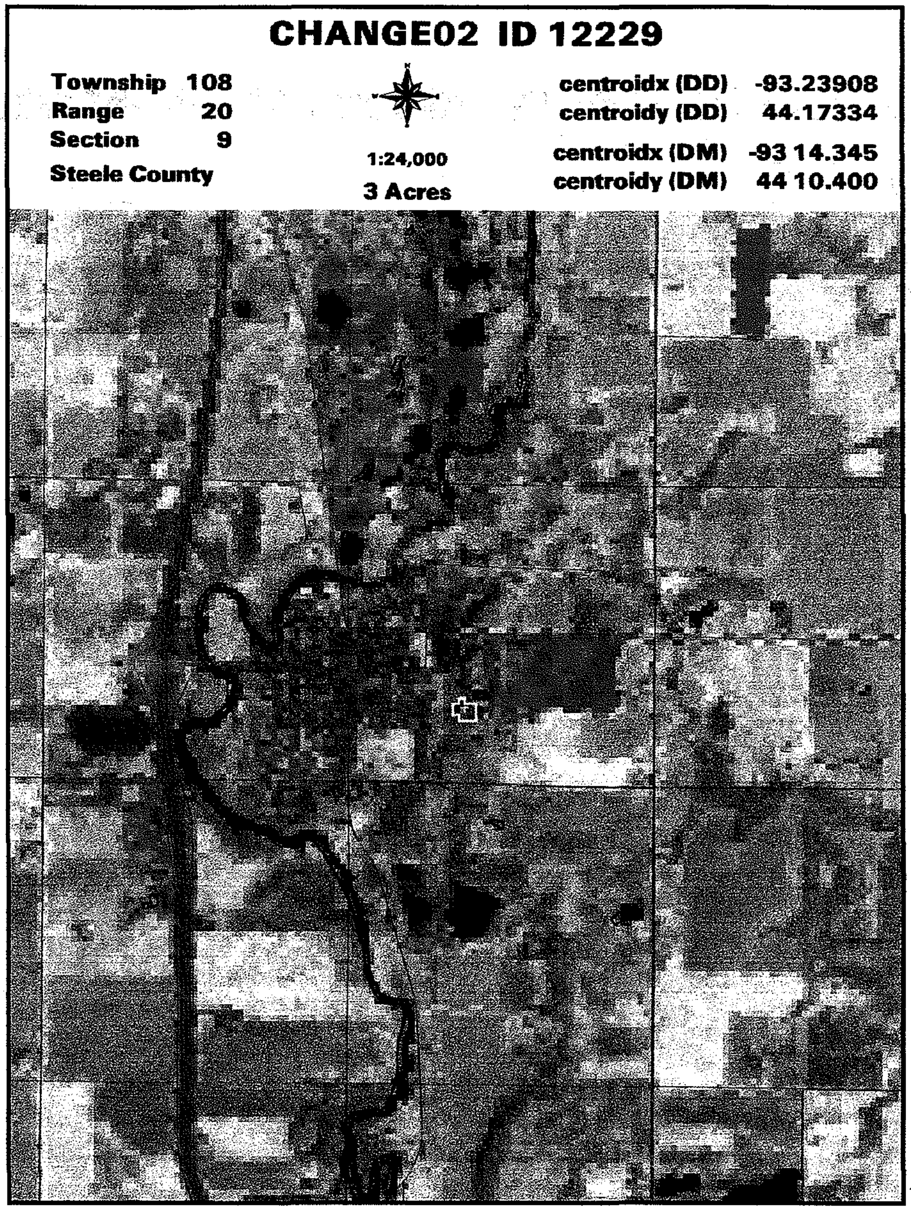

Figure 6: Individual site maps made from Landsat images guided aerial photographers to correct locations for sample photos. The satellite-detected disturbance site itself, at Medford MN (between Faribault and Owatonna, same site as Figure 3), is outlined in yellow at the center of the image. Marginal information gives geographic coordinates, legal description and satellite-measured disturbance acreage.

