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Estimating gap age using tree-ring width in combination with carbon isotope discrimination in a temperate forest, Northeast China

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Abstract

Key message: The accuracy of gap age estimation can be improved from 5–6 to 2 years by analyzing the annual width and carbon isotope discrimination of the rings of gap-surrounding trees.

Context: Gap age has a direct link to the composition and structure of regeneration. However, the accuracy of gap age estimation is still limited.

Aim: We aim to improve the accuracy of gap age estimation by analyzing the width in combination with carbon isotope discrimination ($\Delta^{13}C$) of the rings of gap-surrounding trees.

Methods: Twenty-four gap-surrounding trees (nine *Ulmus laciniata*, eight *Fraxinus rhynchophylla*, and seven *Juglans mandshurica*) were selected from eight artificial gaps created in December 2004. First, the growth release (i.e., peak time of percent growth change) for sample trees was measured based on the tree-ring width to identify the rough time range of gap formation. Then, the $\Delta^{13}C$ of rings during the time range were analyzed for determining the precise year of gap formation.

Results: The peak time of percent growth change occurred from 2005 to 2010 for *U. laciniata*, 2004 to 2008 for *F. rhynchophylla*, and 2002 to 2007 for *J. mandshurica*. Within the range of 2002 to 2010, the $\Delta^{13}C$ of rings for all sample trees significantly reduced in 2005–2006 ($p < 0.05$), which was the estimated year of gap formation.

Conclusion: The introduction of $\Delta^{13}C$ analysis could effectively reduce the estimating deviations of gap age by only considering tree-ring width analyses and finally improve the accuracy of gap age estimation within 2 years, which can provide reliable information for gap management.

Keywords: Canopy opening, Gap formation, Tree rings, Growth release, Carbon isotope discrimination

1 Introduction

Gap, caused by the death of one or more trees in the canopy, is one of the common disturbances in many forest ecosystems worldwide (Watt 1947; Whitmore 1989; Zhu et al. 2015). Gaps play an important role in accelerating plant reproduction and growth, increasing light availability and spatial heterogeneity, influencing nutrient cycles, and maintaining the complex structure of the late-successional forests (McCarthy 2001; Richards and Hart

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2011; Lu et al. 2015). Recently, more and more researchers have shown extensive interest in the relationships between the microenvironmental conditions of gaps and gap characteristics, including gap shape, height of border trees, gap size, and gap age (Gagnon et al. 2004; Hu and Zhu 2009; Petritan et al. 2013; Muscolo et al. 2014; Zhu et al. 2021). Of these gap characteristics, gap age, defined as the "time since gap formation" (Liu and Hytteborn 1991), is an important parameter to be considered in forest management as it can permit the identification of the current phase during the whole canopy closing process (Whitmore 1989). In addition, it has been demonstrated that gap age is correlated with regeneration density and species (Schliemann and Bockheim 2011). Consequently, gap age is an important parameter that can provide essential information for forest management in adjusting strategies and regenerating species.

Hitherto, there are several main methods for estimating gap age, including whorl counts, the degree of decomposition, and tree-ring analyses (Schliemann and Bockheim 2011). These previous studies for estimating gap age may be summarized as follows.

(i) Runkle (1982) suggested that the gap age could be calculated by counting whorls of saplings or shrubs within gaps, but this method is highly dependent on the time at which saplings settled in gaps.

(ii) The gap age may also be estimated by the degree of decomposition of gap-maker trees (the dead trees for forming gaps), including little decay (having intact twigs and bark), intermediate decay (absence of twigs, fragmented bark), and mostly decayed (absence of twigs and bark), which corresponded to a young gap, intermediate gap, and old gap, respectively (Lertzman and Krebs 1991; Liu and Hytteborn 1991; Vargas et al. 2013). However, this method is less precise and subjective, especially for older gaps (Schliemann and Bockheim 2011).

(iii) Analysis of growth release of trees surrounding gaps is the most accepted method for estimating gap age (Kathke and Bruelheide 2010; Weber et al. 2014). When a gap is formed, the trees that were suppressed by the gap-maker trees would experience growth release, which leads to increased width in the ring (Lorimer and Frelich 1989). However, the precision of this method is associated with forest types, the microenvironment, and the sensitivity of tree species. For example, the release occurred more quickly and obviously in coniferous trees than in broad-leaved trees (Pham et al. 2004). Even for the same species, the release of trees surrounding the gap may be delayed or weakened due to the damage caused by the fall of gap-maker trees, thereby the estimated years of gap formation have large deviation. The method of gap age estimation based on tree-ring analyses needs to be further improved to increase its precision.

