

Past century climate and vegetation change: A case study in Tianshan, Northwest China

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Abstract. This study investigates the impact of climate change on vegetation patterns in the Tianshan Mountain over the past century. By analyzing pollen data and meteorological records, we explore the correlation between plant species distribution and climatic factors. The research focuses on developing warmth index (WI) and moisture index (MI) equations to predict future climate trends and their potential effects on regional vegetation. Our findings reveal significant relationships between specific pollen types and climatic variables, suggesting that ongoing temperature increases may alter the ecological composition of the Tianshan region. The study highlights the need for targeted conservation strategies to preserve vulnerable plant species in rapid climate change.

Keywords: Tianshan Mountains, climate change, vegetation change, pollen index, metrological equation.

1. Introduction

Climate change has become an increasingly popular research topic in recent years. The natural and anthropogenic forcing can lead to changes in climate systems, specifically as large-scale and sustained changes in global climate patterns and average temperature (Khadka and Nitesh, 2023). In the continuous climate change, China has been continuously affected by climate change, especially the Tibetan Plateau in the western China is very responsive to climate (Piao and Shilong, 2010). The Tianshan Mountains located on the Tibetan Plateau in China have a serious impact on climate change. The Tianshan Mountains glaciers melt rapidly due to climate warming (Wang and Shengjie, 2011), so the Tianshan Mountains have attracted a lot of research and become an important region for studying climate change in China. Due to the dependence of plant growth on the surrounding environment, the change of temperature and precipitation caused by the climate change will directly affect the existence

of plant species, so we can reflect the climate change by analyzing the plant species present at different time periods. For the study of plant species changes at different times, pollen data recording is the most direct study method. The study of surface soil pollen assemblages serves as a crucial tool in reconstructing paleoclimatic conditions. By examining the relationship between modern pollen distributions and environmental factors, researchers can infer past climate conditions and understand how vegetation responded to climatic changes. Several studies have focused on different regions and utilized various methods to explore these relationships, revealing both the strengths and limitations of current approaches in paleoclimatology. Studies on surface soil pollen assemblages across various regions have revealed key environmental factors affecting pollen distribution and their significance for paleoclimate reconstruction. In northern Xinjiang, Zhang et al., (2023) found that precipitation, temperature, wind speed, and altitude significantly influence pollen assemblages, highlighting the impact of these variables on plant growth. In Northeast China, Cui's research showed that pollen assemblages reflect the climatic conditions corresponding to different vegetation types, such as forests, grasslands, and meadows (Cui, 2020). Niu et al., (2022) found that in the Western Tianshan Mountains of Xinjiang, higher elevations are associated with increased precipitation and lower temperatures. This pattern aligns with the physiological traits of certain plant species. In the northeastern Tibetan Plateau, Chen et al. identified that specific pollen types indicate different climatic conditions (Chen, 2014). These studies collectively demonstrate that precipitation, temperature, and altitude have significant similarities and differences in their effects on pollen distribution across different regions and vegetation types, reflecting the complex interactions between climate and vegetation. Although these past research papers studied the relationship between pollen and climate, they did not make climate predictions or provide ecological recommendations. Based on these existing studies, we decided to analyze the existence of plant species in the past century, and the climate data in the past 100 years, to find the relationship between plant species and climate change. In this study, we through China established on the Tianshan Mountains climate station records, the temperature of the past 100 years and precipitation data, as well as in the existing research papers cited in the past 100 years Tianshan Mountains about pollen data to present and analyze the data, and through the formula will show plant species change and climate change relationship. This article will offer suggestions for ecological environment construction and develop a comprehensive equation to predict the future temperature and precipitation change.

2. Material and methods

2.1. Study area

In this study, we present high-resolution data collected in the past century from the north slope of the Tianshan mountain located in Xinjiang, northwest China. According to UNESCO, the Tianshan is the largest among all mountains located in Earth's temperate arid region, ranging about 2500km across central Asia.

