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Comparison of the responses of radial growth to climate change for two dominant coniferous tree species in the Guancen Mountain, north-central China

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开题报告

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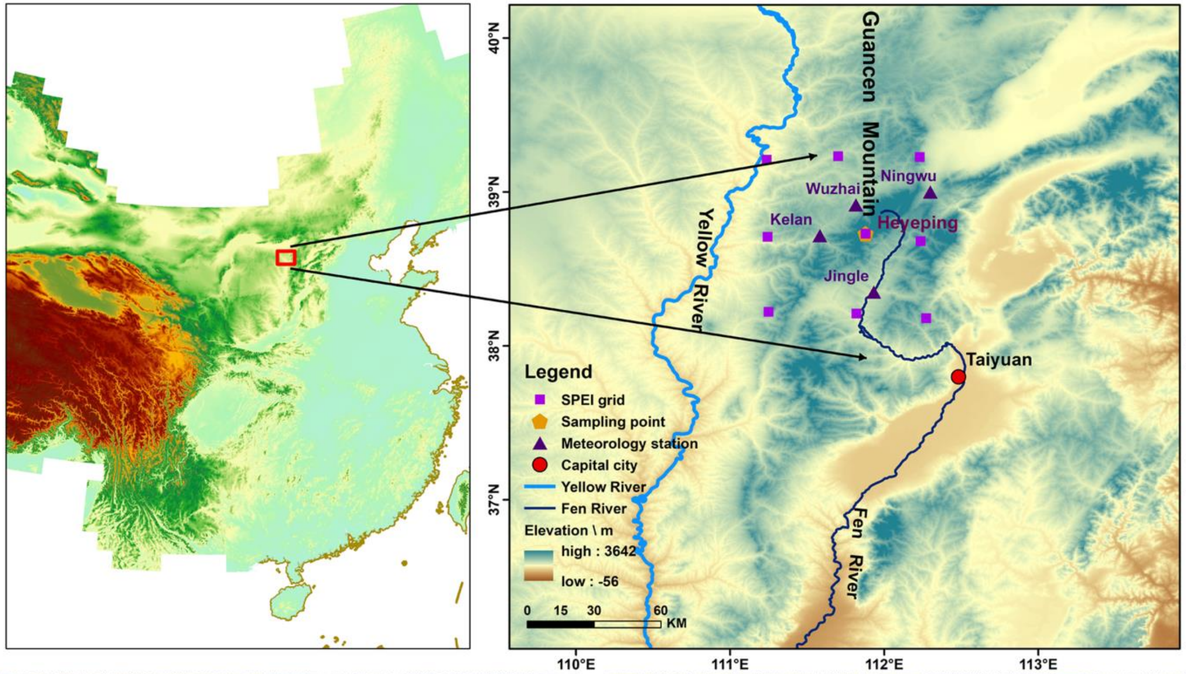
Graphical Abstract



Title: Comparison of the responses of radial growth to climate change for two dominant coniferous tree species in the Guancen Mountain, north-central China

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Highlights:

1.the standard chronologies of *Larix principis-rupprechtii* and *Picea meyeri* contained rich climate information, and the radial growth of *L. principis-rupprechtii* was more sensitive to climatic factors than that of *P. meyeri*;

2.on a long-term scale, changes in the radial growth of *L. principis-rupprechtii* and *P. meyeri* in response to the monthly mean temperature and standardized precipitation evapotranspiration index (SPEI) were unstable;

3.after the abrupt temperature change, the interannual basal area increments (BAIS) of the two dominant species followed an unward trend, and the radial growth rate of *L. principis-rupprechtii* was much greater than that of *P. meyeri*.

Abstract and Keywords

Abstract: The radial growth of coniferous trees in the mid-high latitudes of the Northern Hemisphere has an unstable response to climate warming. We analyzed the differences in the radial growth patterns of the two dominant species (*Larix principis-rupprechtii* Mayr and *Picea meyeri* Rehd. et Wils.) on Guancen Mountain, north-central China, and the differences in the stability of their radial growth in response to climate change. Pearson correlation and sliding analysis were performed to study the correlations and dynamic relationships between radial growth and climatic factors. The main results are as follows: (1) the standard chronologies of *L. principis-rupprechtii* and *P. meyeri* contained rich climate information, and the radial growth of *L. principis-rupprechtii* was more sensitive to climatic factors than that of *P. meyeri*; (2) on a long-term scale, changes in the radial growth of *L. principis-rupprechtii* and *P. meyeri* in response to the monthly mean temperature and standardized precipitation evapotranspiration index (SPEI) were unstable; (3) after the abrupt temperature change, the interannual basal area increments (BAIs) of the two dominant species followed an upward trend, and the radial growth rate of *L. principis-rupprechtii* was much greater than that of *P. meyeri*. The results of this paper can help to understand the response of the radial growth of coniferous forests in north-central China to future climate change, and provide a basis for future forest cultivation in the middle and high latitudes of the northern hemisphere.

Keywords: Dendroclimatology; Tree-ring width; Climate response; Dominant conifer species

