



Forest structure modeling with combined airborne hyperspectral and LiDAR data

Hooman Latifi^{*}, Fabian Fasnacht, Barbara Koch

Dept. of Remote Sensing and Landscape Information Systems, University of Freiburg, Tennenbacherstraße, 4, D-79106 Freiburg, Germany

ARTICLE INFO

Article history:

Received 10 June 2011

Received in revised form 16 January 2012

Accepted 17 January 2012

Available online 17 February 2012

Keywords:

LiDAR

Hyperspectral

Forest structure

GA

Spatial models

ABSTRACT

The interest in the joint use of remote sensing data from multiple sensors has been remarkably increased for environmental applications. This is because a combined use is supposed to improve the results of e.g. forest modeling tasks compared to single-data use. To explore the ability of combined airborne 2D and 3D information to describe the forest structure in local level, we employed various height/intensity metrics from Light Detection and Ranging (LiDAR) data and original reflectance, indices, and linear transformations of airborne hyperspectral HyMap data to build spatial models of stem density, above ground total biomass, and biomass of coniferous species in a temperate forest site in Germany. The study area was stratified into coniferous, deciduous and mixed strata using the plot information from forest inventory data. Combinations of data sources were tested, and an evolutionary Genetic Algorithm (GA) was used to tailor the numerous predictor variables to final parsimonious sets. Most Similar Neighbor (MSN) approach based on variance-weighted canonical correlations were used to make simultaneous single-Nearest Neighbor (NN) models of the attributes, where NN was searched either within the whole geographical domain or within the restricted forest strata. Results were evaluated by leave-one-out cross validations on 1000 bootstrap resample data. They showed that the LiDAR height metrics (descriptive statistics and percentiles) provided the most effective information amongst the entire data source combinations, while the HyMap metrics contributed only slightly to describe the variation beyond those explained by ALS data. Furthermore, restricted NN search improved the performance and returned approximately unbiased models of all the responses. The GA-screened HyMap predictors corresponded well to the atmospheric windows in visual and NIR domains, as well as to the mean reflectance curve of Scots Pine across the study area. It is concluded that GA-screened models featuring 9–12 predictors containing LiDAR height metrics and few HyMap original channels can be suggested for timely-efficient, unbiased modeling of area-based forest structural attributes.

© 2012 Elsevier Inc. All rights reserved.

1. Introduction

Remote sensing has been previously proven to be a functional tool to support ground based inventory systems. Different tools have shown potentials for the derivation of forest attributes, amongst which Light Detection and Ranging (LiDAR) has been reported as a promising data source for description of complex forest structure thanks to its ability to capture 3D features such as canopy height and density. While Hyypä et al. (2008) summarized the studies employing LiDAR for forest inventory in the Nordic countries, Koch (2010) reviewed the current status of optical and LiDAR remote sensing application for forest biomass assessment, in which the magnitude of joint application of those data was highlighted. The benefit of a combined use of LiDAR and multispectral data for single tree or area-based models of forest attributes has been reported by a number of state-of-the-art studies in the literature e.g. Breidenbach et al. (2010a), Latifi et al. (2010), Latifi et al.

(2012) and Straub et al. (2010). Using different modeling schemes from the family of so called Nearest Neighbor (NN) spatial models is one common issue amongst the above-mentioned studies. In NN models a weighted mean of the response variables from the most similar neighbors (when the number of neighbors is greater than one) is used to assign the value of response to a target unit being predicted (Haapanen et al., 2004). The Most Similar Neighbor (MSN) is a special case of NN method in which the distances between the target and (neighboring) reference units are weighted using the canonical correlations of the predictor variables. Here an adaptation of MSN will be used, in which the canonical correlations are weighted by their variances (Crookston et al., 2002).

