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Temperature and precipitation trends in Minqin Desert during the period of 1961–2007

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Abstract: This paper analyzed the data of temperature and precipitation in Minqin, typical desert area in northwest China, during the period of 1961–2007 by linear regression. The result indicated that the increasing rate of the mean annual temperature in Minqin was higher than that of the average of China; and the temperature in February increased by 3.01ºC averagely in the past 47 years. The climate in Minqin displayed an evident warming trend. However, there was no evidently increasing trend of precipitation in the past 47 years, and drought occurred during the whole growing season.

Keywords: temperature; precipitation; global climate; Minqin

Global warming is now a hot topic worldwide. The 3rd evaluation report by IPCC (Intergovernmental Panel on Climate Change) indicated that the average temperature in the world rose by (0.6±0.2)ºC in the 20th century, and the 1980s and 1990s were the warmest years in this century (Gao *et al*., 2002). In the past decades, 125 lakes around the Arctic disappeared due to global warming. By 2100, "the most possible magnitude" of temperature to rise globally will be 1.8–4ºC, and the sea level will rise by 18–59 cm (Yang, 2007). The latest IPCC report said that the temperature in northern hemisphere has risen by 0.4–0.8ºC averagely from 1860 till now, and the temperature rise of the 20th century is most marked in the millennium, and the average temperature from 1990 to 1999 was the highest in the millennium (Qin *et al*., 2002).

In the 20th century, the temperature in China has risen by 0.4–0.5ºC, which is slightly lower than the world's average (Ding *et al*., 2002; Wang *et al*., 2002). Northeastern China is one of the most sensitive regions responding to global warming, where the average temperature in the past 20 years rose by 1ºC (Sha *et al*., 2002). The temperature rising in the northeast and north of China as well as in Xinjiang Uygur autonomous region was in consistence with the warming of northern hemisphere. Since the 1980s, the climatic variation in Xinjiang was consistent with the climate warming in China and in the world (Liu *et al.*, 2004; Qin *et al.*, 2007), however, there were remarkable variations in different seasons and regions. The temperature rising rate in northern Xinjiang was apparently higher than that in southern Xinjiang (Cao *et al*., 2011). In northern Xinjiang and Tianshan Mountains, the average temperatures in recent 10 years were 0.7ºC and 0.4ºC, respectively, which were higher than the average in the past 30 years (Ding *et al.*, 2002). In the recent 50 years, the temperature in the arid areas in northwest China displayed a rising trend (0.22ºC/10a) (Ren and Yang, 2007), e.g., the average annual temperatures in Shaanxi and Gansu provinces, and Ningxia Hui autonomous region in the past 50 years displayed a rising trend, with higher increase in winter and spring, while the precipitation showed a decreasing trend (Ding and Yan, 2007). The climatic variation trend in Minqin basin (1953–2004) was researched (Ding *et al.*, 2007), however, the effect of climatic

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warming on precipitation was not analyzed.

The response of temperature rising to global warming was distinct in different regions with varying land forms (Ding, 2002). In arid and semi-arid areas, the eco-environment is closely related to temperature rising (Hu *et al.*, 2001; Ma *et al.*, 2002; Zha, 2002; Zhao *et al.*, 2002; Yan *et al.*, 2003). The climate in desert is quite different from that in other regions (Chang and Zhao, 2006). How does Minqin, the typical desert area in northern China, respond to global warming? Kitoh *et al.* (1997), applying a global coupling atmosphere–water circulation model, researched the variation of summer wind in Asia when the air CO_2 content increased. The result revealed that the rainfall induced by summer monsoon from the India Ocean was apparently increased with global warming. The studies by Jin *et al.* (2005) and Leng *et al.* (2007) indicated that the increase/decrease of precipitation in the arid areas of northwest China was, to some extent, related to the global temperature rise/drop. The aim of the research is to analyze the trends of precipitation and temperature, and their relationship in Minqin Desert.

1 Study area

Minqin county is located at the lower reaches of the Shiyang River in northwestern Hexi corridor in Gansu province, and the western fringe of Tengger Desert (102°03′–104°03′E, 38°05′–39°06′N), with an area of 16,016 km^2 and the elevation of 1,300–1,350 m. The landscape in Minqin can be classified into 3 types: the natural one in Han dynasty (2,100 years ago), the degraded one since Han dynasty, and the man-made one since 1949.