1. Introduction

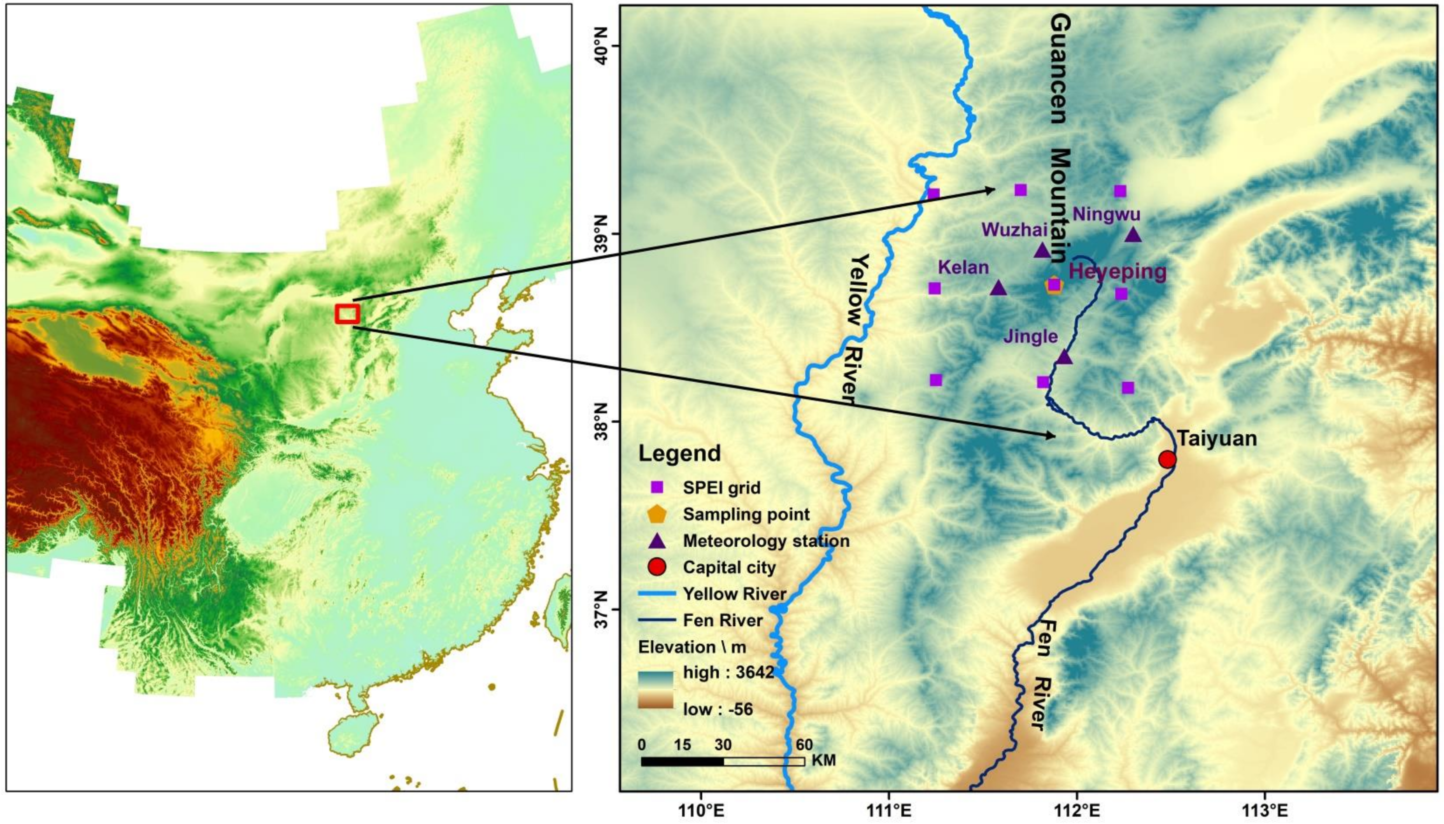
Climate warming has a significant impact on entire ecosystems, and its impacts on the structure and function of **forest ecosystems** are particularly prominent (Kerhoulas and Kane 2012; John 2015).

Tree species that border the **high-altitude tree line** are more sensitive than other species to climate change, making this the ideal area to study tree-ring climatology (Smith et al. 2009; Qin et al. 2016; Guo et al. 2019). The same tree species have distinctly different responses to climate warming in different habitants (Bai et al. 2020; Gou et al. 2021), as do different tree species in the same habitat.

In this study, the dominant species in the tree-line region of Guancen Mountain (***L. principis-rupprechtii*** and ***P. meyeri***) were investigated, and tree-ring width was used to study tree-ring climatology.

1. Introduction

1.1 Overview of the study areas and species

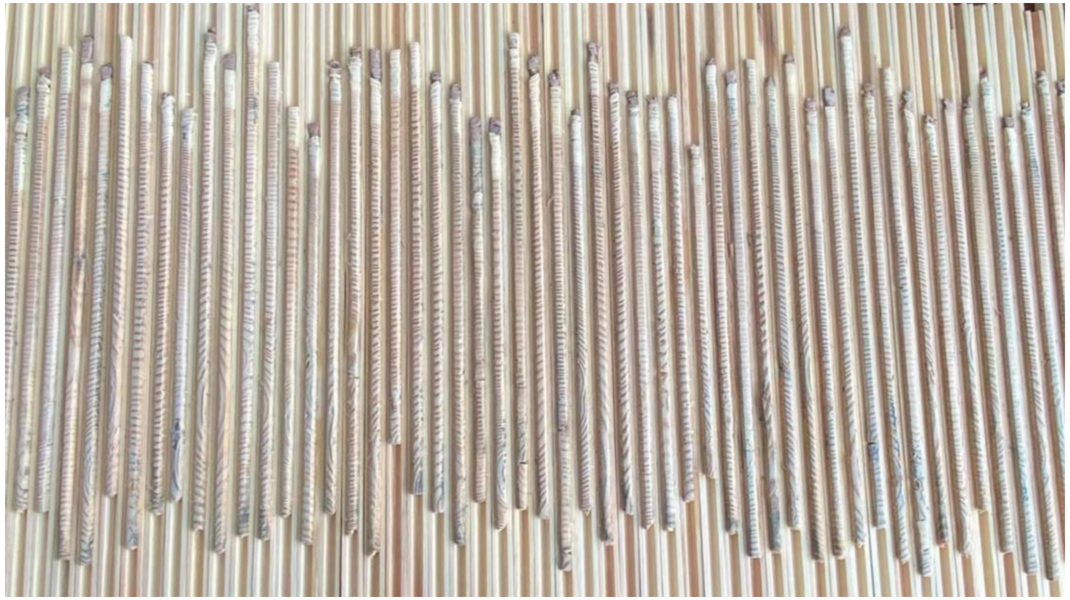


L. principis-rupprechtii is a deciduous coniferous species, and *P. meyeri* is an evergreen coniferous species. *L. principis-rupprechtii* completes flowering and fruiting and establishes nutrient reserves before winter. Their unique circadian rhythms cause these two dominant species to have different requirements for climatic conditions (Brauning and Mantwill 2004; Sun and Wang 2013; Zhang et al. 2015).

