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Rise and Fall of Dunhuang: Changes of Silk Road Hubs Driven by Political and Climatic Factors

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Abstract. This article focuses on the rise and fall of Dunhuang caused by political and climatic factors from the Han Dynasty to the Yuan Dynasty. Data were collected from different international organizations, and the study examines both historical articles, environmental evidence, and interdisciplinary intersection that combines methods from history, climatology, and economic geography to break through a single perspective. Using these data, it was found that the rise and fall of Dunhuang reveals the demand for dynamic balance of land and sea trade routes, climate change during different historical periods, and the trajectory of merchants as well as residents in Dunhuang. Simultaneously, the study highlights the interaction of "climate trade politics" factors over a long period of time. In conclusion, this work provides a comprehensive analysis of both historical experience and risk warning for the rise and fall of Dunhuang City and the Belt and Road" initiative.

Keywords: History, Dunhuang, Trading, Climate, Politics.

1. Introduction

1.1. Research background and significance

Dunhuang is a county-level city in Northwestern Gansu Province of western China. It was a major stop on the ancient Silk Road and is best known for the nearby Mogao Caves. It is always considered the most important hub of the Silk Road on land, which has enjoyed prosperity for thousands of years from the Han Dynasty to the Yuan Dynasty. During a long period of time in history, Dunhuang was a hub of trade between the East and the West [1]. However, Dunhuang does not play a significant commercial or trade role in modern society, and this contrast between history and modernity has prompted many scholars to reflect on the decline of Dunhuang. As usual, historians have always considered the decline of Dunhuang due to multiple factors such as geographical, political, and commercial factors.

The paper points out that the decline of central authority in the Tang Dynasty in the 9th century disrupted trade, which led to a decrease in sponsorship and a slowdown in mural production: the political atmosphere can affect the trade route in different aspects. At the same time, the fluctuation of trade volume is closely intertwined with climate change. The decline of Dunhuang (around the 14th century) is often attributed to the rise of the Maritime Silk Road, but this explanation ignores natural constraints such as climate aridification, oasis ecological collapse, and non-linear effects of

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multiple factors. Therefore, revealing the driving mechanism behind Dunhuang's transition from prosperity to marginalization not only deepens the study of the history of the Silk Road, but also provides a historical mirror for understanding the sustainable development of contemporary land sea corridors.

1.2. Research gap

Admittedly, all of these previous studies have given a lot of evidence about Dunhuang's decline, and most studies believe that the decline in Dunhuang's position as a land transportation hub was due to the development of maritime transportation, such as the Maritime Silk Road, economic globalization, and port trade. These studies are obviously of great reference value, but people often overlook the impact of multiple factors, such as geopolitical factors, on the declining status of Dunhuang as a land transportation hub.

In previous research, all papers are simply focused on the role of climate or geopolitics alone, which did not attribute the decline of Dunhuang to multiple or even two or more factors; therefore, this results in a gap and limitation in our experiment. What we need to do now is to fill this gap and take the Dunhuang studies further. Dunhuang is a very famous commercial city in the history of China and even the world. When we talk about climate change, we think of the Little Ice Age, and when we talk about political separatism, we think of the Hundred Years' War between the Song Dynasty and the Western Xia Dynasty. These factors all contribute together. The decline of Dunhuang. Of course, it also includes the opening of the Maritime Silk Road; therefore, the study aims to fill the current gap; therefore, the research value of our topic is the correlation between climate change and regional political stability. It also triggers people's thinking on maintaining environmental sustainability and geopolitical stability.

1.3. Research topic

Based on the previous background knowledge, the study is focus on the following questions:

1. How does climate change affect the prosperity and decline of Dunhuang?
2. The relationship between the increase or decrease in the trade volume of the overland Silk Road and the change in the status of Dunhuang.
3. How did the rise of the Maritime Silk Road weaken Dunhuang's hub function?
4. How multiple factors (natural and cultural) interact to lead to the decline of Dunhuang?

1.4. Paper structure

The study focuses on the different causes of the rise and fall of Dunhuang city.

In the literature review, the study focuses on: The historical status of Dunhuang and how climate change affects Dunhuang; geopolitics and trade route security; the rise of the Maritime Silk Road and the changes of trade routes; and environmental determinism and path dependence. In the literature review section, we provide various explanations for the decline of Dunhuang in different papers, including factors such as a decrease in trade volume, climate change, and geopolitical instability.