Minqin is characterized by the typical desert landscape. Statistic result shows that the desert, gobi, alkali-saline land, low hills and dunes occupy 94.2% of the total area, among which desert area is 8,813.3 km^2 (55.03%), gobi 800.0 km^2 (5.0%), desertified rangeland 5,466.67 km^2 (34.13%). The total population is 307,200 and the population density is 19.18 persons/km^2.

At present, the eco-environmental degradation becomes worse in Minqin, which is reflected in the following three aspects. Firstly, the underground water dramatically drops. Since the 1950s, great amount of groundwater was used for irrigation, which resulted in more than 20-m drop of water table and water shortage

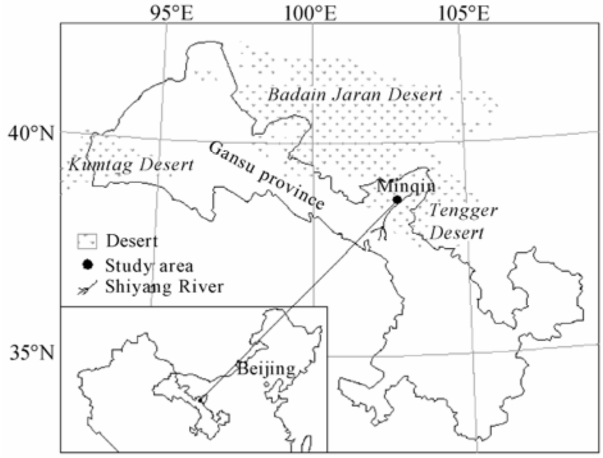

Fig. 1 Location of the study area

inside and around the oasis. Due to insufficient water supply, the farmland of 2 × 10^4 hm^2 in the lower reaches of the Shiyang River has been abandoned. The abandoned land was desertified. Secondly, large areas of vegetation withered and died, and rangeland degraded. In the 1960s and 1970s, large numbers of sand-fixing trees such as *Eleganus angustifolia* were planted in Minqin. However, *Eleganus angustifolia* with an area of 300 hm^2 was dead, and that of 5,800 hm^2 is now at a verge of death. Sixty percent of *Haloxylon ammondendron* trees with an area of 44.6 hm^2 is not growing well or degrading. The area of natural *Nitraria tangutorum* is 73,300 hm^2. However, the coverages of less than 30% and 10%, which account for 67.7% and 17.5%, respectively. At the beginning of the 1980s, there was *Populus euphratica* of 372.6 hm^2 in Minqin, however, the plant species disappeared now. The desertified rangeland in Minqin has still be degrading at a large area now. Thirdly, the gales and sandstorms occurred more frequently. The data observed by Minqin Desert Control Experiment Station showed that there was annually 28.2-day gales with ≥17 m/s, 25.8-day sandstorm, 37.8-day sand-driven wind, and 30.2-day dust drift since the 1970s.

Eco-environment degradation in Minqin has attracted the attention from China's central government. The central government has invested over 4 billion yuan to restore the degraded eco-environment in Minqin (Zhao, 2007).

2 Methods

2.1 Data

The meteorological data during the period of

1961–2007 are from the Minqin Desert Control Experiment Station. The climate parameters include sunshine, air temperature, air pressure, precipitation, humidity, ground temperature, wind speed and wind direction, days of gale and sandstorm. In this study, the time series of monthly and annual average temperature, monthly maximum and minimum temperatures, monthly and annual precipitation and the diurnal rainfall intensity were used for long-term trend analyses.

2.2 Methods

Linear regression method was used to analyze the varing trends of the average, maximum and minimum temperatures. Variance analysis was used to test the significance of precipitation variation in different periods (1960s, 1970s, 1980s, 1990s and 2001–2007). The correlation coefficients between the monthly and annual average temperatures were calculated and T-test was done. Climagram was used to analyze the distribution of arid and semi-arid seasons.