This area contains preserved native forests and human-made secondary forests that are in good condition.

1. Introduction

1.2 Sample collection and chronology establishment



Sample cores

Increment borers

An increment borer with an inner diameter of 5.15 mm was used to collect two sample cores at the position of the diameter at breast height and the position of the base diameter of the tree (86 sample cores from 43 trees were collected from *L. principis-rupprechtii*, and 52 sample cores from 26 trees were collected from *P. meyeri*).

1. Introduction

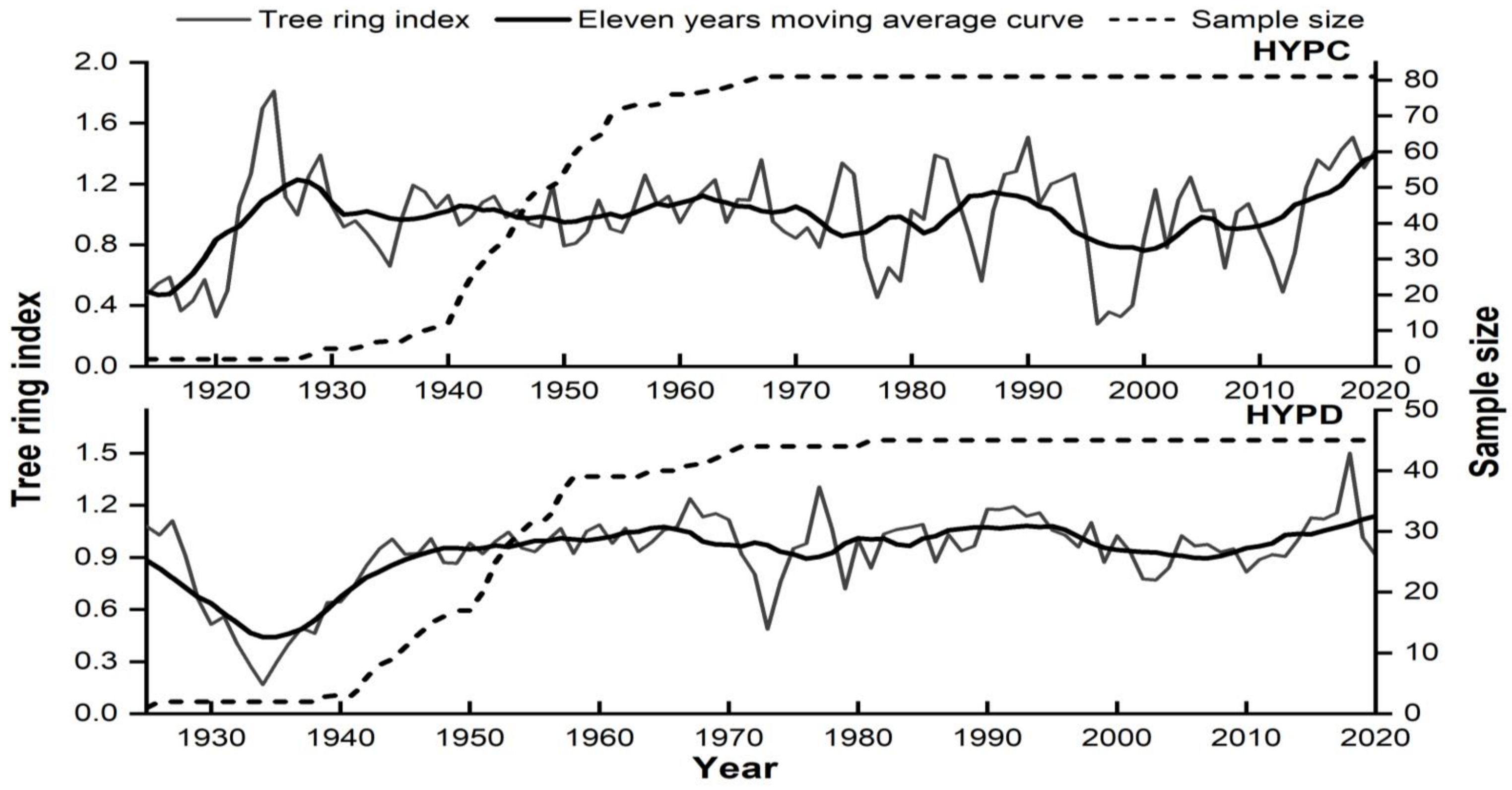
1.2 Sample collection and chronology establishment

LinTab™ 6 tree-ring width measuring instrument (Rinntech, Heidelberg, Germany)

The COFECHA program was used to check the dating and measurement results. Samples that were poorly correlated with the main sequence and difficult to cross-date were eliminated (5 sample cores from *L. principis-rupprechtii* and 7 sample cores from *P. meyeri* were removed), and the retained samples were used to establish the chronology (Holmes 1983). The linear function and negative exponential function in the ARSTAN program were used to fit the growth trends of the trees (Holmes et al. 1986) and eliminate the influences of nonclimatic factors and the growth trend of trees.

