Desertification in the Hexi Region and Its Response to High-Intensity Human Activities over the Past 1 ka: Postprint

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Abstract

The Hexi region is situated in the transitional zone between the Qinghai-Tibet Plateau region and the northwest arid region, and constitutes an important corridor for advancing the great Belt and Road strategic initiative. Simultaneously, this region is also one of the areas most severely affected by desertification in China. This study analyzes the dominant factors driving desertification in the region over the past 1 ka through a comprehensive comparative analysis of published aeolian sand accumulation events in the Hexi region with historical warfare, population size, and precipitation variations. The results demonstrate: (1) Over the past 1 ka, desertification in the Hexi region mainly occurred during the periods of 0.91 ka, 0.74 ka, 0.68 ka, 0.44 ka, 0.32, 0.24 ka, 0.18-0.12 ka, and <0.1 ka; (2) Desertification during the periods of 0.91 ka, 0.74 ka, 0.68 ka, 0.44 ka, and 0.24 ka exhibited a sensitive response to high-intensity warfare activities, while desertification during the 0.32 ka period was a response to low regional precipitation; (3) Desertification over the past 200 a has been a response to rapid population growth.

Full Text

Abstract

The mechanism of desertification has always been a hotspot of academic research. The Hexi region, located in the transitional zone from the Qinghai-Tibet Plateau to the arid area in Northwestern China, is a key region for construction of the Belt and Road Initiative. Hexi area is the bridge of material and cultural interaction between East and West China during historical period; meanwhile, Hexi is also one of the areas with the most serious desertification in China. The worsening desertification has seriously affected the development of local economy and culture and threatened the smooth implementation of the Belt

and Road Initiative. Therefore, grasping the causes and evolution mechanisms of desertification clearly in Hexi area will have great significance in formulating desertification control strategies and controlling desert expansion.

The ecology and environment in Hexi area is very sensitive to the intensity of human activities and to climate change. A large number of studies have shown that desertification was controlled by climate change before 3 ka, and then human activities gradually became the dominant factor of desertification after 3 ka. But the way in which human activities affect the desertification process has not been reported. Based on coupling with histories of desertification, warfare, variation of the population and climatic background, this paper analyzed the mechanism of desertification over the past 1 ka.

The following results were obtained: (1) During the latest 1 ka, desertification in the Hexi region happened in intervals of 0.91 ka, 0.74 ka, 0.68 ka, 0.44 ka, 0.32 ka, 0.24 ka, 0.18–0.12 ka and <0.1 ka. (2) Desertification sensitively responded to intensified human activities except that happened at around 0.32 ka as a consequence of low precipitation. (3) Desertification during the recent 200 years is a response to rapid growth of human population.

Main innovation points of this paper include as follows: (1) There were 8 desertification processes occurred in the Hexi area during the latest 1 ka. (2) The wars occurred in the region was regarded as a strong human activity on desertification in the paper.

Keywords: mechanism of desertification; Hexi region; Silk Road Economic Belt

2. Data and Methods

2.1 Study Area and Chronological Framework

The Hexi Corridor represents a critical transitional zone between the Qinghai-Tibet Plateau and the arid interior of Northwest China. To reconstruct the spatial and temporal patterns of desertification over the past millennium, we compiled geomorphological and chronological data from aeolian deposits across the region. The chronological framework was established using optically stimulated luminescence (OSL) and radiocarbon dating, with ages expressed in kiloannum (ka) before present.

2.2 Spatial Database Construction

We systematically collected data on dune accumulation events from published literature and field investigations. Geographic coordinates and chronological information were standardized and integrated into a GIS database for spatial analysis. The dataset includes 13 sampling locations spanning the entire Hexi Corridor, from the Shiyang River basin in the east to the Shule River basin in the west.

Table 1. Spatial and temporal distribution of dune accumulation in the Hexi region during the latest 1 ka

Sample ID	Latitude	Longitude	Age (ka)
B0719	39°42 07 N	105°44 03 E	<0.1
TD13-5	39°43 56.9 N	105°33 19.5 E	<0.1
TD13-6	39°32 36.3 N	105°28 46.2 E	<0.1
TGL-4-4	39°34 12.9 N	105°31 45.6 E	<0.1
TGL-5-2	39°36 12.5 N	105°35 07.5 E	<0.1
TGL-5-3	39°44 11.3 N	105°34 21.9 E	<0.1
	40°02 56.25 N	103°53 46.11 E	0.12±0.03
	39°39 22.94 N	103°09 32.31 E	0.18±0.01
	39°13 37.37 N	104°35 06.55 E	0.91±0.06
	39°19 59.98 N	104°47 19.09 E	<0.1
	37°25 58.8 N	104°17 56.40 E	0.09±0.01
	37°25 58.8 N	104°18 0 E	0.68±0.05
	37°25 58.8 N	104°18 0 E	0.32±0.02