In the data analysis part, both qualitative and quantitative analyses are used: we use visual charts to explain the trade volume of different periods. In qualitative analysis, a detailed analysis was conducted on the role played by Dunhuang in different historical periods. For quantitative analysis, we can understand the prosperity of Dunhuang at that time and its current decline through data and

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excerpts from ancient literature. in terms of the limitations of the final research, we deeply examined the shortcomings of this study, such as insufficient depth in quantitative learning and analysis, insufficient authoritative data selection, and belonging to second-hand historical materials.

At the same time, there are indeed some uncontrollable factors that have caused some data to be missing, and we can only imagine within a reasonable range. Due to the lack of relevant research before, this field is relatively blank. The research also provides a relatively valuable analysis for this aspect with reference value.

2. Literature review

2.1. The historical status of Dunhuang

Dunhuang is a strategically important city, commercial center, and cultural dissemination base in western China. The development of Dunhuang continued until the Western Han and Eastern Han dynasties, and reached its peak during the Sui, Tang, and Five Dynasties periods. During the Song and Yuan dynasties, Dunhuang was occupied by the Tang and Mongolians; From then on, Dunhuang was no longer under the control of the Central Plains dynasties.

At the same time, with the rise of the Maritime Silk Road, Dunhuang gradually lost its important role as a land transportation hub [2]. With the development of the Maritime Silk Road, the influence of Dunhuang gradually weakened.

2.2. How climate change affects Dunhuang

Climate change has significantly impacted the prosperity and decline of Dunhuang, Historically, Dunhuang's decline was influenced by factors such as the shift in trade routes and desertification, but recent climate changes have brought new challenges. During ancient times, according to the recording by 'Zizhi Tongjian', Dunhuang, as well as the Hexi Corridor, was a very humid place at first. However, with the increase in population, the resources become so fragile that they cannot support so many people living there. Therefore, people tend to leave Dunhuang. A lot of reservoirs have been established, but the water in the river dried out as a consequence.

The impact of the medieval warm period (such as the Sui and Tang dynasties) and aridification (such as the Song and Yuan dynasties) on the northwest oasis. Data shows that during the Little Ice Age, the average temperature of global seawater decreased by one to two degrees Celsius. Due to the high specific heat capacity of water, the energy required to cool seawater may cause temperatures on land to be tens or even tens of degrees lower than usual in previous years. For caravans that rely on supplies and require long-term inland transportation for more than a few months, it is even more full of uncertainty. That was one of the reasons why merchants abandoned the route to Dunhuang.

2.3. Geopolitics and trade route security

Political instability was also one of the decisive factors in the decline of Dunhuang. Dunhuang has always been regarded as a very precious territory in Chinese history. Due to the importance of Dunhuang's geographical location, both the Central Plains and ethnic minority regimes wanted to compete for this land rich in water and grass. Dunhuang was ruled by the Han and Tang dynasties and was occupied by different regimes at different times. Therefore, merchants often have to bear enormous risks when transporting goods, as it is uncertain whether they will be robbed by different forces; Therefore, they gave up the route through Dunhuang.

DOI: 10.54254/2753-7048/2025.LD28595

2.4. The rise of the Maritime Silk Road and the changes of trade routes

The driving factors for the decline of the overland Silk Road and the rise of the maritime Silk Road are technology, politics, and economy. Before entering the era of the Maritime Silk Road, people mainly relied on land transportation stations along the way and oases in the desert to obtain energy for supplies. When the route belonged to different regimes, it was difficult for various countries' caravans to obtain effective supplies. Compared to the Maritime Silk Road, which could be obtained by stopping at ports at will, the Land Silk Road made it more difficult for caravans to find direction. The number of times they obtained supplies would decrease, which also resulted in caravans from different countries not passing through the land transportation.

2.5. Environmental determinism and path dependence

2.5.1. Environmental selection

Environmental selection, also known as environmental determinism, refers to the theoretical perspective of natural environmental factors such as climate, water resources, and terrain. Specifically, in research in western China, scholars have found through proxy data such as ice cores and tree rings that climate change (such as the humid periods of the Han and Tang dynasties and the dry periods after the Song and Yuan dynasties) is highly correlated with the rise and fall of oasis cities along the Silk Road. Ma et al. pointed out in their study on the evolution of oases in the Tarim River Basin that the stability of ecosystems is deeply influenced by the periodic changes in precipitation and temperature, especially in environments where agricultural irrigation systems are highly dependent on groundwater and inland rivers. Extreme weather events often lead to productivity collapse and population migration.

