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Anthropogenic Impact on the Terrestrial Environment in the Lake Dian Basin, Southwestern China during the Bronze Age and Ming–Qing period

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Abstract: The role of human activity in shaping the terrestrial environment has been a core scientific issue of interest across various disciplines. However, it remains unclear whether there are significant differences in the patterns of the anthropogenic impact on the terrestrial environment in terms of spatial and temporal dimensions, and we are yet to identify the underlying factors that have driven it. Here, we present an analysis of sporopollen and geochemical proxies from a section of the Anjiangbei site (AJB) on the Yunnan Plateau, spanning the Ming–Qing period, in order to explore the spatio-temporal variation in the anthropogenic impact on the terrestrial environment in the Lake Dian basin. Integrating the reported multidisciplinary evidence, we aim to reveal the influencing factors of anthropogenic impact. Our results show that there were remarkable differences in anthropogenic impact on the terrestrial environment in the Lake Dian basin between the Late Bronze Age and the Ming–Qing period. Changes in crop vegetation and the forest were all affected by human activity in the Lake Dian basin during the two periods, and were more evident during the Ming–Qing period. The heavy metal pollution in the soil was obvious during the Ming–Qing period. The increase in the intensity of human activity, especially the rise in population, could be attributed to changes in the hydrological environment in the Lake Dian basin during the Late Bronze Age and to geopolitical change during the Ming–Qing period. This study reveals the different patterns in human impact on the terrestrial environment in the Lake Dian basin during the Late Bronze Age and the Ming–Qing period, providing new evidence to enable a deeper understanding of past human–environment interactions on the Yunnan Plateau.

Keywords: anthropogenic impact; hydrological change; geopolitical patterns; Lake Dian basin; Late Bronze Age and Ming–Qing period

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1. Introduction

Past human–environment interactions have attracted increasing attention in disciplines as diverse as geography, archaeology, and history [1–3], among which the anthropogenic impact on the ecological environment has emerged as a core issue [4–6]. Evidence from multiple indicators has shown that environmental changes due to anthropogenic impacts can be traced back to the Early Holocene [7], with a clear inconsistency in spatial and temporal patterns [8,9]. For example, the pollen records for the South China Sea suggest that crop cultivation have led to the changes in the forest composition in the south of China since 6000 BP [10], while the anthropogenic impact on the forest has not involved regions such as the Hexi Corridor, Northeastern Plateau [11,12]. Geochemical analysis in northern China has indicated that heavy metal pollution also showed spatial–temporal differences in China during the Bronze Age [13].

The different intensities of human activity across spatial and temporal dimensions were likely responsible for this, closely related to climate and social changes [14,15]. For example, a suitable climate could have promoted an increase in agricultural production, leading to population growth and intensified human activity [16,17]. Major technological innovations and variation in geopolitical patterns have also been influencing factors in changes in the intensity of human activity [18,19]. However, it remains unclear whether there are significant differences in the driving factors of anthropogenic impacts on the environment in terms of spatial and temporal dimensions.

The Lake Dian basin on the Yunnan Plateau is sensitive to climate change, and many hydrological changes in the lake basin during the Holocene have been confirmed by examining paleoclimate records [20,21]. Regional hydrological changes have had significant impacts on human activity. For example, the hydrological changes in southeast Inner Mongolia led to the decline of the Hongshan culture [22]. The collapse of the Loulan Kingdom was also closely related to hydrological changes [23]. In addition, since the Late Holocene, the Lake Dian basin was a significant channel for cultural exchanges along the north–south direction of the Silk Road [24,25]. The expansion of crop cultivation (foxtail and broomcorn millet, wheat, and barley) had a profound impact on the social environment in the Lake Dian basin [26]. Thus, the Lake Dian basin is an ideal area for revealing the significant differences in the patterns in anthropogenic impacts on the environment in the spatial and temporal dimensions and their influencing factors. Paleoclimate records on the lake sediment suggest that past human activity in the Lake Dian basin has had an impact on the environment, including the forest dynamics, the rate of soil erosion, and heavy metal pollution [27–29]. However, the relevant studies have mainly focused on how human activity affected the environment over the duration of the prehistoric period. The anthropogenic impact on the environment during the historical period remains unclear. There is an urgent need to reveal the influencing factors underlying the differences in the intensity of human activity in the Lake Dian basin between the prehistoric and historical period.

In this paper, the Lake Dian basin was selected as the study area because it was one of the most densely populated areas of human settlement on the Yunnan Plateau in both the prehistoric and historical periods [30]. The Lake Dian basin served as the cultural center of Dian in the late Bronze Age and also as the provincial capital from the time of the Yuan Dynasty [31]. The analysis of sporopollen and geochemical proxies was carried out in a section of the Anjiangbei site (AJB), which is located on the southeast bank of Lake Dian. We aimed to explore the spatio-temporal variations in anthropogenic impacts on the terrestrial environment in the Lake Dian basin during the Bronze Age and the Ming–Qing period. By integrating the reported multidisciplinary evidence, the differences in human activity intensity over the two periods, as well as their influencing factors, were revealed.

