Quantifying partial harvest intensity and residual stand composition among stable and changing forest landowner groups in northern Maine

Principal Investigator:

Steven A. Sader, Professor and Director of Maine Image Analysis Laboratory (MIAL), School of Forest Resources, 260 Nutting Hall, University of Maine, Ph. 207 581-2845, Fax. 207 581-2875, E-mail. sasader@maine.edu

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• The research demonstrates a practical approach to combine digital and manual remote sensing interpretation methods using free, public domain satellite and aerial imagery to examine multiple landowner harvest intensity and their effect on residual stand composition and density.

• Interpretation of high resolution stereo photo plots from 1997 and 2007 revealed significantly higher overstory crown closure removals for forestland that changed from (1) Industrial ownership to TIMO/REIT and (2) from Industrial to other Non industrial owners, compared to stable industrial owners.

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Project Summary

This research utilizes multi-temporal and multi-resolution remote sensing methods to examine differences in harvest intensity and post-harvest stand composition among stable and changing private forest ownership types on unorganized townships in Northwestern Maine.(1.8 million ha). We applied a two-level sampling approach based on satellite change detection and aerial photo interpretation to quantify approximately 14 years of harvest intensity and residual stand composition and density .

A spatial database of private landownership groups (1993-2007) composed of parcels which experienced unique histories of ownership change were combined with time-series harvest maps to develop a sampling frame for photo interpretation. Scanned stereo aerial photos were acquired at 3 time periods (circa 1992/93 – 1997- 2007). 725 two hectare stratified random photo sample plots were selected within the ownership groups and visually interpreted to record overstory and understory forest type (S,SH,HS,H), and crown closure percent at pre and post harvest dates. Significant differences in crown closure percent (indicator of harvest intensity) were observed among forestlands with different landowner change history. Softwood dominant stands had the highest crown closure changes and hardwood species represented higher percentages in post harvest stands. The methods are applicable to other regions.

Background and Justification

Major land sales among different landowner groups, particularly in the past two decades, along with forest policy changes, have influenced harvesting practices that have shifted from clearcutting in the late 1970s and 1980s to extensive partial harvesting in the late 1990s to present. There are gaps in our knowledge about the intensity of partial harvesting and the composition and density of residual stands in Maine's privately owned forests. Extensive partial harvesting may lead to landscape level composition and stand structure changes that could affect stand quality, biodiversity, and wildlife habitat for some keystone species.

Ground-based forest measurement data spatially distributed over large regions and multiple ownerships is expensive and time-consuming to acquire. Landsat time-series satellite imagery has proven to be a cost-effective tool to map broad forest types and monitor forest disturbance and trends. Landsat imagery, however, with ¼ acre ground pixel resolution is less capable of quantifying stand density accurately. Photo interpretation has been long accepted in remote sensing research as a tool to map forest type and stand density to support larger landscape mapping studies using satellite imagery.

Background and Justification

The research demonstrates a practical approach to combine digital and manual remote sensing interpretation methods using free, public domain satellite and aerial imagery to examine landscape scale patterns of multiple landowner harvest intensity and their effect on residual stand composition and density. The methods are transferable to other northern forest regions and applicable for statewide analysis.

The study area (figure 1) is approximately 1.8 million ha, generally flat to rolling with a few mountains. Forest types consist primarily of spruce (*Picea spp*.), balsam fir (*Abies balsamea*) maple (*Acer spp.)*, ash (*Fraxinus spp.)*, and northern white cedar (*Thuja occidentalis)* wetlands.

Urban and residential development is minimal. Harvesting is the common disturbance type for this area. Forest ownership types and the recent history of ownership change within this region are broadly representative of the unorganized townships of northern Maine.

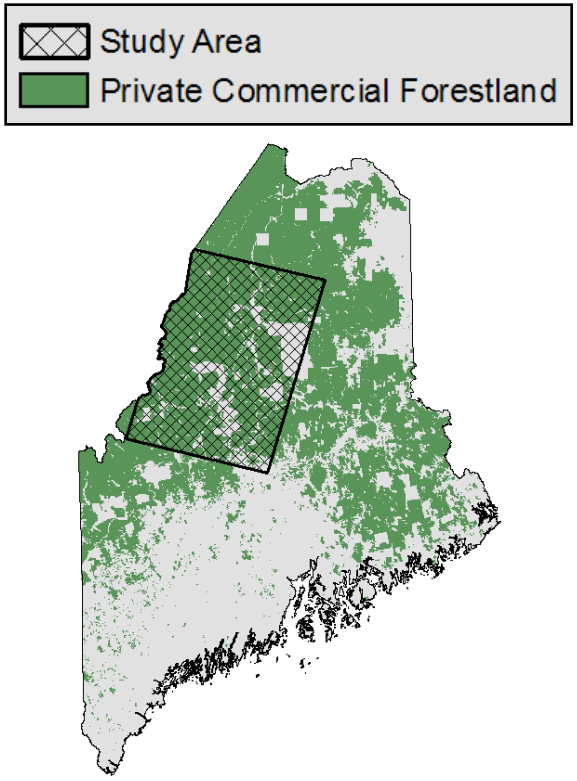


Figure 1. Northern Maine study area

Methods

We combined time-series (1993, 2000, 2004 and 2007) Landsat image processing for regional forest disturbance mapping and traditional aerial photo interpretation methods on sample areas to quantify residual stand composition and harvest intensity. Landowner maps (1993/94, 2000, 2004, and 2007) obtained from a private forest engineering company were integrated to define parcels with common histories of forestland ownership.

