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Original Article

A Study on the Relationship between Teak (*Tectona grandis* L.f.) Growth and Climate Change using Dendrochronology in Mae Ka Sub-district, Mueang District, Phayao Province

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Abstract:
The relationship research between the growth of Teak trees and climate change (temperature and rainfall) using dendrochronological methods in Mae Ka Subdistrict, Mueang District, Phayao Province. The study was conducted in two areas: the teak experimental plot in front of the University of Phayao and the plot in the Ban Mo Kaeng Thong community, by placing a plot of 50x20 meters, and collecting the wood core samples for annual rings using dendrochronological methods. The annual ring width was measured, and analyzed the correlation between tree growth and information related to climate data (temperature and rainfall) over the past 39 years from Phayao Meteorological Station. The results revealed that the growth rates of Teak in both study areas were unstable. During 1-2 years of the growth, significantly high during the first 1–2 years, followed by fluctuating patterns of increase and decrease in subsequent years. Furthermore, the study shows that temperature had no significant correlation with tree-ring growth in both locations. On the other hand, rainfall was revealed to have a significant relationship with tree-ring growth in both locations.
Keywords: Teak, Tree growth, Annual ring, Dendrochronology

Introduction

The growing awareness of the climate change crisis all over the world, and the research on yearly growth rings and cambial growth dynamics have been the subject of numerous studies in tropical rainforests in order to predict the climate in the future (Kaewmano et al., 2022; Altman et al., 2025; Krutovsky, 2022). Currently, many countries have attempted to mitigate, address global warming, and predict climate to ensure the well-being of people both now and in the future, such as global warming, floods, dry climate, and others, which are likely to affect tree growth around the world. (Sahoo et al., 2023; Das et al., 2024; Rajkhowa, and Sarma,2021) Especially in Thailand, PM2.5, hot weather, and precipitation fluctuation, which are found in Thailand, are confronted with issues, including heavy rainfall events and sea level rise susceptibility, which impact coastal agricultural systems and raise concerns about the frequency of flooding in both urban and rural areas in 2025. Climate change poses a concern to Thailand, as extreme weather events are predicted to become more frequent and severe in the upcoming decades. (Rao et al., 2020; Maharjan et al., 2020; de Oliveira-Júnior et al., 2025). Particularly, forests are being impacted by climate change, which is leading to higher mortality and deterioration of the forest ecosystem. These effects are likely to get worse as global warming increases, especially in terms of many tropical forest regions, where the growth, physiology, and hydraulic function of trees have been adversely impacted by drought and global warming. (Djahangard et al., 2025; Quiñones et al., 2021; Thamtanajit, 2020; Zuidema et al., 2025)

Therefore, using climate models is a significant prediction about climate trends; however, the accuracy of these weather forecasts in the future depends heavily on understanding the nature and causes of past climate variations, including assessment of relationships between climate and tree growth (Wilmking et al., 2020). In recent decades, climate models have been greatly enhanced, mostly through better spatial resolution and parameterization of unresolved phenomena. Additionally, ensemble forecasting has been created to capture strong, predictable signals. (Alizadeh, 2022). Recoding climate information in long-term and high precision is essential for testing the accuracy of climate models. Although recording Current meteorological conditions is short-term, various natural proxies can be Excellent tools for recording climate over the long term include natural evidence such as biological evidence like tree rings (Yu and Li, 2025).

In this study, the authors aim to analyze the annual rings of teak using Dendrochronology in Mae Ka Sub-district, Mueang District, Phayao Province, because teak (*Tectona grandis* L.f.) is one species in tropical zone that scientists have tested first in 1870, and in the current period, this species can accurately predict climate variables due to the clear characteristics of ring width and can provide information related to the effects of climate change on tree growth can be better understood with the use of remote sensing technologies and tree-ring width. (Carmo et al., 2022; Zaw et al., 2020)

In terms of temperature and rainfall, these are critical factors influencing the growth of Teak. Using dendrochronological studies allows us to understand the response patterns and relationships between Teak growth and climate change. Variations in tree-ring width are influenced by temperature and precipitation factors. (Upadhyay et al.,2021). Therefore, dendrochronology is utilized to assess the relationship between growth and climate through ring-width analysis and retrospective climate study in order to be a guideline for preparing and adapting to future climate change in Thailand. For these reasons, the researcher is interested in studying the ring width of Teak by analyzing wood core samples. The goal is to establish a database for comparing annual growth with temperature and rainfall data, which will serve as a valuable resource for further applications and research.

2. Materials and Methods

2.1. Field Equipment

Global Positioning System (GPS), hammer, compass, machete, plastic twine (Raffia rope), calculator, 50-meter measuring tape, diameter tape (Tree circumference tape), orbital sander (Vibrating sander), Increment borer, and clinometer.

2.2 Research methodology

2.2.1 Selection of Study Areas

The study was conducted in two locations: the teak experimental plot in front of the University of Phayao and the plot in the Ban Mo Kaeng Thong community. Considering the study sites were selected by a survey of teak places with a minimum age of 10 years. In each study area, two 50×20 meter subplots were established using a random sampling method, which would result in a total of four study plots, and gather from these plots for further analysis. (Table 1).

Table 1 Survey plot layout using the Quadrat method (Size 50x20 meters)

Experimental Plot	Coordinates		meters above sea level
	Latitude	Longitude	
University of Phayao Frontage			

• Experimental Plot A	19°01'48.71"N	099°55'21.51"E	469
• Experimental Plot B	19°01'48.94"N	099°55'16.62"E	469
Mo Kaeng Thong Point			
• Experimental Plot C	19°00'29.60"N	099°54'09.09"E	469
• Experimental Plot D	19°00'32.46"N	099°54'11.82"E	470

2.2.2 Sampling Timeline

The field survey and plot establishment were initiated to gather data and samples from the Teak seed in front of the University of Phayao in January 2018. Subsequently, the establishment of study plots and sample collection at the Ban Mo Kaeng Thong community was conducted in February 2018.

