In the analysis of forest structure, several parameters play an important role. Measurements deal with woodland growth, volume, density and specie inventory, covering today also wildlife, watershed management and hydrological cycle. The collection of these data is both time-consuming and costly: these parameters are estimated with models derived from the measurement of permanent research plots established over a range of tree species and site conditions. With minimal effort, the ground-based laser scanning system generates dense and accurate 3D point clouds. It provides the effective record of forest spatial variables such as DBH, stem density, height, stem taper and canopy structure. Moreover, this technique can contribute to the monitoring over time of the growth of the forest.

However, the morphology of Japanese forests is quite complex, due to the high density of trees, the local geometry of the ground, the presence of steep ground, and the presence of low vegetation.

As a consequence, the rough point cloud obtained during the survey is not suitable to be treated because it does not have a uniform distribution in the 3D space: firstly, points do not have a defined volume, and secondly, the point cloud has a higher density close to the scanner. Moreover, due to occlusions generated by dense canopies, the point cloud can result partial and incomplete, causing substantial underestimation of canopy height and canopy density at extremities.

For this reason, in order to extract pertinent data that can contribute to calculate geometric variables on the forest, on one side, it is necessary to reduce the density of the point cloud in a homogeneous way (i.e. by exploring common voxel-based techniques), and, on the other side, it is essential to quantify the error due to missing data (i.e. by comparing bottom-to-top scans with side scans for every specie).

Despite some studies deal with the data-processing necessary to be carried out in order to extract forest variables from 3D raw data, few studies attempt to define a common methodology to derive spatial parameters and to verify obtained results with traditional measurement techniques. The goal of this study is to apply a ground-based laser scanning system in order to provide quantitative tree measurements and to obtain an accurate estimation of variables in densely stocked plantation forests.

In particular, the canopy structural analysis with ground-based laser scanner concentrates on two main aspects.

Firstly, the density of the canopy over collectors needs to be estimated in an accurate way (Figure 1). Density parameters can be crossed with other variables in order to understand canopy \cdot radiation or canopy \cdot transpiration interactions. In this specific case, according to the density of the canopy, leaves and branches at the inferior levels can cause occlusions. For this reason, an error margin needs to be estimated for the density over collectors, including the volume of leaves that cannot be measured by the scanner.

Secondly, it is essential to investigate the opening of the canopy (Figure 2). In this case, the gap fraction estimated with the 3D model need to be compared with the gap fraction values obtained from digital hemispherical photographs. This analysis can be performed over time in order to evaluate the
expansion of the vegetation (i.e. before and after thinning). This analysis requires to compare scans performed with similar meteorological condition, so to avoid distortions due to strong wind.

The methodology will be validated on several plot areas characterized by different conditions for slope, low vegetation, density of canopy, and variety of species. These sites concern Japanese forest compartments located in 5 prefectures (Tochigi, Aichi, Mie, Fukuoka, Kochi), and belong to Core Research for Evolutional Science and Technology CREST Project.

key words: terrestrial laser scanning, geometrical features, temporal states, canopy opening, spatial density.