2. Regional Setting

2.1. Present Climate and Vegetation in the Lake Dian Basin

Lake Dian, situated in the Asian monsoon region, is the largest lake on the Yunnan Plateau (Figure 1a). Due to its extensive surface area, Lake Dian plays a significant role in regional climate regulation. The annual average precipitation in the Lake Dian basin reaches ~1000 mm, primarily concentrated between the months of May and October. The annual average temperature is approximately 14 °C, with relatively minor fluctuations, resulting in an estimated frost-free period of around 230 days [32,33]. Over the past half-century, there has been a rising trend in the annual average temperature in the Lake Dian basin, while there has been a slight decrease in precipitation [34]. The modern water environment of Lake Dian has been significantly influenced by anthropogenic activities, resulting in high concentrations of heavy metal elements and severe eutrophication [35–37]. Despite substantial investment in the lake's restoration efforts, the effectiveness of these efforts has been limited, with the current water quality classified only as Class IV [38].

As shown in Figure 1b, the natural vegetation in Lake Dian is dominated by subtropical, semi-humid broad-leaved evergreen forests, with species such as *Cyclobalanopsis glaucoides*, *Castanopsis delavayi*, *Castanopsis orthacantha*, and *Keteleeria evelyniana* [39]. *Lithocarpus craibianus*, *Tsuga*, and *Abies* forest are distributed in mountainous areas with elevations above 2500 m [21]. However, compared with that in the historical period, the natural evergreen broad-leaved forest has been extensively damaged by human activity, and secondary or semi-artificial forests, such as *Pinus yunnanensis* and *Pinus armandii*, currently occupy 61.1% of the watershed forest area [40]. In addition, shrub grasslands and crops such as wheat, rice, and corn have also become the dominant vegetation types, especially in the alluvial plains surrounding Lake Dian [40]. There are 15 types of aquatic vegetation occupying about 6.8% of the total area of Lake Dian, with common types including *Potamogeton pectinatus*, *Myriophyllum spicatum*, *Azolla imbricata*, and *Zizania latifolia* [41].

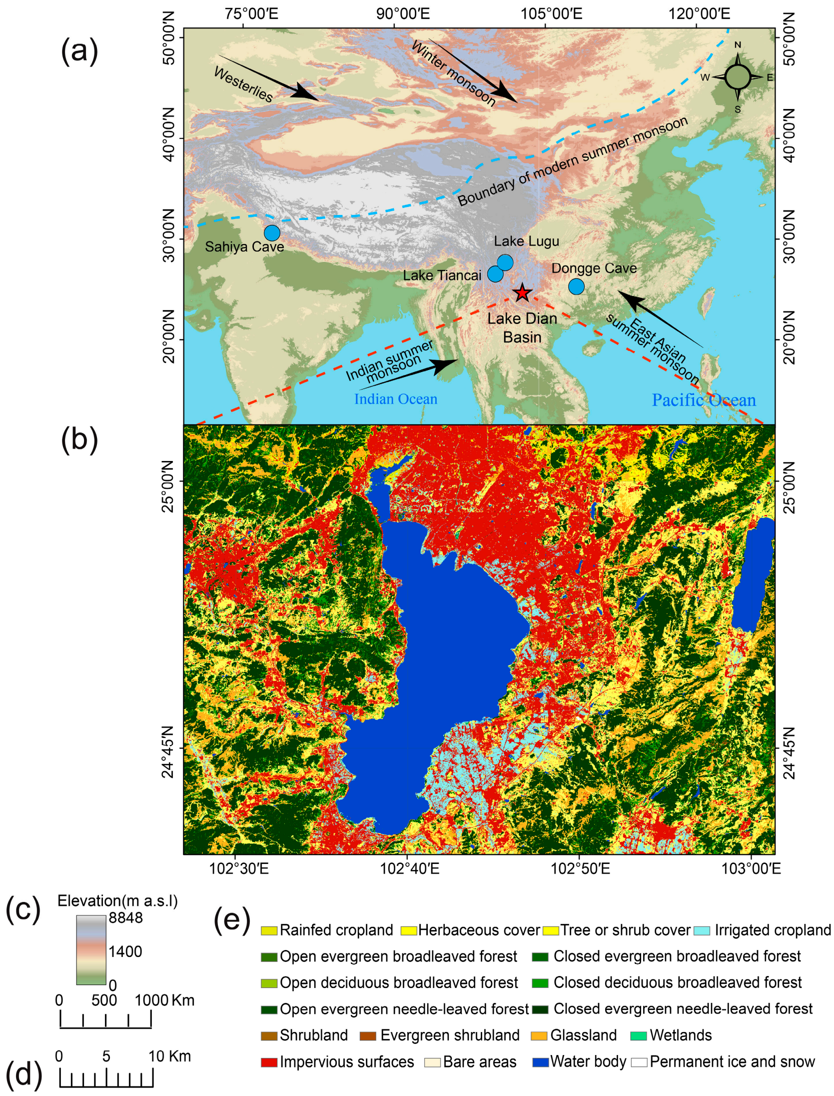

Figure 1. Geographical location of the study area and surrounding vegetation cover. (**a**) Geographical location of the Lake Dian basin and other paleoclimate records mentioned in the paper; The Red Star is the location of the Lake Dian basin. (**b**) The land cover data map around Lake Dian [42]. (**c**,**d**) The legends of (**a**,**b**), respectively. (**e**) The legends of (**b**), representing the relationship between color and vegetation type.