Preparation of time-series forest harvest and ownership maps provided a sampling frame for aerial photo interpretation of harvest intensity and residual stand condition among different landowner groups. 1 meter imagery from the National Agricultural Imagery Program and the National Aerial Photography Program were processed using Leica Photogrammetry Suite and coupled with a 10m digital elevation map to create orthorectified stereo imagery. ArcGIS Stereo Analyst Extension was employed to interpret 725 plots stratified across ownership groups. The photography acquired for 1992/93, 1997, and 2007 provided sufficient temporal depth to assess harvest practices among the major ownerships types, including stable industrial forest products companies, stable family-owned non industrial entities, other non industrial owners, changing landowners, timber investment management organizations (TIMO) and real estate investment trusts (REIT).

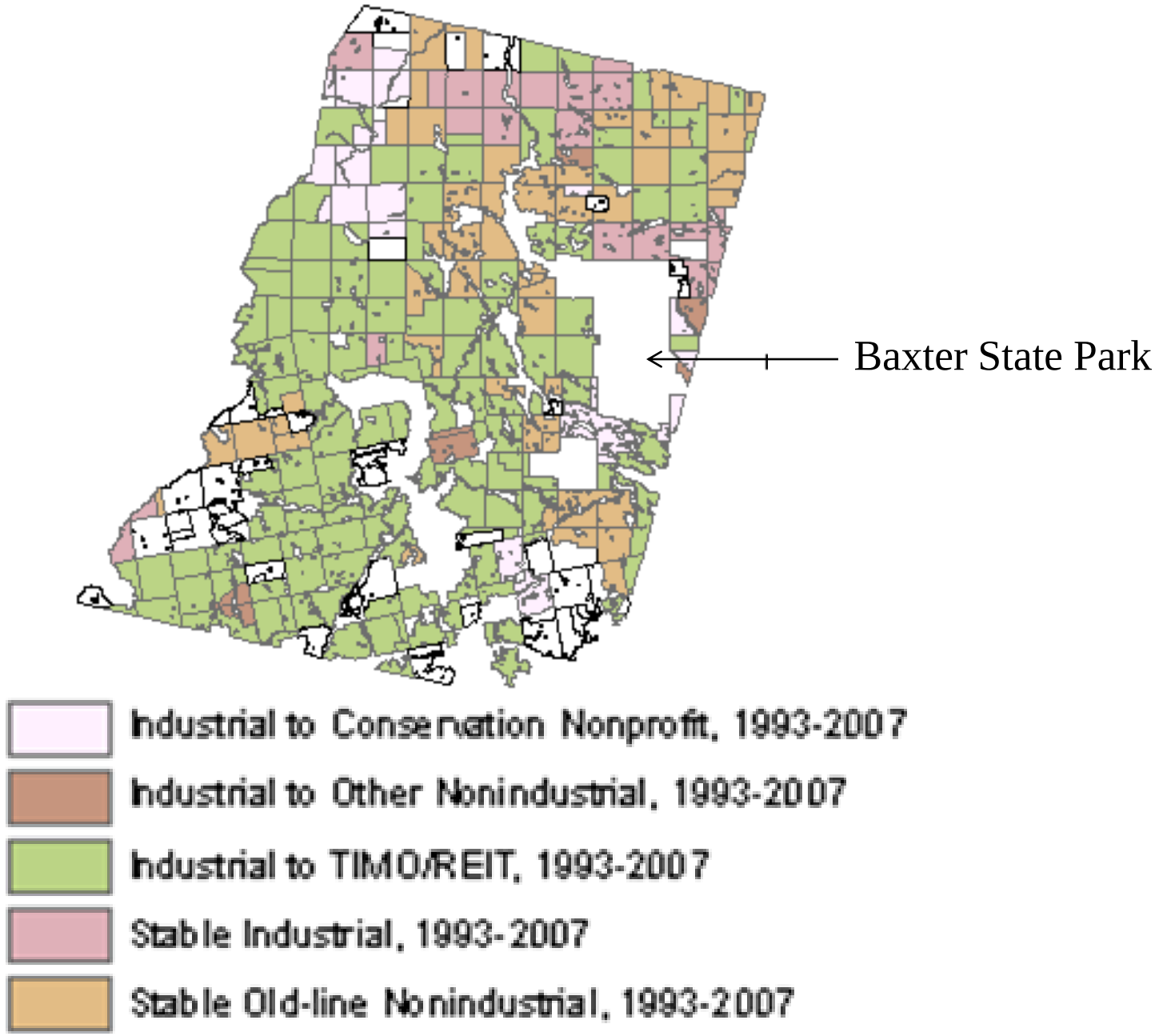
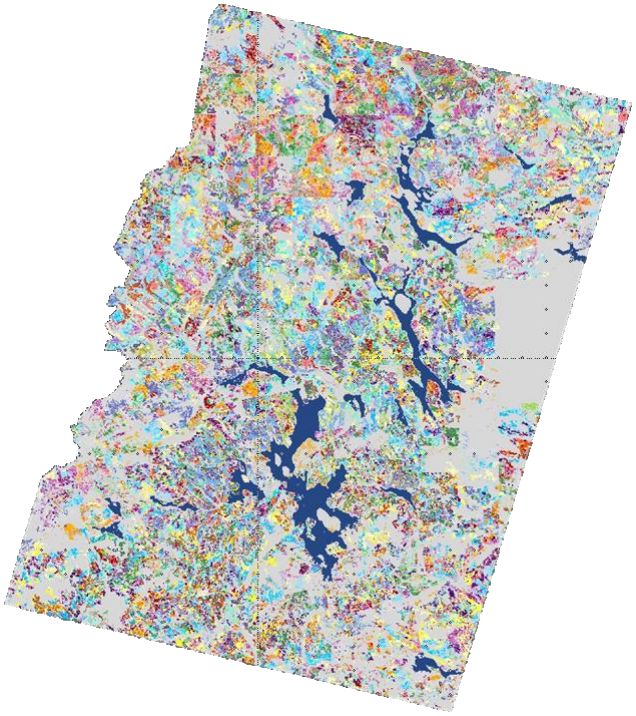


