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Unambiguous determination of full bloom date in *Prunus verecunda* and bud flush date in *Fagus japonica* based on video recording archives

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1. Introduction

Tree phenology has been considered to become an ecological indicator for global climatic change.[1)] Meteorological Agency indicated that cherry blossoms tend to bloom earlier throughout Japan.[2)] Trees used in the meteorological observation is normally located in the vicinity of city. However, trees in a natural forest must be essential as an ecological indicator of influence on forest ecosystem.

However, daily and long-term observations of tree phenology are difficult in a natural forest due to low accessibility. Then, previous studies on the tree phenology of the natural forest were conducted less frequently than that of urban areas, with interval of 3 to 7 days for several years. [1) 3) 4)] Consequently, no daily observations have been conducted over ten years.

This problem can be solved by automatic picture taking system. Recently, several systems have been developed. For example, the phenology of *Betula ermanii* is being observed with fixed photographic images in the Nature Education Park of Shinshu University, which has been located in a mountainous region since 1986.[5)] This previous study showed possibility of phenology observation by automatic picture taking system, but the accuracy of the method is not examined.

We started video recording from 1995, in University Forest in Chichibu, the University of Tokyo. Long-term data of 13-year video recording archives are available for examining tree phenologies, such as full bloom date and bud flush date.

The purpose of this study was to examine the usefulness of video recording of full bloom date in *Prunus verecunda* and bud flush date in *Fagus japonica*. Furthermore, we evaluated trends of the tree phenology in the natural forest.

2. Materials and methods

2.1 Subjects for the analysis

We set a robot-camera for recording the forest landscape (35° 56′ 42″ , 138° 48′ 59″ ; 1070 m) in the University Forest in Chichibu (Ohtaki, Chichibu-shi, Saitama) since 1995. In this study, we

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used series of shot 1 shown in Figure 1, which was considered appropriate for observing tree phenology at the individual tree level. Digital data were archived daily at around noon for 15 seconds. The individual tree species used in this study were *P. verecunda* (35° 56′ 40″ , 138° 49′ 20″ ; 985 m) and *F. japonica* (35° 56′ 40″ , 138° 49′ 20″ ; 983 m) specimens (Fig. 1). We used 13-year data of tree phenology from 1997 to 2009.

2.2 Determination of the distinguishing date of tree phenology

Observations were performed based on the criteria described below to determine distinguishing date of tree phenology by visual observation in daily units.

For *P. verecunda*, 'the day before the day on which the ratio and appearance of flowers does not change', was considered the 'full bloom date' (Figs. 2 and 3). This criterion was based on the definition in the phenological observation guidelines that the full bloom date is 'the first day on which approximately 80% or more of the flower buds of the tree under observation have opened".[6] For *F. japonica*, 'the day on which green leaves were visible for the first time' was considered the 'bud flush date' (Fig. 3).

In case distinguishing date could not be determined because visual observations were not possible due to low visibility from adverse weather conditions or due to lack of images resulting from missed filming, the last day on which the criteria could be confirmed to have been fulfilled was set as assumed distinguishing date.

2.3 Trends of full bloom date in *P. verecunda* and bud flush date in *F. japonica*

To evaluate trends in tree phenology during 13 years, a correlation analysis between year and the distinguishing date of tree phenology was performed. The distinguishing date of tree phenology was set as the cumulative number of days starting from March 1.

Furthermore, to consider the difference of the influence of the climate change by the species, differences of date between the full bloom date of *P. verecunda* and the bud flush date of *F. japonica* was plotted.

3. Results

3.1 Determination of the distinguishing date of tree phenology

Status of video recording is shown in Table 1. We used digital data of 390 days (from April 15th to May 14th) in total. There were 43 days (about 11 %) when the phenologies were not able to be observed from adverse weather. There were 31 days (about 8 %) when the picture was not taken. Therefore, there were 316 days (about 81 %) when the phenologies were able to be observed.