1. Introduction

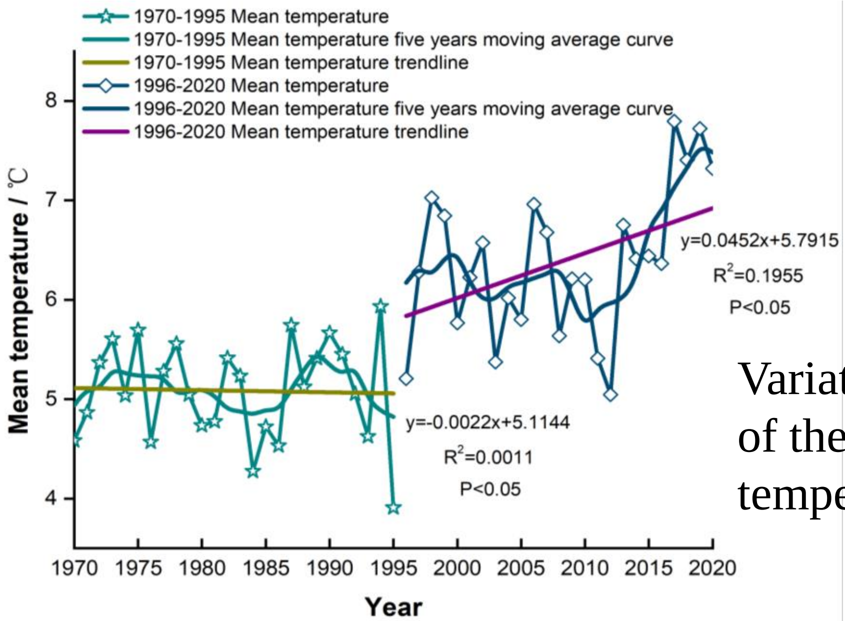
1.2 Sample collection and chronology establishment



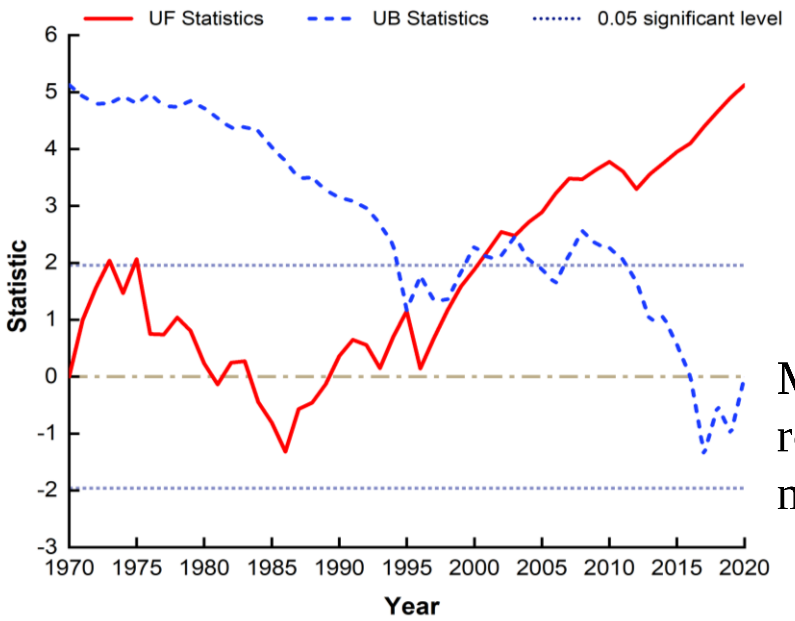
Standard chronologies and sample sizes of the annual ring widths of *L. principis-rupprechtii* and *P. meyeri*.

1. Introduction

1.3 Data analysis



Variation in the trends of the annual mean temperature



Mann-Kendall test results of annual mean temperature

Pearson correlation analysis was performed in SPSS software to analyze the correlations between the tree-ring width chronologies of the two dominant species before and after the abrupt temperature change and the monthly climatic factors. The dynamic relationships between the tree-ring width chronologies of the two dominant species and their responses to climatic factors over time were analyzed using the sliding correlation function of Dendroclim 2002.

2. Results

2.1 Chronological characteristics of the two dominant species

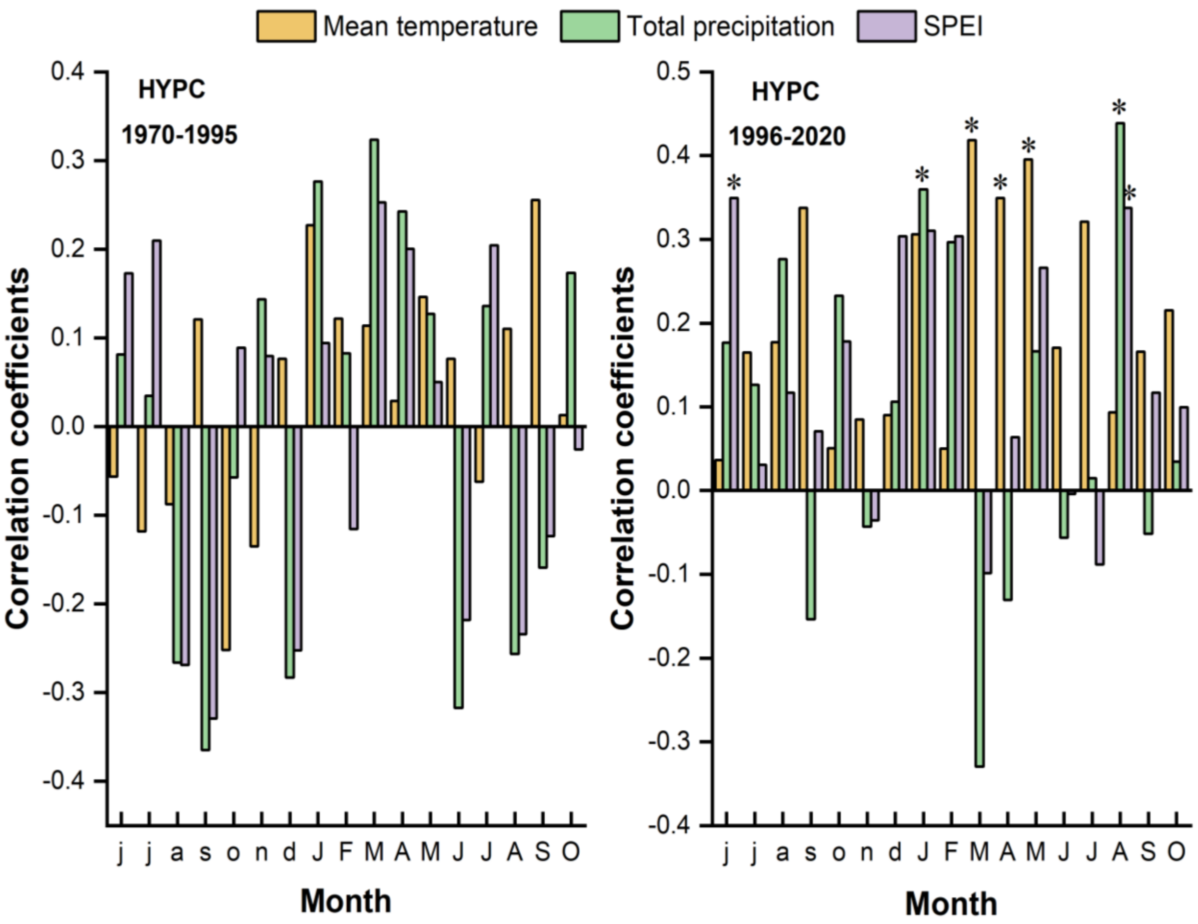
Dendrochronological parameters	*L. principis-rupprechtii* (HYPC)	*P. meyeri* (HYPD)
Sample size (tree\core)	43\86	26\52
Time span (SSS>0.85)	1947-2020	1957-2020
Standard deviation (SD)	0.307	0.227
Mean sensitivity (MS)	**0.217**	**0.135**
All series mean correlation (R)	0.623	0.489
Within-trees mean correlation (R_1)	0.647	0.559
Between-trees mean correlation (R_2)	0.619	0.475
Signal-to-noise ratio (SNR)	**77.579**	**34.390**
Expressed population signal (EPS)	**0.987**	**0.972**