For Dunhuang, the influence of environmental choices is particularly important. Dunhuang, as a typical oasis city, relies entirely on underground water and river irrigation formed by the melting of snow in the Dulan Mountains for its agricultural foundation. Once the trend of climate aridification forms and water sources shrink, it not only directly weakens agricultural production, but also affects population gathering, military and political defense line maintenance, and commercial supply, fundamentally shaking its position as a hub of the Silk Road. Therefore, in the view of many scholars, the geographical decline of Dunhuang is not accidental, but a passive response to the deterioration of the natural environment.

2.5.2. Path dependency theory

The path dependence theory was initially proposed by economists Paul David [3] and Brian Arthur to explain why technological or institutional evolution often exhibits a "self reinforcing" trend, meaning that once early unexpected choices are established, they will continue to dominate in later stages due to factors such as switching costs and institutional inertia. This theory has been widely introduced into political science, geography, and historical research to explain the formation and continuation of historical inertia. In the study of trade networks, path dependence often manifests as: once a certain location forms a node advantage (such as a transportation hub, military stronghold, logistics distribution center), its position will be continuously consolidated due to the "agglomeration effect". As stated in Krugman's [4] "New Economic Geography" theory, the concentration and geographical distribution of economic activities are not solely dependent on current conditions, but are deeply influenced by historical initial conditions [5].

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The historical development of Dunhuang reflects a typical path dependence logic. Since Emperor Han Wu's "Zhang Qian's Journey to the Western Regions", Dunhuang, as a key town at the western end of the Hexi Corridor, gradually assumed a composite function of diplomacy, military, religion, and commerce. The Tang Dynasty particularly demonstrated its path dependence: with frequent trade in Central Asia and the strengthening of Buddhist dissemination, Dunhuang formed institutionalized cultural expression mechanisms such as cultural murals and scripture caves. Even though the power of the central dynasty declined later, the area continued to operate independently for a period of time based on its old institutional foundation and regional network.

However, this path dependence may also become a source of 'lock-in effect'. When there is a sudden change in the external environment (such as the rise of the Maritime Silk Road, rapid climate droughts, and frequent regime changes), the original development path actually limits the flexibility of urban transformation. Dunhuang's failure to transform into a regional administrative center or land-sea connectivity node in a timely manner reflects the "path lock-in" in its system and transportation path.

In summary, the theory of environmental choice and path dependence provides two dimensions for understanding the rise and fall mechanism of Dunhuang: firstly, starting from external natural conditions, it reveals that the fate of the city is limited by ecology and climate; Secondly, starting from the historical institutional trajectory, it emphasizes how successful experiences in the early stage can solidify and affect coping abilities in the long term. This study will attempt to integrate these two theoretical frameworks in subsequent chapters and construct a multi-factor model that covers the interaction between "nature system economy", in order to more comprehensively reveal the deep mechanism of Dunhuang's transition from prosperity to decline.

3. Research methodology and data analysis

3.1. Methodology introduction

This study adopts an interdisciplinary comprehensive approach, starting from multiple dimensions such as historical documents, climate geography, geopolitics, and economic networks, in order to construct a systematic causal chain that explains the rise and fall of Dunhuang.

Climate proxy data analysis utilizes ice cores and tree ring records, and lake sediment data from northwest China to reconstruct climate change trends. By analyzing the changes in precipitation and temperature anomalies, determine the environmental risk intervals related to the Dunhuang agricultural infrastructure system. Compare these climate events with historical milestones such as the prosperity of the Han and Tang dynasties and the decline of the Yuan dynasty to examine the direct or indirect effects of climate change on the fate of cities.

Case comparison and system dynamics model are used to analyze the differences and convergence logic of urban destinies under different paths by selecting Silk Road cities with similar geographical conditions to Dunhuang (such as Kucha and Gaochang) and alternative nodes (such as Quanzhou and Guangzhou). By combining system dynamics methods, a causal loop diagram (CLD) is constructed to simulate a closed-loop model of "climate → agriculture → population → political power → security → commercial routes → urban status", thus elucidating how multiple factors interact to trigger the decline process.

DOI: 10.54254/2753-7048/2025.LD28595

3.2. Climate change

Since the Land Silk Road was prospered thousands of years ago, some climate data of western Mainland China can no longer be found [6]. However, we can analyze the climate change of Dunhuang (Northwest China) from Eastern China over the years; at the same time, historians and researchers from Qinghai-Tibet Plateau Research Institute of the Chinese Academy has collected some data about ice cores and tree rings can also be used to infer the local climate of Dunhuang, as it is located in the northern part of the Qinghai Tibet Plateau.