The distinguishing dates of tree phenology and the range of the days on which the criteria could be confirmed to have been fulfilled are shown in Table 2. The full bloom dates of *P. verecunda* could not be determined in 1998 due to adverse weather. The bud flush dates of *F. japonica* could not be determined in 1999 due to lack of image and in 2003 and 2008 due to

Fig. 1 Shot for tree phenology observation (May 1, 2009)
Prunus verecunda in the red circle, *Fagus japonica* in the yellow circle.

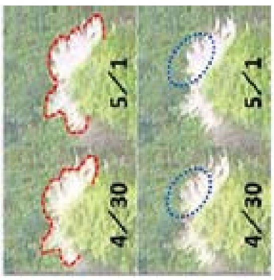

Fig. 2 Change in the ratio and appearance of flowers
In 2005. A red sign is a change in shape, and a blue sign is a change in amount.

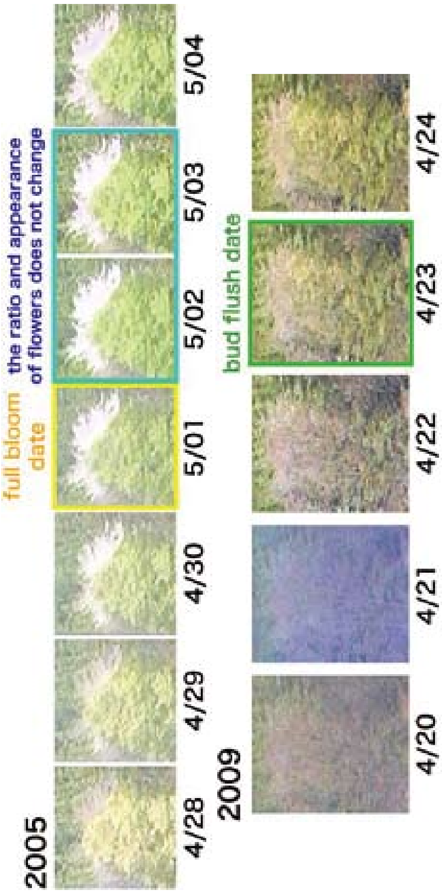

Fig. 3 Decision method of "full bloom date" of *Prunus verecunda* (Example in 2005) and of "bud flush date" of *Fagus japonica* (Example in 2009).

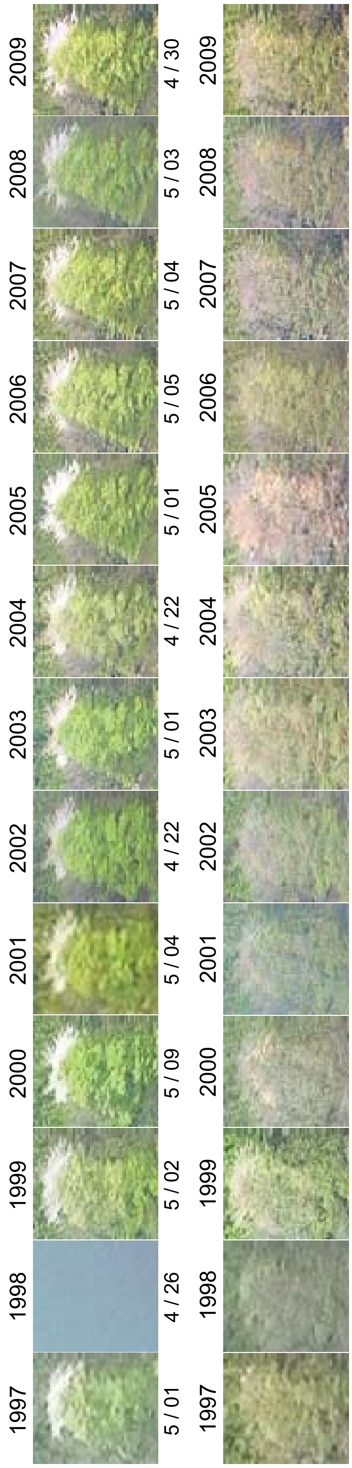

Fig. 4 Annual image at full bloom date of *Prunus verecunda* and bud flush date of *Fagus japonica* (1997-2009).