Stable carbon isotope has been widely used as a very useful technique for climate reconstruction (Schleser et al. 2015). It has been demonstrated that the carbon isotope discrimination ($\Delta^{13}C$) in tree rings decreased after gap formation (van der Sleen et al. 2014). When the researchers try to estimate gap age by analyzing the chronology of $\Delta^{13}C$ in tree rings, however, they find that it is difficult to distinguish gap formation precisely and rapidly. This is because when little is known about the rough gap age in the field, the variations in $\Delta^{13}C$ cannot be confirmed as the result of gap formation rather than other disturbances (e.g., drought, insect attack) (van der Sleen et al. 2017). Especially, for the older gap-surrounding trees with more rings, it is hard to measure the whole rings due to the limited time and cost. Thus, it is rare to estimate gap ages by only measuring the stable isotopes, although the measurement of stable isotopes is accurate.

Above all, the estimated gap age is less accurate by analyzing the growth release in the few gap-surrounding trees, and meanwhile, the ^{13}C in tree rings of gap-surrounding trees is critically precise but hardly to distinguish gap formation if we cannot obtain the information of approximate range of gap formation. Therefore, we hypothesized that the combination of tree-ring analysis and stable isotope measurements may allow the accurate identification of gap formation, i.e., obtaining the accurate gap age. This study was carried out in eight artificial gaps with exactly known ages in a temperate secondary forest in Northeast China. The cores of 24 trees for three species surrounding the gaps and 24 control trees with similar DBH far from the gaps were collected and investigated to (1) firstly determine the approximate time range of the gap formation by means of the growth release signal based on tree-ring width and then (2) explore whether the accuracy of gap age estimation can be improved by introducing the stable carbon isotope analyses. Our results may contribute to increase the accuracy of gap age estimation.

2 Material and methods

2.1 Study area

The research was carried out in the Qingyuan Forest CERN (Chinese Ecosystem Research Network), National Observation and Research Station. The study site is located in a mountainous region of Liaoning Province, Northeast China (41° 51′ 9.94″ N, 124° 56′ 11.22″ E, elevation 550–1116 m). It has a continental monsoon climate with hot-rainy summer and cold-dry winter. The mean annual temperature is 4.7 °C, and the temperature ranges from −37.6 to 36.5 °C. The annual precipitation is 700–850 mm, 80% of which from June to August. The frost-free period is 144 days. The soil type is a typical brown soil (Lu et al. 2018).

The study area was dominated by natural broadleaf-Korean pine (*Pinus koraiensis* Sieb. et Zucc.) forests until the 1930s. Most original forests have been replaced by secondary forests after decades of destructive exploitation. The primary tree species include *Acer mono* Maxim., *Fraxinus rhynchophylla* Hance, *Juglans mandshurica* Maxim., *Phellodendron amurense* Rupr., *Populus davidiana* Dode, *Quercus mongolica* Fisch. ex Ledeb., and *Ulmus laciniata* (Trautv.) Mayr (Zhu et al. 2017).

2.2 Core collection

Eight forest gaps were made in December of 2004 by cutting trees using a chainsaw. All the gaps were approximately ellipses with a 1.5 ratio of major axis to minor axis, and their major axis was in the east-west direction. All the trees higher than 2 m in the gaps were removed. These gaps with the sizes of 113.8–621.1 m^2 were randomly distributed, and their site conditions were similar (slope ranges from 17 to 26°, elevation ranges from 640 to 690 m, and aspect varies from 140 to 170°) (Table 1). The gaps were at least 20 m apart. Three gap-surrounding trees (i.e., sample trees) from each gap, i.e., a total of 24 sample trees, were selected in 2017 with diameters at breast height (DBH) ranging from 25 to 30 cm. The 24 sample trees included nine *Ulmus laciniata* (Trautv.) Mayr., eight *F. rhynchophylla*, and seven *J. mandshurica* (Table 2). To eliminate the growth releases caused by forces not related to gap creation (e.g., drought, insect attack), we also purposively selected in the surrounding forest 24 trees of the same species and comparable diameter (control trees, CT) away from gaps of 20 m. For all the sample and control trees, a core was taken along the direction from the gap center to the border by a 22-mm increment borer (Sweden, Haglof) for tree-ring width measurements.