2.2. History of Cultural Evolution in the Lake Dian Basin

The early occupation of the Lake Dian basin was by hunter gatherer groups, and can be traced back 13,000 years [43]. However, the establishment of regimes in this region was much more asynchronous compared to northern China [31]. The earliest regime on the Yunnan Plateau was the Dian Kingdom (278–109 BC), whose cultural center was located on the southeast bank of Lake Dian [44]. The Yunnan Plateau was nominally under the rule of the Central Dynasty from 109 BC to AD 738, while the cultural center migrated from the Lake Dian basin to the Qujing and Huaning area from the time of the East Han Dynasty [45]. From the Mid-Tang Dynasty, the cultural center of the Yunnan Plateau migrated to the catchment area of Lake Erhai, while the city of Dali successively became the capital of Nanzhao (AD 738–902) and Dali Kingdom (AD 937–1254) [46]. In AD 1254, the Mongol army defeated the Kingdom of Dali and incorporated the Yunnan Plateau into the territory of China. The cultural center migrated to the Lake Dian basin from AD 1276, and the city of Kunming became the cultural center of the Yunnan Plateau again [47,48]. During the Ming–Qing period, the population and intensity of human activity in the Lake Dian basin gradually increased [49,50].

2.3. The Anjiangbei Site

The site of Anjiangbei (AJB) was excavated in 2020 (Figure 2). The cultural relics discovered suggested that the chronology of AJB could be traced back to the Late Bronze Age, which belonging to the Dian culture (~1000 BC–1 AD) and the Ming–Qing period (AD 1368–1911). The cultural layer of Dian was not found in that section of AJB. Thus, the section from 1 to 200 cm was investigated. The section lithology was composed of reddish fine-grained clay (1–100 cm) and fine-grained clay with green–gray (100–200 cm) (Figure 3). Some ceramics from the Ming and Qing dynasties have been found in the section from 1 to 200 cm.

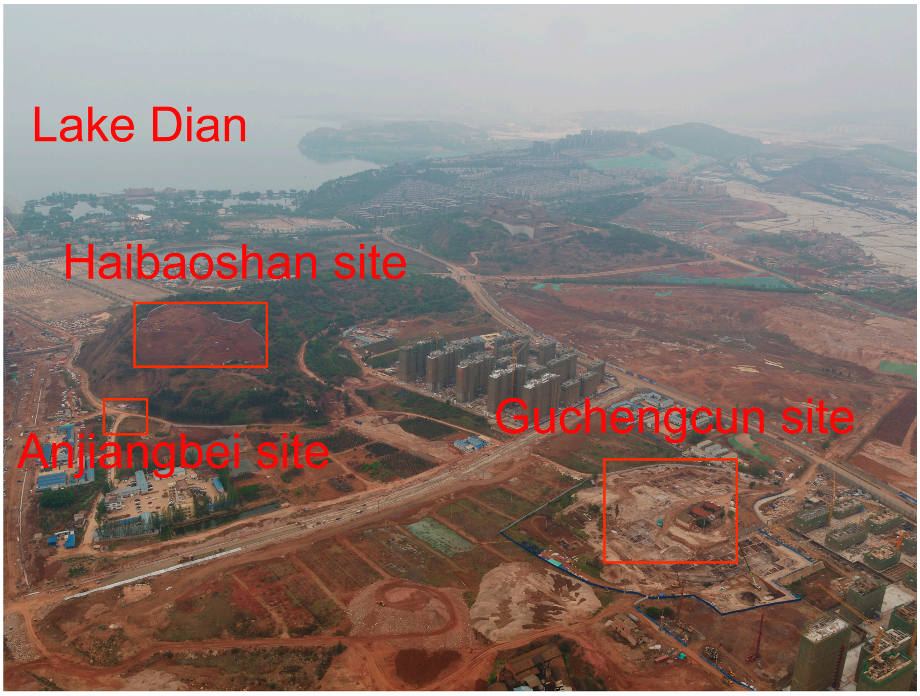

Figure 2. The location of the Anjiangbei site relative to Lake Dian, Haibaoshan site, and Guchengcun site.

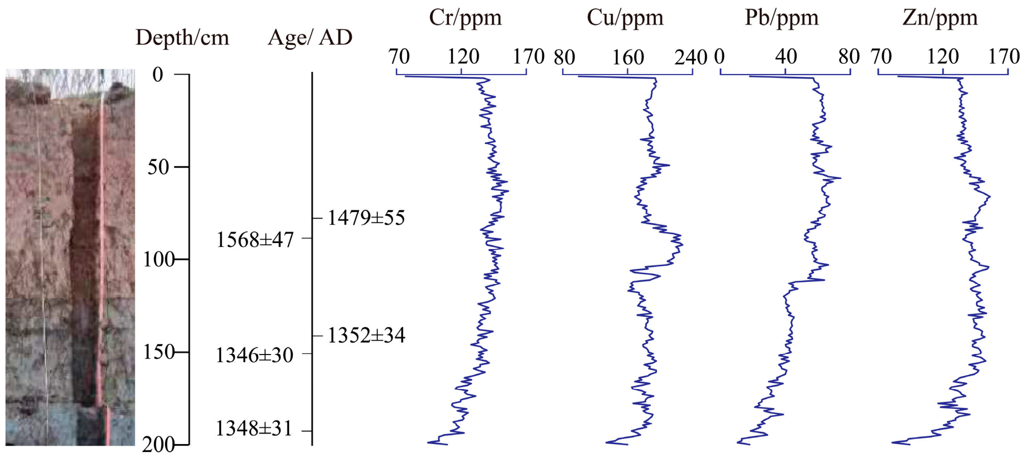

Figure 3. Field characteristics, chronological results, and concentrations of heavy metal elements in the AJB section.

