Remote Sensing as a Tool for a Survey of Defoliation and Yield Losses

Docent Päivi Lyytikäinen-Saarenmaa,
Department of Forest Ecology, University of Helsinki,
E-mail: paivi.lyytikainen-saarenmaa@helsinki.fi
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Introduction

- Impact of forest damage agents (storms, droughts, pest insects, diseases...) have dramatically increased
- High need for monitoring, risk assessment and early warning
- Large variety of monitoring methods
- Methods for damage survey must have low costs
- Modern and cost-efficient damage survey needed
Projections of Future Changes in Climate

European Commission, Green Paper 2007
Threats for Forest Health

- Frequency, intensity and spatial range of insect outbreaks are increasing
- Changes in pest status
- Range extensions towards north
- Exotic alien species
- Impact of forest insects as disturbance agents is increasing all over the world
Remote Sensing and Forest Protection

- Rapid development in remote sensing and GIS technology provides applications for inventory and survey of forest damage

- We have focused on: Optical satellite imaging, digital aerial photography, laser scanning (ALS and TLS) and microwave satellite imaging (radars)

Lyytikäinen-Saarenmaa et al., unpublished
Main Objectives of the Projects

1. Use of data for identification the extent of a damage on different scales:
   individual tree – stand – landscape

2. Identification of the intensity of a damage → classification

3. Annual change detection

4. Models and simulations of growth losses

5. Risk assessment of forest stands and early warning

6. Development of predictions and distribution models under the climatic change scenarios → bioclimatic models
Outbreak Cases in North Karelia: *Diprion pini*

The Common pine sawfly (*Diprion pini* L.)

Chronic outbreak in Iломantsi district
- Field clusters and area for laser scanning covers 34.5 km²

- Clusters measured in June 2007, defoliation estimated in 2007, 2008 and 2009

- Aerial photos and Landsat TM data in 2007

- Laser scanning (ALS and TLS) and LAI measurements in July and September 2008 (LAI-2000 Plant Canopy Analyzer)

- TerraSAR X, Radarsat 2 and ERS data 1999-2008
Ground Reference Data in Ilomantsi

Adaptive Cluster Sampling in 2009

- 180 circular sample plots
- tree and stand variables
- locations (plots and trees)
- defoliation level (visual estimation)
- core and soil samples

- all development classes of stands and site types were represented
Outbreak Cases in North Karelia: The European pine sawfly *Neodiprion sertifer*

- Outbreak was already present in 2008
- Defoliation covers appr. 50,000 ha in 2009: seedlings to mature trees

Outbreaks by *N. sertifer* appr. 400,000 ha
20 circular study plots were measured in early June 2009 → additional plots in 2010
- Height, $D_{1.3}$, distance and direction from mid point
- Core samples

- Defoliation level:
  - visual estimation (early June and late July)
- TLS simultaneously with defoliation assessment

- Radar data: X-band SAR
## Classification of Defoliation: Percentage correct & kappa values, Maximum likelihood -method

<table>
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<th>N classes</th>
<th>Aerial photo</th>
<th>Landsat</th>
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<tbody>
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<td>87,3 %</td>
<td>85,9 %</td>
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<td>3</td>
<td>83,1 %</td>
<td>70,4 %</td>
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<td>4</td>
<td>56,3 %</td>
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Airborne Laser Scanning

Individual Tree Detection is Based on:
1) creation of a 3D tree height model
2) segmentation of individual tree crowns
3) calculation of plotwise/standwise characteristics based on individual tree parameters

- Pulse density  20-40 pulses / m²
- Defoliation mapped in two scans to produce LAI (leaf area index)
- LAI is based on laser pulse penetration through a canopy
Airborne Laser Scanning (Lidar)

- LIDAR data recalculated to 10x10 m raster for LAI (leaf area index)
- The rasters segmented into stands
- Exclusion of small stands: minimum 1.4 ha

Images: Svein Solberg
Terrestrial Laser Scanning

- Hemispherical scanner, allow to scan into almost all directions (360 °)
- Radius < 100 m, can provide smaller footprints
- Very first application of tree defoliation in the world
- Acquiring field reference data by means of TLS measurements
SAR Images: Processing

- Images were delivered from ESA as detected products (non-interferometric processing)
- Image-to-image registration (master image 10.9.1999)
- Calculation of average amplitude and standard deviation of amplitude
- Geocoding to UTM zone 35/WGS84 coordinate system using NLS-DEM25 elevation model (UTM35N = ETRS-TM35FIN)

Source: Deutsches Fernerkundungsdaten-zentrum des DLR
SAR: Results
Red+Green: Average amplitude,
Blue: Standard deviation of the amplitude
Palokangas SAR image: combination of images 1999-2008
Yield Losses: Connection Between Defoliation and Growth Losses
- defoliation decrease annual increment → timber yield of a stand lower than estimated
- timing and organism crucial

The Relationship between Defoliation Intensity and Annual Growth Losses of Scots pine
Yield Losses: Measurements & Simulations

- Easy to detect effect of defoliators and other agents from growth rings (annual rings) → estimation of other parameters, e.g. volume, basal area

- WinDendro tree-ring and wood density analysis software applied

https://.../images-plateforme/WinDendro.jpg
- Simulation of growth for a certain period or for a rotation period \(\rightarrow\) SIMO simulator (SIMulation and Optimization for next-generation forest planning)

- The aim is to analyse effects of forest damages to forest growth and expected net present value by means of tree and stand level forest management planning simulations

- Comparison between damaged and undamaged stands / trees is based on the differences in the expected net present value (NPV) of next harvest in the stand \(\rightarrow\) forest value
Conclusions

- Remote sensing is a promising tool for monitoring forest health
- Combination of laser scanning and leaf area index (LAI) ideal for damage surveys
- High-density scanning suitable for needle mass or defoliation measurements and mapping of insect outbreak
- Detection of areas affected by needle defoliation by radar data → promising method without weather limitations
- Simulations of yield losses due to forest disturbances with SIMO simulator

- Further step: combination of RS and field data, and growth estimates into bioclimatic envelope models
Co-operation
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- University of Freiburg, FeLIS
- Finnish Geodetic Institute
- University of Joensuu, Mekrijärvi Research Station
- The Tornator Company

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Thank you!
Questions & comments?