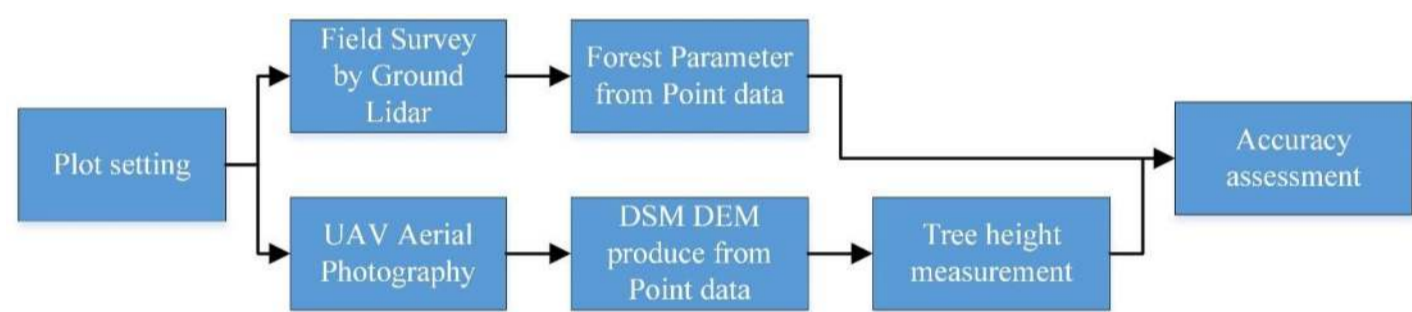
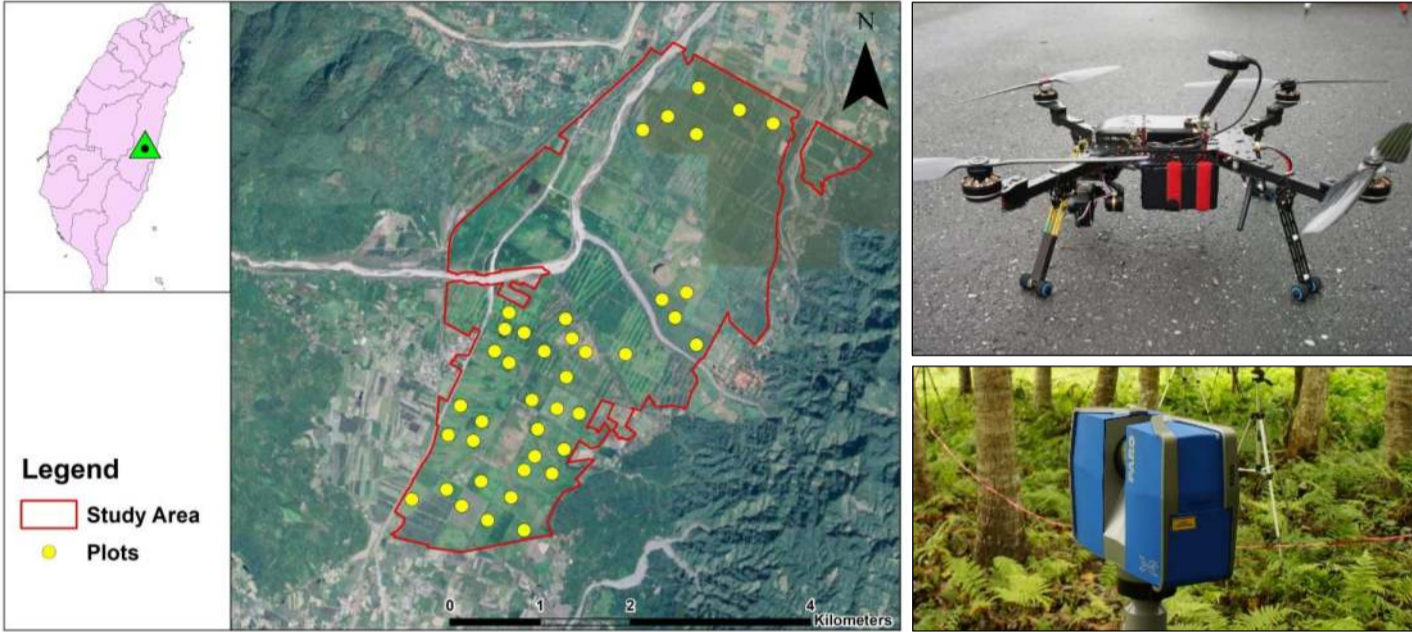


Introduction

Forest resource inventory provides essential information for forest management, where the stand height is an important variable for estimating the stock volume of large-scale forests. Unmanned Aerial Vehicle (UAV) aerial photography has the advantages of quickly acquiring the large-scale surface information, high-resolution image, and low flight cost. Nowadays, high-density stereo point cloud data can be obtained through image-matching, which is suitable for stand height extraction. The purpose of this study was to extract the stand height using the UAV aerial imagery produced a canopy height model (CHM) and to verify the tree height of each tree inventory data in the ground plots.