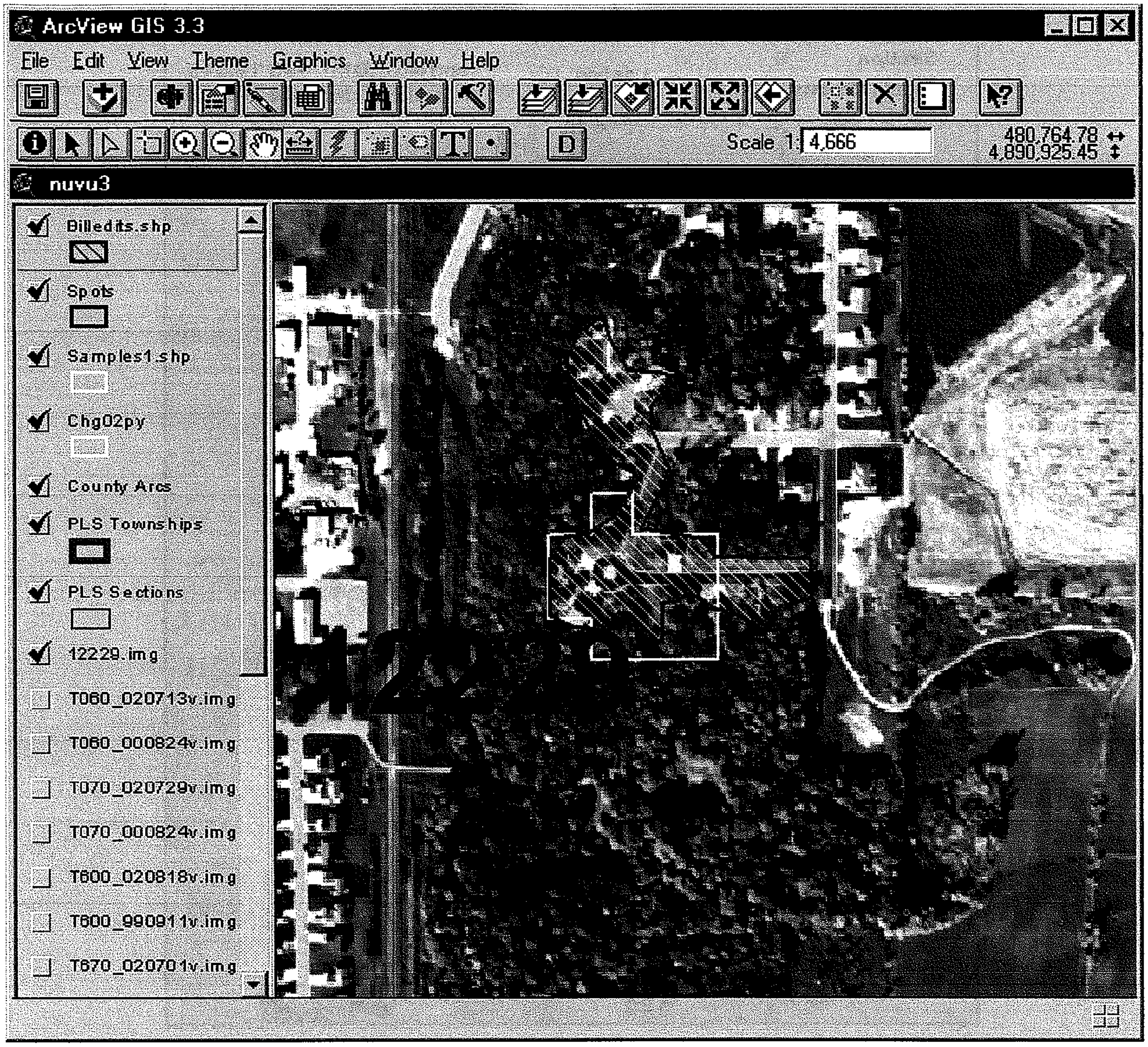

Figure 7: Interpreters viewed satellite-detected forest disturbance (yellow outline) against a rectified aerial photo image in ArcView GIS, and visually delineated the corresponding actual disturbance (red polygon with hatching). Acreage of the polygon outlined by the interpreter was calculated by ArcView. Photo-measured acreages were then regressed on satellite-measured acreages. Site is the same as in Figures 3 and 6.

Data Analysis

Satellite-detected removals were annualized by dividing their acreage by the years separating the image dates on which they were detected. Photo-measured acreages were similarly adjusted. For the 280 sampled removal sites, photo-measured acreages were regressed on satellite-measured acreages (Figure 8). From the regression relationship, total annual harvest acreage was calculated for the forested portion of the satellite image coverage area, and then expanded to include both cloud-masked forest within the Landsat imagery footprint and the forested portion of the state outside the footprint, assumed to be harvested at the same rate. Acreage calculations excluded the Boundary Waters Canoe Area Wilderness (BWCA) and Voyageurs National Park (VNP), where no harvesting is permitted.

Photo-delineated removals were overlaid on the existing statewide 200-foot Riparian Management Zone (RMZ) coverage to estimate the fraction of harvests affecting riparian areas; this was also expanded to a statewide figure as above.