[Figure 1: see original paper]

Figure 1. Geographical setting of the Hexi region

2.3 Integration of Historical Records

Historical documents, including county annals, military records, and census data, were digitized and georeferenced to quantify human activity intensity. Special attention was paid to warfare frequency and population fluctuations, which served as proxies for anthropogenic pressure on the landscape. Climate proxy data from tree-ring reconstructions and ice core records were synchronized with the desertification chronology to disentangle natural and anthropogenic forcings.

3. Results

3.1 Temporal Pattern of Desertification Events

Our analysis identified eight distinct phases of enhanced aeolian activity and dune mobilization during the past millennium. These occurred at 0.91±0.06 ka, 0.74 ka, 0.68±0.05 ka, 0.44 ka, 0.32±0.02 ka, 0.24 ka, 0.18–0.12 ka, and <0.1 ka. The 0.91 ka event represents the most extensive desertification phase, while the <0.1 ka event corresponds to historical desertification recorded during the modern era.

3.2 Human Activity Intensity

Warfare emerged as a critical factor destabilizing the landscape, particularly during the 0.68 ka and 0.44 ka intervals, which correspond to periods of military conflict documented in historical records. Population pressure showed exponential growth after 0.24 ka, coinciding with agricultural expansion into marginal lands. The correlation coefficient between population density and desertification extent reached $ n (cid:150) ···1 % g ‰ (cid:190) ¿ (cid:192) (cid:141) (cid:129) 1 4 C (cid:142) (cid:143), (cid:157)f 2 (cid:239)¨。(cid:219)(cid:181)(cid:142)(cid:143)≪K#Zq(cid:210)]´ ˆ%(cid:190)(cid:239)(cid:132)F˜¯、˘`、¨`V(cid:223)¸[19,35,42−43], H (cid:255),(cid:142)(cid:143) £¨(cid:129)%(cid:190)L(cid:181)(cid:201)(cid:132)(cid:201)œ ‘F]E 4,˚ł¸‰(cid:190)¿(cid:192)F(cid:142)(cid:143)fifl(cid:204)x(cid:131)q‰(cid:190)″¸ (cid:127)øCDEF(cid:143)(cid:190)Cˇ。jVW>?<(cid:159)(cid:160)(cid:129)ł¸ ‰(cid:190)–(cid:209)(cid:210)(cid:211)F](cid:190),H(cid:255)CDEF(cid:143)(cid:190)#(cid:212)S 14C (cid:142)(cid:143)fifl(cid:147)VW>?(cid:159)(cid:160)F(cid:210)(cid:211)](cid:190)(cid:239)ˇ(cid:152)F]E 2 efghijklmnopY&’ (Zq Tab. 2 Sanddune accumulation events during the latest 1 ka in the Hexi region ‰(cid:190) 1 (cid:144)(cid:137)=„(cid:190) 2 ˜(cid:216)(cid:217)(cid:190) 3 ,(cid:216)(cid:218)(cid:190) 4 (cid:144)(cid:137)=T(cid:190) 5 0(cid:219)(cid:220)(cid:190) 6 z(cid:221)(cid:220)(cid:190) 7 ‰(cid:190) 8 (cid:222)(cid:219)(cid:223)(cid:190)(cid:220) ¿(cid:192) 14C (cid:142)(cid:143)fifl ⁄aBP [42] 780 ± 50 6130 ± 50 195 ± 50 1900 ± 50 484 ± 50 260 ± 50 860 ± 50 473 ± 50 (cid:213)#(cid:214) 14C (cid:143)(cid:215) ⁄calkaBP 0.724 ± 0.067 0.644 ± 0.064 0.180 ± 0.038 0.177 ± 0.056 0.509 ± 0.054 0.180 ± 0.035 0.875 ± 0.034 0.497 ± 0.063 (cid:210)(cid:211)](cid:190) ⁄ka [42] %(cid:142)FCDE(cid:143)(cid:190) 0.74∼0.6 (0(cid:190)’ U) 0.39∼0.09 (1(cid:190)) 0.15∼0.09 (1(cid:190)<(cid:214)U) 0.3∼0.15 (1(cid:190)<U) 0.39∼0.09 (1(cid:190)) 0.39∼0.09 (1(cid:190)) 0.74∼0.39 (0(cid:190)’ U) 0.74∼0.39 (0(cid:190)) 0.72∼0.600.39∼0.090.15∼0.09 0.17∼0.1500.39∼0.090.18∼0.090.87∼0.600.49∼ 0.39 @ 2 (a) (cid:224)‡Æ–(cid:226)[a]ˇ(cid:143)(cid:228)NO3(Fw 1 ka xy(cid:136)(cid:137)(cid:138), ‡>? [54]; (b) (cid:224)‡‰(cid:190)¿(cid:192) 1 4 C (cid:142)(cid:143)fifl(cid:131)(cid:153)C(cid:154)ˇ(cid:223) O S L (cid:142)(cid:143)fifl%(cid:135)FCDE(cid:143)(cid:190)。v<(cid:153)C›ˇ(cid:143)(cid:190)‡>? [23−24,33,42];(c)···1%g&(cid:242)(cid:156)(cid:229)(cid:230)F](cid:145), ‡>? [49]; (d) 1 ka xy···1%g^(cid:231)Ł(cid:138)|E, ‡>? [21, 38−41]。Ø*Œf¨(cid:136)(cid:137)(cid:138)º(cid:181)(cid:236)(cid:237)(cid:238)F]U, (cid:239)Œ(cid:240)(cid:201)(cid:190)fCæbE(cid:229)Ł Fig. 2 (a) Precipitation in Hexi region during the latest 1 ka [54]; (b) Ages associated with desertification in the Hexi region which are inferred from 14C dating results of ancient city and OSL dates from sand dunes [23−24, 33, 42]; (c) Temporal distribution of warfare in the Hexi region during the latest 1 ka [49]; (d) Vari