2.2.3 Location of Experimental Plots

The study areas in Phayao Province were divided into two locations: the Teak seed in front of the University of Phayao and the Ban Mo Kaeng Thong community forest plantation. These two areas are approximately 6 kilometers apart, and both areas are 469 meters above sea level.

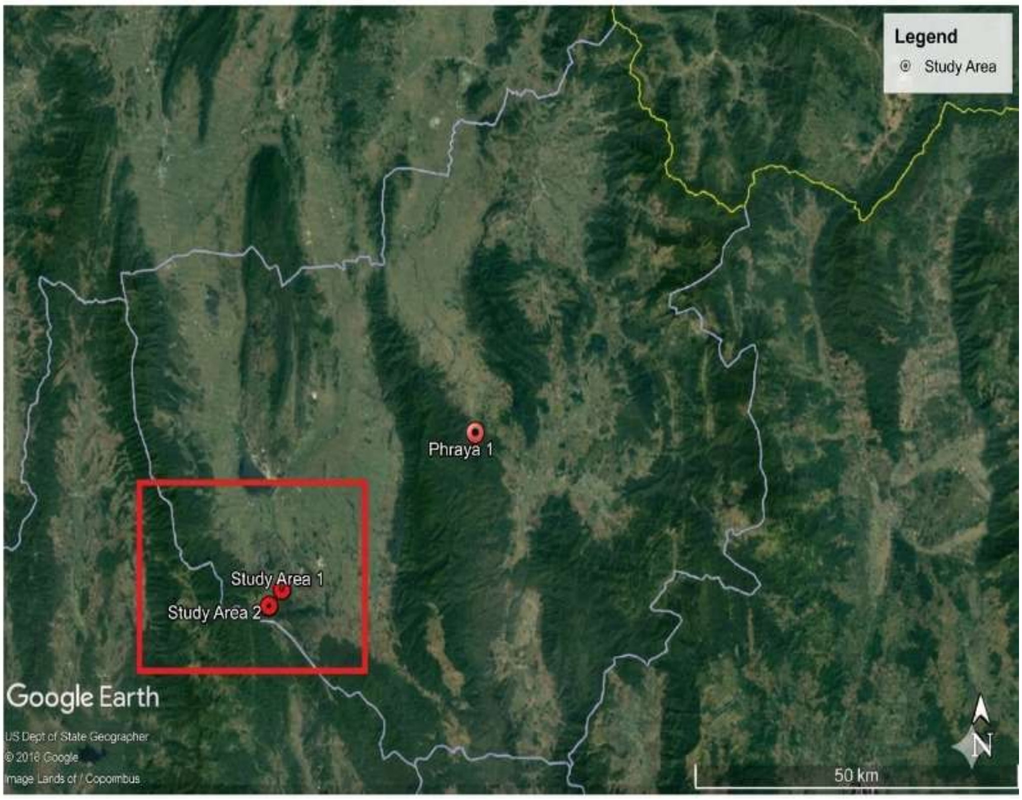

Figure 1 Map of survey locations in Phayao Province

Figure 2 Map showing survey points of teak seed breeding plots in front of University of Phayao.

Figure 3 Map showing the survey points of the teak plantation plots in the Ban Mo Kaeng Thong community.

2.2.4 General Data Collection of Teak in the Study Areas

General data were recorded within the established plots, including Girth at Breast Height (GBH) measured at 1.3 meters above the ground, height of the first branch, canopy height, crown width, and the specific coordinates of each tree within the sample plots. The sample by collecting teak data at GBH 1.3 meters from 50 centimeters and up.

2.2.5 Analysis of tree ring **(Pumijumnong and Eckstein, 2011)**

1) Sampling and Sample Preparation

Wood core samples were collected using an increment borer. Core samples were drilled from every tree within the established plots, 2 repeats. The collected samples were stored in tubes, sealed with adhesive tape, and labeled with the tree and sample numbers. The samples were incubated in a hot-air oven at 50°C for approximately 48 hours.

The incubated samples were sanded using an orbital sander, from coarse to fine, to enhance the visibility and clarity of the tree rings. Finally, the complete five trees per plot were analyzed and selected to study the dendrochronology.

2) Sampling and Sample Preparation

The wood samples were analyzed to determine the age of the growth rings using standard dendrochronological methods. Tree-ring widths were measured using an OLYMPUS SZ2-ILST stereo microscope, and the growth ring width data in each year were used to compare tree growth patterns with temperature and rainfall data over the past from the Phayao Meteorological Station (Pumijumnong and Eckstein, 2011). This analysis and data were conducted using the Olympus PD21 software.

2.2.6 Construction of Profile Diagrams and Tree Coordinates

A 50×20 meter plot was established by the profile diagrams. Measure the height of the first fresh branch, the height of the canopy, and take the coordinates of the teak trees within the plot, placing them along the x- and y axes, and the canopy on all four sides of each teak tree. Additionally, the crown spread was measured in four directions for every tree. In cases where tree crowns overlapped, a solid line was used to represent the upper canopy layer, while a dashed line represented the lower canopy layer.

2.2.7 Correlation and Statistical Analysis

1) Correlation Coefficient Analysis

1.1) Analysis of the relationship between the mean tree-ring width index and climate variables (temperature and rainfall).

3. Results

3.1. Temperature and Rainfall Data from the Phayao Meteorological Station (1978–2017)

According to data from the Phayao Meteorological Station, the average temperature ranged between 24–26°C, while the average rainfall was recorded between 796.7–1,579.6 mm.

