Remote sensing of forest health

Svein Solberg, Norwegian Forest Research Institute, Høgskoleveien 8, 1432 Ås, Norway
Svein.solberg@skogforsk.no

Abstract

Remote sensing is a promising tool for monitoring forest health. Foliar mass, or correspondingly leaf area index (LAI), together with chlorophyll concentration in the foliage, are two suitable measures of forest health. So far, airborne laser scanning has proven to be very suitable for measuring LAI. The work is in progress, and still in an early phase.

Introduction

Remote sensing technology has been rapidly developing during the last years, and at Skogforsk we are investigating whether and how this tool could be applied for forest health monitoring. We are mainly aiming to develop a monitoring system, which is generally applicable, i.e. it can be used for both abiotic and biotic stress situations. An ideal situation would be if a single monitoring variable could integrate the effects of any kind of stress and damage. The rationale for this is the one used earlier regarding the effects of long-range trans-boundary air pollution on forests. If a general stress factor affects the forests, it is likely to result in a number of different damage types and symptoms, these including both direct effects and indirect effects from pests and diseases. Today, the climate change and the spread of pests and diseases across continents could be regarded as an example of such a stress situation. In addition to integrating the effects across damage types, the advantage of having a general health variable is that it could be used to describe spatial and temporal variation in forest health.

Foliar mass and canopy chlorophyll represent variables that are sensitive to most types of stress and damage. Estimation of defoliation and discolouration degree have been widely used as forest health variables in subjective forest health assessments during the last 20 years both in Europe and North-America. Variations in these two parameters correspond to changes in foliar mass (or leaf area index, LAI) and pigment concentration in the foliage (in particular for chlorophyll). When these two variables are multiplied, we get the canopy chlorophyll, given in mass per ground area, which should be a good candidate variable for forest health monitoring.

Results

So far we have successfully estimated LAI and defoliation using airborne laser scanning (LIDAR). In two studies, one with Scots pine and another with Norway spruce, very strong (R^2=0.95) linear relationships were found between state-of-the-art ground measurements of LAI and airborne laser data, based on the Beer-Lambert law (Fig. 1). The idea is simple: the more foliage there is, the less the laser pulses penetrate through the canopy layer and hit the ground. In a mass-attack of pine sawflies in Solør in southeast Norway in 2005, we demonstrated the ability of this method to map the defoliation (Fig. 2, Solberg *et al.* 2006a). We used the same method to produce a map of LAI with a 10m x10m spatial resolution in a part of the Østmarka forest, near Oslo (Solberg *et al.* 2005). This map gives a good representation of the forest area, and it fits well with the distribution of stand densities and stand ages.

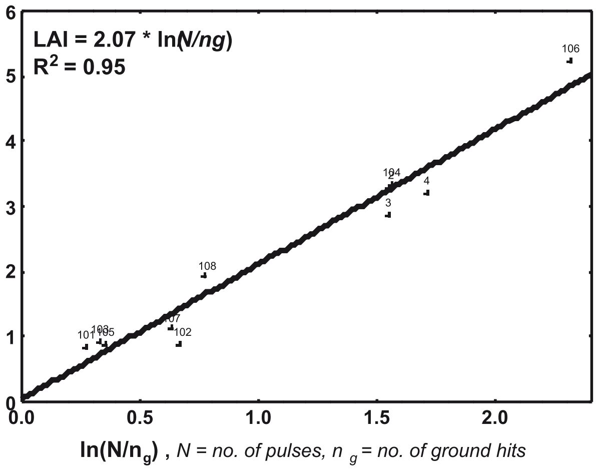

Fig. 1. Linear regression of ground based LAI-2000 measurements against a LIDAR derived variable for eleven 1000 m^2 circular plots of Norway spruce located in Østmarka in Oslo. Accurate geo-referencing of the ground plots was obtained by differential GPS measurements.

The NDVI vegetation index from SPOT satellite data did not correlate well with the LIDAR derived LAI data. This was somewhat surprising, as the NDVI reflects the amount of green biomass. The reason for this was apparently that the NDVI is mostly reflecting the surface characteristics of the vegetation, and it gets saturated at rather low LAI-values, i.e. it is only sensitive to LAI values up to a certain point. Also in young stands the ground vegetation growing between the trees can give a strong NDVI signal, which could easily be mistaken as high LAI values. Anyway, we are searching for other vegetation indexes and other satellites and sensors to try to produce LAI estimates.