Figure 2. Landowner change and stable ownership groups within the Maine study area. Lakes and other conservation area shown in white background.

Forest Harvest Time-series



Colors represent different periods of harvesting

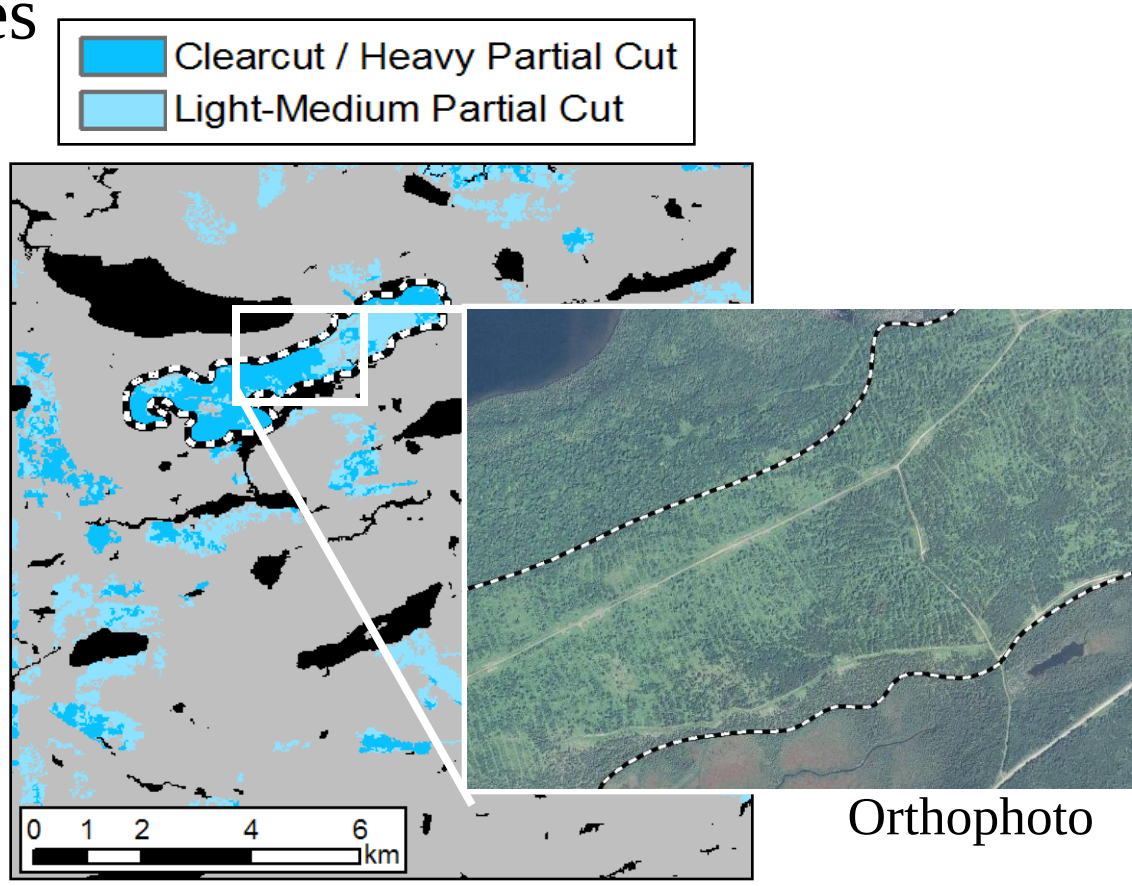


Figure 3. Landsat time series harvest maps differentiate two harvest intensity classes, interpreted as clearcut/heavy partial (CHP) and light-medium partial (LP) harvest. The period (1993– 2007) coincides with the expansion of partial harvest practices following the adoption of the Maine Forest Practices Act.