3.2. General Characteristics of Teak (Tectona grandis) in the Study Area

Form collecting the data from January to February 2018 in front of University of Phayao and the Ban Mo Kaeng Thong Community. Four sample plots were divided into four plots: Plots A and B, located at the University of Phayao Teak Seed Orchard, and Plots C and D, located at the Ban Mo Kaeng Thong Community. (Table 2) In terms of Average Tree Circumference, University of Phayao Frontage, experimental plots A, B, C, and D were 108.80 ± 25.19, 101.33 ± 18.22, 90 ± 22.65, and 92.63 ± 20.14 cm, respectively. Average heights were 21.03 ± 2.03, 16.64 ± 1.56, 17.41 ± 2.25, and 18.73 ± 1.63, respectively.

Table 2 General information about the study area

Study Area	**Number of Trees**	**Average Tree Circumference (cm)**	**Average Height (m)**
		$\bar{x}$ ± S.D.	$\bar{x}$ ± S.D.
University of Phayao Frontage			
• Experimental Plot A	14	108.80 ± 25.19	21.03 ± 2.03
• Experimental Plot B	16	101.33 ± 18.22	16.64 ± 1.56
Mo Kaeng Thong Point			
• Experimental Plot C	15	90 ± 22.65	17.41 ± 2.25
• Experimental Plot D	15	92.63 ± 20.14	18.73 ± 1.63

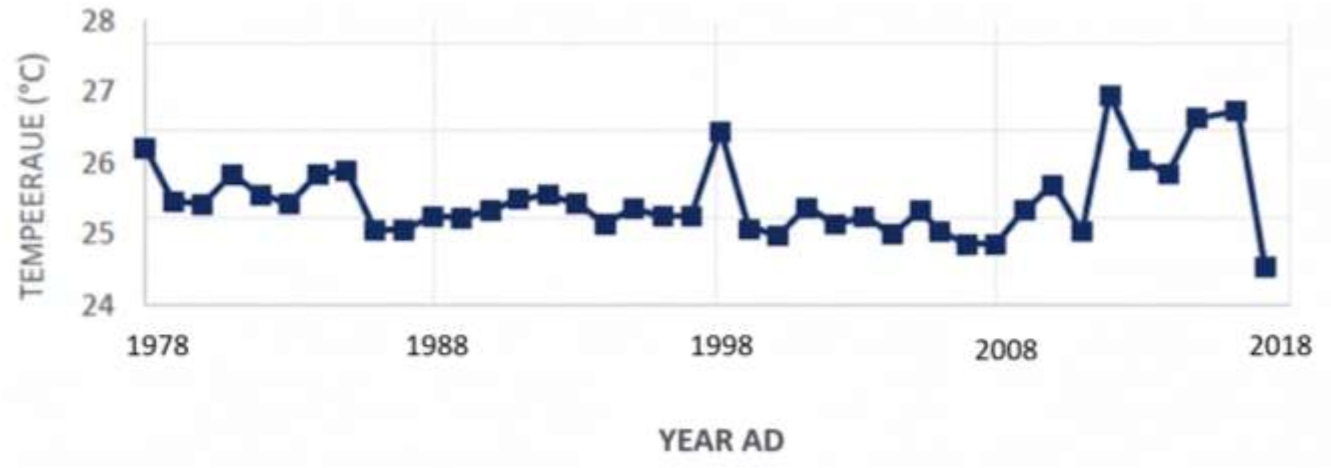

Figure 4 Annual Average Temperature (1978–2017)

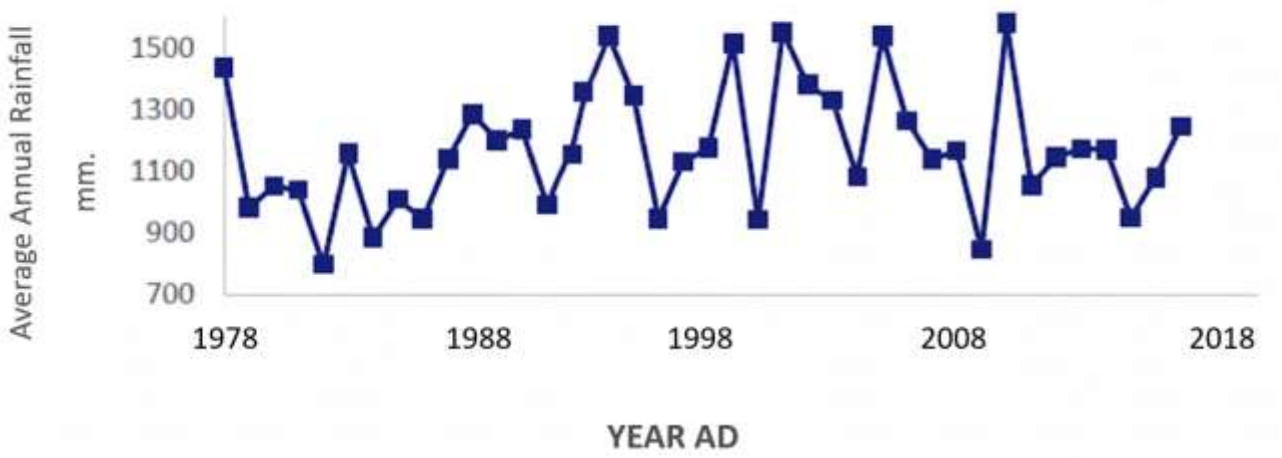

Figure 5 Average Annual Rainfall (1978-2017)