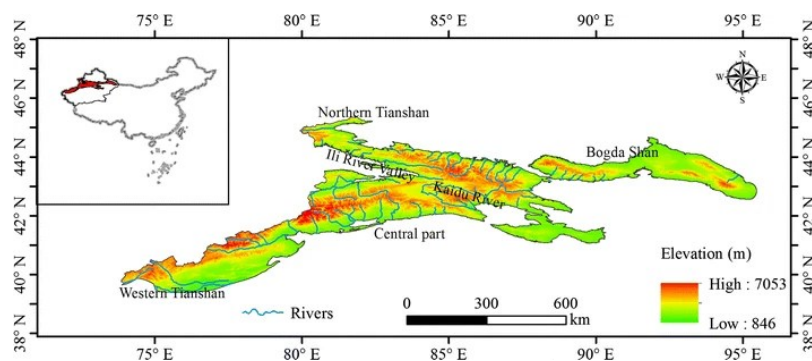


Figure 1. The geographical location of Tianshan Mountains (After Liu et al., 2016)

2.2. Data collection

We present pollen samples gained from sites on the Tianshan north slope. From Wusu city in the west and Mulei county in the east, the sample sites range across 500kms. They include pollen data collected in Daxigou, Xiaoxigou and Huashuwozi. Altitudinally speaking, the north slope of Tianshan can be divided into 6 belts of vegetation of the north slope of are divided into the alpine cushion vegetation zone (>3400 m), the alpine subalpine meadow zone (3400 ~ 2700 m), the zhongshan forest zone (2700 ~ 1720 m), the forest steppe transition zone (1720 ~ 1300 m), the semi-desert zone (1300 ~ 700 m) and the typical desert zone (<700 m) (Ni,2011).

Our study includes the mean temperature and precipitation collected between 1917 and 2004. These meteorological data are collected from the Daxigou meteorological station which is at an altitude of 3593 m and located 3 km southeast of the Glacier Urumqi No. 1 on the Tianshan north slope. (Yue,2017)

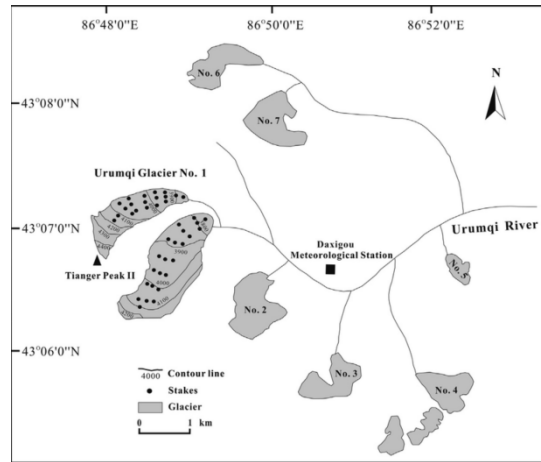


Figure 2. The geographical location Daxigou Meteorological Station (Zhang,2014)

2.3. Data analysis

This study would mainly present datasets of three categories: precipitation data, temperature data and pollen data. Such datasets all originate from the past century as the data in this time scale are more accessible. We construct WI(short for warmth index) and MI(short for moisture index) according to the work of Kira and Li. These indices are used to describe hypothermal relationships. In particular, the calculation methods are:

$$WI = \sum (ti - 5) \quad (1)$$

$$MI = \sum \left(\frac{pi}{2 - ti} \right) \quad (2)$$

Among the two indices, ti and pi are respectively the monthly temperature and the mean precipitation per month when the temperature is above 5 °C.

3. Results and Discussion

3.1. Vegetation change and climate factor

As shown in Figure 1, the temperature in Tianshan demonstrates an overall increasing trend from 1917 to 2004. Although the mean precipitation remains stable during this period, there are notable peaks between 1940 and 1960.