Table 1. Status of video recording

Date ＼ Year	4/ 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	5/ 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rate of missing data(%)
1997	F	F	F	F	F	F	F	F	F	T	T	T	□T	T	T	T	○T	T	T	T	T	T	T	T	T	F	T	T	T	W	36.7
1998	W	T	T	T	T	T	□T	T	T	○T	○W	○W	W	T	T	T	T	T	T	F	T	T	T	T	T	T	T	W	T	T	16.7
1999	F	F	T	T	W	T	T	□F	□F	□F	□F	□F	□F	□W	□W	□T	T	○T	T	T	T	T	T	T	T	T	W	F	F	T	40.0
2000	W	T	T	T	T	F	W	T	□T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	○T	T	F	T	T	T	10.0
2001	T	T	T	T	W	T	W	T	T	T	T	T	T	□T	T	W	T	T	T	○T	T	T	T	T	W	T	T	T	T	T	13.3
2002	T	□T	T	T	T	T	W	○T	T	T	T	W	T	T	T	T	T	W	T	T	T	T	T	T	W	W	W	T	T	T	20.0
2003	W	T	T	T	T	W	T	T	T	T	□W	□T	T	T	T	T	○T	T	T	T	T	T	T	W	T	T	T	T	T	T	13.3
2004	T	T	T	T	T	T	□T	○T	T	T	T	T	T	T	T	T	T	T	T	T	W	T	T	T	W	W	T	T	F	T	13.3
2005	T	T	□T	T	T	W	T	T	T	T	T	T	T	T	T	T	○T	T	T	T	T	T	T	T	T	T	T	T	W	T	6.7
2006	T	T	T	T	T	W	T	T	T	T	T	T	T	T	T	T	□T	W	T	T	○T	T	T	T	T	T	T	T	W	T	10.0
2007	T	W	T	W	T	T	T	T	T	F	F	T	T	T	T	□T	T	T	T	○T	T	F	T	T	T	T	T	T	T	T	16.7
2008	W	T	T	F	F	F	T	T	T	T	T	□W	□T	T	T	T	T	T	○T	T	T	T	T	T	T	W	W	T	T	T	20.0
2009	T	T	W	T	T	T	T	T	□T	T	W	T	T	T	T	○T	T	T	T	T	T	W	T	F	T	T	T	T	T	T	13.3

○: Full bloom date in *Prunus verecunda* □: Bud flush date in *Fagus japonica*
T (True): Possible to observe W (Weather): Invisible due to adverse weather F (False): Impossible to observe due to lack of image
Missing data: F and W