Besides LiDAR technology, imaging spectroscopy (also called hyperspectral remote sensing) is a recent field which gained remarkably increased attention in the last years with the introduction of airborne sensors such as AVIRIS (Green et al., 1998) and HyMap (Cocks et al., 1998). It offered sensors with a significantly increased spectral resolution compared to the multispectral sensors. The narrow spectral width of each individual channel in a hyperspectral sensor enables displaying of the complete spectral characteristics of each object. Moreover, the absence/presence of specific absorption

^{*} Corresponding author. Tel.: +49 7612033699; fax: +49 7612033701.

E-mail addresses: hooman.latifi@felis.uni-freiburg.de (H. Latifi),

fabian.fasnacht@felis.uni-freiburg.de (F. Fasnacht),

barbara.koch@felis.uni-freiburg.de (B. Koch).

features allows the differentiation amongst distinct land use classes, e.g. vegetation types, species and even different soil minerals. Hyperspectral data have been successfully used to assess plant biochemical parameters connected to plant stress (e.g. Carter, 1994), forest canopy nitrogen concentration (e.g. Smith et al., 2003) and chlorophyll content (e.g. Malenovsky et al., 2006), as well as to separate tree species (Apan et al., 2009; Goodenough et al., 2007; Middleton et al., 2003). However, few studies were conducted aiming on the retrieval of biophysical and structural vegetation parameters e.g. mean canopy height or Leaf Area Index (LAI) from such data. Schlerf et al. (2007) showed, yet with moderate correlation, that those data contain a certain potential to assess stem biomass in temperate coniferous stands. Other studies targeting on the estimation of forest biomass or carbon using hyperspectral data were frequently located in tropical or semi-tropical areas. Foster et al. (2002) presented moderate results in two test sites (RMSE = 59.1 and 74.4 tons/ha) for the prediction of above-ground carbon using stepwise multiple regression in the Bolivian rainforest. Thenkabail et al. (2003) reported the 36% to 83% increased capability of Hyperion data compared to broadband multispectral data for explaining the variability of African rainforest biomass and land use classes. Optimum wavelength for the prediction of dry weight biomass was found in the visible (682 nm, 692 nm), NIR (1215 nm, 1104 nm, 783 nm, 895 nm) and middle Infrared (1710 nm, 1467 nm, 1659 nm, 2052 nm) domains. Goodenough et al. (2008) found relations between LiDAR estimations, field sampling methods, and the Partial Least Squares-predicted biomass based on AISA and AVIRIS hyperspectral data (r^2 -values of up to 0.91) for aboveground biomass (AGB) estimations. Zhang et al. (2009) reported strong relations between the soil adjusted vegetation index (SAVI) from HJ-1 data and AGB.

Majority of the above-mentioned studies made use of a selected part of the hyperspectral reflectance, mainly as conventional VIs. The overall association between the spectral signature of optical sensors and a number of forest attributes including biomass has been previously examined in several studies (e.g. Franklin, 1986; Roy & Ravan, 1996). The same applies for VIs (e.g. Ponzoni et al., 2010; Zhang et al., 2009). VIs have proven to be correlated to several plant biochemical and biophysical properties (Glenn et al., 2008) while

considerably declining influences originating from atmosphere, soil or anisotropy. In addition to the well established VIs discussed in the literature, imaging spectroscopy data might bear the potential for new VIs using the increased spectral resolution to improve the models of forest attributes. Therefore, we combined original reflectance, well known VIs and linear transformations of HyMap data with various LiDAR metrics (height and intensity of first-pulse data) to explore the main issues of 1) assessment of the potential to improve LiDAR-based AGB and stem density models by hyperspectral data, 2) detection of hyperspectral domains potentially connected to AGB and stem density and 3) exploring the potentials of an alternative MSN as a well-known nonparametric method (aided by the appropriate variable screening and search space) to build models of forest attributes.