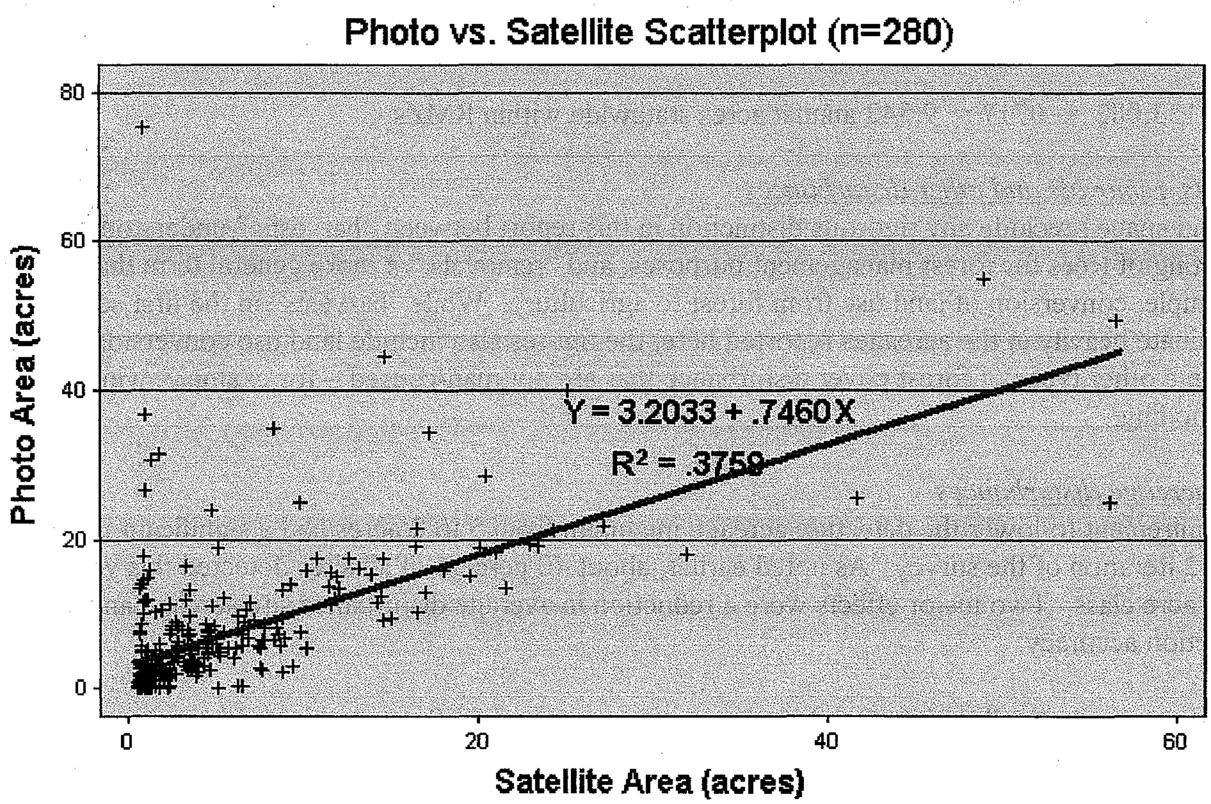

Figure 8: Photo-delineated harvest acreages were regressed on satellite-estimated harvest acreages to adjust the removal estimate prior to its expansion statewide.

Results and Discussion

Statewide annual harvest estimate

The linear regression relationships between annualized satellite-detected and photo-measured harvest acreages were applied to the mean acreage per site and then expanded:

- 3.2033 + (.7460 x 5.78 satellite acres/site) = 7.5152 acres/site ± .886 at 95% confidence
- 7.5152 acres x 12,676 sites = 95,263 annual removal acres in satellite imagery area

Forest acres in the satellite imagery area, excluding BWCA, VNP and cloud area, total 10,684,303. Mapped forest areas in the entire state, again excluding BWCA and VNP, come to 14,927,587, which yields an expansion ratio of 1.397.

- 95,263 x 1.397 = 133,082 annual removal acres statewide, ± 15,690 at 95% confidence

Annual riparian harvest estimate

Of the harvest acreage represented in the 280 photo-measured sites, 7.17 percent lay within mapped RMZs. Applying this:

- 133,082 x .0717 = 9,542 annual acres statewide within RMZs

Harvests, removals and other disturbances

Time and space preclude any rigorous distinction in this report between "harvests," understood as sale and cutting of trees for forest management purposes, and "removals," a more general term that includes, for example, conversion of land use from forest to agriculture. While "harvests" in the first sense predominate heavily in the acreages reported here, the figures also include land use conversions, together with some other types of forest cover disturbance that are not man-caused – for example, windthrow and local flooding.

Small-acreage disturbances

The requirement to lower the detection acreage minimum from 5 to 2 acres had a significant impact on the 2002 iteration of the survey. As noted earlier, about 40 percent of all sites detected this year were in the 2-5 acre class. Two major effects were a reduction in average disturbance site acreage and a disparity in detection accuracy:

- Last year's satellite-detected disturbance sites averaged 21.8 acres; this year's averaged 15.9 acres. Last year's photographed disturbance sites averaged 29.9 acres; this year's averaged 22.4 acres. (Figures are raw, non-annualized acreages.)
- Detection errors were more frequent with smaller-acreage sites. Photointerpreters identified 33 of the 280 samples as "no change" sites, showing no visible forest disturbance at the target. Of these erroneous detections, 26 (79 percent) were in the 2-5 acre class. "No change" sites amounted to 23 percent of all 2-5 acre sites sampled, but only 4 percent of sites greater than 5 acres.

Literature Cited

Befort, W. A. and G. Deegan. 2002. Change analysis applications in DNR resource monitoring. Resource Assessment, Division of Forestry, Minnesota Department of Natural Resources, Grand Rapids. 16p.

--Submitted January 27, 2003