

Evergreen broadleaf forest transition zone changes in Japan from 1961 to 2008 detected by aerial ortho-photos

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Abstract. In order to detect the distribution change of evergreen broad-leaved trees (EBTs) in a old-growth forest on the transitional zone of cool-temperate and warm-temperate zones, we used the ortho-photo data converted from the aerial photos. Comparing the crown map of EBTs in the 1-ha verification plot with the ground truth data of individual tree inventory, 14 out of 17 (82%) upper layer trees were found to be visually read on the aerial photo. We chose two indices for detecting the distribution change of EBTs, crown number and total crown area. We made crown maps of the 20-ha plot based on ortho-photos in 1961, 1975, 1985, 2003, 2005 and 2008, and calculated crown number and total crown area for each photos. The crown number increased at a rate 0.18/year/ha from 1961 to 2000's, and total crown area also increased at a rate 0.21% for the 20-ha plot. The total crown area increase was highly probable because errors of area in ortho-photos were smaller than secular changes of the area.

1. Introduction

Global warming has become one of the most important environmental problems. The average global surface temperature has increased by about 0.8 degree Celsius since 1880. The past climate seems to cause vegetation changes. In this study, we focused the distribution changes of vegetation from the past to the present. There are some papers about the detection of the changes of distribution of vegetation (e.g., [1], [2], [3], [4]), but there are no papers to detect the distribution change of evergreen broad-leaved trees (EBTs) in the old-growth forest on the transitional zone of cool-temperate and warm-temperate zones with high accuracy. In this study we examined the method to detect the distribution change of EBTs with high accuracy.

In order to detect the distribution change of EBTs, we selected the aerial photos. In Japan, aerial photos were taken from the 1930's. From 1950's, Geographical Survey Institute has taken aerial photos all over Japan. And in the 1970's, color aerial photos are taken in all of Japan. So in Japan, the aerial photos are oldest remote sensing data. And the resolution is high enough to interpret crowns of EBTs ([5], [6]).

But in order to use the aerial photos as GIS data, it is necessary to convert the aerial photos into digital ortho-photos. But orthographically errors of the area are left, and changes of distribution of vegetation are occasionally small to ignore the errors.

We defined two indices for detecting the distribution change of EBTs: crown number, which has no connection with the area, and total crown area, which needs the investigation of the error to detect the changes.



2. Study area and data

In this study, we set up two plots in an old-growth forest on the transitional zone of cool-temperate and warm-temperate zones on the southern slope of Mt. Tsukuba in Japan. This forest has been protected as shrine forest of Tsukubasan Shrine. Deciduous broad-leaved trees are distributed over the high altitude with EBTs over the low altitude. One was the 1-ha verification plot, in which individual tree inventory was done in 2007, and the other one was 20-ha plot (actually 20.4 ha) for crown reading on ortho-photos. We selected aerial photos and ortho-photos, where were taken in the defoliation periods between winter and spring (table 1).

Table 1. Ortho and aerial photo data

Date of photography	Color/BW	Focal distance		Pixel size		Single /Stereo	Ortho/Aerial
		(mm)	Flight height	(cm)			
2008/5/21	color	152.90	2,429	20.0		Single image ortho	ortho only
2008/5/7	color	152.90	2,429	20.0		Single image ortho	ortho only
2005/11/18-28	color	100.00		8.0		Single image ortho	ortho only
2003/11/17	color	151.61	2,416	20.0		Single image ortho	ortho only
1986/11/6	color	151.43	1,640	20.0		Single image ortho	ortho and aerial photo
1975/1/21	color	152.69	1,580	18.0		Stereo matching	ortho and aerial photo
1961/2/1	BW	210.36	5,300	50.0		Stereo matching	ortho and aerial photo

3. Method

3.1. Making crown maps

First, we made a crown map of EBTs in the 1-ha verification plot, using ortho-photo taken in 2005. We determined whether every tree crown was evergreen broad-leaved or not by visually reading, and made the polygon for each tree crown. We also used the 2003 and 2008 ortho-photos as assistant data for visually reading. We compared the crown map with the ground truth data of individual tree inventory in the 1-ha verification plot to confirm the accuracy of visual reading.

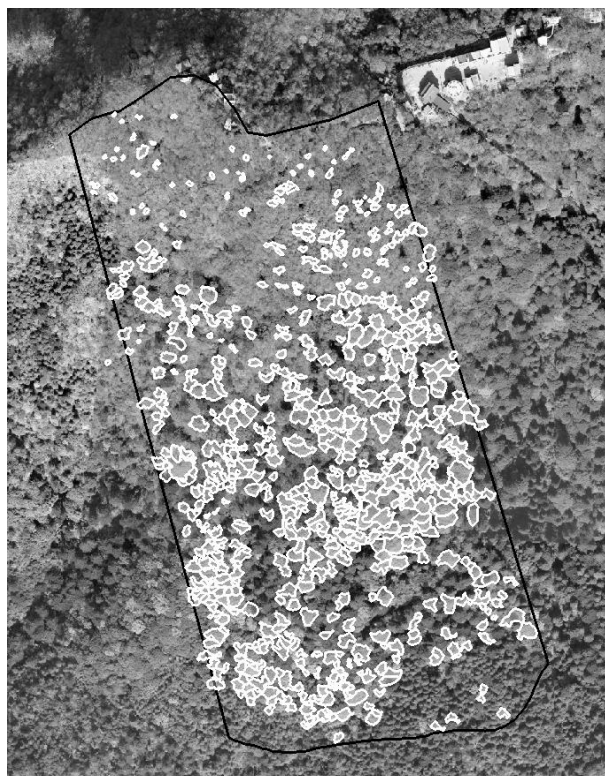


Fig. 1. The crown map of EBT in large plot (white line), using the 2005 ortho photo