3. Materials and Methods

3.1. Section Collection and Dating Method

A 200 cm long section of AJB (102.74° E, 24.759° N) was recovered from the southeastern bank of Lake Dian in 2020. A total of 200 soil samples at 1 cm intervals were collected and dried. To accurately detect the chronological sequence of this section, five accelerator mass spectrometry (AMS) radiocarbon ages across the entire section were measured, with three dating samples in the section of 100–200 cm and two samples from 1–100 cm, and the charcoal provided the dating samples (Table 1). The charcoal samples were pretreated using a standard acid–base–acid procedure. Graphite targets for the obtained samples were prepared using the AGE3 (Automated Graphitization Apparatus 3) system and measured using MICADAS. They were analyzed at the MOE Key Laboratory of Western China's Environmental Systems, Lanzhou University, and at the BETA laboratory in Cleveland, Ohio, USA. All ages were calibrated using the OxCal v4.2.4 software and the IntCal20 calibration curve [51] and reported as 'cal BC or AD' ('calendar year after AD 1'). The use and details of this analysis software can be found on the online site (https://c14.arch.ox.ac.uk/oxcal.html (accessed on 1 September 2023)).

Table 1. Radiocarbon dates from the AJB section.

Sample ID	Depth (cm)	Material	^{14}C Age (a BP)	±(y)	Calibrated Age (AD) (95.4%)	Medium Age (AD)	σ
LZU20654	79	Charcoal	390	20	1447–1621	1479	55
LZU20655	90	Charcoal	340	20	1479–1635	1568	47
Beta 583919	143	Charcoal	640	30	1285–1397	1352	34
LZU20657	151	Charcoal	580	20	1311–1410	1346	30
Beta 583920	194	Charcoal	610	30	1299–1404	1348	31

3.2. Elemental Content and Sporopollen Analysis

The soil samples were dried and ground into powder before testing. Magix PW2403 Wavelength-Dispersive X-ray fluorescence with an analytical precision of better than 1–2% was used for the elemental content analysis. This was conducted at the MOE Key Laboratory of Western China's Environmental System, Lanzhou University.

A total of 21 soil samples at approximately 10 cm intervals were selected from the AJB section for sporopollen analysis. Then, 20 g of each sample was weighed, and a known number of *Lycopodium* spore (27,637/slice) was added. The sample was treated with HCl and HF sequentially and soaked for a sufficient amount of time to remove impurities. Each sample was examined to identify at least 550 terrestrial pollen grains, or the whole sample was counted when the quantity was insufficient. Sporopollen identification involved referring to pollen atlases of subtropical areas and common cultivated plants in China [52–54]. The pollen diagram was generated using Tilia 3.0.1 [55,56]. This software provides functions for standardization, statistics, and plotting of pollen data, and the use of this software was referenced from Shu et al. (2018) [57]. The pretreatment and identification were conducted in the Key Laboratory of Desert and Desertification, Northwest Institute of Eco-environment and Resources, Chinese Academy of Sciences, and Hebei Normal University, respectively.

4. Results

4.1. Chronology

The radiocarbon dates from the AJB section are shown in Table 1. All the radiocarbon dates were calibrated and are presented at 95.4% confidence, and the median age is used for showing the chronology of the AJB section. This sedimentary profile may have been in existence for 600 years. The oldest date is at the bottom of the AJB section (150 cm), dating to AD 1346. The date from a depth of 194 cm corresponds to AD 1348, while the date from 90 cm corresponds to AD 1568. The date from a depth of 79 cm is little older than expected, given the radiocarbon ages below this depth. This may be due to the bioturbation of terrestrial sediments, a phenomenon that has also occurred in the terrestrial sediments of archaeological sites [58,59]. Nevertheless, all the dates fall within the period of the Late Yuan and Ming–Qing Dynasties (AD 1271–1911), indicating that the AJB section corresponds with the period of AD 1346–1911. The archaeological evidence also unearthed ceramics dating back to the Ming–Qing period.

4.2. Element Content

The element contents of Cu, Cr, Pb, and Zn are high in the AJB section, of which the Cu and Pb elements show a similar pattern of variation (Figure 3). The Cu content is the highest, ranging from 99.5 to 227.7 ppm, while the Cr and Zn contents are slightly lower than that of Cu, with ranges of 76.9–156.1 ppm and 80.7–156.2 ppm, respectively, during the Ming–Qing period. Among the four elements in the AJB section, the Pb content is the lowest, ranging from 10.4 to 74 ppm in the period.