ationofpopulationintheHexiregionduringtherecent1ka [21, 38−41]. Lightyellowbarsindicateyearswithlowprecipitation, andgraycolumnsrepresentyearsofdesertificatione f g % ChinaXiv 合作期刊 E。q(cid:129)(cid:243)(cid:181)(VW>?<(cid:159)(cid:160)F^_bcx(cid:244)F(cid:143)(cid:190) (cid:141) (cid:150) ı, > > (cid:150) 1 4 C (cid:142) (cid:143) fi fl » (cid:132) Calib6. 1 [66] (cid:141)(cid:129)(cid:213)#, v (cid:246)f 2。h》<I¢ “e^f, g:h i, ^ j ⋯ 1, g j ⋯ 1, ^k1(cid:146)”。(cid:204)(cid:246)⋯1%gIJY:(cid:131)QeF 1„lm,jnK(cid:221)1(cid:222)>0(cid:216),ÆoF=pq(cid:23(cid:150)a'^SCæ(cid:154)ˇ(cid:223)<(cid:247)(cid:155)F O S L (cid:142)(cid:143) (cid:147)<irs„tD„、1@1(cid:146)、T-¶•F&’ A x(cid:131)>>(cid:224)‡%(cid:190)¿ (cid:192) % (cid:135) F C D E (cid:143) (cid:190) (@ %, /(cid:158)3hF(cid:224),、uxF&’ %· 。#H(cid:157)(cid:255), 2 b) , (cid:204)(cid:246)⋯1% g S 0. 9 1 ka、0. 74ka、0. 68ka、 ¤(cid:201)(cid:155)⋯1%gGqænˆ(cid:242)%, SVW]U˜ 0. 44ka、0. 32、0. 24ka、0. 18∼0. 12ka (cid:147) <0. 1ka V(cid:129)Zv,8(cid:240)w、ØŒ(cid:231)Ł((cid:229)(cid:230)(cid:231)Ł‘E(cid:156)K](cid:145)(cid:127)ø(cid:129)(cid:156)#łEyøFCDE。3 +,-.r9stuvw(3. 1 rxyz (cid:231)Ł(cid:138)F|EK⋯1%g _bcfi(cid:243)—J (cid:253)FIk£(cid:157)。‡《{œ· %X(cid:158)》(cid:159)ß,S{}(cid:252) x’,⋯1%gøb(cid:134)[hwx(cid:253)Œø*(cid:147)(cid:254)(cid:255)! (cid:229)(cid:230)ø*Fj”、†#x(cid:131)(cid:214)yF$ ($p<0.01$) for the period 0.24–0.1 ka.

4. Discussion

The coupling analysis reveals that seven out of eight desertification episodes were closely associated with intensified human activities, including military campaigns, land reclamation, and overgrazing. The exception at 0.32 ka coincided with a severe drought event recorded in regional tree-ring reconstructions [**?**], indicating climate-driven desertification.

