Development of a growth prediction system for regional forest resources using remote sensing data: A case study of Japanese cedar plantation forests

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Abstract : This study aimed to develop a local area forest growth prediction system using airborne LiDAR data and a Local Yield Table Construction System. First, we estimated stand condition, such as diameter distribution and average tree height, based on airborne LiDAR data. Second, we checked the accuracy of average tree height and diameter growth predicted from the Local Yield Table Construction System (LYCS) using permanent plot data. Finally, we input the data of stand condition derived from airborne LiDAR data into the LYCS and predicted the growth of stand volume for 10 m × 10-m plots. The simulation showed that the goodness of fit for observed data depending on the initial value of average tree height and DBH. In this study, we confirmed that it was possible to estimate local forest resources by considering differences of average tree height and diameter in actual stands conditions.

Key words : airborne LiDAR data, Local Yield Table Construction System, stand growth

I Introduction

In recent years, the visual literacy and surface imagery of remote sensing technology has become highly developed. In particular, airborne LiDAR data enable us to estimate various stand factors, such as tree height and crown information (*6*). Alternatively, based on information on specific stand conditions, a growth model can be applied to various forest types and tree species (*2*, *3*, *4*). If the stand information derived from airborne LiDAR data could be input to the growth model it is possible to predict forest resources at a regional level. This study aimed to predict future forest growth based on the linkage of airborne LiDAR data and an existing growth model.

II Method

The study area was the University Forest in Chiba. The forest belongs to the University of Tokyo and is located in Chiba Prefecture, Japan, between 50 and 370 m above sea level.

In this study we checked the accuracy of estimates predicted by the Local Yield Table Construction System (LYCS: *7*), and estimated local forest resources by linking airborne LiDAR data and the LYCS. We set the observed values of diameter distribution at a stand age of 20 years as an initial value, and then input the thinning plan to the LYCS according to historical records of silvicultural practices in a Japanese cedar permanent plot. We then compared the estimated and observed values of the mean DBH, diameter

Tohru NAKAJIMA (Research Fellow of the Japan Society for the Promotion of Science, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo, 113-8657, Japan), Takuya HIROSHIMA, Satoshi TATSUHARA, Satoshi TSUYUKI, Norihiko SHIRAISHI (The University of Tokyo), Yasumasa HIRATA, Mitsuo MATSUMOTO, Naoyuki FURUYA, (Forestry and Forest Products Research Institute, 1 Matsunosato, Tsukuba, Ibaraki 305-8687, Japan) Development of a growth prediction system for regional forest resources using remote sensing data: A case study of Japanese cedar plantation forests distribution, and tree height. We also checked the accuracy of estimated tree height and DBH by comparing tree height and DBH derived from airborne LiDAR data with observed value in the study site.

Next, we estimated local forest resources by linking airborne LiDAR data and the LYCS. Figure 1 shows the flow chart of the procedure for prediction of forest resources. We used the airborne LiDAR data collected and analyzed in a previous study (5). A DEM and a DSM for the study area were prepared from the airborne LiDAR data, with a 25-cm cell size. Data for the digital canopy model, which delineates canopy height from the ground, were calculated by subtracting the DEM from the DSM. We conducted watershed analysis with a reverse DCM and identified the crown area and tree position using a local maximum filter. We calculated average tree height and stand density by DCM and counting tree numbers in a 10 × 10-m grid. DBH was calculated by applying the allometric formula estimated by Hirata (1) to the crown area derived from the watershed analysis. Based on stand density and DBH of individual trees, we calculated diameter distribution by counting tree numbers per 2 cm diameter classes. Finally, we input the average tree height, stand density, and diameter distribution into the LYCS and simulated the future stand volume in a 10×10-m grid.

Ⅲ Results and Discussion

Figure 2 provides a comparison between the mean DBHs estimated with the LYCS and those given for the permanent plots of residual trees. Although the error rate at some stand ages was as high as 12%, both DBHs were close in value, with an average difference of about 7%. Figure 3 shows a comparison between tree heights estimated with the LYCS and those reported in the permanent plots. This comparison shows that the values are almost identical, with an average difference of about 9%. Figure 4 shows a comparison between the estimated and observed diameter distributions. Setting the diameter distribution at age 20 years as the initial value, we predicted the diameter distribution of the stand at 45 and 102 years old. The results of the prediction of diameter distribution were accurate; however, the curves of the distributions of the observed and estimated data were not in accordance in some DBH classes. Based on these results, we confirmed the accuracy of average tree height and diameter growth predicted with the LYCS using permanent plot data.

Figure 5 shows the comparison between observed and estimated tree height and DBH using airborne LiDAR data. The respective coefficients determined from this relationship were 0.81 about tree height and 0.90 about DBH. A comparison of the tree height and DBH estimated using airborne LiDAR data with values observed in the permanent plot showed that the values were almost identical, with average tree height differences of about 4.6% and DBH differences of about 15.5 %.