We can see that from 750 to 1000 AD, the average temperature in the winter half year of eastern China decreased by 0.5 to 1 degree Celsius compared to 500 to 700 AD.

Due to the fact that the eastern region is closer to the sea, the specific heat capacity of water is relatively larger. Affected by temperate monsoon climate. Due to multiple effects, its winter temperature may be more stable compared to the western region. So we can draw a conclusion that during the same period, the temperature changes in the western inland areas, especially in winter. It's even colder than we imagined. May not even be able to accommodate the normal survival of vegetation.

Due to the fact that land transportation often lasts for several months, the harsh climate may lead to the closure of stations along the way, a lack of supplies, and even a shortage of water sources. So, during this period, the climate has caused blockages in trade routes, preventing merchants from obtaining effective supplies and resources, and this route may be abandoned.

In the Warm Period of Han and Tang Dynasties and the Prosperity of Dunhuang, the humid climate supports oasis agriculture, water resource supply, and population growth.

Irrigation system and grain production in Dunhuang during the Tang Dynasty. During the Sui and Tang dynasties, large-scale water conservancy projects were constructed in Dunhuang. Based on the previous foundation, there were over 90 main and branch canals, as well as more than 20 springs, lakes, and marshes [7].

In Drought and ecological pressure since the Song and Yuan dynasties, water scarcity has led to agricultural decline and population migration. The intensification of desertification has limited the capacity of commercial roads. Along the overland Silk Road, there are mostly arid areas that rely on oases for replenishment, and climate change (such as desert expansion) has exacerbated the difficulty of transportation; Sea routes rely on monsoons and ocean currents, making navigation conditions more predictable.

3.3. The substitution effect of trade routes

Table 1. Difference between Land Silk Road and Maritime Silk Road

	Land Silk Road	Maritime Silk Road
Carrying capacity	small(camel caravan)	Large (thousand ton sailboat) Compass, shipbuilding technology Song Yuanming
Cost	high(supply, risk)	Low (wind power, cost saving)
Political security	easily affected by regime change	Relatively stable (with many ports)
Technology relies	animal transportation and oasis supply	Compass, shipbuilding technology
Dominant period	Han, Tang, Song	Yuan and Ming

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As shown in the table, during the Han and Tang dynasties, the function of Dunhuang was a trading hub since the central government had great power to ensure the safety of their merchants. Conversely, when the central government is unable to control the Hexi Corridor and ensure its relative travel safety, this trade route will be controlled by separatist regimes or a few nomadic tribes, resulting in the inability to transport goods from the Central Plains dynasties to Central Asia and even European countries. Regional political patterns can be considered a significant issue of the rise and fall of Dunhaung as well. At the same time, with the development of maritime technology and the arrival of the Age of Discovery, the Maritime Silk Road has gradually become a more efficient and low-cost mode of transportation. The overland Silk Road had to cross complex terrains such as deserts and mountains, resulting in high transportation costs and risks [8] (such as banditry, climate disasters), while sea transportation significantly reduced the transportation cost per unit of goods through large-scale transportation. After the 15th century, the prosperity of the Maritime Silk Road directly led to a sharp decline in the trade volume of the Land Silk Road. This is always considered to be the substitution effect of trade routes. The caravans of the overland Silk Road relied on camels and horses, with limited single transport volume and taking several months; A large merchant ship can carry thousands of tons of cargo and has a relatively stable voyage time. Sometimes, high-value commodities such as silk and porcelain are gradually shifting towards sea transportation, while land trade is more limited to regional short-distance commodity exchanges.

3.4. Gradual decline about Dunhuang

During the Song and Yuan dynasties, the driving factors for the decrease in trade volume were the Central Plains regime's control over the northwest weakened (such as the rise of the Western Xia), and this political instability had deeply affected the whole route. Therefore, the destruction of commercial security by war and political separatism caused the decline of Dunhuang. Due to the government's inability to control the western land transportation hub, the Song Dynasty government began to develop maritime transportation [9]. The rise of the Maritime Silk Road promoted the prosperity of coastal port cities such as Guangzhou, Quanzhou, and Ningbo, while the hub cities of the Land Silk Road, such as Chang'an and Samarkand, gradually lost their advantageous position due to the decline in trade volume.