Statistical characteristics of the tree-ring width chronologies of *L. principis-rupprechtii* and *P. meyeri*

According to the statistical parameter (MS, AC1, SNR) analysis, it concluded that the standard chronologies of the two dominant species contain relatively rich climate information; therefore, they are suitable for tree-ring climatological analysis and research. Many characteristic values of the standard chronology of *L. principis-rupprechtii* are better than those of the standard chronology of *P. meyeri*, indicating that the radial growth of *L. principis-rupprechtii* is more sensitive than that of *P. meyeri* to climate change.

2. Results

2.2 The relationships between the standard chronologies before and after the abrupt temperature change and the monthly climatic factors

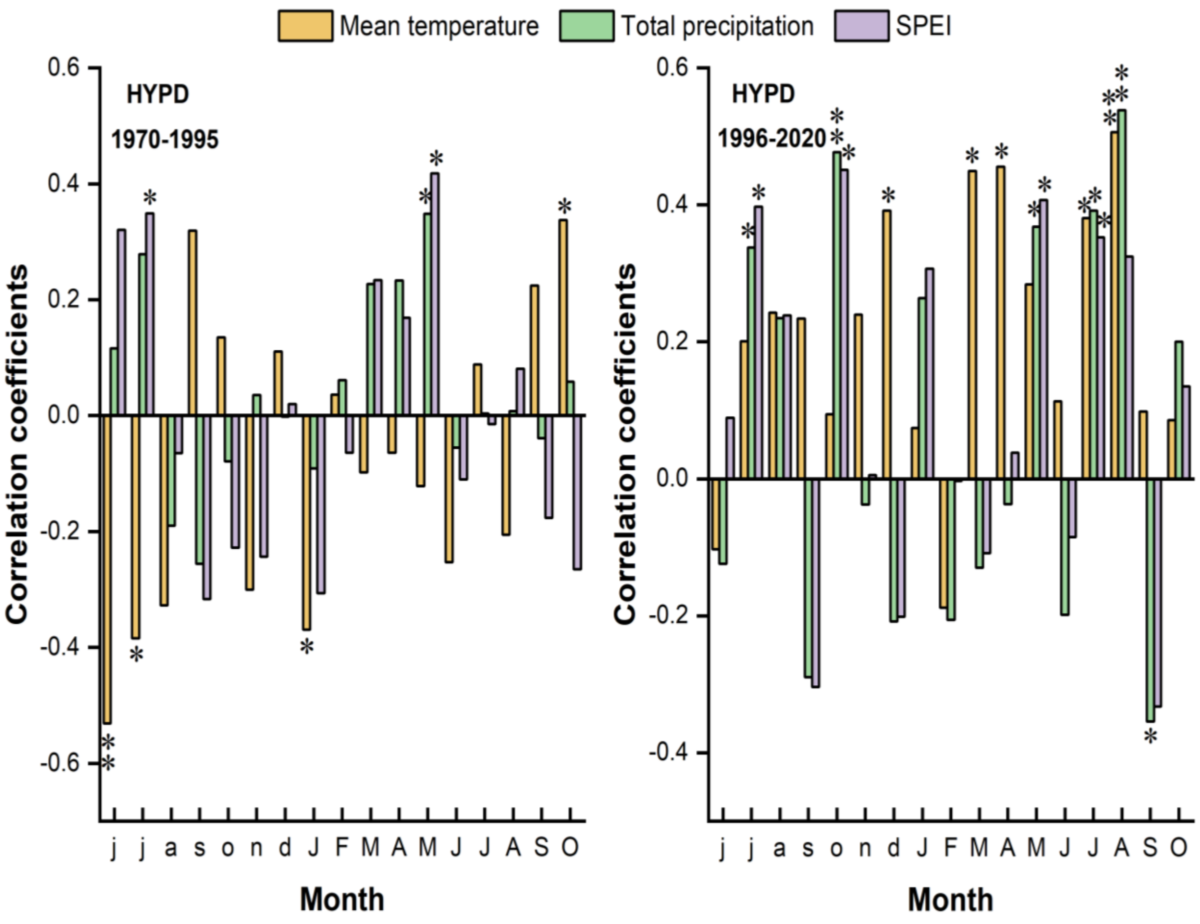


Before the abrupt temperature change, the correlations between the standard chronology of *L. principis-rupprechtii* and climatic factors were not significant.