Methods

Random samples of 2 ha aerial photo plots in harvested sites were selected from six townships in four ownership groups. Many plots were not interpretable on all dates of acquired photos due to sun glare or low-angled photos and removed from the analysis, giving a final count of 725 plots. Photo interpretation quantifies stand composition and canopy percent cover before and after harvests.

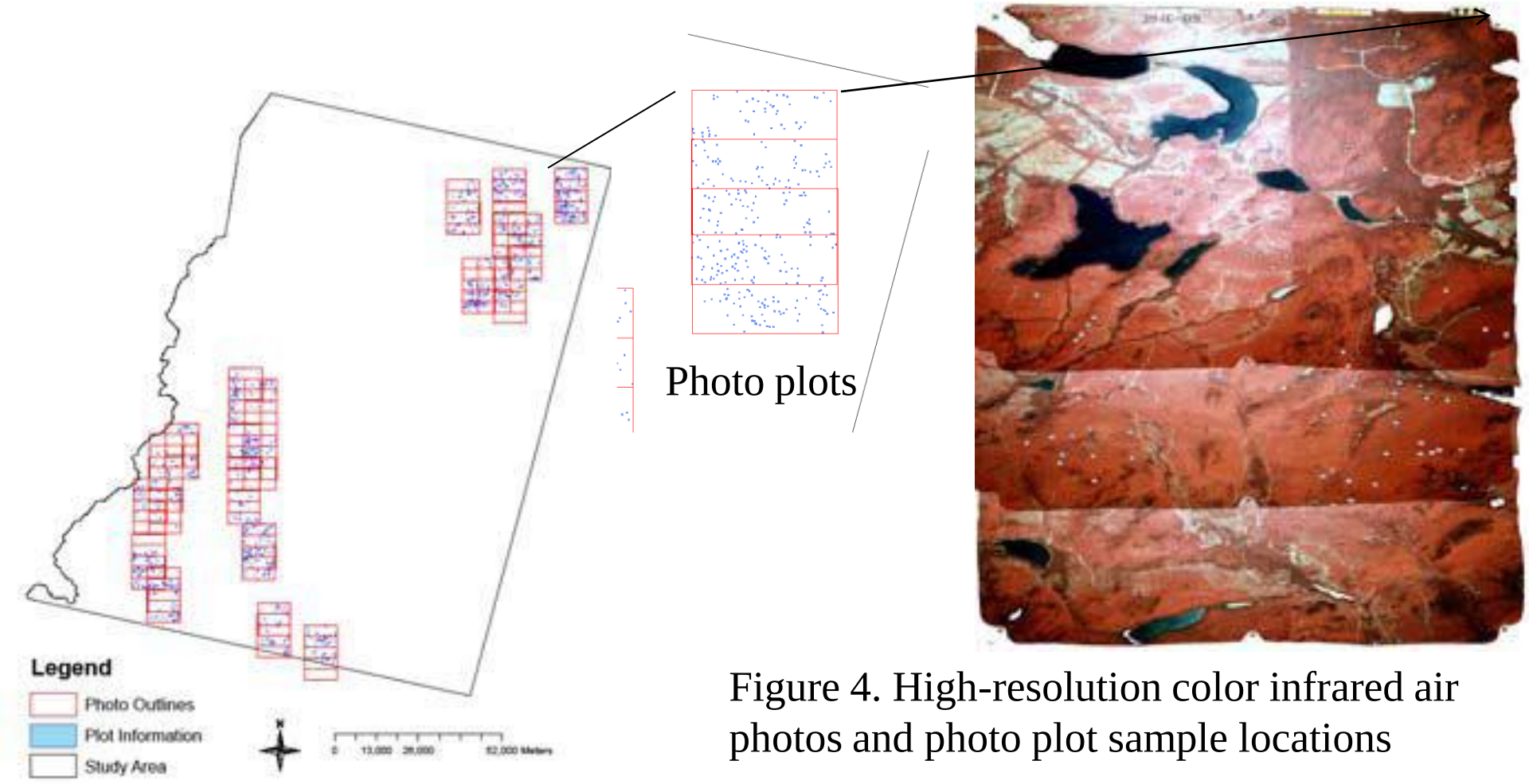


Figure 4. High-resolution color infrared air photos and photo plot sample locations

Results

Interpretation of high resolution stereo photo plots from 1997 and 2007 revealed significantly higher overstory crown closure removals for forestland that changed from (1) Industrial ownership to TIMO/REIT and (2) from Industrial to Non industrial owners, compared to Stable industrial owners. Other non industrial is a diverse group of owners, including logging companies interested primarily in shorter term timber extractions, and some conservation organizations with biodiversity goals that de-emphasize short term harvest on much of their lands.

Majority land ownership shifted from primarily Industrial in 1997 to TIMO/REIT by 2007. This trend has been documented in U.S. Forest Service, Forest Inventory and Analysis reports. In comparing ownership type at time of harvest and time since harvest, industrial owners had the largest change in percent overstory crown closure while Old-line non-industrial owners had the least change. Other non industrial owners maintained the lowest canopy closure before and after harvest. Industrial owner plots which moved to TIMO/REIT owners also experienced an elevated removal of overstory when compared to Stable industrial and Stable old-line owners. Plots with dominant softwood component had the largest changes in percent overstory. However, fewer pure softwood stands were available for harvest (and fewer softwood plots were represented) as a result of the past industrial ownerships that harvested softwood to supply pulp mills. Final results are pending the completion of an MS thesis.

