ESTIMATION OF FOREST ATTRIBUTES AT SINGLE TREE LEVEL USING HYPERSPECTRAL AND ALS DATA

Michele Dalponte, Lorenzo Frizzera, Damiano Gianelle

Department of Sustainable Agro-ecosystems and Bioresources, Research and Innovation Centre, Fondazione E. Mach, Via E. Mach 1, 38010 San Michele all'Adige (TN), Italy

Hyperspectral and airborne laser scanning (ALS) data can be very useful remote sensing data sources for forest inventory applications. ALS data showed to be appropriate for the characterization of structural forest attributes (height, volume, DBH) (Montaghi et al., 2013; Næsset & Økland, 2002), while hyperspectral data are useful for the characterization of tree species distribution (Dalponte et al., 2014). These two data can be considered complementary and their fusion allows estimating all the forest attributes needed for forest inventories. In this paper the attention is focused on ITC level forest inventories, that require the estimation of forest attributes for each individual tree. This means that for each tree in the analyzed area, all the attributes (height, DBH, volume, species) will be estimated.

The goals of this study were mainly two: i) to fuse hyperspectral and ALS data for ITC level forest inventory; and ii) to compare the results obtained at ITC level with the ones obtained with a normal inventory at stand level. In this way we want to understand advantages and disadvantages of using these methods, and their real applicability in a practical forest inventory context.

The study area of Pellizzano (32 km^2) is located in the Italian Alps. The forest is dominated by Norway spruce, with the presence of also other coniferous species (e.g., Silver fir, European Larch, Swiss pine) and broadleaves species (e.g., Aspen, Birch). ALS data were acquired between 7th to 9th of September 2012 with a Riegl LMS-Q680i sensor. The scan frequency was 400kHz and up to 4 returns were recorded. The point density was of at least 10 points per square meter. Hyperspectral data were acquired between 400 nm and 990 nm (65 bands) on 13th of June 2013 with an AISA Eagle II sensor. The spatial resolution was of 1 m. Field measurements were carried out in 52 sample plots. Species, DBH, volume and height were measured for some trees inside each plot. In this way we obtained 3776 trees for which the species information was recorded. Among these trees for 1401 the DBH, and volume were measured, and for 121 also the height was measured.

Two processing chains were developed for the two data sources. Regarding ALS data, first of all the rasterized CHM was generated, and it was used as input to the Individual Tree Crowns (ITC) delineation. The ITC delineation was carried out using the algorithm of Ene et al. (Ene et al., 2012). From each ITC 70 variables (e.g. height percentiles, coverage variables, coefficient of variation, etc.) were extracted from the ALS point cloud from all the available returns (from 1 to 4). The most informative variables for the estimation of the stem volume and of the DBH were selected using a stepwise model selection by exact AIC. These variables were used as input to a generalized linear regression model. The stem volume was estimated in two ways: i) directly from the ALS variables; and ii) using dendrometric equations having in input the DBHs estimated from ALS data and the species predicted from hyperspectral data.

Regarding the hyperspectral data, first of all the acquired images were mosaicked and radiometrically normalized. A selection of the most informative pixels inside each ITC was carried out according to the findings of Dalponte et al. (Dalponte et al., 2014). The hyperspectral bands, fused with the mean tree height derived from ALS data were used as input to a Support Vector Machine classifier. The pixel level map obtained in this way was aggregated at ITC level according to a majority rule inside each ITC.

A mean class accuracy (the average of the producer's accuracies) of 85.1% was obtained considering the classification of 10 classes. The kappa accuracy was of 76.3% and the overall accuracy of 82.4%. The producer's accuracies (PA) ranged from a maximum of 100% for Scots Pine to a minimum of 73.2% for Swiss Pine. These results are at ITC level for an independent validation dataset. The mean tree height derived from ALS data was very important for the detection of Green Alder (91.1% PA) that is characterized by a mean height very different from the other broadleaves species.

Regarding the DBH estimation, among all the variables extracted from each ITC the variable selection process selected 21 variables. These variables were used to estimate the DBH. The DBH estimation results were as follows: Adjusted-R^2=0.83; Mean Absolute Error = 5.8 cm; Normalized Root Means Square Error % = 6.0.

The results for the stem volume estimation using the first approach (stem volume estimation from ALS variables) were as follows: Adjusted-R^2=0.89; Mean Absolute Error = 0.48 m^3; Normalized Root Means Square Error % = 6.9. Considering the second approach (stem volume estimation using dendrometric equations having in input the DBHs estimated from ALS data and the species predicted from hyperspectral data) were as follows: Mean Absolute Error = 0.49 m^3; Normalized Root Means Square Error % = 7.0.

Starting from the results obtained at ITC level we plan to extrapolate estimations of forest attributes at stand level and to compare them with the ones of a standard forest inventory in order to understand its applicability in real forest inventories.

Dalponte, M., Ørka, H. O., Ene, L. T., Gobakken, T., & Næsset, E. (2014). Tree crown delineation and tree species classification in boreal forests using hyperspectral and ALS data. *Remote Sensing of Environment*, *140*, 306–317. doi:10.1016/j.rse.2013.09.006

Ene, L., Næsset, E., & Gobakken, T. (2012). Single tree detection in heterogeneous boreal forests using airborne laser scanning and area-based stem number estimates. *International Journal of Remote Sensing*, *33*(16), 5171–5193.

Montaghi, A., Corona, P., Dalponte, M., Gianelle, D., Chirici, G., & Olsson, H. (2013). Airborne laser scanning of forest resources: An overview of research in Italy as a commentary case study. *International Journal of Applied Earth Observation and Geoinformation*, *23*, 288–300. doi:10.1016/j.jag.2012.10.002

Næsset, E., & Økland, T. (2002). Estimating tree height and tree crown properties using airborne scanning laser in a boreal nature reserve. *Remote Sensing of Environment*, *79*(1), 105–115. doi:10.1016/S0034-4257(01)00243-7