3.3. Profile Diagram Illustrating Shrub Coordinates and Vertical Height of Teak Trees in the Study Plots

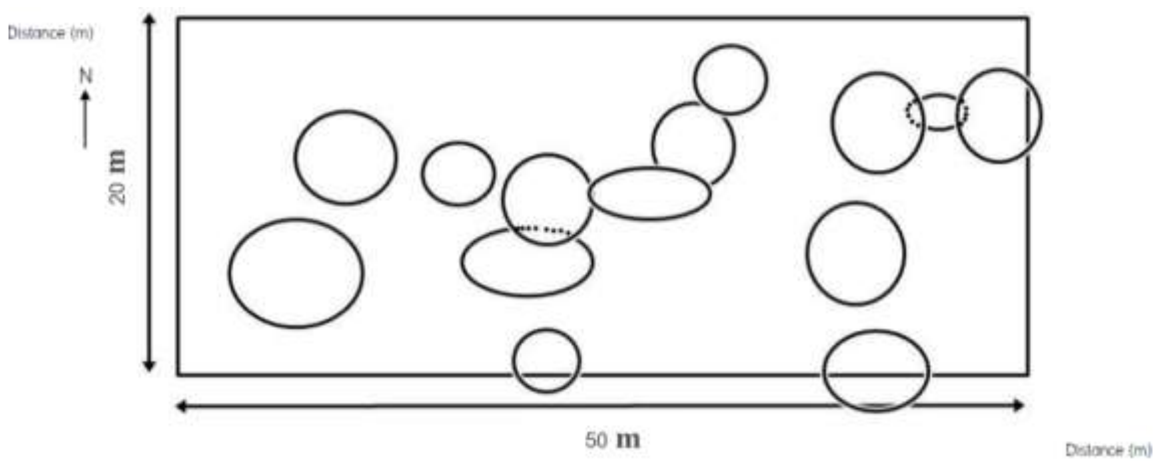

Figure 6 The profile diagram above, plot A, shows the coordinates and canopy shape of a study point in front of the university

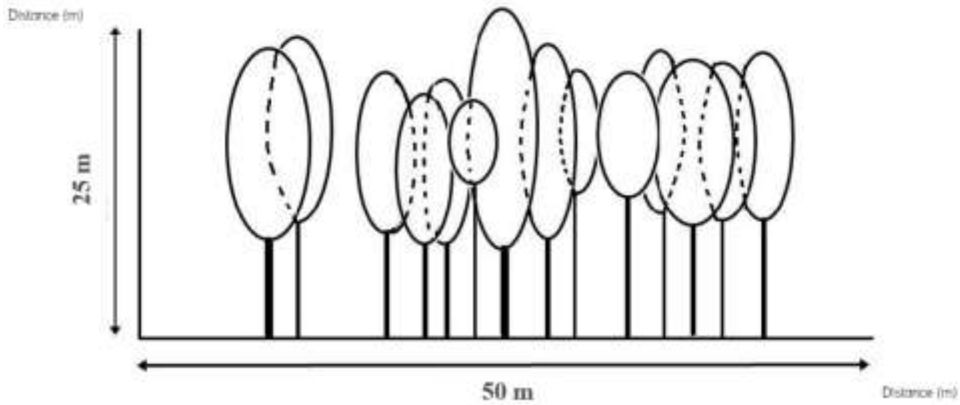

Figure 7 Profile diagram of the side view of plot A, study point in front of the university

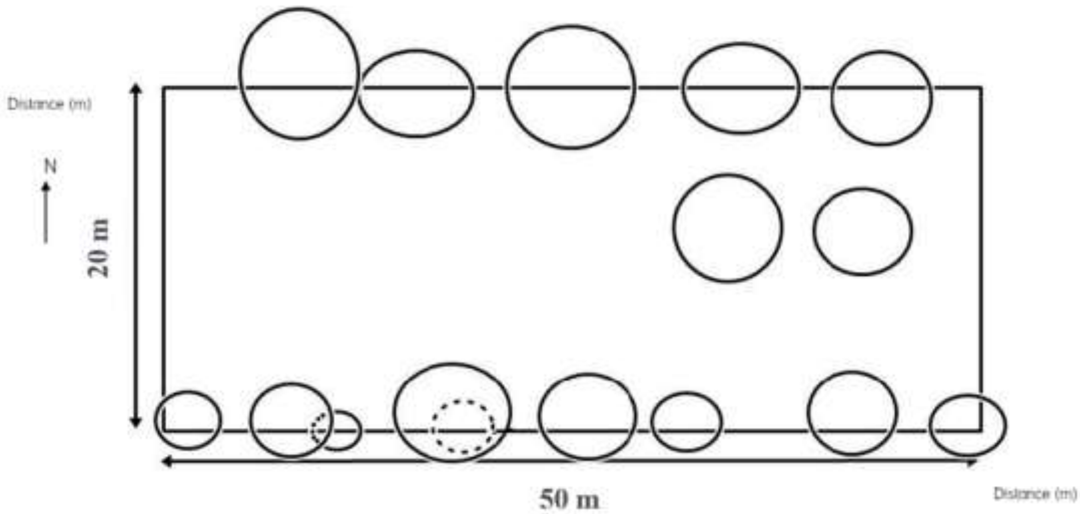

Figure 8 The profile diagram above, plot B, shows the coordinates and canopy shape of a study point in front of the university