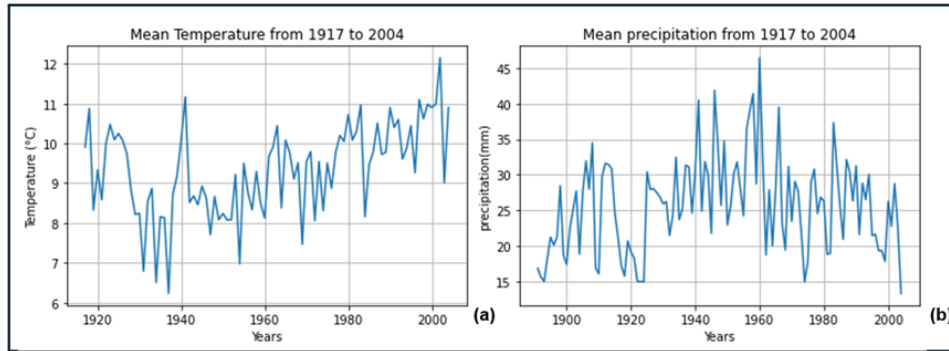


Figure 3. The temperature and precipitation trend from 1917 to 2004.

After transferring the temperature and precipitation data to MI and WI index, the correlation figures of pollen data and MI, WI index in different sections are showing below.

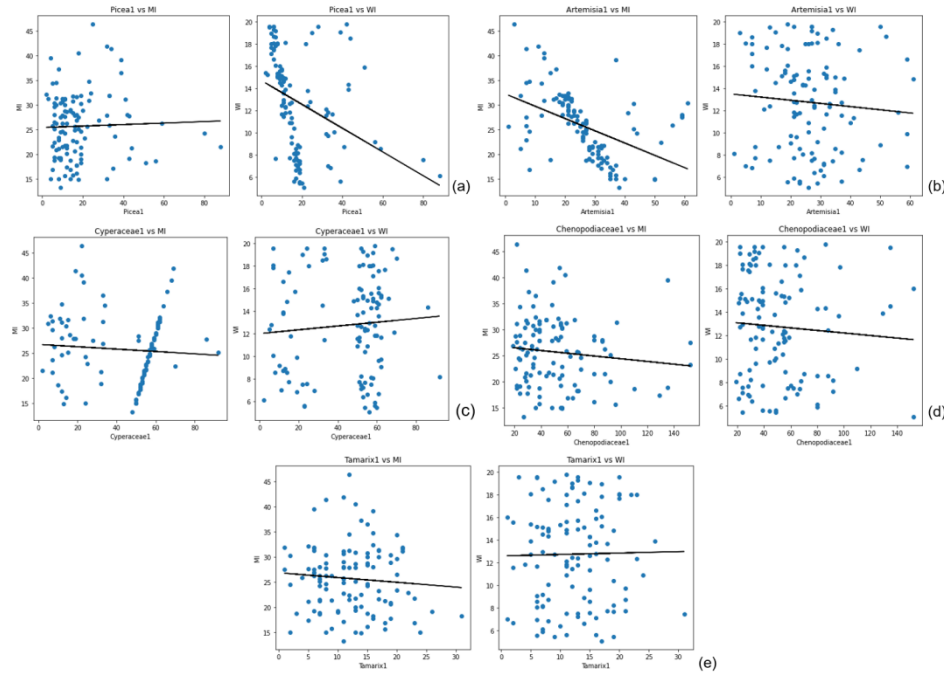


Figure 4. The correlation between different Pollen types and WI/MI index in Daxigou section

Table 1. The correlation index and P value in Daxigou section.

pollen	WI	MI
Picea	-0.552(P<0.01)	0.007(P=0.946)
Artemisia	-0.08(P=0.429)	-0.543(P<0.01)
Cyperaceae	0.073(P=0.468)	-0.057(P=0.571)
Chenopodiaceae	0.065(P=0.520)	-0.156(P=0.121)
Tamarix	0.01(P=0.919)	-0.094(P=0.351)