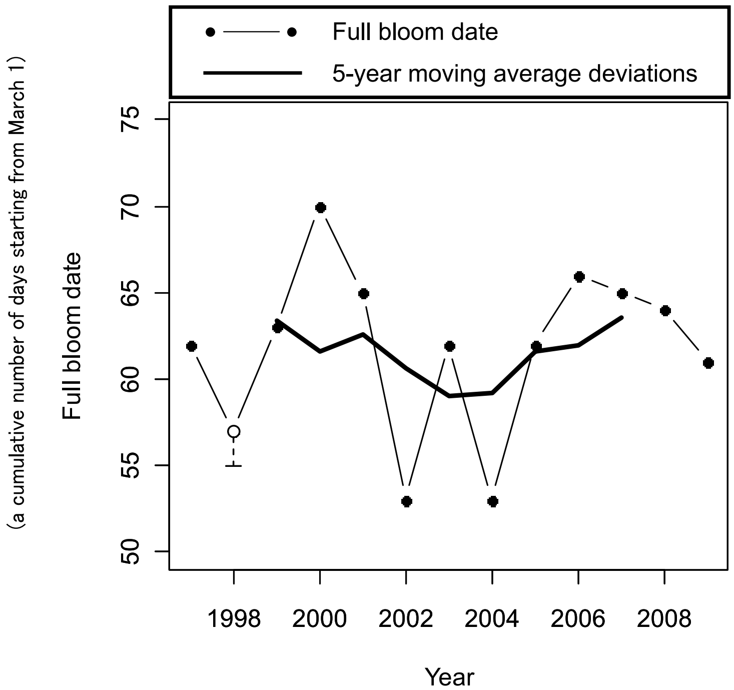

Fig. 5 Annual changes in the full bloom date of *Prunus verecunda*
The point of a white pull-out is assumed to be the distinguishing date. The dashed line shows the range of with probability.

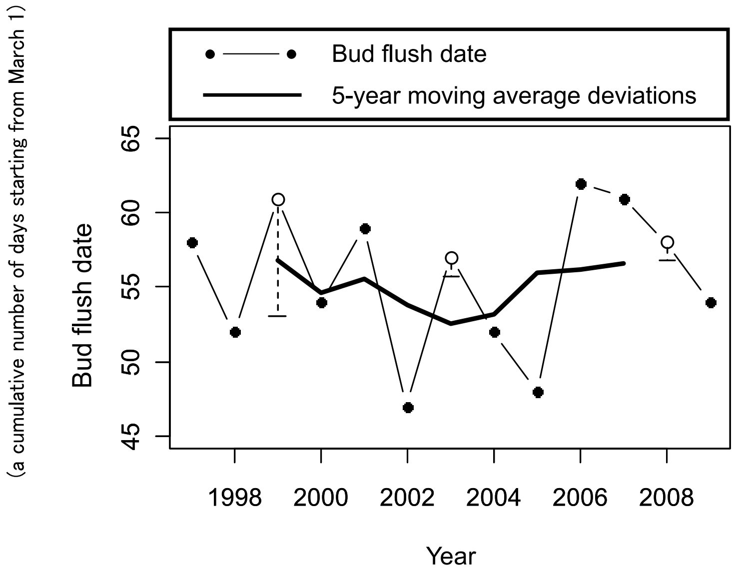

Fig. 6 Annual changes in the bud flush date of *Fagus japonica*

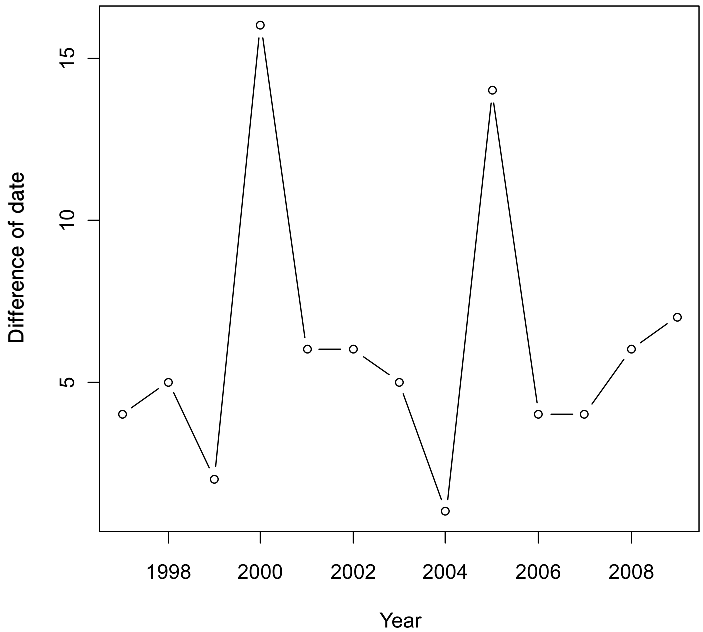

Fig. 7 Difference between full bloom date of *Prunus verecunda* and bud flush date of *Fagus japonica*

adverse weather.

Annual images of the *P. verecunda* full bloom date and the bud flush date of *F. japonica* are shown in Figure 4. The results are represented as graphs in Figure 5 and 6.