Table 2 General characteristics of the sample deciduous tree species

Species	Shade tolerance	Sample number	Mean DBH (cm)
Ulmus laciniata	Shade tolerant	9	27.5
Fraxinus rhynchophylla	Neutral	8	27.4
Juglans mandshurica	Shade intolerant	7	27.7

2.3 Estimation of rough time range for gap formation by tree-ring width measurements

The cores were air-dried and polished using grits up to 1000 (Bruchwald et al. 2015) . The ring widths were measured using a LinTab 6 and the TSAPW software (Rinntech, Germany) with a precision of 0.01 mm. The growth ring in 2017 was excluded from analysis due to the incomplete radial growth. To eliminate the juvenile effects of young trees (< 30 years), the age of sample and control trees was determined by a visual examination of tree rings. We did not measure the specific age for each tree but could confirm that the age of selected trees was greater than 60 years by detecting tree rings. The ring widths from 1993 to 2016 were chosen to determine growth release.

The growth release was determined based on the percent growth change (PGC) proposed by Black and Abrams (2003). In previous studies, the 10-year moving window and 50% PGC threshold were widely used for identifying release. In this study, a 5-year moving window was used because we found that most gaps would be closed in 10 years in this study area (Lu et al. 2015); a 5-year moving window could therefore grasp the growth release in the selected gaps. In addition, a 10-year moving window did not fit the short sampling sequence of tree rings (1993–2016) in this study. In order to determine the threshold, we started with 50% PGC for identifying the growth releases,

Table 1 General characteristics of the sampled gaps at the Qingyuan Forest CERN, National Observation and Research Station

Gap number	Area of canopy gap (m^2)	Mean height of trees surrounding gap (m)	Elevation (m)	Slope (°)	Aspect (°)
G1	513.9	18	650	17	170
G2	621.1	17	670	23	150
G3	267.3	17	640	24	140
G4	174.1	16	690	20	155
G5	307.9	16	673	25	145
G6	321.2	17	681	25	160
G7	113.8	17	655	26	145
G8	124.5	15	669	24	165

resulting in only some samples of *U. laciniata* surpassing the threshold. Thus, we adjusted the threshold from 50% PGC to 25% PGC for catching more growth release information. It is necessary to note that the 5-year moving window and 25% PGC threshold had also been used for identifying release in other gap age estimation researches (Wang and Zhao 2011; Cartera et al. 2021). The PGC for a given year was calculated by $(M_2–M_1)/M_1$, where M_1 is the mean tree-ring width during the prior 5 years (including the given year) and M_2 is the mean tree-ring width during the subsequent 5 years (excluding the given year). When the PGC was higher than 25% in continuous 3 years, growth release would be considered to occur (Rubino and Mccarthyz 2004; Hart et al. 2011). During the period of growth release, the year with the largest difference in PGC between sample and control trees was defined as the gap formation year (i.e., rough gap age) (Fig. 1). The years of gap formation in the 24 selected trees could be composed of the rough time range for gap formation.

2.4 Gap age estimation by introducing stable carbon isotope analyses

After obtaining the time range of gap formation, the rings in the range for three tree species were chosen for stable carbon isotope analyses (Fig. 1). The $\Delta^{13}C$ is the proxy for the carbon isotope composition of plant material in the absence of changes in the atmospheric CO_2 concentration. It would decrease quickly due to (1) the increased photosynthesis as the enhanced light and (2) the decreased stomatal conductance as the declined water availability after gap formation (Cernusak et al. 2009; van der Sleen et al. 2014). Thus, the significantly decreased $\Delta^{13}C$ was an accurate sign for gap formation (Fig. 1).

The cores from sample and control trees in the time range were divided at a biennial interval because the rings of sample trees were too narrow to be cut per year. Thus, the estimation time resolution for gap formation was 2 years. The cores were shattered and homogenized in a grinding mechanism (DHS TL2020, China). Approximately, 5 mg of each ground sample was weighed into a tin capsule and combusted in an elemental analyzer (vario MICRO cube; Elementar Analyser Systeme GmbH, Hessen Hanau, Germany) for ^{13}C enrichment (‰) measurement.