3 Results

3.1 Temperature variation

3.1.1 Average temperature

From 1974 to 2007, the mean annual temperature showed an evident rising trend, with the rate of 0.11ºC/10a (Fig. 2). The annual mean temperature were 7.73ºC, 7.65ºC, 7.44ºC, 7.93ºC and 8.20ºC during the periods of 1961–1970, 1971–1980, 1981–1990, 1991–2000 and 2001–2007, respectively. The annual average temperature during the period of 2001–2007 was higher than that during the period of 1974–1980. From 1961 to 2007, the temperatures in January, February, April and December displayed a rising trend, with the maximum rising rate of 0.64ºC/10a in February, followed by that in April (0.24ºC/10a). The average temperatures in July, August and September displayed a decreasing trend (Table 2). The correlation coefficients between the monthly and annual average temperatures are significant, except for May (Table 2).

The result of variance test indicated that the correlation between temperature variation in February and the annual mean temperature was significant during the periods of 1961–1970, 1971–1980, 1981–1990, 1991–2000 and 2001–2007 (Table 1). Accordingly, the temperature-rising in Minqin mainly occurred in spring.

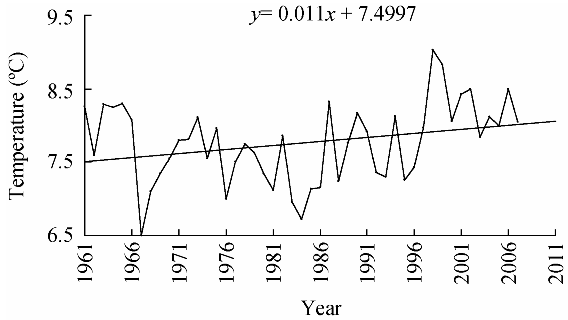

Fig. 2 Annual average temperature during the period of 1961–2007

3.1.2 The maximum temperature

From 1961 to 2007, the annual maximum temperature increased with a rate of 0.05ºC/10a, and with big fluctuation (Fig. 4). The fluctuant intensity was weak before 1985 (38.4ºC in 1975), and became strong after 1985. The maximum temperature in 1997 was 41.0ºC which reached the peak value; while in 1993 it was 33.6ºCwhich was the lowest value in the past 47 years. Within the 47 years, there were 27 years in which the maximum temperature occurred in July, 16 years in August, 3 years in June, and 1 year in July and August, respectively.

Table 1 Trend line slope of annual average temperature and mean square ratio during the period of 1961–2007

Parameters	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Trend-line slope (ºC/10a)	0.015	0.064	0.008	0.024	0.009	0.009	−0.001	−0.014	−0.013	−0.001	0.010	0.022	0.011
Mean square ratio	0.527	2.757^{**}	1.970	0.991	0.985	1.879	0.405	1.119	0.686	1.013	1.273	0.842	2.687^{**}

Note: ** indicates the significant difference at the level of $P < 0.01$.

Table 2 Correlation coefficient of the monthly and annual average temperatures and T-test during the period of 1961–2007

Coeffcient	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Correlation coefficient (r)	0.482	0.454	0.544	0.441	0.011	0.393	0.309	0.513	0.377	0.344	0.541	0.405
T-test (t)	3.687^{****}	3.421^{***}	4.350^{****}	3.297^{***}	0.075	2.866^{***}	2.179^{*}	4.012^{****}	2.729^{***}	2.455^{**}	4.314^{****}	2.975^{***}

Note: ****, ***, **, * indicate the significance at the levels of α=0.001, α=0.01, α=0.02 and α=0.05, respectively.