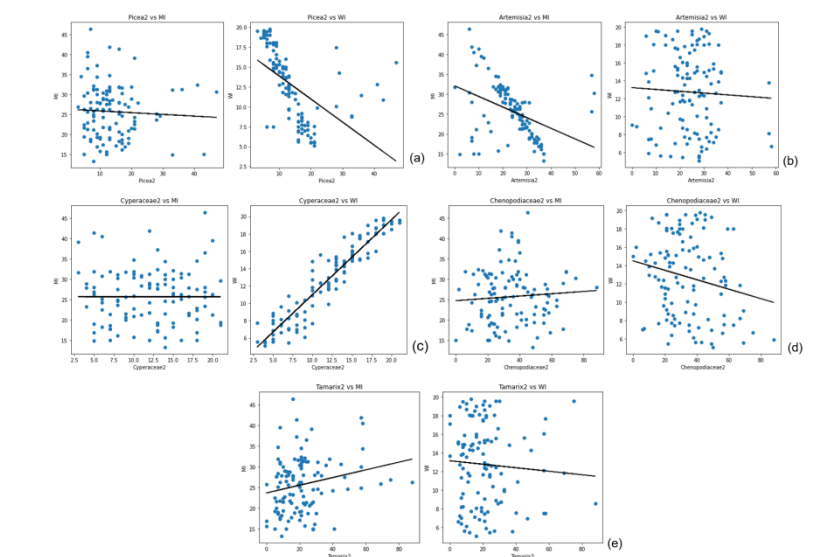


Figure 5. The correlation between different Pollen types and WI/MI index in Xiaoxigou section.

Table 2. The correlation index and P value in Xiaoxigou section.

Pollen	WI	MI
Picea	-0.499(P<0.01)	-0.068 (P=0.946)
Artemisia	-0.054(P=0.429)	-0.565 (P<0.01)
Cyperaceae	0.846 (P<0.01)	-0.01(P=0.925)
Chenopodiaceae	-0.173(P=0.086)	0.135(P=0.182)
Tamarix	-0.056(P=0.581)	0.198(P=0.048)

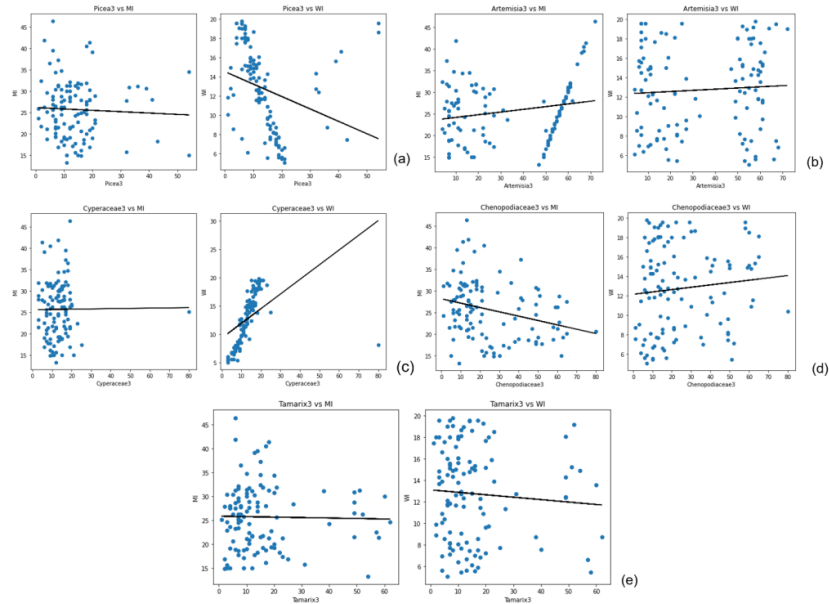


Figure 6. The correlation between different Pollen types and WI/MI index in Huashuwozi section.

