Estimating Stand Volume and Above-Ground Biomass of Urban Forests Using LiDAR (laser scanner) in ERDAS IMAGINE

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Abstract: Assessing forest stand conditions in urban and peri-urban areas is essential to support ecosystem service planning and management, as most of the ecosystem services provided are a consequence of forest stand characteristics. However, collecting data for assessing forest stand conditions is time consuming and labor intensive. A plausible approach for addressing this issue is to establish a relationship between in situ measurements of stand characteristics and data from airborne laser scanning (LiDAR). In this study a group of researchers coordinated by Raffaele Lafortezza and Giovanni Sanesi, professors at Dipartimento di Scienze Agro-Ambientali e Territoriali, Università degli Studi di Bari "Aldo Moro", in cooperation with the Center for Global Change and Earth Observations (CGCEO) of Michigan State University assessed forest stand volume and above-ground biomass (AGB) in a broadleaved urban forest, using a combination of LiDAR-derived metrics, which takes the form of a forest allometric model, using the Point Cloud Toolbar and others powerful tools of ERDAS IMAGINE.

Article:

Assessing forest stand conditions in urban and peri-urban areas is essential to support ecosystem service planning and management, as most of the ecosystem services provided are a consequence of forest stand characteristics. These forests are established by cities to achieve their regulatory requirements for clean air, soil quality, and water management while revitalizing livelihoods and human well-being.

In this context, estimating and characterizing ecosystem services, such as stand volume and above-ground biomass of urban forests (shrubs and trees) in urban and peri-urban areas, is an emerging activity. However, collecting data for assessing forest stand conditions is time consuming and labor intensive. A plausible approach for addressing this issue is to establish a relationship between in situ measurements of stand characteristics and data from airborne laser scanning (LiDAR). In this study, a group of researchers coordinated by Raffaele Lafortezza and Giovanni Sanesi, professors at Dipartimento di Scienze Agro-Ambientali e Territoriali, Università degli Studi di Bari "Aldo Moro", in cooperation with the Center for Global Change and Earth Observations (CGCEO) of Michigan State University, developed an innovative methodology for the biomass estimation in urban areas from LiDAR (laser scanner) data and the results were published on the Remote Sensing (April 2016) magazine. The study was made over an urban forest plantation located in the metropolitan area of Milan, Northern Italy: Parco Nord Milano. The entire area covers ~600 ha, with 100 ha as forest

plantation and the remaining area as green space (e.g., tree rows, agricultural areas) and other recreational facilities or artificial areas (e.g., sports fields).

The group collected quantitative measurements of the forest at 10 sample plots (13 m radius) inside the park. In these areas, have been detected a series of data associated with the estimation of the volume and of the biomass (shrubs and trees). The *in situ* data in the field were collected by GPS receiver with sub-meter differential correction and precision. In the same period of the field campaign, a high-resolution LiDAR "point cloud" (~10 points/ m^2) was collected from airborne.

Data processing with Hexagon Geospatial tools

The analysis process was conducted using Hexagon Geospatial software.

The methodology developed includes two main steps:

- **Step 1** – Data production:
  - Pre-processing and filtering of the LiDAR point cloud data to identify and extract profiles and 3D Views of the trees inside the area of interest.
  - Point cloud classification based on orthophoto and land use map.

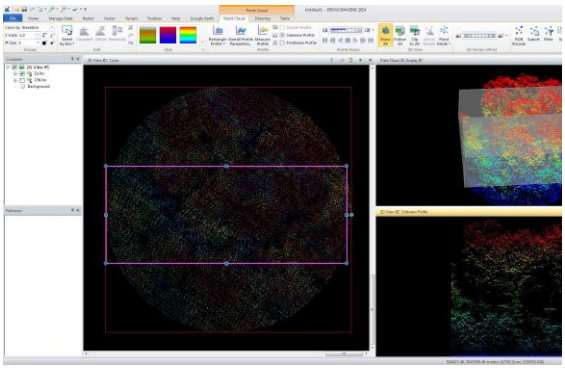

Figure 1. Pre-processing of the point cloud in ERDAS IMAGINE

- **Step 2** – Modelling:
  - Analysis of the LiDAR point cloud, to derive variables as proxies of the biomass.
  - Development and validation of mathematical model for biomass estimation.

In the preparation of the database, the LiDAR points were classified as ground or vegetation, using the *Classify tool* of the Point Cloud toolbar in ERDAS IMAGINE. Orthophotos were produced with ERDAS IMAGINE, using airborne images with a resolution of 0.30m. ERDAS IMAGINE was also used for the production of land use maps, through the photointerpretation of orthophotos.

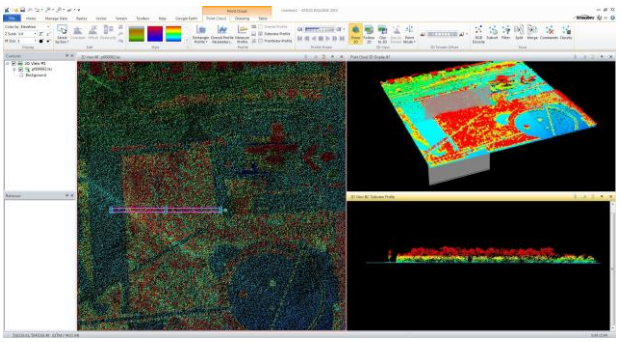

Figure 2. Point Cloud of Parco Nord, Milan, Italy. Profiles and 3D views derived from the LiDAR point cloud.

The DTM (Digital Terrain Model) was extracted with the ERDAS IMAGINE *Terrain Prep Tool*. The quality of the DTM was verified, using 16 control points derived from a topographical survey, which allowed to evaluate an average and standard deviation of about 10 cm error.

The DTM was, then, used to map the actual height at each LiDAR point. The LiDAR points were converted into ASCII format and imported into the statistical analysis open source software R 3.1.3 (R Development Core Team). Through the development of *ad hoc* mathematical models it was possible to estimate the amount of biomass present in the study area.

Results

The average biomass estimated in the context of North Park Milan amounts to about 81 Mg/ha, which corresponds to a carbon stored content of about 40.5 Mg/ha. The model developed has a mean square of 19.59 Mg/ha error (23.9%) and a coefficient of determination (R^2) of 0.77. The results obtained are very similar to other studies conducted on the basis of *in situ* data.

The study done by the research group of the University of Bari has great potential for future applications in the estimation of carbon sinks field in urban areas (metropolitan cities). For example, these models can support the reporting of carbon credits through easily collectable quantitative data from remote sensing sources. In this trial, the Hexagon Geospatial software tools have proven particularly suitable for complex processing of geospatial data, ensuring accuracy, reliability and productivity during all processing phases, from the relief to the synthetic data production.

The cooperation between the University of Bari and the Michigan State University is a tangible sign of the University of Bari internationalization process that is leading to very important results in scientific research - new research projects and publications -, also thanks to the continuous exchanges of students, young researchers and teachers between the two institutions.

To read the complete paper: http://www.mdpi.com/2072-4292/8/4/339