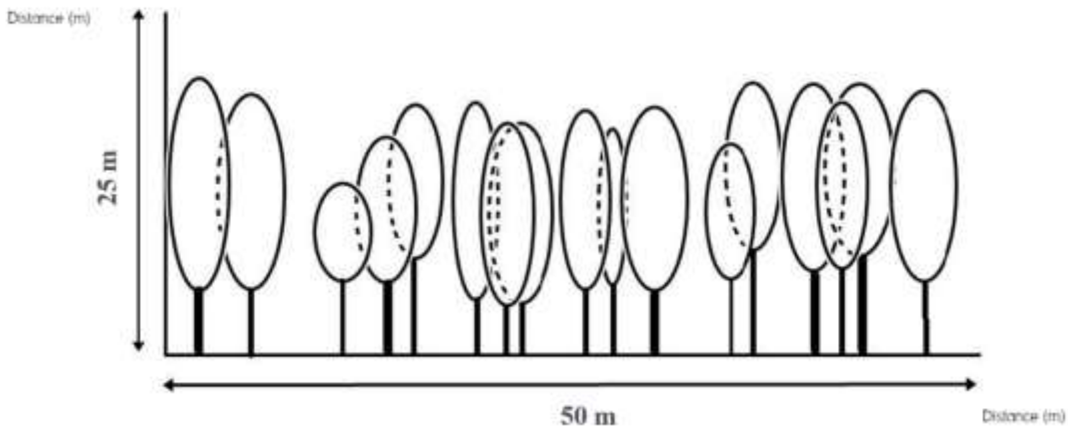

Figure 9 Profile diagram of the side of plot B, study point in front of the university

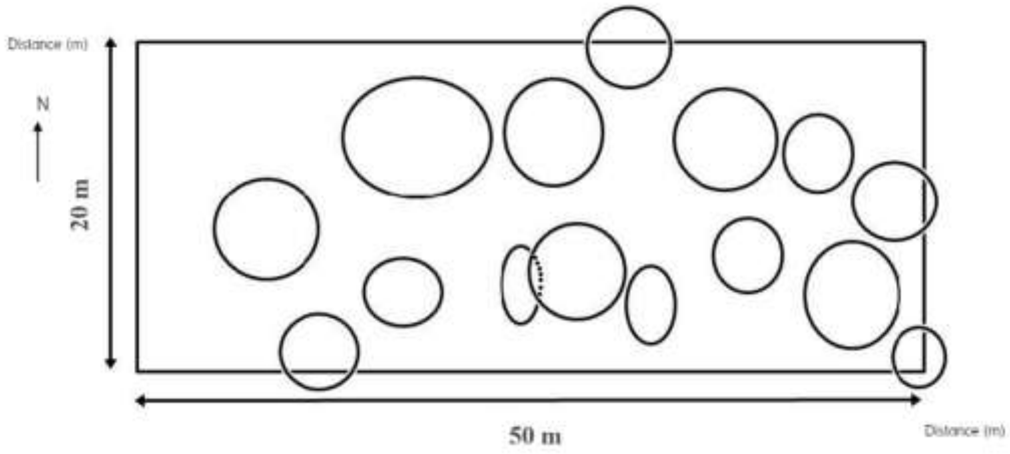

Figure 10 The profile diagram above, plot C, shows the coordinates and canopy shape of the Ban Mo Kaeng Thong

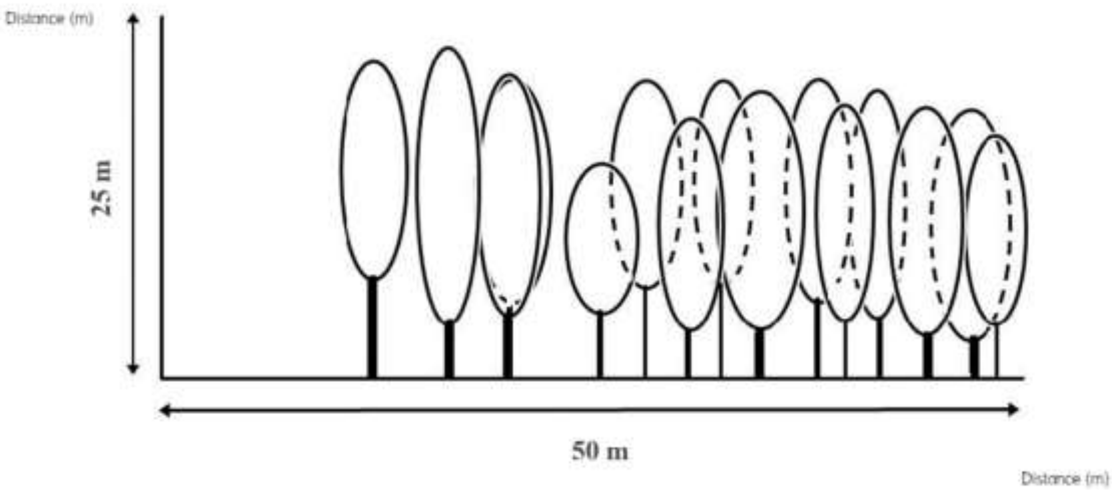

Figure 11 Profile diagram of the side of plot C, Ban Mo Kaeng Thong

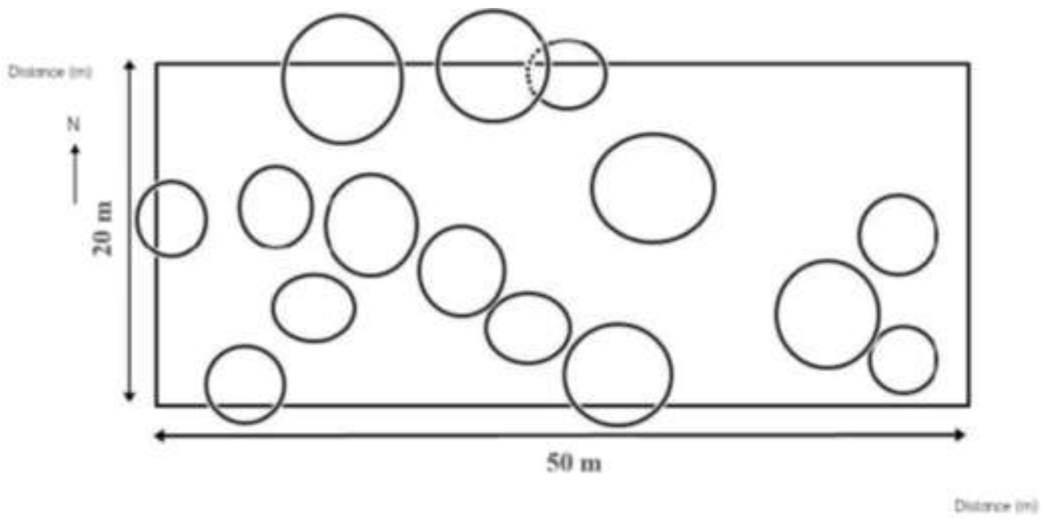

Figure 12 The profile diagram above, plot D, shows the coordinates and canopy shape of the trees at the Ban Mo Kaeng Thong