The carbon isotope composition ($\delta^{13}C$, in %) was calculated as $\delta^{13}C_{tree\ ring} = (R_{sample}/R_{standard}-1)\times 1000$, where R_{sample} is the $^{13}C/^{12}C$ ratio of a sample and $R_{standard}$ is the $^{13}C/^{12}C$ ratio of an internationally recognized standard material (V-PDB). The carbon isotope ^{13}C discrimination ($\Delta^{13}C$) was calculated as $\Delta^{13}C=(\delta^{13}C_a-\delta^{13}C_{tree\ ring})/(1 + \delta^{13}C_{tree\ ring})$, where $\delta^{13}C_a$ is the $\delta^{13}C$ of atmospheric CO_2. The $\delta^{13}C$ of atmospheric CO_2 was −9.37 ‰ in the study forest measured by a Picarro G2101-i analyzer (Picarro, Sunnyvale, CA, USA).

2.5 Statistical analyses

The two-way ANOVA was used to test the effects of year and individual trees on the PGC. $\Delta^{13}C$ between sample and control trees were tested year by year with the one-way ANOVA. For verifying the effectivity of isotopes in identifying promptly the tree's response to gap formation, the variations of $\Delta^{13}C$ between different intervals for sample and control trees were analyzed by using

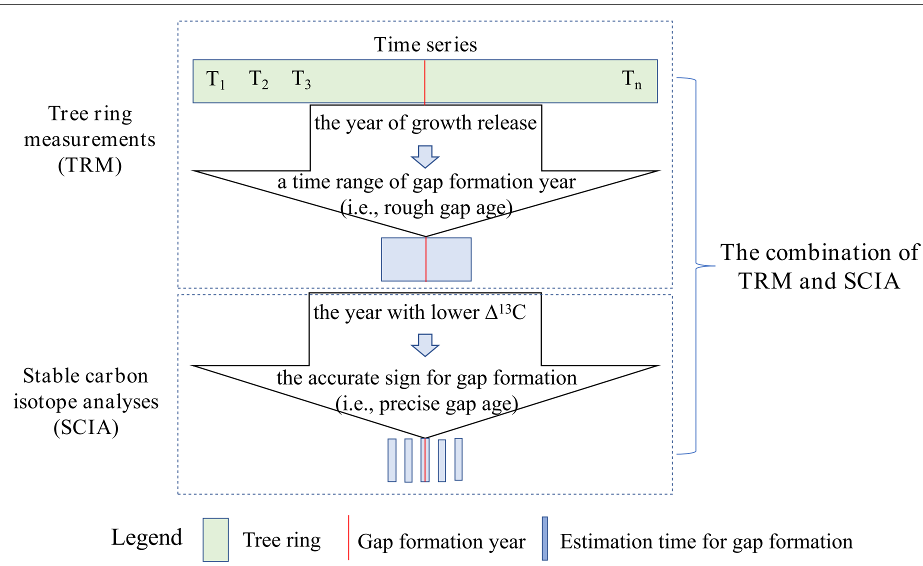

Fig. 1 The sketch map for the combination of tree-ring measurements and stable carbon isotope analyses

one-way ANOVA and Tukey's post hoc tests. The difference at a level of $p < 0.05$ was considered significant. All statistical tests were carried out in SPSS 22.0 (SPSS Inc., Chicago, USA).

3 Results

The year had significant effect on the PGC both for the sample and control trees (Table 3). The mean duration of growth release for sample *U. laciniata* was 6 years (from 2005 to 2010), and the maximum difference of PGC between sample and control trees occurred in 2009 (Fig. 2). For *F. rhynchophylla*, the mean duration of release was 5 years (from 2004 to 2008), with the maximum release year in 2007 (Fig. 2). The release of *J. mandshurica* lasted for 6 years (from 2002 to 2007), and the maximum release year was 2005 (Fig. 2). A total of 77.7%, 87.5%, and 100% of the sample *U. laciniata*, *F. rhynchophylla*, and *J. mandshurica* Maxim. trees had growth release, respectively (Table 4). The rough time range of gap formation estimated by tree-ring width was 2002 to 2010 and varied among sample trees.