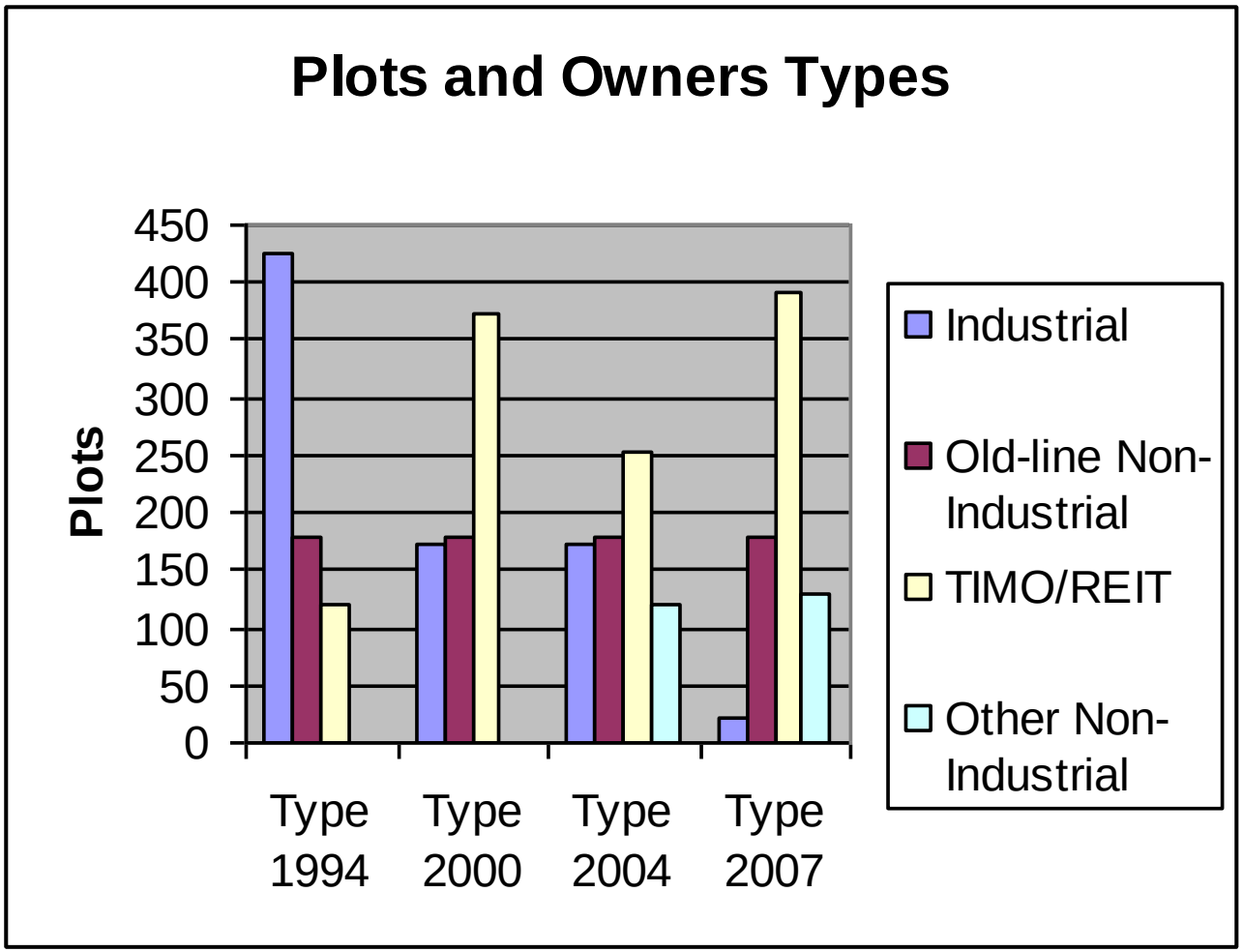


Figure 5. The major landownership type for all 2 ha aerial photo sample plots at associated dates. From 1994 to 2007 there was a large decline in industrial ownership coinciding with a large increase in TIMO/REIT, and the emergence of Other Non-Industrial owners by 2004.