Table 3. The correlation index and P value in Huashuwozi section.

Pollen	WI	MI
Picea	-0.445(P<0.01)	-0.05(0.621)
Artemisia	0.053(P=0.599)	0.276(0.025)
Cyperaceae	0.547(P<0.01)	-0.01(P=0.925)
Chenopodiaceae	-0.287(P=0.04)	0.072(P=0.474)
Tamarix	0.066(P=0.514)	-0.058(P=0.564)

Figures 2, 3, and 4, along with Tables 1, 2, and 3, illustrate the correlation between different pollen types and the Wetness Index (WI) and Moisture Index (MI) in the Daxigou, Xiaoxigou, and Huashuwozi sections of Northern Tianshan. *Picea* has a strong negative relationship with warmth index in all three sections. In the Xiaoxigou and Huashuwozi sections, *Cyperaceae* exhibits a positive correlation with WI. Except the Huashuwozi section, *Artemisia* also showing a negative correlation with moisture index. On the other hand, *Chenopodiaceae* and *Tamarix* have no significant relationship between warmth and moisture index.

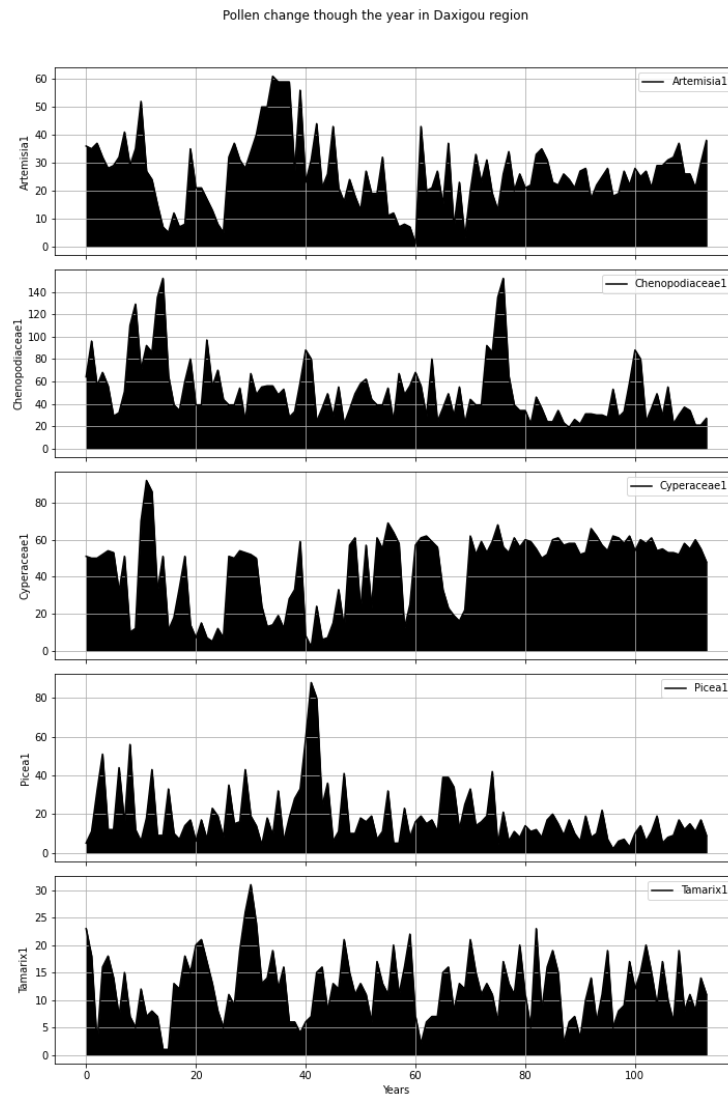


Figure 7. The pollen spectrum in Daxigou section.