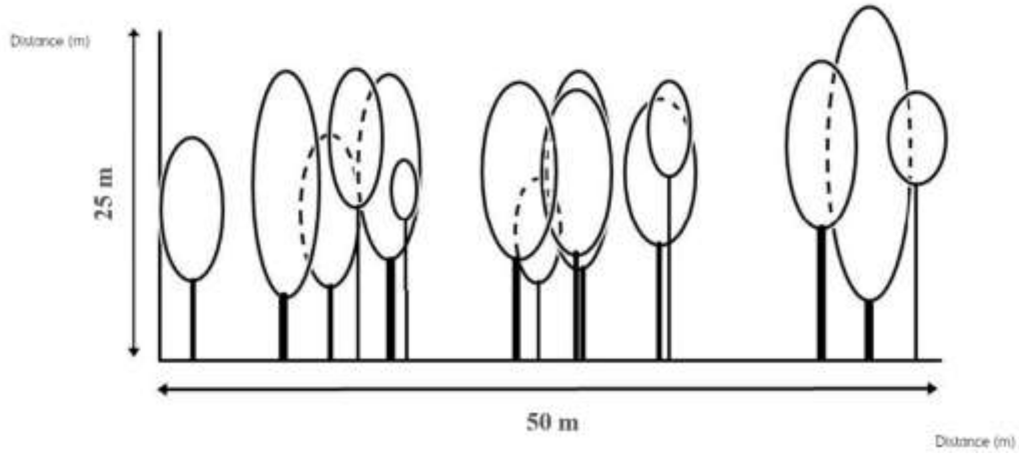

Figure 13 Profile diagram of the side view of plot D, study point: Ban Mo Kaeng Thong.

3.4. Dendrochronology

3.4.1 Growth Rate of Teak (Tectona grandis)

Determining the age of teak trees using dendrochronological methods provides the average annual ring width in the study area. This allows for the calculation of growth rates over specific periods. The analysis reveals that the teak samples in all four plots exhibited inconsistent growth rates, whereas the growth rate was lower than in the initial period. As illustrated in Figures 14, 15, 16, and 17.