Figure 6 shows the prediction of stand volume by linking the LYCS and stand condition derived from airborne LiDAR data. The stand volume was relatively high in the part of the southwest area. This area is the highest Japanese cedar plantation forest in the university forest in Chiba. The simulation showed that the adjustability of fit for differences of stand growth depend on a relatively steep slope and complex terrain in this area. Figure 5 also showed that stand volume increased with stand age. This simulation was based on estimates predicted by the LYCS. As mentioned above, the accuracy of the average tree height and diameter growth was checked using permanent plot data; therefore, it was considered that the accuracy was similar among the methods. In this study, we confirmed that it may be possible to estimate local forest resources, taking into consideration differences of average tree height and diameter in actual stand condition.

Ⅳ Conclusion

This study constructed a system for the simulation of forest resources by linking remote sensing and a growth model. We confirmed the accuracy of average tree height and diameter growth predicted with the Local Yield Table Construction System using permanent plot data. It was found that local forest resources, taking into consideration differences of actual stand conditions, could be predicted based on airborne LiDAR data and the Local Yield Table Construction System.

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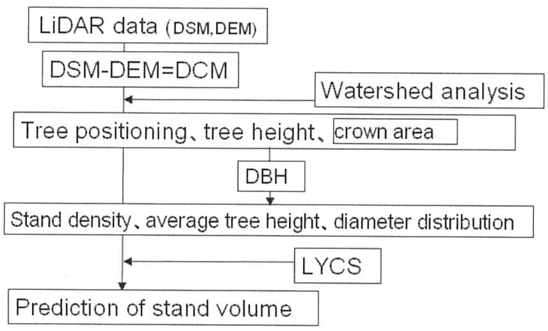


Fig-1. Flow chart of the procedure for prediction of forest resources in a 10 × 10-m grid

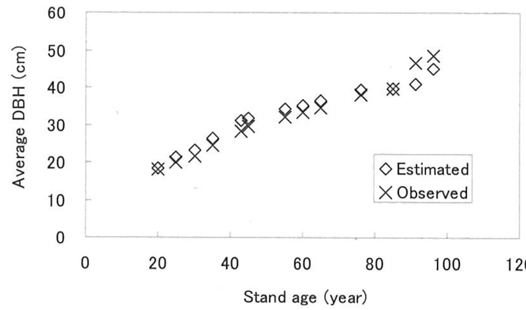


Fig-2. Average DBH comparison between the observed and estimated data for permanent plots

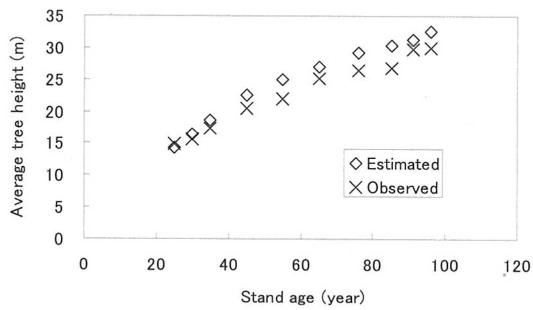


Fig-3. Average tree height comparison between the observed and estimated data for permanent plots

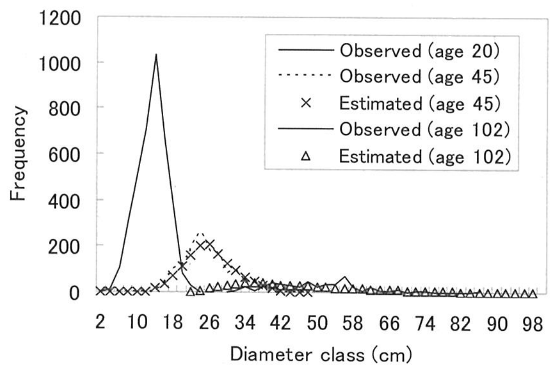
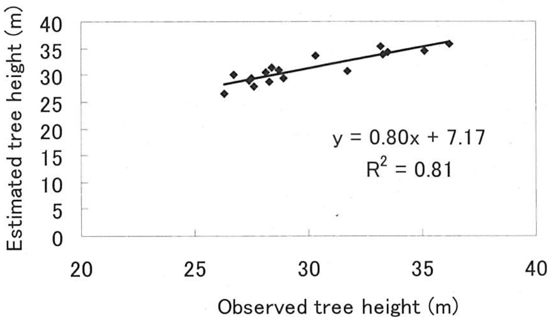


Fig-4. Diameter distribution comparison between the observed and predicted data for permanent plots of Japanese cedar in the University Forest in Chiba, the University of Tokyo

(a)



(b)