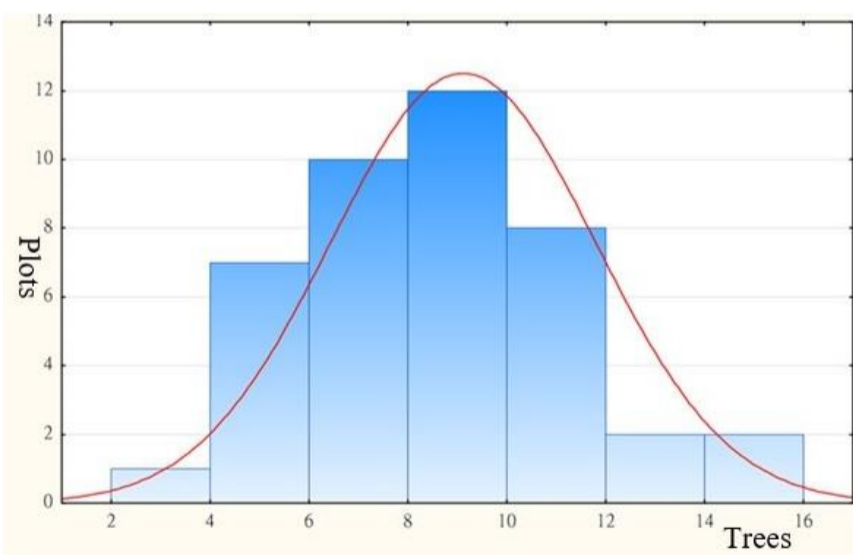
Materials and Methods

Located in Danongdafu forest park, Hualian, Taiwan.



Result

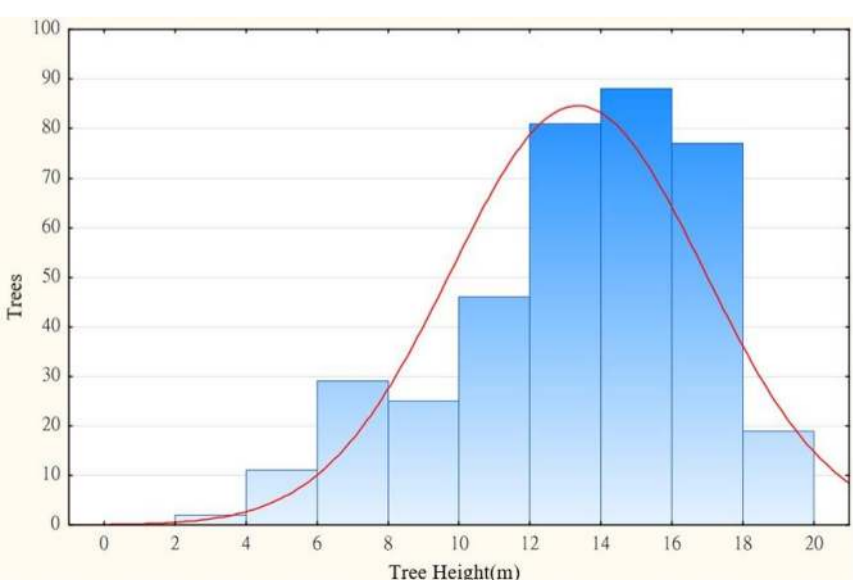
In this study, 40 0.01 ha plots were set according to different forest densities. The tree species are *Liquidambar formosana* Hance, and forest age is 16 years. DBH and tree height were measured by ground Lidar. The number of plants in the plots were 378. The number of plants in the plots were from 2 to 16 trees. The Kolmogorov-Smirnov test indicated that the number of plants in the sample area was normal. According to the distribution pattern of the sample area, the forest density was divided into three levels: high density (10 or more), medium density (7-9), and low density (6 or less).



	Average	Max	Min	Median
DBH(cm)	15.68±5.30	33.6	4.10	15.40
Tree Height(m)	13.35±3.56	19.88	2.88	13.88

The measure of tree height and stand height

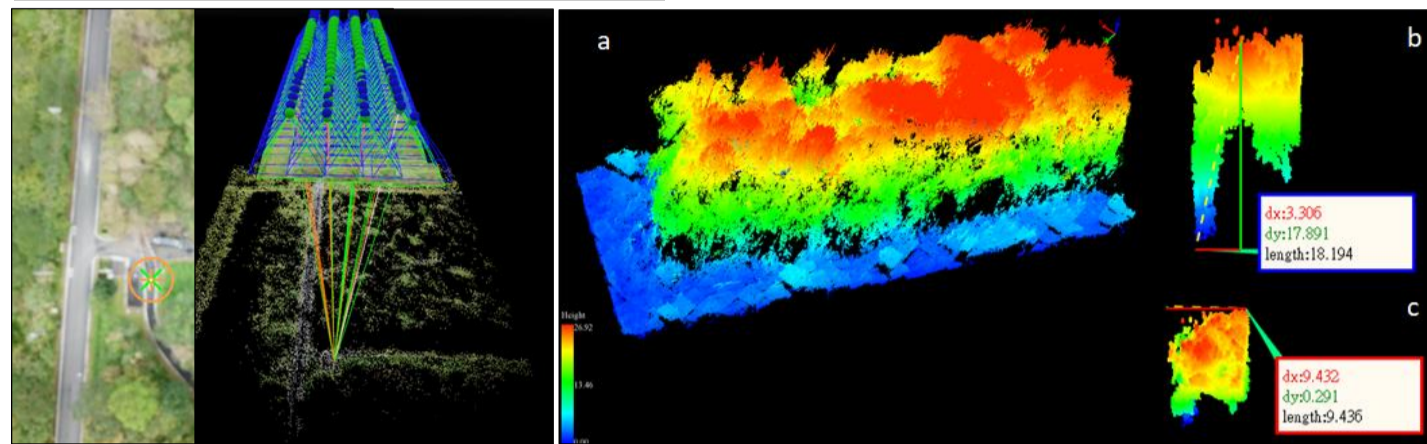
The height of trees is mainly distributed from 88 to 16 m, accounting for 23.28%, followed by 12 to 14 m and 16 to 18 m, respectively, 81 and 79.