Table 3 Effects of year and individual tree on the percent growth change of rings in the sample and control trees

Species	Effect	Sample trees		Control trees	
		df	*p*	*df*	*P*
Ulmus laciniata	Year	13	0.023	13	0.023
	Individual tree	8	0.536	8	0.634
Fraxinus rhynchophylla	Year	13	0.047	13	0.021
	Individual tree	7	0.196	7	0.374
Juglans mandshurica	Year	13	0.012	13	< 0.001
	Individual tree	6	0.231	6	0.431

From 2002 to 2010, the average $\Delta^{13}C$ in sample *U. laciniata* trees was significantly lower than those in control trees over the intervals of 2005 to 2006 ($p < 0.05$) and 2007 to 2008 ($p < 0.05$) (Fig. 3). For *F. rhynchophylla*, a significant difference of mean $\Delta^{13}C$ between sample and control trees was only found in the interval of 2005 to 2006 ($p < 0.05$) (Fig. 3). For *J. mandshurica*, the differences of mean $\Delta^{13}C$ between sample and control trees were significant in the intervals of 2005 to 2006 ($p < 0.05$), 2007 to 2008 ($p < 0.05$), and 2009 to 2010 ($p < 0.05$) (Fig. 3). The results showed the $\Delta^{13}C$ of sample trees significantly lower than those of control trees in the intervals of 2005 to 2006, which could be considered as the year of gap formation.

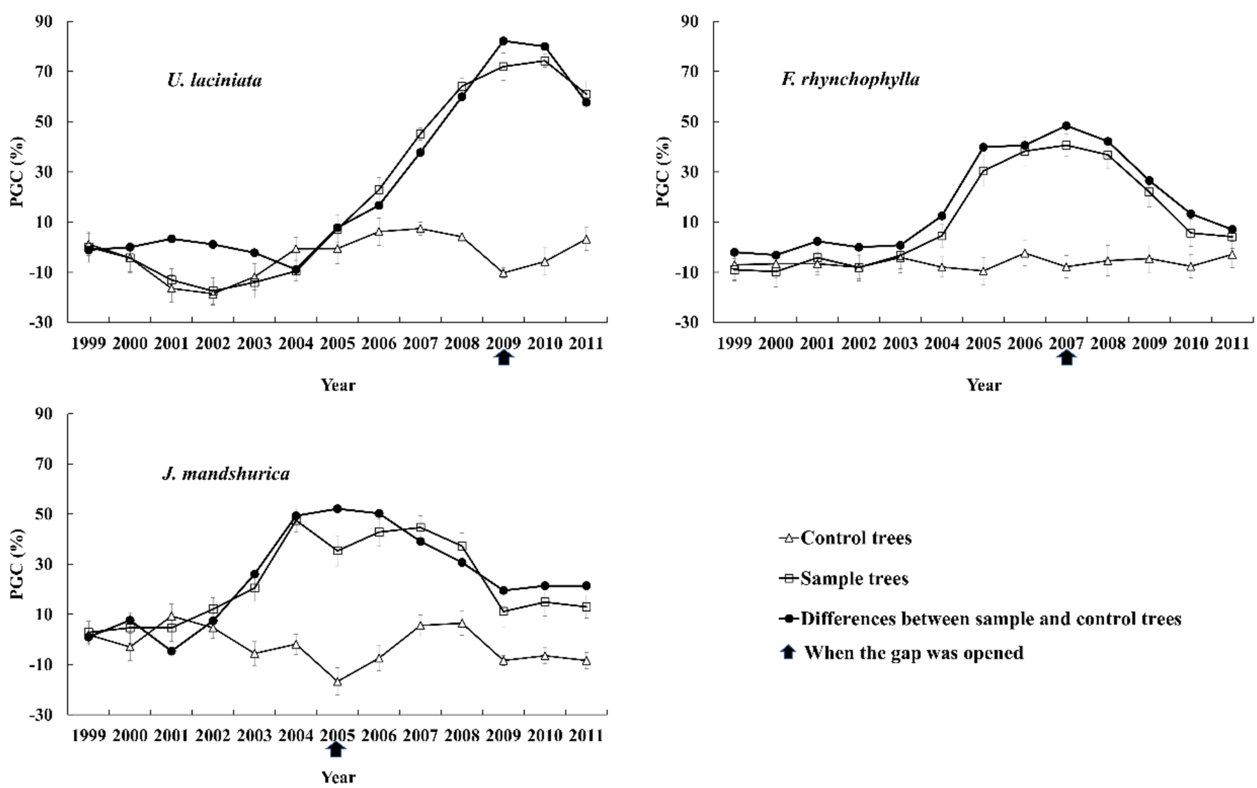

Fig. 2 The percent growth changes (PGC) of sample trees and control trees and their differences for *Ulmus laciniata*, *Fraxinus rhynchophylla*, and *Juglans mandshurica* in different years