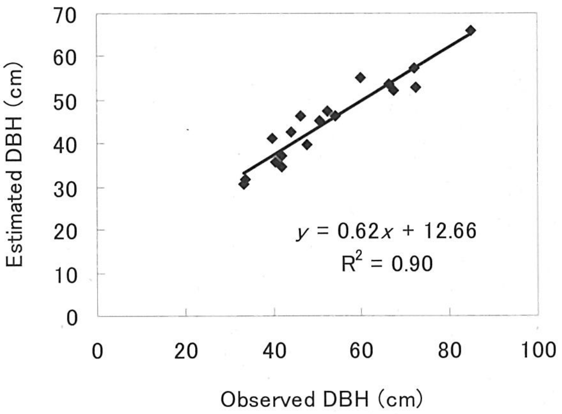
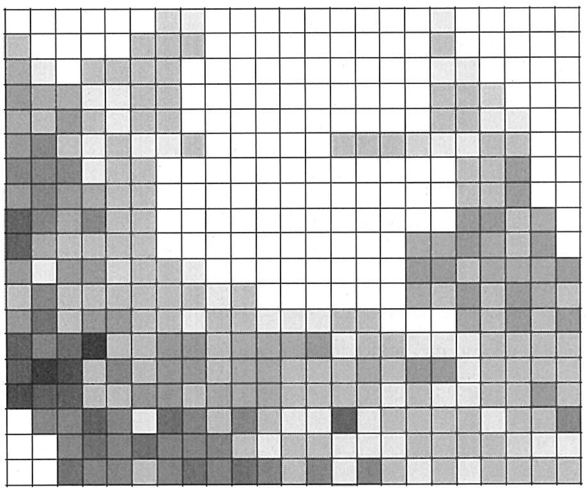
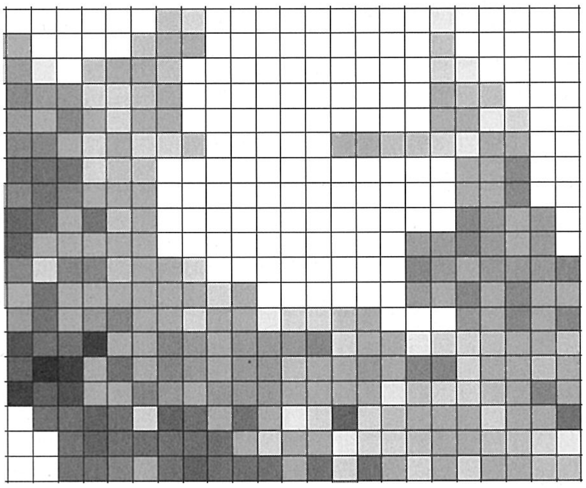


Fig-5. The comparison between observed and estimated (a) tree height and (b) DBH using airborne LiDAR data

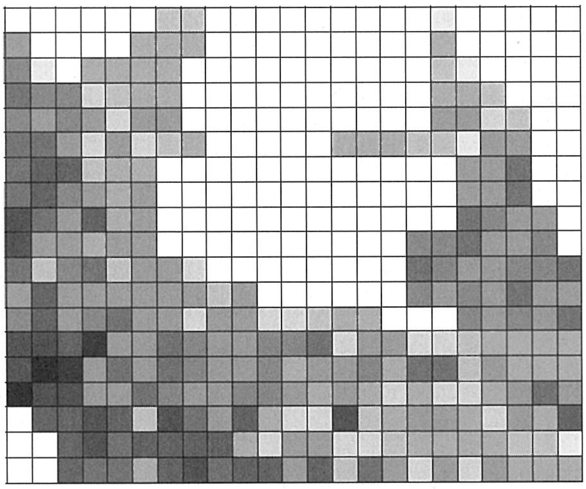
(a: age 102)



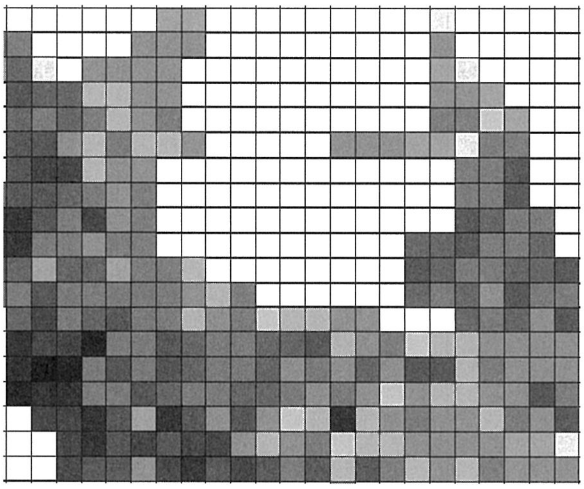
(b: age 112)



(c: age 122)



(d: age 132)



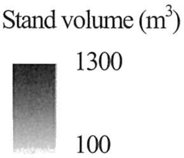


Fig-6.The prediction of stand volume by linking Local Yield Table Construction System and stand condition derived from airborne LiDAR data (Grid size : 10 m × 10-m).