The spatial pattern shows that desertification was most severe in the eastern Hexi Corridor (Shiyang River basin), where population density was highest. The western regions (Shule River basin) exhibited more localized dune activity, primarily along river courses where oasis agriculture was concentrated.

5. Conclusion

Desertification in the Hexi region during the past millennium was predominantly driven by human activities, with warfare and population growth being the primary forcing factors. Climate played a secondary but important role, particularly during multi-decadal drought periods. The recent acceleration of desertification (<0.1 ka) reflects unprecedented anthropogenic pressure and highlights the urgent need for sustainable land management strategies in this critical region of the Belt and Road Initiative.

References

[[23]] Wu Xiaojun. Innovation Zone [?]. The Silk Road, 2014, (12): 16-19.

[[24]] Historical variance of the ecological environment in the inland river area along the Hexi Corridor [?]. Journal of Lanzhou University (Social Sciences), 2000, (4): 46-49.

[[29]] Han Lanying, Wan Xin, Fang Feng, et al. Desertification assessments of Hexi regions [?]. efg%X, 2013, 36(1): 131-138.

[[34]] Chen Hongyi. Study on desertification in Hexi region during historical period [?]. Lanzhou: Lanzhou University, 2007.

[[35-37]] Li Bincheng. Investigation on the ancient ruins in the western sandy land of Minqin County [?]. Journal of Chinese Historical Geography, 1990, 10(2): 35-42.

[[38-41]] State Council Census Office. China 2010 census data [?]. Beijing: China Statistics Press, 2012.

[[41]] Feng Ting. War affects society [?]. Lanzhou: Northwest Normal University, 2011.

[[42]] Chen Hongyi, Wang Naiang, Li Yu, et al. Desert ancient city in Hexi region and its environmental significance [?]. International Symposium on Historical Geography, 2004.

[[43]] Li Bincheng. A study on the site of Huizhou in the Tang Dynasty and other related problems [?]. Journal of Chinese Historical Geography, 2016, 31(3): 46-53.

[[44]] Li Bincheng. Aspects of the relationship between war and environment during the Wei, Jin, and the Northern and Southern Dynasties [?]. Academic forum of Nandu, 2016, 36(5): 23-29.

[[48]] Li Bincheng. Study on the ancient city of Huizhou in Tang Dynasty [?]. Journal of Chinese Historical Geography, 2016, 31(3): 46-53.

[[49]] Guan Yaxin. Destruction and influence on the ecological environment of the west Liao River induced by war in late Ming and early Qing Dynasty [?]. Journal of Harbin Institute of Technology (Social Sciences Edition), 2013, 15(3): 131-136.

[[50]] Wu Xiaojun. Historical variance of the ecological environment in the inland river area along the Hexi Corridor [?]. Journal of Lanzhou University (Social Sciences), 2000, (4): 46-49.

[[51]] Tang Guoan, Yang Xin. ArcGIS spatial analysis experiment tutorial of GIS [?]. Beijing: Science Press, 2012.

[[54]] Yang B, Qin C, Wang J, et al. A 3500-year tree-ring record of annual precipitation on the northeastern Tibetan Plateau [?]. Proceedings of the National

Academy of Sciences, 2014, 111(8): 2903-2908.

[[56]] Guan Yaxin. Destruction and influence on the ecological environment of the west Liao River induced by war in late Ming and early Qing Dynasty [**?**]. Journal of Harbin Institute of Technology (Social Sciences Edition), 2013, 15(3): 131-136.

[[57]] Li Wentao. Case study of the relationship between war and environment during the Wei, Jin, and the Northern and Southern Dynasties [**?**]. Academic forum of Nandu, 2016, 36(5): 23-29.

[[60]] Liu Zuai. Human, war and environment [**?**]. National Defense Science and Technology, 2002, (7): 62-65.

[[61]] Wang Tao. On the general history of Gansu [**?**]. 2003.

[[64]] Wu Xiaojun. Innovation Zone [**?**]. The Silk Road, 2014, (12): 16-19.

[[65]] Tang Guoan, Yang Xin. ArcGIS spatial analysis experiment tutorial of GIS [**?**]. Beijing: Science Press, 2012.

[[66]] Stuiver M, Reimer PJ. Extended (super 14) C database and revised CALIB 3.0 (super 14) C age calibration program [**?**]. Radiocarbon, 1993, 35(1): 215-230.

Note: Figure translations are in progress. See original paper for figures.