4.3. Sporopollen Records

A total of 77 sporopollen species were identified in the AJB section, consisting of 24 species of woody plant pollen, 8 species of shrub pollen, 27 species of herbaceous pollen, and 18 species of spores. *Pinus*, *Quercun(E)*, and *Quercus(D)* are the main woody plant pollen that were identified in the AJB section. Additionally, pollen from Betulaceae, *Abies*, and *Tsuga* appeared frequently. Poaceae, *Artemisia*, Chenopodiaceae, and Polygonaceae pollen are the main herbaceous plant pollen that were identified. Pollen grains larger than 35 μm from the Poaceae (>35 μm Poaceae) and *Fagopyrum* Mill are considered to originate from human cultivation activities [48]. The sporopollen diagram (Figure 4) displays a total of 17 pollen types, categorized into three groups: arboreal pollen, non-arboreal pollen, and spore.

The pollen (57,865.92 grains/g) and spore concentrations (5357.41 grains/g) are shown as being exceptionally high during AD 1348–1568. The percentage of *Pinus* pollen is the predominant pollen type at this stage, with a content of 61.80%. The total percentage of pollen from *Artemisia* and Chenopodiaceae is only 1.74%. The ratio of *Quercus(E)*/*Quercus(D)* is 0.17. Polypodiaceae emerges as the most abundant spore type in terms of percentage abundance. However, its highest percentage only reaches 38.6%, while the average percentage abundance stands at 17.95%.

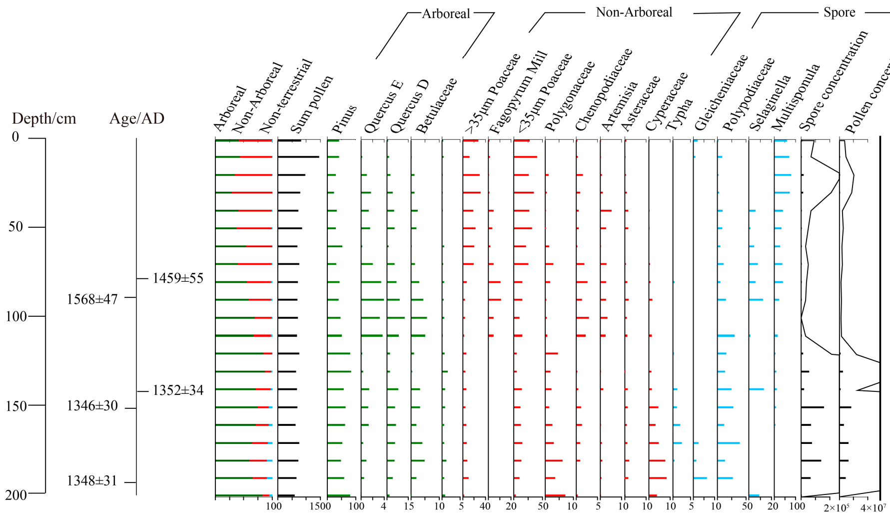

Figure 4. Sporopollen percentage (%)/concentration (grain/g) diagram of selected taxa of the AJB section. The concentration curves of sporopollen have been exaggerated by 20.

The high percentage of crop pollen (>35 μm Poaceae and *Fagopyrum* Mill) is the main characteristic since AD 1568. The percentage of crop pollen is 22.72%, while that of the Poaceae pollen is 26.22%. Correspondingly, at this depth, there is a noticeable decrease in the percentage abundance of pollen from *Pinus* (35.98%). The percentage of pollen from *Quercus* also shows a continuous decreasing trend. However, the *Quercus(E)*/*Quercus*(D) ratio remains relatively high (0.29). During this stage, there is a rich variety of spore types. The abundance of spores from *Multisponula* exhibits significant changes during this stage. It replaces Polypodiaceae as the most dominant spore species, with average concentrations of 42.91%.

5. Discussion

5.1. History of Anthropogenic Impacts on the Terrestrial Environment in the Lake Dian Basin during the Bronze Age and the Ming–Qing Period

Since the Early–Middle Holocene, human activity has had a significant impact on the terrestrial environment on the local and regional scale [60–62]. Forest changes due to anthropogenic impacts have represented one of the most pervasive processes associated with landscape change around the world [7,63]. For example, forest degradation in northern Italy began with large-scale human wood cutting during the Bronze Age [64]. Wood burning by Neolithic groups led to an increase in black carbon in lake sediments and natural sections in northern China, and then a decline in woody vegetation [8]. Wood cutting by humans also led to regional changes in woody assemblages, such as that on the northeastern Tibetan Plateau during the Neolithic and Bronze Ages [12].