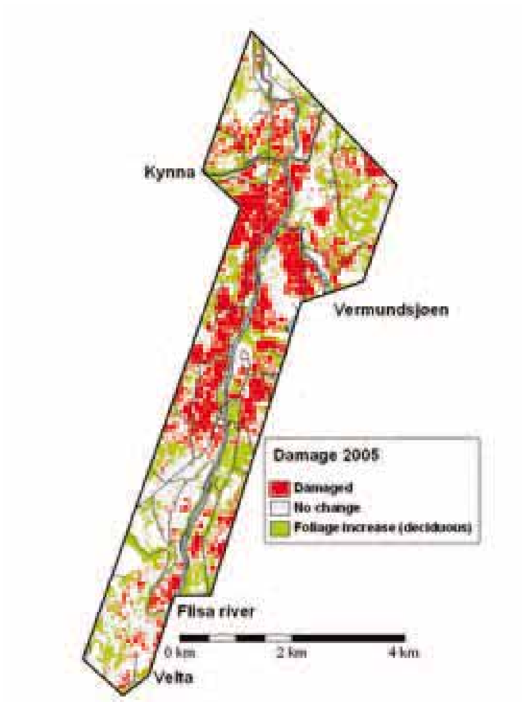

Fig. 2. A map of pine sawfly defoliation during the summer 2005 in Solør in Norway. The colours represent the change in LAI between two flights of laser scanning, performed in May and August.

The approach for remote sensing of foliar mass (and defoliation) presented above is supplemented with another approach for chlorophyll estimation based on airborne, hyper-spectral imagery. The sensor we use here is the Airborne spectral imager (ASI) having 160 bands covering visible and infrared light. This data set has a high spatial resolution (18cmx32cm) allowing modelling of single trees. In order to estimate chlorophyll data from single trees using airborne hyper-spectral data, segments (the outline of horizontal projection of the tree crowns) of single trees were developed from single-tree modelling of the laser data (Solberg *et al.* 2006b). A digital surface model representing the canopy layer was developed (Fig. 3), and single-tree segments were derived from that based on the geometry of the DSM. Foliar chlorophyll concentrations are measured from spruce branches obtained by tree climbing. The results from this work are still preliminary, and not presented here.

Finally, multi- or hyper-spectral data may be useful for detecting diseased trees. We have another data set of hyper-spectral data obtained from the ASI airborne sensor. This scene covers a homogeneous stand of about 2000 young spruce trees in a stand heavily attacked by the spruce needle rust *Chrysomyxa abietis*. A preliminary result (Fig. 4) shows the spectral signature of one healthy and one diseased tree from this stand. As expected, the diseased tree has a higher reflectance in the red light area, and a lower reflectance in the near-infrared bands.

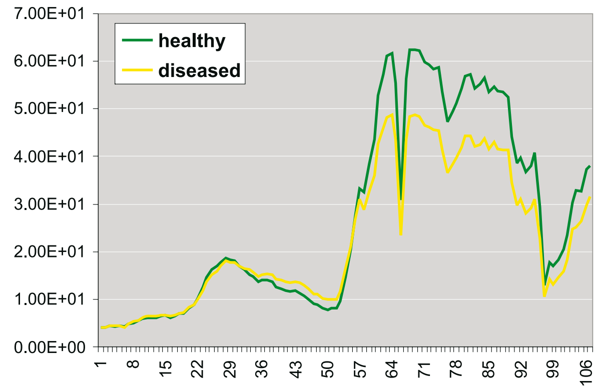

Fig. 4. A spectral signature of two Norway spruce trees in a stand attacked by Chrysomyxa abietis*; showing one healthy tree and one diseased. The band number 1–106 is indicated on the x-axis and goes from 400 nm (left) through visible and NIR-light wavelengths.*

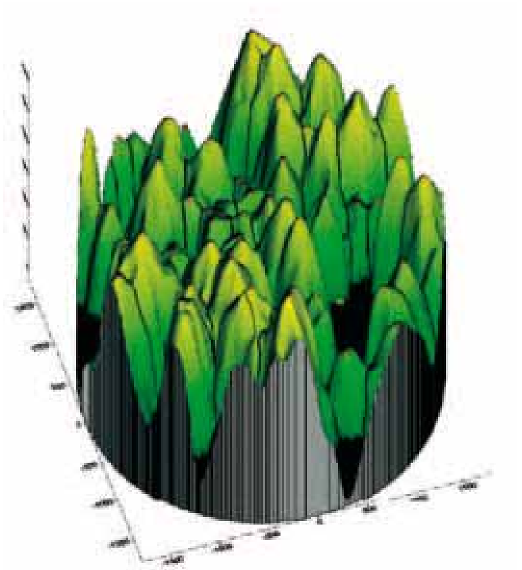

Fig. 3. Digital surface model (DSM) of a 1000 m2 plot.

References

Solberg S, Næsset E, Aurdal L, Lange H, Bollandsås OM & Solberg R 2005. Remote sensing of foliar mass and chlorophyll as indicators of forest health: preliminary results from a project in Norway. In: Olsson, H. (Ed.) Proceedings of ForestSat 2005, Borås, May 31-June 3. Rapport 8a.

Solberg S, Næsset E, Hanssen KH & Christiansen E 2006a. Mapping defoliation during a severe insect attack on Scots pine using airborne laser scanning. Remote Sens Environ (in press).

Solberg S, Næsset E & Bollandsås OM 2006b. Single tree segmentation using airborne laser scanner data in a heterogeneous spruce forest. Photogramm Eng Remote Sens (accepted).