After the abrupt change in temperature, the standard chronology of *L. principis-rupprechtii* was significantly positively correlated with the monthly mean temperatures in March, April and May of the current year ($r = 0.42$, $r = 0.35$, $r = 0.40$, $p < 0.05$); the precipitation in January and August of the current year ($r = 0.36$, $r = 0.44$, $p < 0.05$); and the SPEI values in June of the previous year and August of the current year ($r = 0.35$, $r = 0.34$, $p < 0.05$).

2. Results

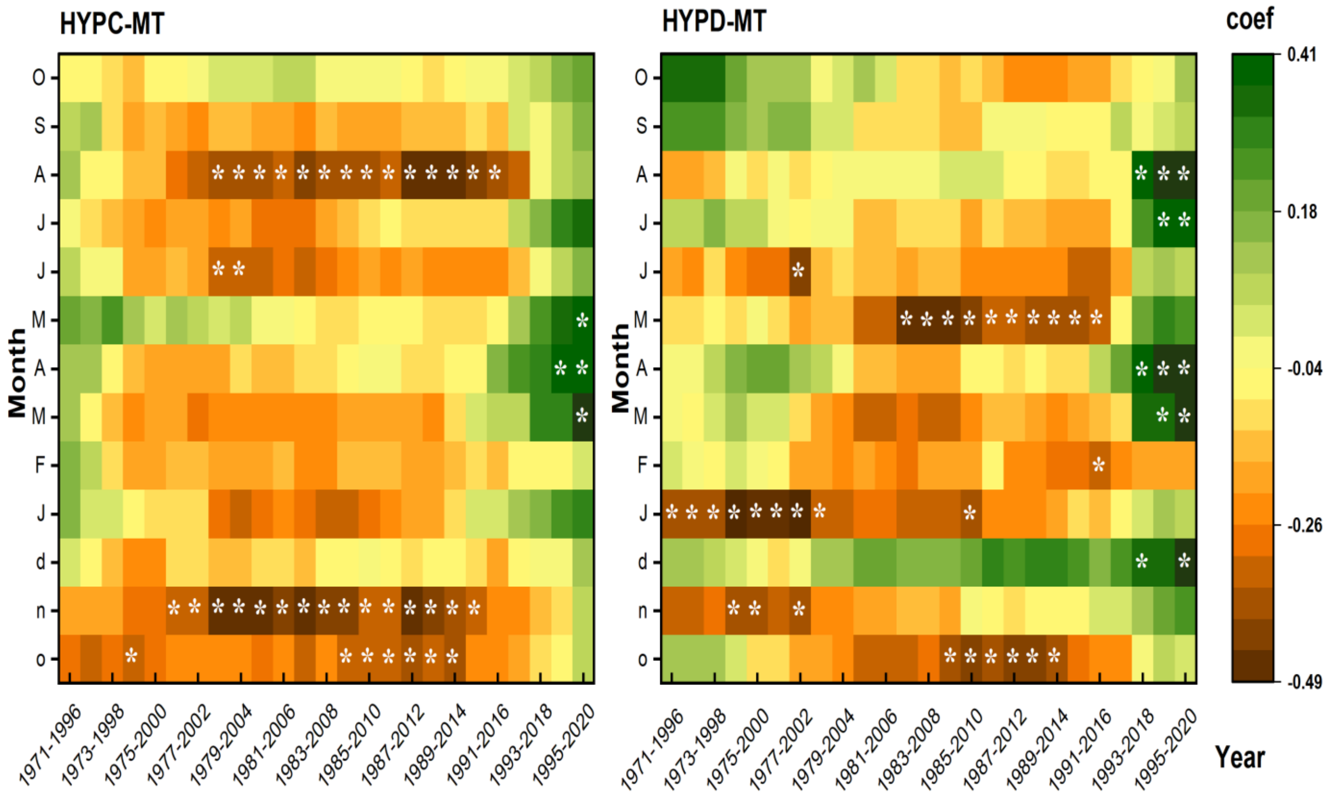
2.2 The relationships between the standard chronologies before and after the abrupt temperature change and the monthly climatic factors



After the abrupt temperature change, the standard chronology of *P. meyeri* was significantly positively correlated with the monthly mean temperature in December of the previous year and March, April, July and August of the current year (0.38 < r < 0.51, p < 0.05); the precipitation and SPEI values in July and October of the previous year and May and July of the current year (0.34 < r < 0.48, p < 0.05); and August precipitation (r = 0.54, p < 0.01). After the abrupt temperature change, the standard chronology of *P. meyeri* was also significantly negatively correlated with September precipitation (r = -0.35, p < 0.05).