Human activity also affected the forest dynamics in the Lake Dian basin during the Late Holocene. Xiao et al. [21] suggested that the terraneous pollen concentrations (TPCs) (152,411 grains cm^{-3}) and the percentage of *Pinus* pollen (59.0%) were the highest during the period of BC 3450–BC 450, while there was a significant decline in them from BC 450 to AD 850. The Poaceae pollen (>40 μm) first increased (0.8%), and the concentrations and accumulation rates of charcoal particles >125 mm were relatively high. The marked decrease in the pollen percentages of *Pinus* and TPCs indicates that the *Pinus* forest and vegetation coverage decreased significantly. The rapid increase in the concentrations and accumulation rates of charcoal particles >125μm indicate that local fire events have been frequent in the Lake Dian basin since BC 450. Combined with the archaeological evidence, this change in the environment in BC 450 can likely be attributed to human activity around Lake Dian [21,31]. During the same period, the forest dynamics in the Lake Erhai basin, Lake Cheng basin, and Lake Qinghai (Tengchong) were also affected by human activity [27,65,66].

The anthropogenic impacts on the Lake Dian basin was more obvious during the historical period, especially during the Ming–Qing period. The sedimentation rate was the highest in Lake Dian (up to 1.1 cm year^{-1}) during the same period [21]. The pollen record from the AJB section suggests a much higher amount and percentage of Poaceae pollen (>35 µm) than arboreal pollen since AD 1352 (Figure 4), indicating that crop cultivation and wetland replaced the forest as the main landscape on the southeast bank of Lake Dian during the Ming–Qing period. This is confirmed by the pollen record of Lake Dian sediment. Xiao et al. [21] suggested that the woody vegetation coverage was very low after AD 850, showing a significant decline in evergreen oak pollen and the highest percentage of Poaceae pollen. Apart from the deforestation, the highest sedimentation rate in Lake Dian could also be a result of the soil erosion caused by mineral mining. The geochemical proxies in the AJB section show high levels of the heavy metals Cu, Cr, Pb, and Zn during the Ming–Qing period (Figures 3 and 5). Compared with other records for the Yunnan Plateau, the heavy metal content was at the highest level in the Lake Dian basin during the Ming–Qing period. Historical records (e.g., *Mingshi*, the historical record of the Ming dynasty) suggest that the mining and metallurgy industry developed rapidly on the central Yunnan Plateau from the Ming Dynasty onward, establishing the area as having the highest level of metal production. This indicates that heavy metal pollution in the soil around the Lake Dian basin has been relatively prominent in its history.

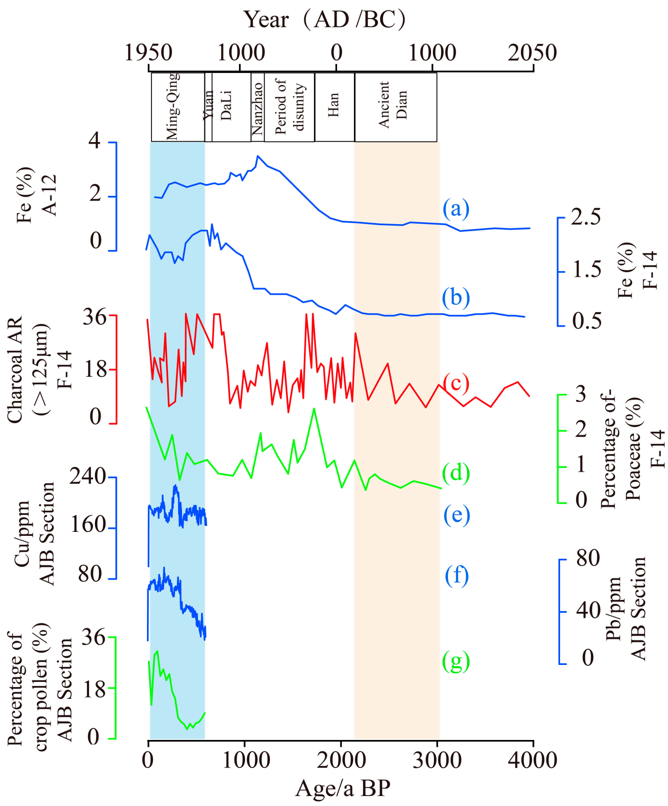

Figure 5. Sediment records of the anthropogenic impacts on the terrestrial environment in the Lake Dian Basin. (a,b) Concentrations of Fe from A-12 and F-14 core [28]. (c,d) Relative pollen content of Poaceae and flux of >125 µm charcoal from F-14 core [21]. (e–g) Concentrations of Fe and Cu and the relative pollen content of crop pollen from the AJB section (this study).

In summary, human activity had a significant impact on the terrestrial environment in the Lake Dian basin during the Bronze Age and the Ming–Qing period. Changes in vegetation were all affected by human activity during the two periods, while the heavy metal pollution in the soil was more evident during the Ming–Qing period. The significant differences in the patterns of anthropogenic impact on the terrestrial environment were likely due to changes in the intensity of human activity. However, it remains unclear what influencing factors affected human activity intensity in the Lake Dian basin during the Bronze Age and the Ming–Qing period.