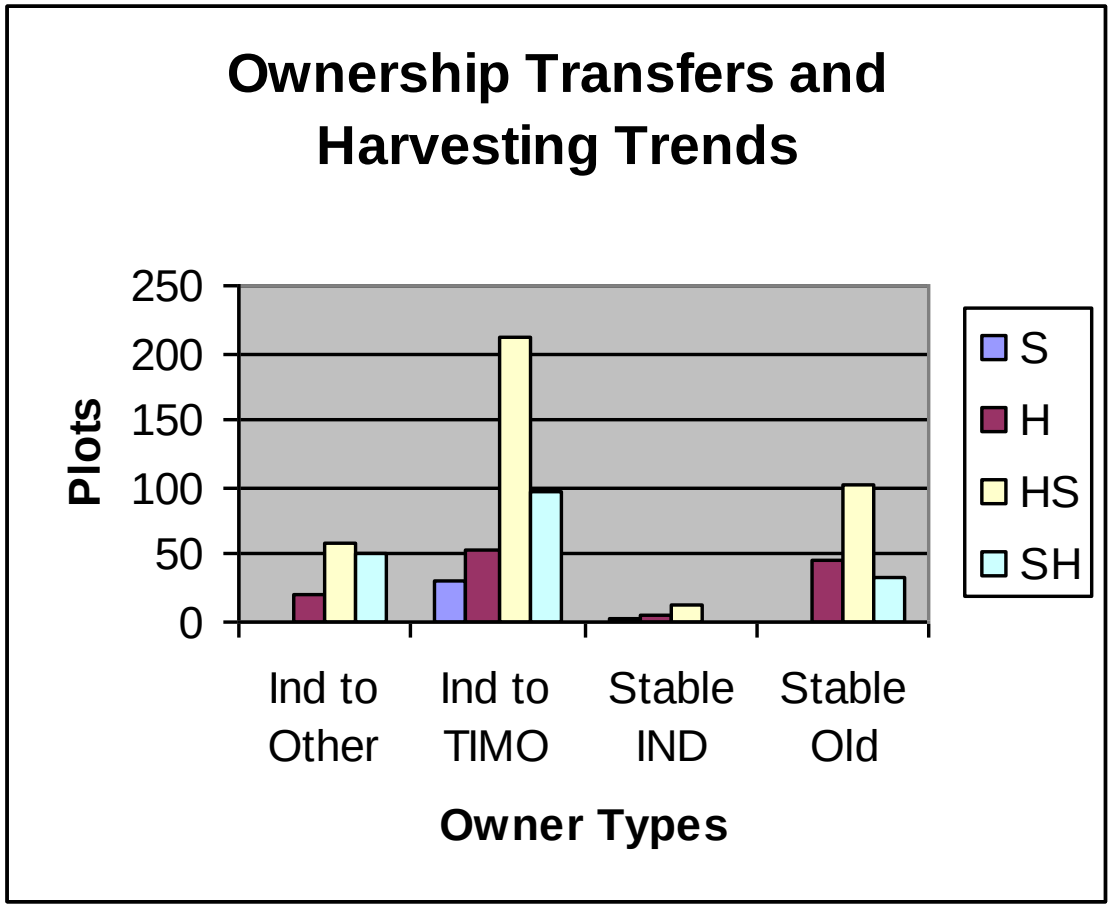


Figure 6. Plot count of landowner transfers between 1994 and 2007 and stable owners throughout the same time period, and species type (derived from photo interpretation) at time of harvest. S- softwood, H – hardwood, HS – hardwood/softwood, SH – softwood/hardwood, Ind – Industrial, TIMO – timber investment management organization and real estate investment trust, Other – non industrial, Old – old line non industrial