Pollen change though the year in Xiaoxigou region

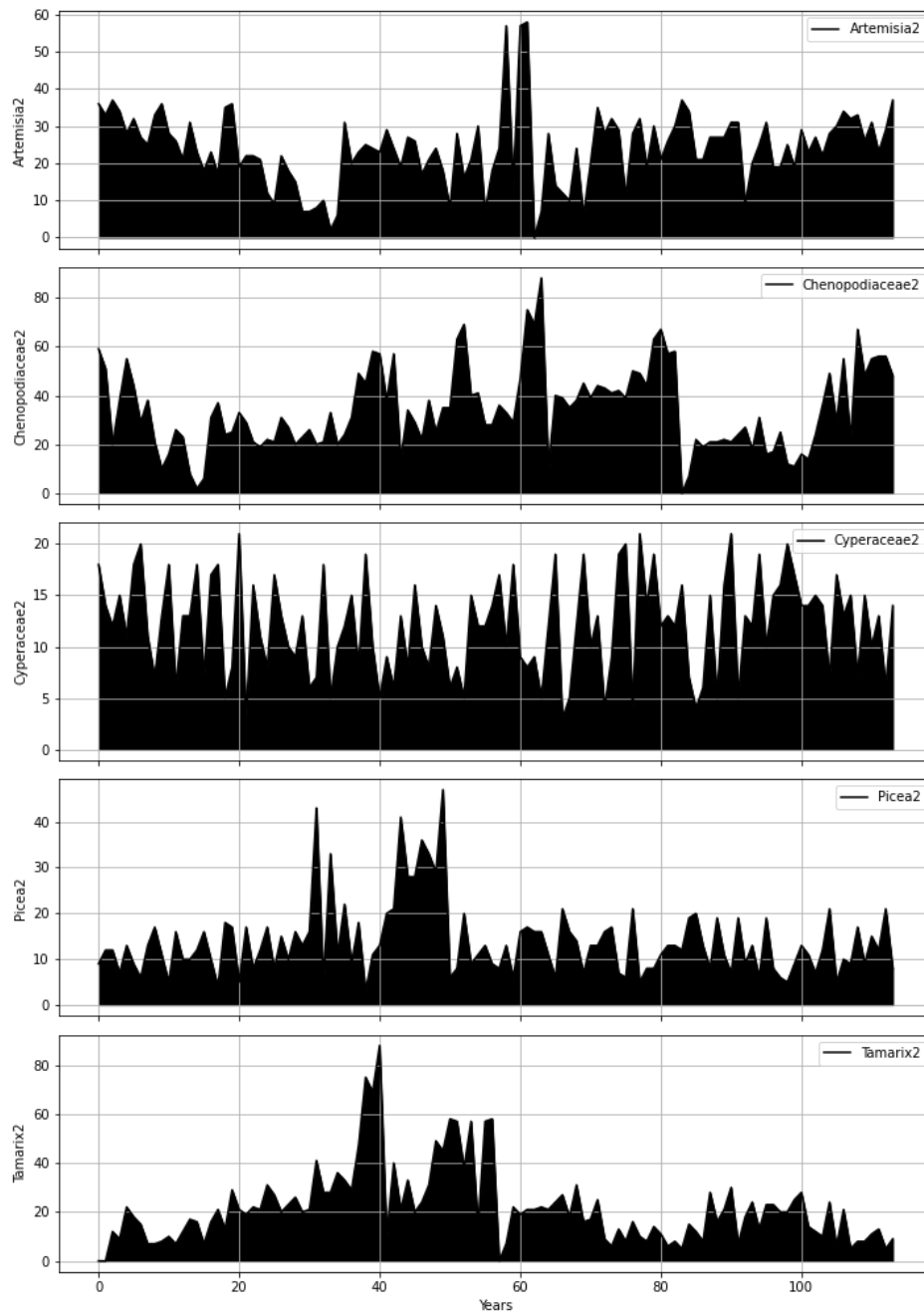


Figure 8. The pollen spectrum in Xiaoxigou section.