5.2. Human Activity Intensity and Its Influencing Factors in the Lake Dian Basin during the Bronze Age and the Ming–Qing Period

The factors affecting changes in human activity intensity have encompassed both natural and social aspects. Natural environment changes due to climate fluctuation have played a significant role in the intensity of human activity on a local and regional scale [67,68]. For example, a suitable climate during the Mid-Holocene promoted an increase in crop production, leading to a rise in population and the expansion of human habitat on the Loess Plateau [14]. Climate deterioration, in contrast, could have brought about a serious ecological crisis and suppressed the increase in the intensity of human activity, which could even have led to the decline of ancient cultures and the collapse of ancient kingdoms [69]. In addition, climate deterioration on a regional scale could also have forced human migration and led to a decline in the intensity of human activity in out-migration areas but an increase in immigration zones [70]. The social factors affecting the intensity of human activities included major technological innovations and their expansion, as well as changes in geopolitical patterns. The emergence of crop cultivation and animal domestication from the Early Holocene greatly promoted the rapid increase in global population growth [71], and agricultural intensification in both West and East Asia played a significant role in the expansion of human habitats, especially in regions with extreme climates [18]. During the historical period, geopolitical changes in northern China promoted human migration to the Hexi Corridor and increased the intensity of human activity in this location [72]. In this study, we aimed to explore the effects of natural and social factors on the intensity of human activity in the Lake Dian basin during the Bronze Age and the Ming–Qing period, respectively.

5.2.1. Natural Factors Influencing Human Activity Intensity in the Lake Dian Basin during the Bronze Age

The Lake Dian basin experienced several remarkable changes in climate during the Holocene [21,73,74]. It had a warm-humid climate during the Early and Middle Holocene, with the temperature at least 2 °C higher than today and with higher precipitation. The warm and humid climate promoted the inhabitation of semi-humid evergreen broad-leaved forest around Lake Dian [21]. During the Late Holocene, especially in the Bronze Age (BC 1600–0), the climate in the Lake Dian basin became colder and dryer [74]. The pollen record from Lake Dian suggests that the *Pinus* pollen increased significantly, replacing semi-humid evergreen broad-leaved trees as the dominant forest around the Lake Dian basin [21]. It is worth noting that the lake level significantly declined, as shown by the records for carbon-to-nitrogen ratios and carbonate precipitation [24]. The shrinking of the lake area due to a relatively cold–dry climate could also be seen in Lake Xingyun and Qilu on the central Yunnan Plateau from BC 1600 to 0 [20,21,75].

Generally, hydrological changes in human habitats are not conducive to an increase in the intensity of human activity [13,76]. However, the increase in human activity intensity in the Lake Dian basin during the Bronze Age was only due to hydrological changes. During this period, human settlements and the intensity of their activity in the Lake Dian basin gradually increased [44]. Humans in the Lake Dian basin adopted an agricultural economy, and crops of rice, foxtail and broomcorn millet, wheat, and barley were cultivated around Lake Dian during the Bronze Age [77]. The changes in the basin area represented the key factor in human crop cultivation during the Bronze Age. The shrinking of Lake Dian could have increased the area of the basin, providing more land for crop cultivation. Although it remains unclear whether the Dian culture primarily relied on crop cultivation for their main subsistence, the agricultural economy was likely one of the influencing factors that enhanced the intensity of human activity in the region during the Bronze Age. Therefore, the hydrological changes due to the cold–dry climate likely represented the main factor that led to increased the intensity of human activity in the Lake Dian basin during the Bronze Age.

During the Ming–Qing period, there were many more human settlements in the Lake Dian basin than there were in the Bronze Age, with a greatly increased the intensity of human activity (Figure 6). However, the climate in the Lake Dian basin during this period differed significantly from that in the Bronze Age. The paleoclimate records suggest that there was a cold–humid climate in the Lake Dian basin during the Ming–Qing period, and the annual precipitation was much higher than that in the Bronze Age [21,78,79]. The changes in the lake level at the Yunnan Plateau were closely related to precipitation [20], while the Lake Dian level in the Ming–Qing period was lower than that in Bronze Age according to the historical records [80]. The much lower lake level increased the basin area around Lake Dian once more during the Ming–Qing period, providing land for human settlement. However, climate change was no longer the key influencing factor promoting human settlements around the lake and increasing the intensity of human activity during this period.