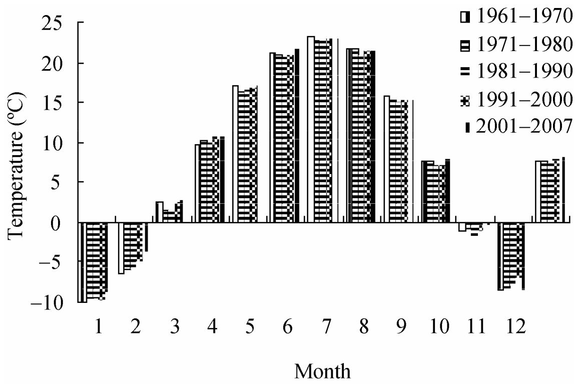

Fig. 3 Monthly average temperature during the period of 1961–2007

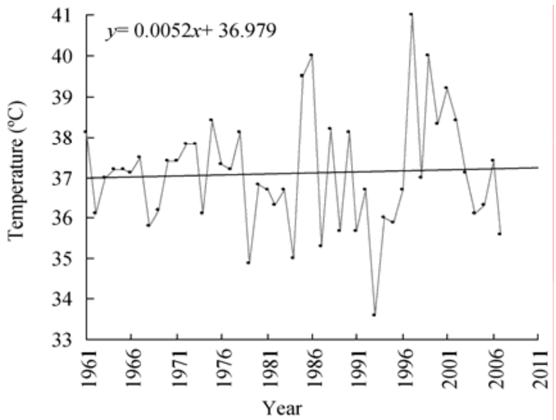

Fig. 4 Variation of maximum temperatures during the period of 1961–2007

3.1.3 The minimum temperature

During the period of 1961–2007, the annual minimum temperature rose slightly (0.025ºC/10a), with the lowest values (–30.8ºC) in 1991 (Fig. 5). During this period, there were 23 years in which the minimum temperature occurred in January, 13 years in December, 10 years in February and 1 year in November.

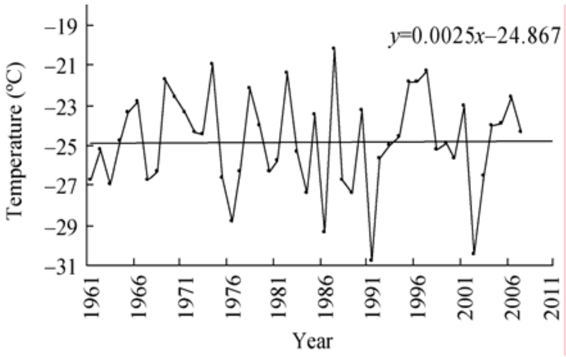

Fig. 5 Variation of minimum temperatures during the period of 1961–2007

The curve of the minimum temperature from December to February during the period of 1961–2007 showed the temperature in the 3 months displayed a rising trend (0.335ºC/10a) (Fig. 6). The winter in Minqin became warming.

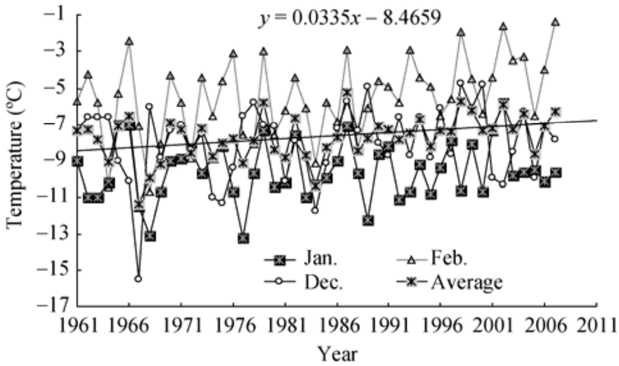

Fig. 6 The maximum temperatures from December to February during the period of 1961–2007

3.2 Precipitation

3.2.1 The amount of precipitation

The mean annual precipitation in Minqin during the period of 1961–2007 was 116.36 mm. The changes of the mean annual precipitation experienced three stages: it increased from the beginning of the 1960s to the mid 1970s, and dropped from the mid 1970s to the mid 1990s, and then increased again since the mid 1990s. The trend line shows the precipitation from 1961 to 2007 was increased (4.29 mm/10a) (Fig. 7).

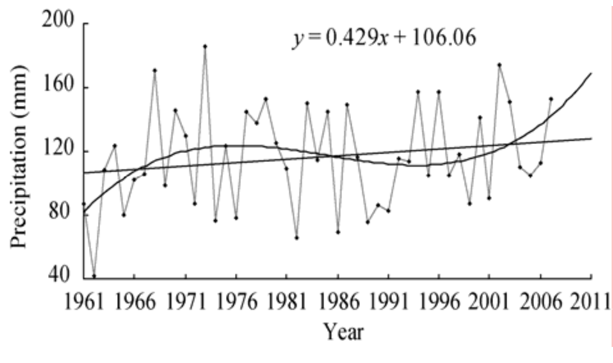

Fig. 7 Variation of annual precipitation during the period of 1961–2007

The maximum precipitation occurred in 1973 (185.8 mm), and the minimum in 1962 (42.2 mm). From 1961 to 2007, the observed maximum diurnal rainfall is 45.4 mm (June 12, 1987). The precipitation was mainly concentrated in August and July, accounting for 25.06% and 20.11% of the annual total, respectively; followed by September, May and April, accounting for 15.44%, 13.12% and 10.14% of the annual total, respectively.