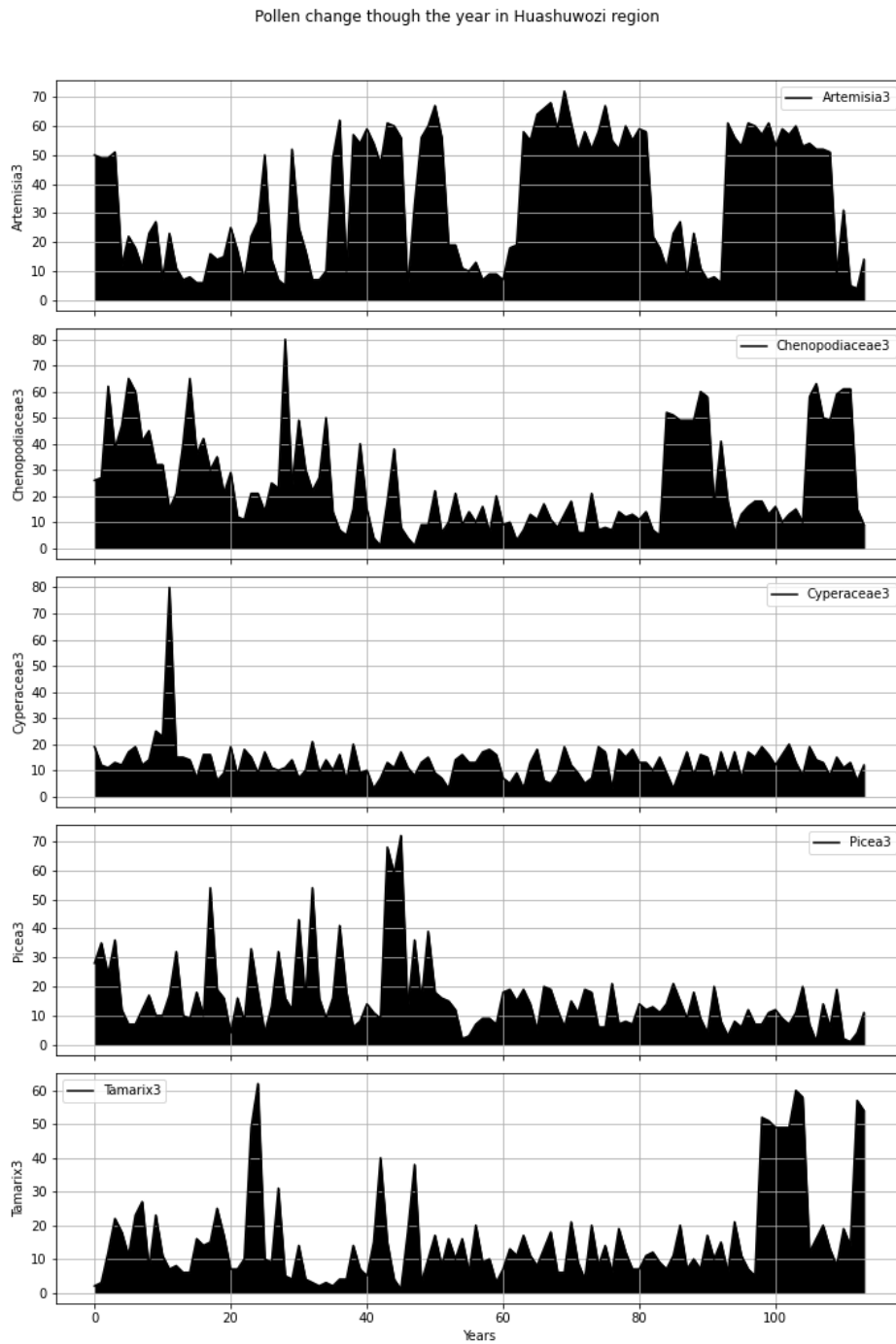


Figure 9. The pollen spectrum in Huashuwozi section.