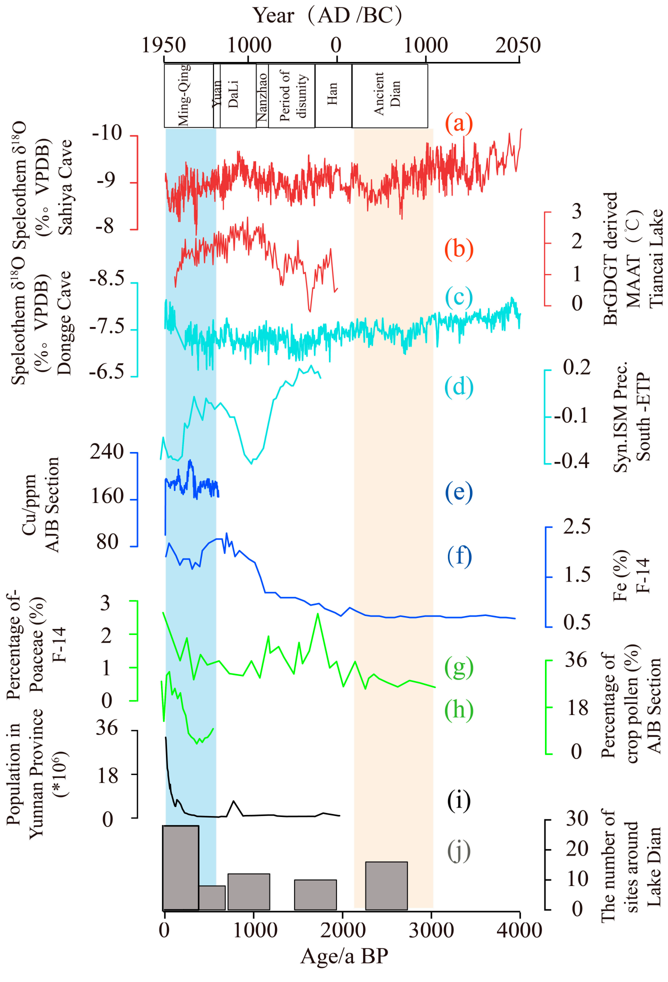

Figure 6. Comparison records of the anthropogenic impact on Lake Dian and the human activity around Lake Dian and other paleo-climatic records in the Asia monsoon area. (a) The Sahiya Cave speleothem $\delta^{18}O$ record [81]; (b) the brGDGT-inferred mean annual air temperature reconstruction record from Tiancai Lake [79]; (c) the Dongge Cave speleothem $\delta^{18}O$ record [82]; (d) the composited precipitation over Southern Tibetan Plateau areas [78]; (e,f) heavy metal element concentrations from the AJB section and F-14 core ([28]; this study); (g,h) relative pollen content of crop pollen from F-14 core and the AJB section ([21]; this study) (i) population of Yunnan Province [83]; (j) the number of sites around Lake Dian [84].

5.2.2. Social Factors Influencing Human Activity Intensity in the Lake Dian Basin during the Ming–Qing Period

Social environments were formed by humans through long-term, intentional social labor, which shaped the natural environment and initiated the production of edible resources; changes in social environments could lead to variations in the intensity of human activity [3,85]. The intensification of social resilience and increasing complexity were significant indicators of changes in the social environment, in which human migration, as well as major technological innovations, and their expansion, played significant roles [86–88]. During the prehistoric period, climate change on a regional scale could have motivated major technological innovations and human migration. For instance, the rise in agriculture during the Early Holocene was probably affected by rapid climate changes (Younger Dryas) in the Northern Hemisphere [89,90]. Several human migrations in the region during the Mid–Late Holocene were also due to climate deterioration [91,92]. However, geopolitical changes were likely the most significant factor affecting the human social environment, and then the intensity of human activity, during the historical period.

Several case studies in China demonstrate the impact of geopolitical changes on human social environment changes during the historical period. Li et al. (2023) [19] suggested that geopolitical changes in northern China affected the intensity of human activity during the 12th century. The increased intensity of human activity in the Hexi Corridor were closely related to geopolitical changes in northern China during AD 220–1280 [72]. The remarkable increase in intensity of human activity in the Lake Dian basin during the Ming–Qing period was also affected by geopolitical changes at the Yunnan Plateau. According to *Yuanshi* (the historical record of the Yuan Dynasty), the Mongol army invaded and occupied the Yunnan Plateau during AD 1253 and settled the region of *Zhongqinglu* (Kunming city) as the capital of the Yunnan area in AD 1276. In the same year, officials of the Yunnan Plateau initiated water control works for Lake Dian and opened the lake's outlet. This led to an obvious decrease in the lake level and an increase in farmland around Lake Dian [47], which provided favorable conditions for large-scale human settlement. During the Ming–Qing period, there was a rapid increase in population in the Lake Dian basin (Figure 6), due to several mass human migrations forced by the central government, as shown in the *Mingshi* and *Qingshi* records [50,93]. The rise in population enhanced the intensity of human activity; this also confirmed via the *Stalagmite* record for the Guizhou area [94].

In summary, there was a significant difference in the factors affecting changes in the intensity of human activity in the Lake Dian basin during the Bronze Age and the Ming–Qing period. Hydrological changes due to climate change promoted human settlement in the Lake Dian basin and then increased human activity intensity during the Bronze Age. Moreover, variations in geopolitical patterns replaced climate change as the key factor influencing the hydrological environment and population dynamics in the Lake Dian basin during the Ming–Qing period.

6. Conclusions

In this study, we examined the different patterns of anthropogenic impact on the terrestrial environment of the Lake Dian basin during both the Bronze Age and the Ming–Qing period using the combined AMS^{14}C dating, geochemical analysis, and sporopollen analysis of a section from AJB site. The results show that the intensity of human activity led to a significant decline in forest cover in the Lake Dian basin both in the Bronze Age and the Ming–Qing period. The heavy metal pollution in the soil during the Ming–Qing period was more obvious in the Lake Dian basin. The hydrological changes in the Lake Dian basin are likely to be responsible for the increased intensity of human activity over the duration of the Bronze Age, while the increase in the intensity of human activity in the Ming–Qing period was due to geopolitical change. This study has revealed the different patterns in human impacts on the terrestrial environment in the Lake Dian basin during the Late Bronze Age and the Ming–Qing period, providing new evidence to enable a deeper understanding of past human–environment interactions and a long-term historical background of the water pollution crisis in Lake Dian on the Yunnan Plateau.

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