Second, we made an EBT crown map of 20.4-ha plot based on ortho-photo taken in 2005 (Fig 1). We used 2003 and 2008 ortho-photos as assistant for visually reading. Next, we made the crown maps based on ortho-photo taken in 2003 and 2008 with reference of the crown map of 2005. We made crown maps based on ortho-photos taken in 1961, 1975 and 1986. In order to improve the accuracy of visual reading, we used the history data for each crown. We collected the presence-absence data for each crown in each photo, and used them to improve the accuracy.

3.2 Crown number and total crown area

We selected two indices, crown number and total crown area, in order to detect the distribution change of EBTs.

In order to use the aerial photos as GIS data, we converted the aerial photos into ortho-photos. There are errors of area because of orthographically errors, boundary lines errors and so on. It is too difficult to measure the crown area on the ground, and we can't know the true value of crown area. For this reason, we chose crown number as the index irrelevant to error of area. But it has another difficulty in separating EBT crowns, based on the shape and texture. Thus, to increase accuracy of this index, we identified each crown on ortho-photos of 2000's at first. Crown number of 2003, 2005, and 2008 was all same numbers. But it took a lot of time and we must repeat to adjust the boundary whenever ortho-photos were added. So for 3 data of 1900's, we calculated the crown number from crown history data (presence-absence data for each year of photography).

For determining crown number in ortho-photos in 1900's, we identified each crown in connection with that of ortho-photos in 2000's to make crown history data (presence-absence data for each year of photography).

The other index we chose was total crown area, sum of the crown polygons area, and it isn't necessary to identify the each crown. But in order to detect the distribution change by total crown area, we must consider errors of area. We assumed "errors of area" as follows:

1. From 2003 to 2008, the change of true total crown area is 0. Then "true total crown area" of 2000's is defined as mean of total crown area in 2003, 2005 and 2008.
2. The biggest value in three differences between true total crown area and each total crown area of 2000's is defined as the "error of area".
3. The "error of area" and secular changes between true total crown area and total crown area of 1900's is compared. If

"Error of area" < "distribution changes"

over the time, we detect the distribution change by total crown area.

4. Result and Discussions

4.1 Determination accuracy on visual reading of EBT crowns

Comparing the crown map of EBTs in the 1-ha verification plot with the ground truth data of individual tree inventory, 14 out of 17 (82%) upper layer trees were found to be visually read on the aerial photo (Table 2). None of the middle-layer and lower-layer trees were detected.

Table2. Accuracy on visual reading of evergreen broad-leaved crowns

	Upper	Middle	Lower
Ground truth	17	47	23
Visual reading	14	0	0

4.2 Change of crown number and total crown area.

Total crown number in the 20-ha plot increased almost lineally at a rate 0.18/year/ha from 1961 to 2000's (Fig.2 Top). That increased steadily in every elevation between 500m and 850m, especially in the high elevation, more than 750m (Fig. 2 Bottom).

4.3 Change of total crown area.

The differences (D) between true total crown area (M) and total crown area of each photos are shown in Table 3. The maximum difference of D/M in 2003, 2005 and 2008 was 4.2%, which was assumed to be the error of total crown area of ortho-photos. D/M in 1961, 1975 and 1986 was between 21.08 and 40.22, which was much larger than the error of total crown area. This results suggested that total crown area increased from 1961 to 2000's steadily.

Table 3. Total crown area, "true total crown area", and "errors of area" in 20-ha plot

Year	Total crown area(m ²)	M-total crown area (D)	D/M (%)
2008	43959	646	1.45
2005	46480	-1876	4.20
2003	43376	1229	2.76
"True total crown area" (M)	44605		
1986	35201	9403	21.08
1975	30430	14175	31.78
1961	26663	17942	40.22

Total crown area increased linearly at a rate of 0.21% in the 20-ha plot, and total crown area of 2000's is 1.67 times larger than that of 1961 (Fig.2 top). Total crown area increased steadily in every elevation between 500m and 850m (Fig.2 bottom). The increase was the largest in middle elevation, between 600m and 650m.

These results that crown number and total crown area increased from 1961 to 2000's indicated that EBTs increased in the past 47 years.