Picea species typically thrive in cool climates and high-altitude areas, where low temperatures are optimal. The rising temperatures in the Tianshan region have likely reduced the suitable habitat ranges for *Picea*, leading to a decline in their population as indicated by the negative correlation with the WI across all sections. This suggests that ongoing temperature increases could further threaten *Picea* populations in the future.

As shown in the Figure 5,6,7, between the 1940 and 1960, the number of the *Artemisia* species are generally lower than the other time. This indicates that high precipitation has a negative impact on

Artemisia growth. In addition, from 1910s to 1920s the precipitation level and number of Artemisia pollen are all below the average. The low precipitation may also affect the Artemisia species because it cannot supply enough water for Artemisia growth.

Cyperaceae exhibits the strongest positive correlation with the WI, especially in the Xiaoxigou and Huashuwozi sections. This indicates that higher temperatures may be more suitable for Cyperaceae growth, possibly due to their adaptability to warmer conditions. Their positive correlation with the WI suggests that Cyperaceae could become more dominant in these regions as temperatures continue to rise.

Given the observed trends and relationships between vegetation and climatic factors, it is important to develop and implement adaption strategies to manage and protect the ecosystems in the Tianshan region effectively. Because the rising temperatures may reduce suitable habitats for Picea, therefore promote the establishment of Picea plantations at higher altitudes where temperatures remain suitable and reduce the human activity in the habitat area may have positive effect on Picea species. Artemisia is vulnerable to the precipitation level, High or low precipitation level both affect its growth. To support Artemisia populations, Through implementing water retention strategies and maintain soil moisture levels are benefit for Artemisia growth.

3.2. The metrological equation

By monitoring climate changes and implementing targeted management practices, it's important to develop a comprehensive equation to predict the future temperature and precipitation change.

As shown before, Picea and Cyperaceae have the strongest correlations with warmth index, through multiple regression method, the equation are showing below.

$$WI=0.954C+0.015P \quad R^2=0.892 \quad (3)$$

Where, WI is warmth index, C is the number of Cyperaceae, P is the number of Picea. Furthermore, the Artemisia has the strongest correlation with moisture index

$$MI=-0.443A \quad R^2=0.622 \quad (4)$$

Where, MI is moisture index, A is the number of Artemisia

3.3. Limitations

This study has several limitations that should be considered when interpreting the results and implications. Firstly, the temperature and precipitation data used in this study were obtained from a single meteorological station in the Tianshan region. Therefore, the climatic conditions recorded at this single station may not accurately represent the conditions across the various pollen sampling sites. Ideally, corresponding meteorological data from multiple stations located near each pollen sampling site would provide a more comprehensive and accurate understanding of the climatic factors affecting vegetation changes. Secondly, the pollen samples analyzed in this study were collected from a single soil depth. This approach does not account for the potential variations in pollen deposition and preservation at different soil depths, which could provide additional insights into the historical vegetation changes and climatic conditions. Finally, the equation of moisture index is not robust($R^2=0.622$) because the correlation between the MI and Artemisia are not strong enough. Future studies should consider collecting and analyzing pollen samples from multiple soil depths to gain a more comprehensive understanding of vegetation and climate change across different soil layers.

4. Conclusion

In our study, we introduced the current situation of climate change in western China, noting that the Tianshan mountains have been significantly influenced by rapid climate change. Based on existing studies, we analyzed the existence of plant species and climate data in the past century to find the relationship between plant species and climate change. Using data collected from the Tianshan mountains, our study constructed warmth index (WI) and moisture index (MI) through equations to provide interpretations on future climate and precipitation changes. Despite demonstrating a few

setbacks, our study provides valuable insights into how vegetation changes may correlate with climate factors in the Tianshan region.

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Yang Zhan, Yujie Wang, Yuyi Chen, and Zhengkun Zhang contributed equally to this work and should be considered co-first authors.

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