During the Mongol Empire period (13th century), the overland Silk Road briefly revived, but with the collapse of Mongol rule and the Ottoman Empire blocking the land routes in Central Asia, European countries turned to sea routes for trade with the East, further weakening the importance of the overland route. Sea freight has become the main carrier of long-distance trade due to its cost and transportation advantages, resulting in a significant decrease of 24% in land trade volume.

4. Limitation

Ancient climate data mainly relied on proxy data may have had errors in spatial coverage and temporal accuracy, especially for the microclimate evolution in certain areas of Dunhuang. It is still difficult to accurately depict it on a decade-by-decade and region-by-region basis. Meanwhile, trade data and population migration records are mostly speculative estimates and lack systematic statistical support; this may make the whole study imprecise.

Although this study attempts to introduce cities such as Kucha and Quanzhou as comparative objects, their analysis has not yet formed an equally in-depth analysis, making it difficult to fully explain the specific mechanism of the "substitution effect". Future research can establish similar

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models for other hub cities along the Silk Road to form a more representative 'desert oasis evolution paradigm'.

This study focuses more on natural and structural variables, such as climate, geography, and trade routes, but there is still a lack of analysis on the relationship between technological factors (such as navigation and shipbuilding) and national will (such as the Ming Dynasty's maritime ban policy and the Tang Dynasty's Western Regions protection system) and node fate.

The future expansion direction should be to take "technological leap" and "institutional transition" as the core explanatory variables, and further understand the deep political logic of Dunhuang being "replaced". Further deepening of quantitative analysis (such as trade volume, climate change parameters).

5. Implications and foundations

The rise and fall of Dunhuang reveals the demand for dynamic balance of land and sea trade routes, suggesting that contemporary attention should be paid to the potential threats of climate change and geopolitics to the sustainability of transnational corridors Warning for the development of ecologically fragile areas: The decline of Dunhuang due to climate aridification can provide historical lessons for the development planning of oasis cities in arid regions of Central Asia, such as Kazakhstan and Uzbekistan.

The Dunhuang case can serve as a typical example of the "climate society" coupling system, which verifies the theory that environmental carrying capacity determines the survival of civilization. Warning under the background of global warming: If the drought in Northwest China intensifies in the future, the historical experience of Dunhuang can provide a reference for water resource management in the Hexi Corridor.

6. Conclusion

During the past 2000 years, Dunhuang has faced rise and fall for many reasons. The rise and fall of Dunhuang is the result of the combined effects of natural climate change and cultural and economic choices; at the same time, the appearance of the Maritime Silk Road marked the shift of global trade networks from "land power" to "sea power".

This study examines the historical rise and fall of Dunhuang, including climate and environmental change, geopolitical transformation, and the evolution of global trade network structure, revealing the multiple mechanisms behind its fate. Through interdisciplinary research methods, including climate proxy data analysis and historical literature review, this article points out that Dunhuang's position as a key node on the Silk Road was neither accidental nor dominated by a single factor, but rather due to the interaction between natural and human factors. Research has shown that the trend of climate aridification fundamentally weakens the stability of the Dunhuang oasis ecosystem, leading to a decline in agricultural productivity and population migration. Furthermore, the local fiscal capacity and political control have weakened, and the city's ability to ensure the safety of commercial routes has also significantly decreased. At the same time, the global trade pattern has undergone structural changes, with the Maritime Silk Road gradually replacing traditional land routes, further marginalizing inland nodes such as Dunhuang. Meanwhile, from the perspective of path dependence theory, this article points out that the institutional and geographical advantages accumulated by Dunhuang in its early days played a positive role during its heyday, but instead became a structural obstacle to urban transformation when the external environment suddenly changed. This "path locking" phenomenon limits the city's flexibility and adaptability,

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exposing the vulnerability of desert oasis cities in the face of complex pressures. By constructing a multi-factor causal closed-loop model, this article demonstrates how climate change can trigger agricultural decline, population reduction, and fiscal contraction, thereby weakening political control and leading to unsafe trade routes, ultimately triggering trade route shifts and the loss of urban status. The above variables are not unidirectionally linear, but form a self-reinforcing negative feedback system. Once this closed loop is activated, it is difficult to reverse under historical technological conditions.

Taking all the factors into consideration, the study examines two main factors about Dunhuang's decline and gives a warning for current environmental governance. Due to climate change, agricultural production cannot be completed, the local population is declining, and the central government is gradually losing control over the area. The instability of geopolitics and commercial security has also led to the opening of new commercial routes, and Dunhuang's status as a transportation hub city on the Silk Road has gradually declined.

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