Table 4 The percentage of trees per species surpassing the established thresholds for release during the period of 2005–2010. The percentage was grouped by the peak time of growth releases

Species	2005	2006	2007	2008	2009	2010	Total
Ulmus laciniata	0	0	0	22.2	33.3	22.2	77.7
Fraxinus rhynchophylla	0	25.0	50.0	12.5	0	0	87.5
Juglans mandshurica	57.1	28.6	14.3	0	0	0	100

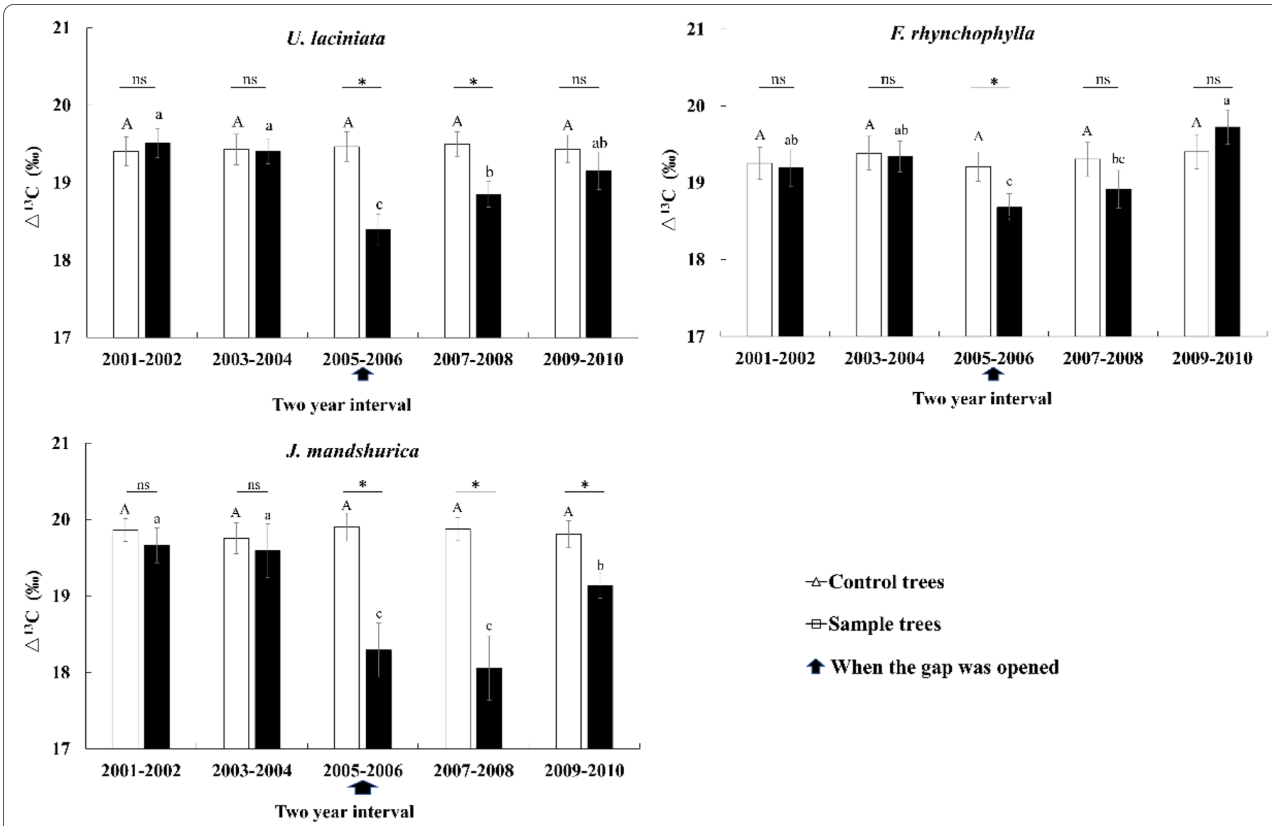

Fig. 3 The $\Delta^{13}C$ of sample and control trees for *Ulmus laciniata*, *Fraxinus rhynchophylla*, and *Juglans mandshurica* in 2-year intervals. Different capital and lowercase letters indicated significant differences ($p < 0.05$) of mean $\Delta^{13}C$ between different intervals for control trees and sample trees, respectively. Asterisk and "ns" indicated significant differences ($p < 0.05$) or insignificant differences of mean $\Delta^{13}C$ between sample and control trees for the same interval, respectively

Besides, there was no significant change for the $\Delta^{13}C$ of control trees between different intervals (Fig. 3). The $\Delta^{13}C$ in sample trees of all species changed insignificantly from 2001 to 2004 but decreased significantly in 2005–2006 (Fig. 3), when the gap was opened.

4 Discussion

4.1 The estimation accuracy for gap age based on tree-ring width measurements in the temperate secondary forest ecosystem

The temperate secondary forest ecosystem is usually composed of diverse tree species and tree individuals, which would affect the estimation accuracy gap age based on tree-ring width (Newton and Cole 1987; Lucia et al. 2010; York et al. 2010). As demonstrated by our results, the range time of gap formation year estimated by tree-ring width in a temperate mixed secondary forest was rather wide (5–6 years), which may be just due to the diversity of species and individual differences of trees surrounding the gap.

On the one hand, different tree species generally presented different degrees of response to gap formation (Schliemann and Bockheim 2011). *J. mandshurica* shows relatively faster response to gap formation than

Table 5 The comparison of methods for gap age estimation

Method	Theory	Materials	Advantage	Disadvantage	References
Whorl counts	Treat the saplings age as gap age	Saplings within gap	Quick, simple	Low precision and accuracy	Runkle 1982; Lusk and Lequesne 2000; Wright et al. 2000
The degree of decomposition	With large gap age, comes high decay degrees for gap maker	Gap maker	Quick, simple	Subjective, accuracy decrease with gap age increasing	Lertzman and Krebs 1991; Kathke and Bruelheide 2010