5. Conclusion

We tested to detect the distribution change of EBTs in an old-growth forest on the transitional zone of cool-temperate and warm-temperate zones, using ortho-photo data, converted from the aerial photos. Two indices, crown number and total crown area, showed the distribution change for 47 years. But both indices have strong and weak points. Crown number does not need to consider the errors of area, but needs to identify each EBT crown. On the contrary, total crown area does not need to identify each EBT crown, but needs to consider the errors of area.

On the southern slope of Mt. Tsukuba, the number and total area of EBT crowns increased from 1961 to 2008 steadily. These results need to ecologically estimate the relation to the fact that the average global surface temperature increased during the past 100 years.

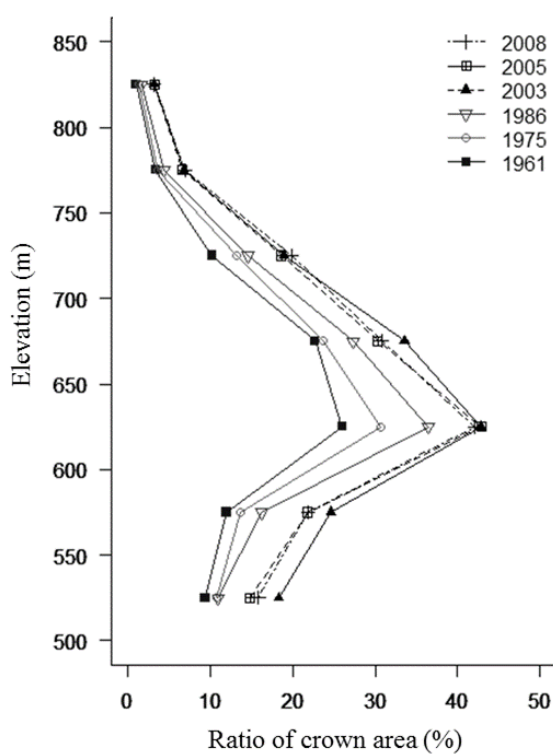
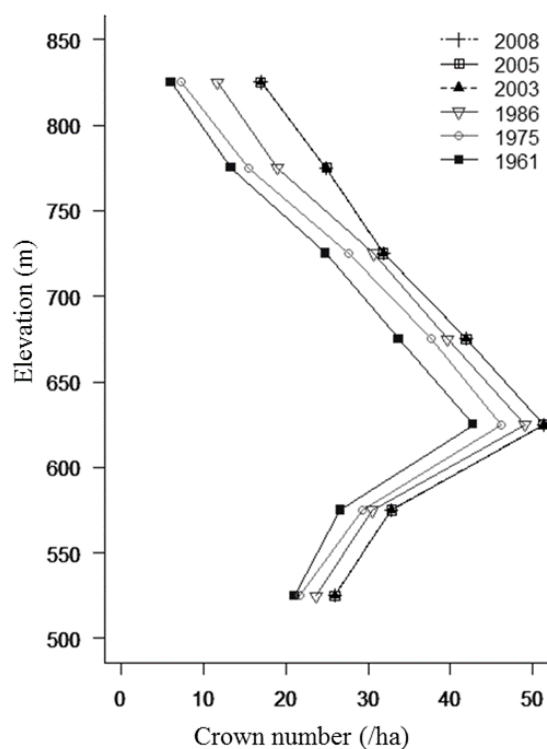
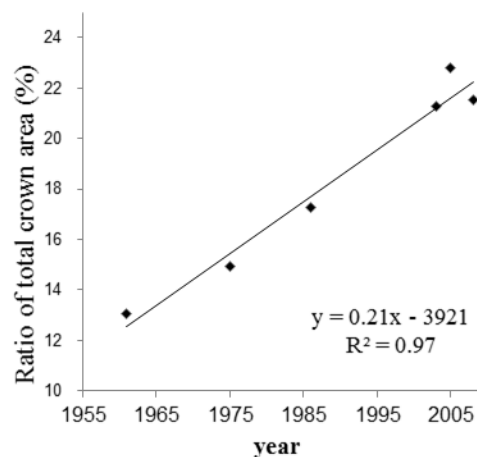
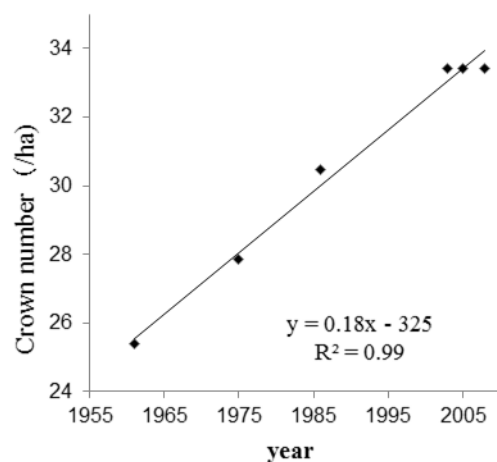


Fig 2: the change of crown number per ha in 20-ha plot.
 Top: whole elevation,
 Bottom: every 50m elevation

Fig 3: the change of ratio of total crown area in 20-ha plot
 Top: whole elevation,
 Bottom: every 50m elevation

Acknowledgement

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