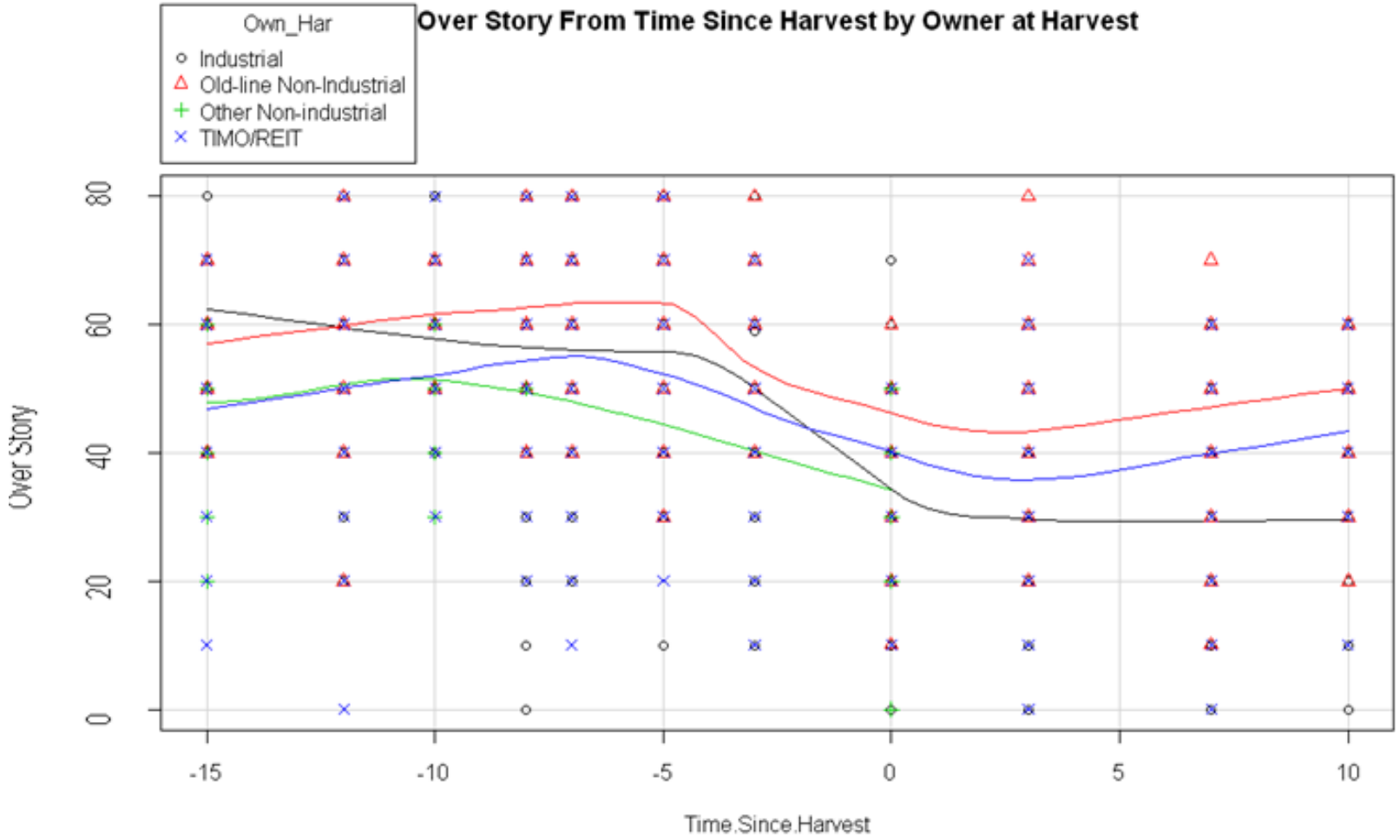


Figure 7. Fitted regression lines pre and post harvest from all photo interpreted plots. Industrial owners had a higher percentage of overstory crown closure reduction after harvest . Old-line non-industrial owners maintained higher pre harvest and post harvest crown closure percent. The predominance of lines falling below 50% canopy closure are influenced by the greater overstory removal on Clearcut/Heavy Partial plots (n=210) versus Light Partial harvested plots (n=515), despite the dominance of the latter (71%).

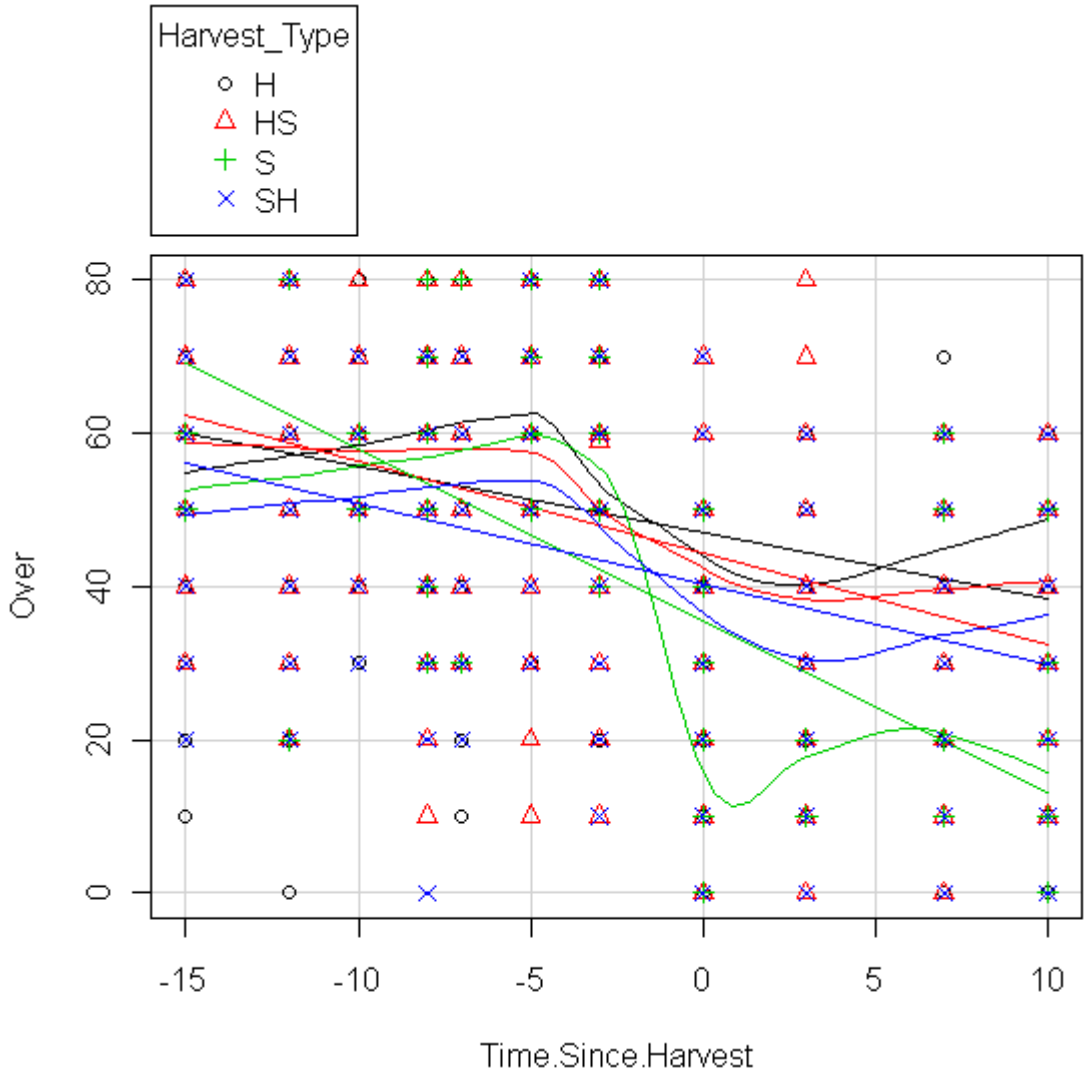


Figure 8. Pre and post harvest photo interpretation plot observations with fitted regression lines. Y- axis depicts Percent Overstory Crown Closure of species group. Note the greater reduction in Softwood (S) overstory crown closure and the increased predominance of Hardwood (H) crown closure from 5 to 10 years after harvest.

