LARGE-SCALE SURVEY OF FLOWERING CHERRY TREES USING AIRBORNE LIDAR

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Introduction

The Japanese are particularly fond of flowering cherry trees. Being the most famous scenic location for cherry blossom appreciation in spring, the landscape at Yoshinoyama, Nara Prefecture, has a history of 1,300 years. In 2004, the landscape was designated as a UNESCO World Heritage Site, the Sacred Sites and Pilgrimage Routes in the Kii Mountain Range. The landscape of flowering cherry trees at Yoshinoyama is an important cultural heritage for the Japanese people and also an important economic resource for local people who benefit from tourism.

Recently, however, diminished tree vigor has gradually become a concern of some of the local people. Upon request, an extensive survey was conducted from 2008 to 2010 [1]. The survey, which focused mainly on the central area of Yoshinoyama (called Nakasenbon), collected data at the individual tree level and attempted to comprehend the possible mechanism of decline and death of trees. Although 74 trees were studied intensively and 22 trees (about 30 %) were assessed as being in decline, the survey could not reveal the status of the cherry trees in the whole area of Yoshinoyama. Therefore, the local government decided to carry out a large-scale survey using remote sensing in order to understand the overall condition of cherry trees throughout Yoshinoyama. This work is a pilot study aimed at developing a new large-scale survey method for obtaining information essential to developing a management plan for the flowering cherry trees.

Methods

Yoshinoyama (34°22′ N, 135°52′ E), located in the center of Nara Prefecture, has an elevation range of ca. 200 to 850 m above sea level, and flowering cherry trees (mostly Japanese mountain cherry, *Cerasus jamasakura* (Siebold ex Koidz.) H.Ohba var. *jamasakura*), have been planted within a total area of about 50 ha. Airborne remote sensing was conducted twice, on April 17 and August 4, 2011. A helicopter with a mounted LiDAR system (LMS-Q560, RIEGL) and a fine-resolution digital camera flew back and forth to cover the whole Yoshinoyama area. An on-ground survey was carried out simultaneously to collect location data of 324 cherry trees and to assess the condition of vigor (using a conventional visual four-rank assessment method by two experts) of 288 cherry trees.

First, individual crowns of cherry trees were delineated manually by referring to the orthophotos and a digital surface model (DSM) derived from the LiDAR data. Orthophotos acquired in April were used to identify cherry trees based on the color of the flowers. Then, the number of cherry trees in the whole area of Yoshinoyama was estimated by considering the detection rate. The detection rate was calculated as N_R / N_A, where N_R is the number of cherry trees detected by remote sensing and N_A is the actual number of trees.

Second, two growth indices were derived for each tree crown from the LiDAR data (converted in advance to 50-cm grid data) to assess cherry tree condition in the whole area of Yoshinoyama:

[Index 1] the Height Index (HI), which indicates the growth of tree height, was calculated as the height difference of the DSM between April and August.

[Index 2] the Density Index (DI), which indicates the density of branches and leaves in the tree crown, was calculated as the laser interception rate L_V / (L_V + L_G), where L_V is the number of laser hits on vegetation and L_G is the number of laser hits on ground.

After calculating these two indices for each tree crown, the two indices, HI and DI, were standardized (i.e., the data were converted to have mean = 0 and S.D. = 1), added together, and then standardized again. This mathematical operation yielded the standardized LiDAR Growth Index (LGI). Lastly, the tree growth condition was evaluated according to a threshold that was established by referring to the results of the simultaneously conducted on-ground survey: Good (Rank 1.0–1.5 in on-ground survey, corresponds to LGI ≧ 0.5); Fairly Good (Rank 1.5 – 2.5, LGI = 0.5–0.0); Fairly Bad (Rank 2.5 – 3.5, LGI = 0.0 – –0.9), and Bad (Rank 3.5 – 4.0, LGI < –0.9).

Results

The number of cherry trees estimated in Yoshinoyama was about 10,300 (about 9,700 to 11,000 at the 95 % confidence level) (Table 1).

Among the 7,246 cherry trees that could be analyzed in the whole area of Yoshinoyama by remote sensing, 13 % of the trees were estimated as being in “Bad” condition. If “Fairly Bad” condition trees and “Bad” condition trees are summed, 48 % of all the cherry trees can be assessed as being in an unfavorable condition (Fig. 1). Smaller trees had a greater proportion of “Bad” condition trees (about 20 % for mean tree crown height < 5 m).

Table 1: Estimated number of cherry trees in the whole area of Yoshinoyama (as of April 17, 2011)

Estimated number of cherry trees in Yoshinoyama (point estimation)	10,252
Estimated number of cherry trees in Yoshinoyama (95 % confidence interval)	9,654 − 11,019
(Reference) Detected number of cherry trees in Yoshinoyama by remote sensing	7,499
Mean detection rate at the on-ground survey sites	73 % (237 out of 324 trees)
95 % confidence interval of mean detection rate at the on-ground survey sites	68 − 78 %