The highest tree height, the average tree height of the three dominant trees, the third tree average tree height and the average tree height were calculated.

Stand Height Table from Lidar	Stand height	Max.	Min.	Median
Highest tree height (m)	16.47±2.03	19.87	12.83	16.96
Average tree height of three dominant trees (m)	15.87±2.00	18.88	12.23	16.37
Third and quartile tree height (m)	15.40±2.12	18.73	11.56	16.03
Average tree height (m)	13.65±2.61	18.06	8.53	13.78

The Estimation of Stand Height

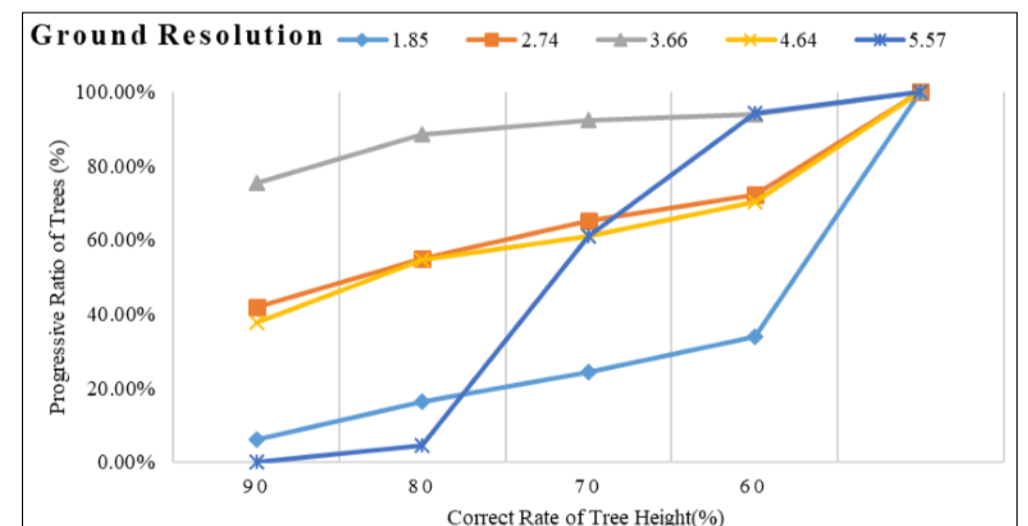


Stand Height Table from UAV	Average	Max.	Min.
Highest tree height (m)	13.37±3.56	19.16	6.91
Average tree height of three dominant trees (m)	12.40±3.47	17.74	6.10
Third and quartile tree height (m)	11.75±3.39	17.56	6.59
Average tree height (m)	10.53±3.29	16.26	4.89

The UAV point cloud data was used to measure the high stand height of the stand, and it was expressed by four kinds of stands.

UAV Point Cloud Data Estimation of Accuracy Assessment of Stand Height

Using the difference between the tree height estimated by UAV and the tree height measured by lidar, the correct rate is calculated, and the relationship between the correct rate estimation and the image resolution is discussed.



In order to understand the UAV optimal stand high measurement method, this study uses the flying height of 100 m and the coverage of 90% for image matching, and the obtained point cloud data are analyzed by regression analysis to discuss the accuracy of the four forest high measurement methods. The results show that the third quartile tree height has a discriminating coefficient R^2 of 0.92 and an RMSE of 3.94 m, while the highest tree height has a discriminating coefficient R^2 of 0.84 and an RMSE of 3.61 m, indicating four UAV stands. All have their accuracy.

Conclusions

Image capture with UAV can obtain stand value. The high maneuverability of UAV shooting can greatly reduce the time and space error, and solve the difficulties caused by the two-stage sampling survey of the past aerial survey data. The UAV can be used to obtain 3D point cloud data at low cost, and is often used in forest resources to measure a tree or stand value, and then to estimate large area accumulation or biomass. In this study, the UAV is used to test the flight altitude and image coverage. The results show that the resolution is close to 3.66 cm, that is, the flying height is about 100 m, and the coverage is 90%, which is the most suitable standard for establishing the image matching point cloud in the UAV forest area. Obtain the high quality stand parameter.