Table 1. ANOVA and Tukey's HSD. NS = non significant , P value < 0.005 indicated in cells

Owner Change Groups	'93 % CC Overstory	'97-'07 % CC Overstory	'93 % CC Understory	'97- 07 % CC Understory
Ind-TIMO vs Stable Ind	NS	0.0001	NS	NS
Ind-Other vs Stable Ind	NS	0.0001	NS	0.0044
Ind-TIMO vs Stable Old Line	NS	NS	NS	NS
Ind –Other vs Stable Old Line	NS	NS	NS	NS
Ind-Other vs Ind-TIMO	NS	NS	NS	0.0008

Implications for the Northern Forest Region

It is critical that we develop methods to address the sustainability challenges presented by large-scale natural disturbance coupled with changing forest management practices, ownership, public policy, and market conditions.

The time-series Landsat forest change analysis provides a spatially explicit perspective of harvest, combined with high resolution photo interpretation on photo plots stratified by ownership type provides researchers and policy makers with a landscape level perspective of changing forest composition and structure compatible with regional or statewide analysis.

Results indicated that significant differences in crown closure percent (an indicator of harvest intensity) following harvest were observed among forestlands with different landowner change history. Plots with a predominant softwood had the largest changes in percent overstory and hardwood composition is increasing in regeneration stands following harvest. Extensive partial harvesting may lead to landscape level composition and stand structure changes that could affect stand quality, biodiversity, and wildlife habitat for some keystone species. Similar trends might be expected in other northern forest states where spruce budworm damage was severe, and where major forest ownership changes have shifted primarily from a few large industrial corporations to TIMO or REIT and other non industrial companies.

Future Directions

In an effort to improve spruce budworm decision support capabilities in advance of the next outbreak, and with support from a NSRC Theme 3 grant (S. Sader –PI) and U. Maine's NSF- EPSCoR Sustainability Solutions Initiative (J. Wilson – PI), we have leveraged the Landsat time-series database to explore broader ecological issues concerning the implications of changing forests on future landscape composition and structure. For example, we coupled field data provided by the USDA Forest Inventory and Analysis (FIA) program with time-series Landsat satellite images to map budworm vulnerability for a 10 million acre northern Maine study area. Host abundance data integrated with forest age maps compiled from satellite-derived time series of stand-replacing disturbance (ca. 1973-2009) have been processed to produce maps of spruce budworm vulnerability.

Two other NSRC projects (K. Legaard and E. Simons – PIs of the separate grants) are using the time-series disturbance data base to research other aspects of landscape scale forest dynamics. Progress on these related research initiatives will be reported by the PIs of the related NSRC projects

List of Products

Peer-reviewed publications:

Noone M.D. and S.A. Sader. 2012. Are forest disturbances influenced by ownership change, conservation easement status and land certification. Forest Science. 58(2): 119-129.

Sader, S.A. and K.R. Legaard. 2008. Inclusion of forest harvest legacies, forest type, and regeneration spatial patterns in updated forest maps: a comparison of mapping results. Forest Ecology and Management 255:3846-3856.

MS. Thesis:

•Noone M.D. 2009. Forest change and cover type monitoring and evaluation of disturbance influences in Maine: 2000 to 2007. M.S. Thesis, December 2009, University of Maine, Orono.

•Timothy Smith, Thesis In preparation

Presentations:

•Smith, T. and S.A. Sader. Evaluation of partial harvesting on multiple ownerships in Maine. New England Society of American Foresters Winter Meeting, Lake Morey, Fairlee, Vermont 03/30/2011

•Noone, M.D. & Sader, S.A. Maine statewide forest change (2000-2007) and forest cover type, NESAF Winter Meeting, Nashua, NH. Poster, March 2009.

•Legaard, K., Simons, E., and S. Sader. 2008. Integration of remote sensing and land cover data to evaluate forest landscape change. Eastern CANUSA Forest Science Conference, 17-18 October 2008, Orono, Maine.

Presentations (continued):

Sader, S.A. Monitoring Maine's forests from above: from science to applications. Keeping Maine's Forests Committee, Buchanan Alumni Center, University of Maine, Feb. 2008.

Presentations (continued):

Sader, S., and K. Legaard. 2008. Forest harvest, composition, and biodiversity trends on easements and changing ownerships. Society of American Foresters National Convention, 5-8 November 2008, Reno, Nevada.

Legaard, K., Simons, E., and S. Sader. 2008. Integration of remote sensing and GIS to quantify forest landscape change in support of wildlife habitat modeling. Society of American Foresters National Convention, 5-8 November 2008, Reno, Nevada.