2. Results

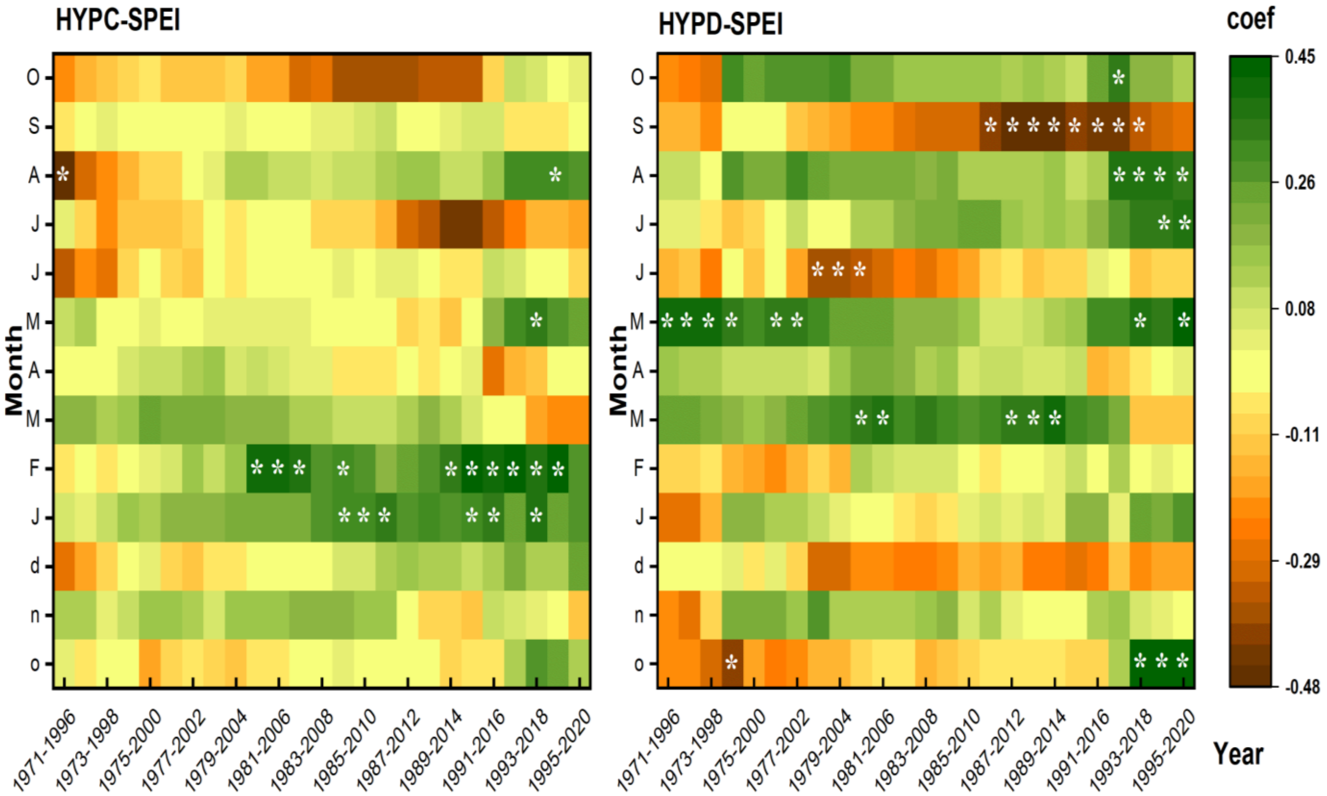
2.3 The stability of the radial growth of *L. principis-rupprechtii* and *P. meyeri* in response to climate change



The radial growth of *L. principis-rupprechtii* was mainly controlled by the mean temperature in spring from 1992–2017; the radial growth of *P. meyeri* was mainly controlled by the mean temperatures in spring and summer from 1993–2018. The mean temperatures in October and November of the previous year and August of the current year showed a weakening trend in restricting the radial growth of *L. principis-rupprechtii*.

2. Results

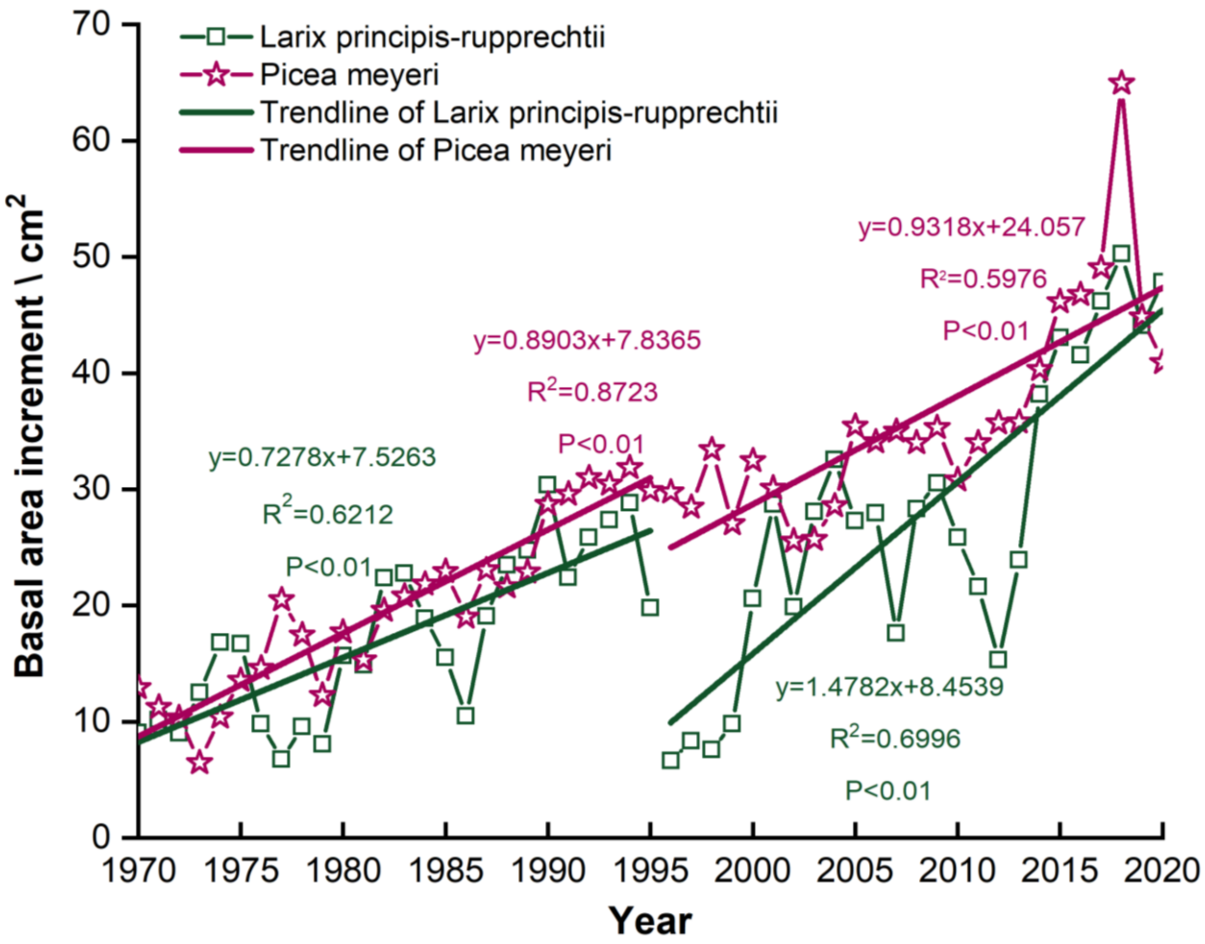
2.3 The stability of the radial growth of *L. principis-rupprechtii* and *P. meyeri* in response to climate change



The radial growth of *L. principis-rupprechtii* was mainly controlled by the drought stress in winter from 1980–2005. The radial growth of *P. meyeri* was mainly controlled by the drought stress in May, July and August from 1992–2017. Overall, on a long-term scale, the radial growth of these two dominant species showed an unstable response trend to the monthly mean temperature and SPEI.