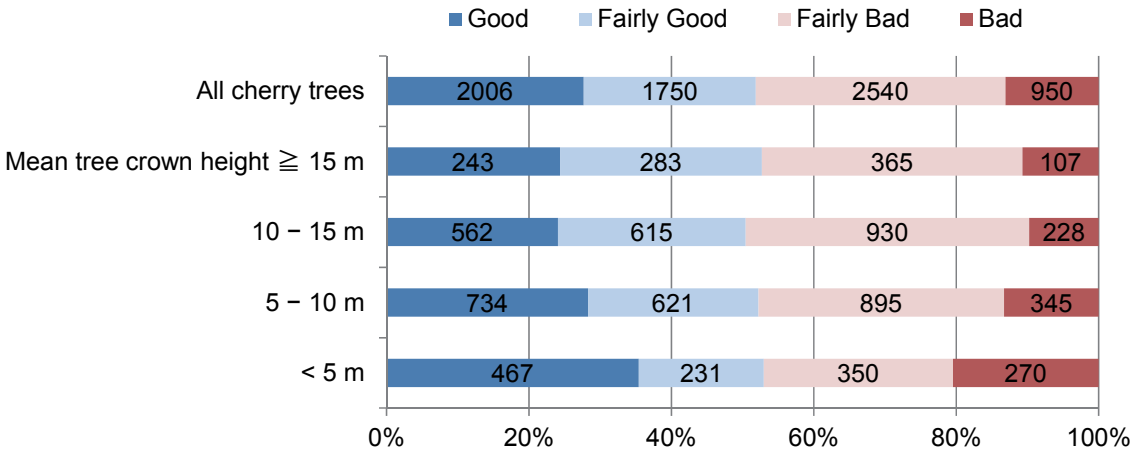

Fig. 1: Estimated growth condition of cherry trees in the whole area of Yoshinoyama

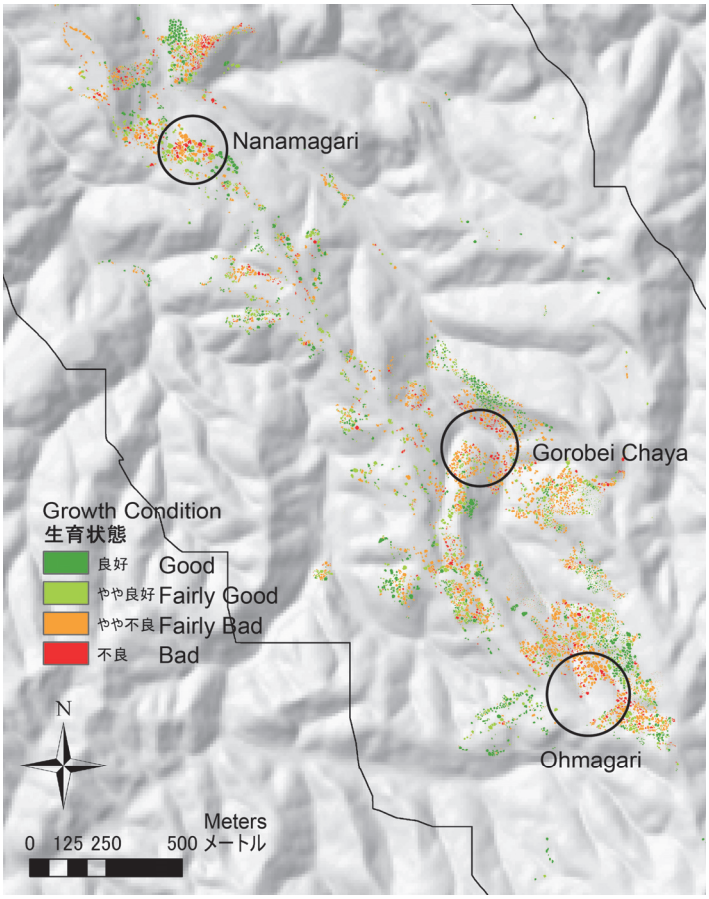

Fig. 2: Spatial distribution of estimated growth condition of cherry trees from the lower area (Shimosenbon) to the upper area (Kamisenbon) in Yoshinoyama

The spatial distribution of tree growth condition showed a distinct structure. For example, the Nanamagari area in the lower area, the Gorobei Chaya area in the central area, and the Ohmagari area in the upper area had more “Bad” or “Fairly Bad” condition trees (Fig. 2).

Discussion

This study revealed that about 10,300 cherry trees were growing in Yoshinoyama at the time of data collection (Table 1). Although a relatively large-scale survey of cherry trees was conducted in Nara Prefecture in 1993 and 1994, the survey covered only one-third of Yoshinoyama and the status of the whole area of cherry trees remained unknown. Therefore, obtaining the total number of cherry trees was important to the local government for considering a future management plan of the flowering cherry trees.

In this study, an evaluation method that utilized airborne LiDAR data of two seasons, spring and summer, was developed. This technique successfully estimated the growth condition of more than 7,000 trees based on two aspects: height growth and branch and leaf density. As a result of the estimation, 48 % of cherry trees were in an unfavorable, “Bad” or “Fairly Bad,” condition (Fig. 1). This percentage was greater than the previously reported 30% estimated from a small population of 74 trees [1]. Thus, it indicates the necessity of taking urgent measures.

Smaller trees, deemed as younger trees, had a greater proportion of “Bad” condition trees. This implies that the initial establishment following planting has some problems, possibly poor condition of seedlings, insufficient light conditions beneath taller trees, feeding damage caused by deer, or unsuitable weather conditions after planting.

The spatial analysis of tree growth condition revealed that trees in undesirable conditions are concentrated in some areas, e.g., the Nanamagari, Gorobei Chaya, and Ohmagari areas. Because these areas are the most visible regions to tourists, it is suggested that an intensive tree care program be implemented in these areas.

Conclusion

The overall condition of flowering cherry trees was estimated by acquiring airborne LiDAR data for two seasons. This unique technique could be implemented successfully in a large-scale survey. It is expected that the results obtained in this study will be utilized effectively to develop a future management plan for the cherry trees in Yoshinoyama.

Acknowledgements

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