Remote sensing	When the patch changes from forest in image of t_1 to gap in image of t_2, the gap formed during t_1 to t_2	Multi-temporal images	High precision and accuracy	Limited by the spatial and temporal resolution of images, not applicable to gap individual	Zhang 2008; Zhu et al. 2021
Tree-ring width analyses	The gap-surrounding trees would experience growth release in ring width when the gap formed	Rings of gap-surrounding trees	High precision	The accuracy is limited in the mixed secondary forest	York et al. 2010; Soliz-Gamboa et al. 2012; Cartera et al. 2021
Stable carbon isotope	$\Delta^{13}C$ in tree rings would decrease after gap formation	Rings of gap-surrounding trees	High sensitiveness	Cannot distinguish gap formation and other small-scale damages, high time and economic cost	Van der Sleen et al. 2014; Van der Sleen et al. 2017
Tree-ring width in combination with $\Delta^{13}C$	First determine the rough time range of gap age by tree-ring analyses and then estimate the accurate time of gap formation by analyzing the $\Delta^{13}C$ during the time range	Rings of gap-surrounding trees	High precision and accuracy	Need further verification in other regions	Our study

the other two species. The different response times of the three tree species are first related to the shade tolerance. Ninemets and Valladares (2006) found that *Ulmus* has the strongest shade tolerance, followed by *Fraxinus*, and the shade tolerance of *Juglans* was the weakest. The growth rate of light-demanding species is sensitive to the changes in light environment; therefore, these species better record the variations of light environment with disturbance events (Song et al. 2011). Instead, the response of relative shade-tolerant species to the increasing light conditions may be delayed by photoinhibition and slow acclimation of leaves (Bebber et al. 2004; Soliz-Gamboa et al. 2012). Second, the tree species with slow response to light environment may allocate the light resources to other functions, such as height growth or recovering from damage, rather than radial growth (York et al. 2010). Before the gaps were created in the winter of 2004, a wind/snowstorm struck the secondary forest in 2003. For this disturbance, the *U. laciniata* was more susceptible, and the *J. mandshurica* was less susceptible (Zhu et al. 2006). Thus, the damaged *U. laciniata* may allocate more resources to recovery than to radial growth. It can be concluded that when the rings of trees surrounding gaps were used for gap age estimation, it might be appropriate to choose species that are photophilous and resistant to disturbances, such as the *J. mandshurica* in our study.