2. Materials

2.1. Study area and field data

The nearly 900-ha study site encompasses a portion of the managed state forest stands and is located in northern part of Karlsruhe in the federal state of Baden-Württemberg in Germany (8° 24' 09" E and 49° 03' 37" N to 8° 25' 49" E and 49° 01' 15" N) (Fig. 1). The dominant tree species include Scots Pine (*Pinus sylvestris* L., 56.3% of timber volume proportion), European Beech (*Fagus sylvatica* L., 17.8%), Sessile Oak (*Quercus petraea* Liebl.) and Pedunculate Oak (*Quercus robur* L.) (jointly 14.9%), whereas other species (other broadleaves, *Picea* sp./*Abies* sp., and *Larix* sp.) negligibly occur within the stands (5.8%, 4.7% and 0.5%, respectively). The mean timber volume is 264 m³/ha which is less than the average rate of 362 m³/ha in the state.

A number of 297 field plots collected in a forest inventory in 2006 based on permanent circular sample plots were used. The inventory was designed based on a regular 200 m × 100 m systematic sampling grid. Each plot consists of four concentric circles of various sizes, on which different tree characteristics were measured. Trees with diameter at breast height (DBH) < 10 cm, < 15 cm, < 30 cm, and ≥ 30 cm were

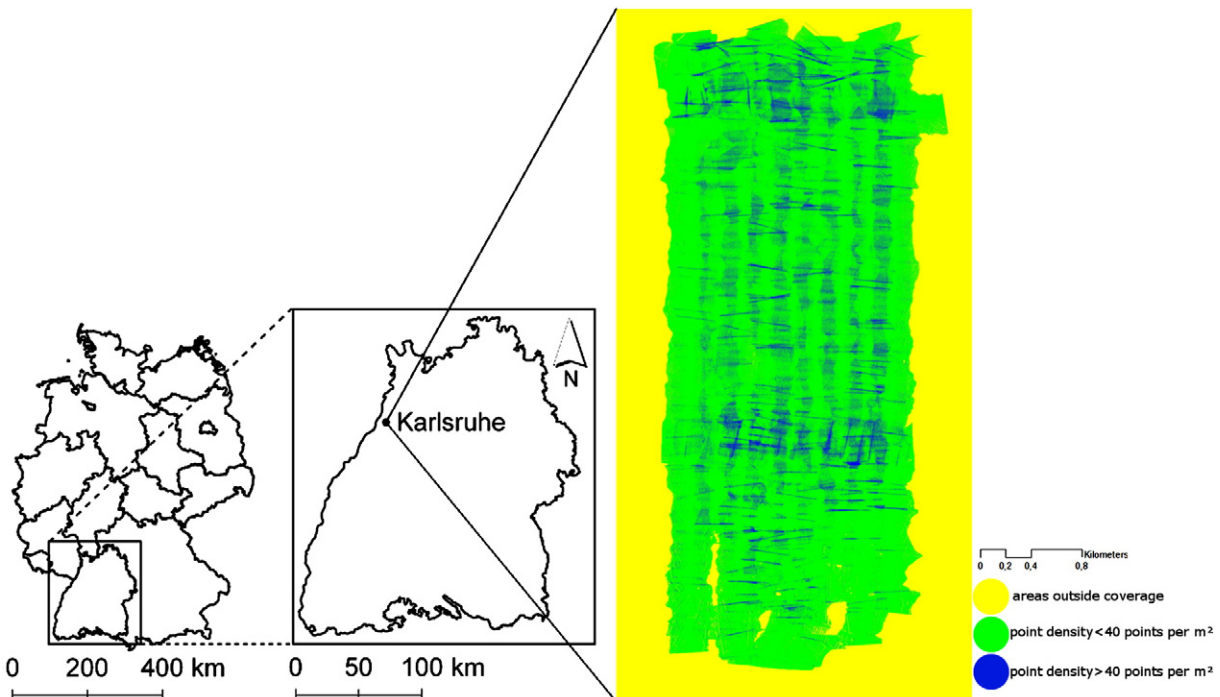


Fig. 1. Location of the study area (left) featuring the laser scanning pattern (right).

Download English Version:

<https://daneshyari.com/en/article/6347449>

Download Persian Version:

<https://daneshyari.com/article/6347449>

[Daneshyari.com](https://daneshyari.com)