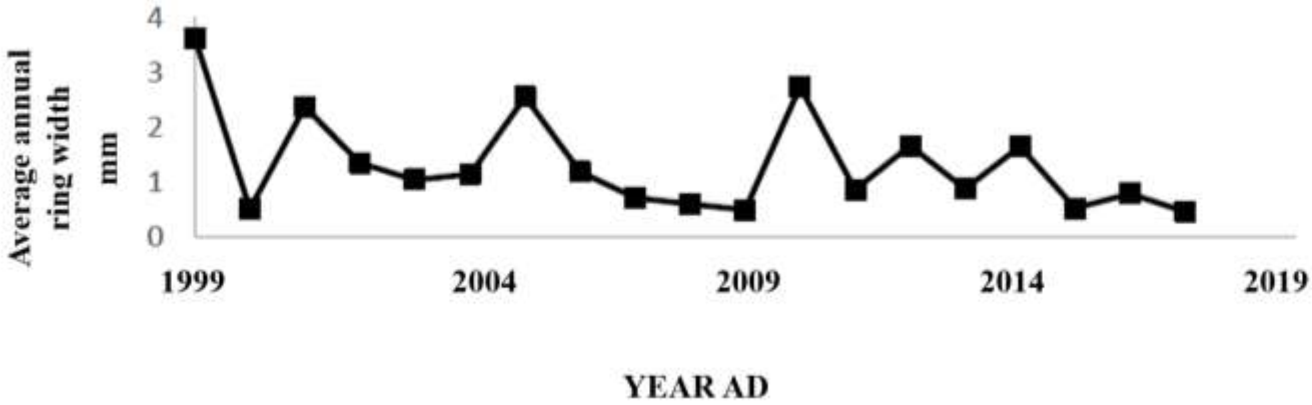

Figure 14 Growth rate of teak trees in plot A during the years 1999-2017

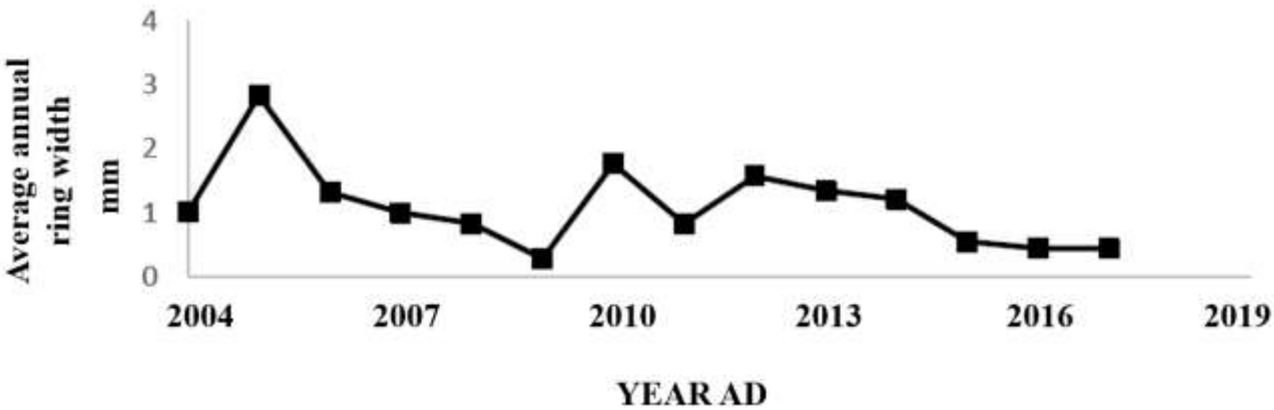

Figure 15 Growth rate of teak trees in plot B during the years 2004-2017

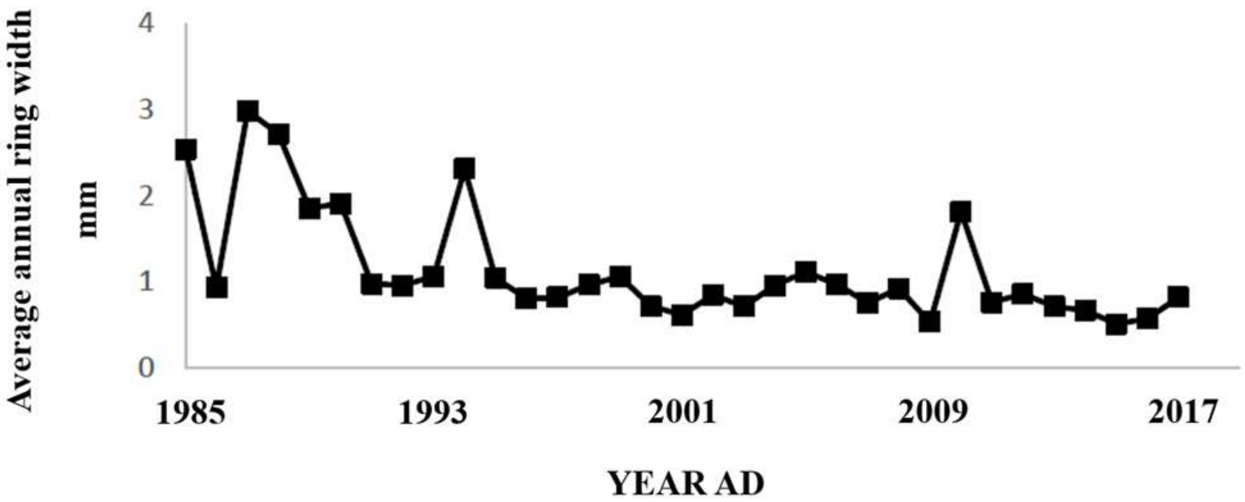

Figure 16 Growth rate of teak trees in plot C during the years 1985-2017

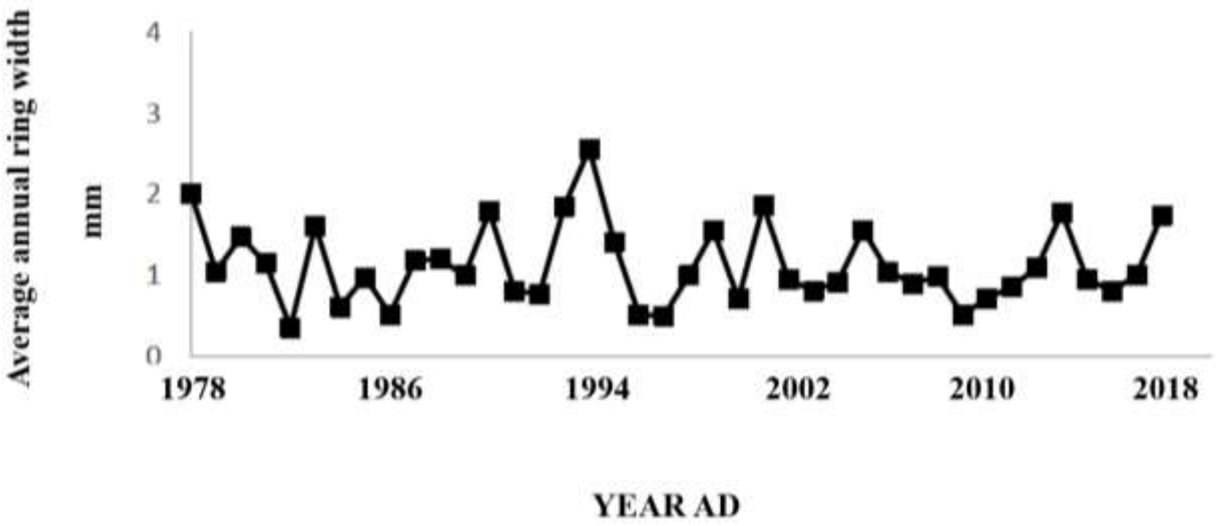

Figure 17 Growth rate of teak trees in plot D during the years 1978-2017

3.4.2. Analysis of the Correlation between Average Annual Ring Width of Teak and Climate Variables (Temperature and Rainfall)

1) The relationship between average annual ring width and average annual temperature and rainfall in the teak seed plot in front of the University of Phayao. The analysis revealed that temperature had no significant correlation with the growth of teak annual rings in both Plot A and Plot B, with correlation values of 0.044 and 0.049, respectively. In terms of rainfall amount, it influenced the growth of the annual ring of teak in both plots, yielding correlation values of 0.834 for Plot A and 0.80 for Plot B.

2) The relationship between average annual ring width and average annual temperature and rainfall in the teak plantation area of Moo Kaeng Thong was studied. It was found that temperature had no correlation with teak ring growth in both plots A and B, with correlation coefficients of -0.137 and -0.061, respectively. However, rainfall correlated with teak ring growth in both plots C and D, with correlation coefficients of 0.258 and 0.66, respectively.