On the other hand, the time of the growth release also differed among individuals of even same species, with up to 3-year variations between different individuals of the same species in this study. One explanation for this is that when a gap formed, older trees with slower growth will respond later to the released light resources (Phillips et al. 2008). Alternatively, the trees located at northern edge of a gap received more light resources than those at the southern edge of a gap (based on the plot monitoring data), showing rapid growth release. A third alternative is that the trees with delayed responses may be suppressed by neighboring trees and be late in the competition for release resources at the time of gap creation (York et al. 2010).

4.2 The accuracy improvement for gap age estimation by the combined analyses of ring width and $\Delta^{13}C$

Verifying the effectivity of isotopes in identifying promptly the tree's response to gap formation is the foundation for improving the gap age estimation by stable carbon isotope technique. Our results indicated that the $\Delta^{13}C$ in sample trees of all species significantly decreased before (2001–2004) and after gap formation (2005–2006), proving the prompt response of $\Delta^{13}C$ to gap formation.

The $\Delta^{13}C$ from 2005 to 2006 significantly decreased regardless of tree species and individuals, suggesting that the $\Delta^{13}C$ can precisely capture the changes of microsite characteristics within gaps. Such a decrease in plant $\Delta^{13}C$ is caused by both changes in the light and water availability (Ehleringer et al. 1986; van der Sleen et al. 2017). Augmented light caused by gap formation can increase the assimilation rates of CO_2, which are relative to the stomatal conductance, and therefore decrease the $\Delta^{13}C$ (Cernusak et al. 2009). The negative relationship between light availability and $\Delta^{13}C$ has also been documented by York et al. (2010). In addition, the decrease in $\Delta^{13}C$ can also be caused by increased water stress. When a gap was formed, the increased irradiance may increase the temperature as well as the evaporation from the soil surface and thus reduce the soil moisture content (Olander et al. 2004). The reduced water availability may decrease the stomatal conductance, as well as the influx of CO_2 into leaves (Brienen et al. 2016), leading to lower $\Delta^{13}C$ in rings. Hence, the reduced $\Delta^{13}C$ after gap formation may be as a result of the combined effect of increased light availability and water stress.

Our results indicated that the combined analyses of tree growth and stable carbon isotope in tree rings may improve the accuracy of gap age estimation to 2 years, which is difficult to achieve by traditional methods (Table 5). For example, based on the tree-ring analyses, our results indicated that the estimated gap ages in the temperate mixed forest had a deviation of 5–6 years among different species and a deviation of 3 years among different individuals within the same species. Thus, we introduced the $\Delta^{13}C$ analysis to improve the accuracy of tree-ring width analyses method for gap age estimation. The released growth in ring width accompanied by decreased $\Delta^{13}C$ may be an accurate sign for identifying gap formation, as well as for estimating gap age. Moreover, this method could reduce the effects of tree species and individual differences on the accuracy of estimation; therefore, it is more applicable for the gaps in the temperate mixed forests.

5 Conclusions

The combined analysis with width and $\Delta^{13}C$ of tree rings in this study is a promising objective and accurate method to measure gap age in temperate mixed forests. All the materials that need to be acquired for gap age estimation are the tree rings surrounding the gaps. More reliable and comprehensive information on gap parameters, site conditions of regeneration, and gap dynamics could be predicated on the accurate gap age, which is the premise of forest management by gap techniques. It is necessary to note that the method for determining the gap age by combination of tree-ring width and $\Delta^{13}C$ in our study is preliminary, and its reliability needs further confirmation in other forest ecosystems.

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Authors' contributions
Conceptualization: JZ and CZ; methodology, JZ and CZ; formal analysis and investigation, CZ, QY, and DL; writing — original draft preparation, CZ, JZ, and QY; writing — review and editing, QY, CZ, JZ, LS, GGW, and DL; and funding acquisition, JZ. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors gave their informed consent to this publication and its content.

Competing interests
The authors declare that they have no competing interests.

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