3.2 Annual changes in tree phenology distinguishing date

The correlation coefficient between year and the full bloom date in *P. verecunda* was 0.08. The correlation coefficient between year and the bud flush date in *F. japonica* was 0.06. These correlation coefficients were not significant.

The distance of date between the full bloom date of *P. verecunda* and the bud flush date of *F. japonica* are plotted in Figure 7.

4. Discussion

4.1 The validity of observing the tree phenology using video recording

The images recorded by the robotic camera allowed us to determine full bloom date in *P. verecunda* and bud flush date in *F. japonica* unambiguously (Tables 1 and 2). If we observed tree phenologies directly with interval of 5 days as previous cases for 13 years, the range of the distinguishing dates will be 65 days. The range in this study is fewer (Table 2: 15 days in full bloom date in *P. verecunda*, 23 days in bud flush date in *F. japonica*). This shows that the accuracy of the method in this study is higher.

Full bloom date in *P. verecunda* (1997-2008) has been already determined by a different

Table 2. The distinguishing date of tree phenology (1997-2009)

	Full bloom date of *P. verecunda*		Bud flush date of *F. japonica*	
Year	Range	Month/Day	Range	Month/Day
1997	1	5 / 01	1	4 / 27
1998	3	4 / 26 (24–26)	1	4 / 21
1999	1	5 / 02	9	4 / 30 (22–30)
2000	1	5 / 09	1	4 / 23
2001	1	5 / 04	1	4 / 28
2002	1	4 / 22	1	4 / 16
2003	1	5 / 01	2	4 / 26 (25–26)
2004	1	4 / 22	1	4 / 21
2005	1	5 / 01	1	4 / 17
2006	1	5 / 05	1	5 / 01
2007	1	5 / 04	1	4 / 30
2008	1	5 / 03	2	4 / 27 (26–27)
2009	1	4 / 30	1	4 / 23
sum	15		23	

observer in previous study[7] with the same method in this study. The date in 1998, when full bloom date is not able to be determined due to adverse weather, is different from the result in this study because we devised new methods for handling low visibility and missed recordings in this study. On the other hand the difference in 2005 is due to observer's personal equation. And in other years, both were corresponding. These results indicate that the accuracy of these criteria was based on individual differences in the range of ± 1 day, depending on the observer.

Therefore the method used in this study can be altered by direct tree phenology observations.

Furthermore, the merit of video recording is that if there are questions regarding distinguishing date results determined in the past, the recordings can be retrospectively observed. To be able to comparison between the distinguishing dates determined in this study and those in previous study[7] shows the reproducibility of the analysis which we can't achieve with direct observation data.

Both adverse weather and lack of image caused being not able to determine the distinguishing date. To overcome adverse weather, recording daily video is preferable in terms of risk diversification. Moreover, it is possible that recording videos of trees in the vicinity is effective. To overcome lack of image, because system trouble mostly causes lack of image, it is thought that using an easier recording method, such as still picture camera, is effective. If the observation criteria of this study are used, observation is possible using still pictures. However, if other type of phenology is observed, recording video might be better. For example, it is reported that video is better for the observation of the nut of *Fagus crenata*.[8]

4.2 Trends of the tree phenology of the natural forest

As the result of correlation coefficient, no clear trends were detected for both the full bloom date in *P. verecunda* and the bud flush date in *F. japonica* in the University Forest in Chichibu during the 13 years. Long-term data of tree phenology in mountainous areas will be useful ecological indicator to monitor climate change in forest ecosystems.

In this study, we compared phonological events of two tree species. As a result, differences of the full bloom date in *P. verecunda* and the bud flush date in *F. japonica* were remarkable in 2000 and 2005 (Fig. 7). Both 2000 and 2005 were mast-seeding years for *F. japonica*[9], and as leaves and flowers unfolded at the same time, trees looked whiter than those observed in the other years (Fig. 4). Alternate bearing may affect the period of leaf unfolding in *F. japonica*. Thus, our study provides such an important finding for the relationship between masting and bud flush phenology. Though tree phenology is possible to become ecological indicator of influence of climate change on ecosystem, it is necessary to consider that there is a species that strongly receives the influences except the climate.