4. Discussion

From this study, we found that the growth rates and the correlation between average annual ring width and climate variables (temperature and rainfall) and the temperature and rainfall data from the Meteorological Department for Phayao Province show that the average temperature ranges from 24 to 26 °C, and the average rainfall ranges from 796.7 to 1579.6 mm aligns with the findings of Ashick Rajah et al. (2025). , who researched analysis of drought and extreme precipitation events in Thailand: trends, climate modeling, and implications for climate change adaptation. Ashick Rajah reported that under controlled environmental conditions, teak thrives best at temperatures between 17 and 43 °C, while temperatures above or below this range lead to decreased growth. Furthermore, teak grows optimally at 75% light intensity and shows significantly less growth at 25% intensity (Leksungnoen et al., 2021). The ideal annual rainfall for teak growth ranges from 900–2500 mm (Dié, 2012), with a distinct dry season of 3–5 months, an elevation of 200–1,000 meters above sea level, and a slope not exceeding 15 degrees. In this study area, the recorded rainfall falls within the optimal range for annual ring development. From data collected in the plots placed in the seedling breeding area of teak in front of the University of Phayao and the teak community plantation plot at Ban Mo Kaeng Thong during January to February 2018, the four plots consisted of plots A and B at the seedling breeding area in front of the University of Phayao, and plots C and D at the teak community plantation in Ban Mo Kaeng Thong depicted that plots A and B have average circumference and average height approximately 108.80 ± 25.19 and 21.03 ± 2.03 m of plots A, and plots B 101.33 ± 18.22 and 16.64 ± 1.56 m, which have higher values than plots C and D (approximately 90 ± 22.65 and 17.41 ± 2.25 m of plots C, and plots D 92.63 ± 20.14 and 18.73 ± 1.63 m). Because the area in front of the university receives more sunlight, it has greater moisture, higher biodiversity, and suitable temperature and rainfall, including the richness of minerals in the soil of plots A and B, which are more suitable for promoting better growth compared to plots C and D (Sengupta et al.,2023).

These results are also consistent with the study of teak annual rings in Northern Thailand by Pumijumnong (2011), which covered five northern provinces. That study found that teak in Northern Thailand responds similarly to temperature and rainfall; specifically, high rainfall during the transition between the dry and rainy seasons results in increased ring width, while the correlation with temperature remains unclear. The vast diversity and complexity of tropical evergreen forests are influenced by environmental factors linked to ISM, such as heavy precipitation (>2500 mm), the frequency of wet days, and improved soil moisture conditions. (Thakur et al., 2021).

The relationship between the average wing width and the average annual temperature and rainfall in the teak seedling cultivation plots in front of the University of Phayao shows that temperature has no correlation with the growth of the teak tree rings in both plot A and plot B, with correlation coefficients of 0.044 and 0.049, respectively. The relationship between the average wing width and the average annual temperature and rainfall in the teak community plantation plots at Mo Kaeng Thong shows that temperature has no correlation with the growth of teak tree rings in both plot A and plot B, with correlation coefficients of -0.137 and -0.061, respectively. Meanwhile, rainfall has a correlation with the growth of teak tree rings in both plot C and plot D, with correlation coefficients of 0.258 and 0.66, respectively. This study observed that temperature has no significant correlation with ring growth in the study area. Consequently, it can be concluded that the growth of teak annual rings in Mae Ka Sub-district, Phayao Province, is not correlated with temperature but is significantly correlated with average annual rainfall. (Buajan et al., 2023; Santos et al., 2021)

This study provides new dendroclimatological evidence of how teak growth responds to climatic variability in northern Thailand, a region where long-term tree-ring based climate-growth studies remain limited. The findings demonstrate that teak growth in the Mae Ka Sub-district is strongly influenced by rainfall variability, while temperature exhibits no significant relationship with radial growth. This pattern is consistent with the ecological characteristics of teak as a deciduous tropical species whose cambial activity is primarily controlled by seasonal moisture availability rather than thermal conditions.

5. Conclusion

5.1.1 Study of growth rates and the correlation between teak annual ring development and climate change using dendrochronological methods. The study was conducted at the teak in front of the University of Phayao and the Ban Mo Kaeng Thong Community in Mueang District, Phayao Province. Data and samples were collected from January to February 2018. A total of 120 samples were obtained from 60 teak trees (2 samples per tree) across four plots. From these, 5 trees per plot with the most complete and distinct annual rings were selected for detailed dendrochronological analysis.

5.1.2 Dendrochronological Analysis of Teak in the Study Areas. The analysis revealed variations in age and annual ring width across the study sites. At the University of Phayao teak, trees in Plot A were found to be 19 years old, while those in Plot B were 14 years old. In the Baan Mo Kaeng Thong Community teak trees in Plot C were 33 years old, and those in Plot D were 40 years old.

5.1.3 Growth rates of teak in both study areas. The growth rates of teak in both areas were found to be inconsistent. Analysis of the average ring width showed that teak trees exhibited non-linear growth patterns. Specifically, growth rates were high during the first 1–2 years, followed by alternating periods of decline and increase in subsequent years.

5.1.4 Correlation between Average Annual Ring Width, Temperature, and Annual Rainfall. The average annual temperature in Phayao Province ranged from 24–26°C, with an average annual rainfall of 796.7–1,579.6 mm. The relationship between average ring width and these climate variables was analyzed using the correlation coefficient. The results indicated that temperature had no significant correlation with ring width growth in Plots A, B, C, and D, with correlation values of 0.044, 0.049, -0.137, and -0.061, respectively. In contrast, average annual rainfall was correlated with ring growth across all plots, with correlation values of 0.834, 0.80, 0.258, and 0.66, respectively.

Data Availability

The data that support the findings of this study are available

on request from the corresponding author.

Conflict of Interest Statement

The authors declare no conflict of interest.

Funding Statement

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