2. Results

2.4 Changes in the radial growth trends of the two dominant species before and after the abrupt change in temperature



Before the abrupt change in temperature, from 1970 to 1995, the BAIs of *L. principis-rupprechtii* (7.28 cm^2/10a) and *P. meyeri* (8.90 cm^2/10a) increased, and the growth rate of *P. meyeri* was higher than the growth rate of *L. principis-rupprechtii*.

After the abrupt change in temperature, from 1996 to 2020, the BAIs of *L. principis-rupprechtii* (14.78 cm^2/10a) and *P. meyeri* (9.32 cm^2/10a) showed a significant upward trend, and the growth rate of *L. principis-rupprechtii* was much faster than that of *P. meyeri*.

Before and after the abrupt change in temperature, the overall annual BAI of *L. principis-rupprechtii* changed more than that of *P. meyeri*.

3. Discussion

3.1 The impact of climate change on the response stability of different tree species

Before the abrupt change in temperature, the response of the *L. principis-rupprechtii* tree-ring width chronology to monthly climatic factors was not significant.

After the abrupt change in temperature, the tree-ring width chronology of *L. principis-rupprechtii* showed a significant positive correlation with the precipitation and SPEI in August. This result indicates that after the temperature rises, the water stress in August is the main factor restricting the growth of *L. principis-rupprechtii*. In August, the temperature is relatively high, and the transpiration of trees is heightened, which significantly reduces the availability of soil water, resulting in a decline in the photosynthetic capacity of trees and slowing their growth (Wang et al. 2003); the higher temperature at night increases the respiration of trees and leads to the consumption of a large amount of nutrients, thereby inhibiting tree growth (Cherubini et al. 1997; Li et al. 2021). In the context of climate warming, the growth and development of trees in many areas, for example, Sabina cypress in Poland and Japan (Cedro et al. 2021), pine in the Alps (Giovanni et al. 2011), larch in Inner Mongolia (Liu et al. 2011), *Quercus liaotungensis* (Li et al. 2021) and *P. tabulaeformis* (Cui et al. 2020) on the North China Plain, and Robinia and Caragana on the Loess Plateau (Wei et al. 2018), are affected and restricted by summer drought stress.

3. Discussion

3.1 The impact of climate change on the response stability of different tree species

After the abrupt temperature change, the tree-ring width chronology of *P. meyeri* was significantly positively correlated with the precipitation in July and August and negatively correlated with the precipitation in September, reflecting the coupling effect of precipitation in different months on the radial growth of *P. meyeri*. From a physiological point of view, the good growth and development of trees requires sufficient precipitation and suitable temperature conditions (Liu and Shao 2000). Within the timeframe of tree-ring growth, precipitation and temperature are critical to the growth and development of trees (Wang et al. 2010; Ren et al. 2020). The radial growth of *P. meyeri* is the most vigorous in July and August. A good combination of water and heat promotes the growth and development of this species (Wu 1990). However, with the shift to autumn beginning in September, the temperature drops, and the radial growth rate decreases. Excessive precipitation is not conducive to the growth and development of *P. meyeri*. Moreover, the growth and development of *P. meyeri* depend on a well-drained soil environment (Schweingruber 1988). Excessive water accumulation can hinder the respiration of the roots. In more serious cases, the roots can be corroded (Zhang et al. 2013; Ren et al. 2020).

3. Discussion

3.2 The impact of climate change on the growth patterns of different trees

After the abrupt temperature change, the sensitivity of the two dominant species to climatic factors did not decrease. Instead, the radial growth rates of *L. principis-rupprechtii* and *P. meyeri* increased, indicating that the warm and humid climate is beneficial to the growth and development of these two locally dominant species.

Previous studies on the responses of Northern Hemisphere temperate vegetation to climatic factors (Wu et al. 2018), Korean pine and Mongolian oak to climate change in northeastern China (Lyu et al. 2017) and two dominant species to climate change in central and northern China (Jiang et al. 2014) have demonstrated that in response to climate warming, the radial growth of trees follows an upward trend, and the radial growth changes are relatively obvious, which further confirms that the results of this study are reasonable.

The monitoring of the growth and development of local trees in an increasingly warm and humid climate should be strengthened to guide the sustainable development of forest ecosystems (Douglass et al. 2015).

4. Conclusions

1.The standard chronologies of both *L. principis-rupprechtii* and *P. meyeri* contained rich climate information and were sensitive to climate change.

2. Before the abrupt change in temperature, the radial growth of *L. principis-rupprechtii* was restricted by the mean temperature in autumn, and the radial growth of *P. meyeri* was affected by the spring drought; after the abrupt change in temperature, the radial growth of *L. principis-rupprechtii* was affected by the winter drought, and the radial growth of *P. meyeri* was mainly restricted by the combination of water and heat in summer.

3. The radial growth of these two dominant species was significantly restricted by the spring mean temperature during the period from 1993 to 2018. The radial growth of *L. principis-rupprechtii* was significantly affected by winter drought during the period from 1980–2005, and the radial growth of *P. meyeri* was significantly affected by drought in the late spring and summer during the period from 1992–2017.

4. Before the abrupt change in temperature, the interannual changes in the BAI values of the two dominant species showed an upward trend from 1970 to 1995, and the growth rate of *P. meyeri* was higher than that of *L. principis-rupprechtii*; after the abrupt temperature change, the interannual changes in the BAI values of the two dominant species showed an upward trend during the period from 1996-2020, and the growth rate of *L. principis-rupprechtii* was much higher than that of *P. meyeri*.

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THANKS

Criticisms and corrections from teachers are welcome！