5. Conclusion

Using video-recorded images filmed by the robot-camera in the University Forest in Chichibu, the University of Tokyo, we can ambiguously determine the full bloom in *P. verecunda* and bud flush in *F. japonica* during daily observations over a 13-year period. By creating an image record, it will be possible to observe these events again, and reproducibility of the analysis will be improved. Adverse weather and lack of image were problems for determination of the distinguishing date. To overcome these problems, it is thought that recording videos in the vicinity or using a simple recording system would be effective.

No clear trends for tree phenology in the University Forest in Chichibu were detected during the 13 years. If phenology observation is conducted for the longer term, tree phenology in the University Forest in Chichibu may be an ecological indicator of influence of climate change on forest ecosystem. However, it is necessary to consider that there is a species that strongly receives the influences except the climate.

Summary

Since natural forests are difficult to reach, no daily and longtime observation is performed. It is believed that this problem can be solved through photos or films. The purpose of this study was to examine the usefulness of video recording of full bloom date in *Prunus verecunda* and bud flush date in *Fagus japonica*. Furthermore, we evaluated trends of the tree phenology in the natural forest.

The visual observation of the images recorded by a robot camera from 1997 to 2009 was undertaken. As a result, the full bloom date in *Prunus verecunda* and bud flush date in *Fagus japonica* could be determined by tree phenology observations based on the original criteria in this study. Tree phenologies were observed daily, rather than at 5-day intervals, and the determination ranges made up less than a third of the directly observed tree phenologies for the 13 years. Moreover, by creating a video recording archive, it will be possible to observe these events again, and reproducibility of the analysis will increase. However, adverse weather and lack of image created an inability to determine the distinguishing date. In response of this, it is thought that

recording videos in the vicinity or using an easier recording method is effective.

No clear trends for tree phenology in the University Forest in Chichibu were detected during the 13 years. If phenology observation is conducted for the longer term, tree phenology in the University Forest in Chichibu may be an ecological indicator of the influence of climate change on forest ecosystems. However, it is necessary to consider that this is a species is strongly influenced by factors other than climate.

Key words : phenology, dynamic picture images, *Prunus verecunda*, *Fagus japonica*

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13 年間のビデオ映像記録に基づく
カスミザクラ満開日とイヌブナ開芽日の高精度の決定

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要　　　旨

天然林では，到達困難性により，長期間にわたる毎日の樹木フェノロジー観察は行われていない。この問題の解決には，写真や動画による撮影が考えられる。本研究では，カスミザクラ満開日およびイヌブナ開芽日をビデオによって記録することの有用性を検証した。また，天然林の樹木フェノロジーの変化傾向も合わせて検討した。

秩父演習林のロボットカメラ映像を 1997 年から 2009 年まで目視観察した結果，本研究で独自に定めた基準に基づいてカスミザクラ満開日およびイヌブナ開芽日を決定できた。その決定レンジは，仮に 13 年間毎年 5 日おきに直接観察したとした場合の三分の一以下となった。また，映像記録があれば，過去に遡って再観察でき，解析の再現性も高まる。ただし，悪天候やシステムダウンで観察ができない場合があるため，その対策として，より近くでの撮影やより簡易な方法での撮影が有効であると考えられる。

また，13 年間のデータでは，秩父演習林の樹木フェノロジーに明確な変化傾向は見られなかった。より長期間の観察を行うことで，気候変動が生態系に及ぼす影響の指標として樹木フェノロジーが機能する可能性もあるが，その際，フェノロジーに気候以外の要因が強く作用する樹種もあることを考慮する必要がある。

キーワード：フェノロジー，動画像，カスミザクラ，イヌブナ