3.2.2 The intensity of precipitation

The mean annual precipitation in Minqin from 1986 to 2007 was 117.23 mm. The rainfalls were 43.20 mm and 18.99 mm with the intensity of ≥ 10 mm and ≥20 mm, which account for 36.85% and 16.20% of the annual total, respectively (Table 4). However, the average annual evaporation from 1986 to 2007 was 2,176 mm. Therefore, the most of the rare rainfall got lost due to high evaporation.

3.3 Climagram

Climagram is an analytical method which can clearly reflect the comprehensive conditions of water and heat (China Vegetation Editorial Committee, 1995). It is normally drawn using Walter method (Walter and Leith, 1960). Figure 8 is the climagram drawing from the data collected from Minqin Desert Control Experiment Station during the period of 1961–2007. The climate of the period from late March to mid October is dry in Minqin; the semi-arid period starts slightly earlier than the arid period, while it ends slightly later than the arid period. In Minqin, arid period dominates the entire growing season (Fig. 8).

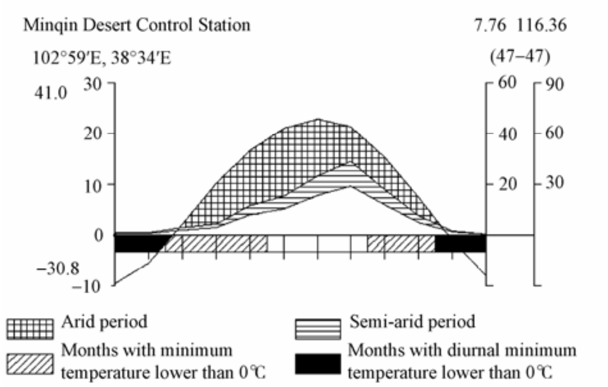

Fig. 8 Climagram for Minqin Desert Control Station

4 Discussion and conclusion

In the past 47 years, the annual average temperature in Minqin rose by 0.517ºC, with a linear tendency of 0.11ºC/10a, which is higher than that of the global average mentioned in IPCC report, and also higher than that of the description as "The temperature in China rose by 0.4–0.5ºC in recent 100 years" (Ding *et al.*, 2002; Wang *et al.*, 2002); while it is lower than that in northeast China where "The annual mean temperature rose by 1ºC in the past 20 years" (Sha *et al.*, 2002), also lower than that "The temperature in the arid areas in northwest China displayed a rising trend in the recent 50 years (0.22ºC/10a)" (Ren and Yang, 2007).

In Minqin Desert, the temperature rising in February is most apparent, followed by that in April, then by that in December and January. Winter in Minqin is warming. In the past 47 years, the average temperature in February rose by 3.01ºC, with a rate of 0.64ºC/10a averagely.

The precipitation from 1961 to 2007 displayed a linear increasing trend (4.29 mm/10a), which is in consistent with the results from other scholars (Chang and Zhao, 2006). However, the differences of annual mean precipitation are not significant. The rainfall with intensity ≥ 10 mm was only 43.2 mm, accounting for 36.85% of the annual mean precipitation. In Minqin, the arid period lasted from late March to mid October, which is also the entire growing season.

Most of the desert land surface is bared due to low vegetation cover. Moreover, both the coefficients of specific heat and heat conductivity of sand particles are rather small, therefore, the temperature in the sandy land rises more rapidly. The bared sandy land reflects most of the solar radiation into near-surface atmosphere, which induces the rapid rising of tem-

Table 4 Precipitation intensity during the period of 1986–2007

Precipitation intensity (mm)	<1	1≤–>5	5≤–>10	10≤–>15	15≤–>20	20≤–>25	25≤–>30	30≤–>35	35≤–>40	40≤–>45	≥45
Average precipitation (mm)	4.65	37.97	31.40	18.60	5.61	7.85	2.42	4.49	0	0	4.24
Percent to the total (%)	3.97	32.39	26.78	15.87	4.78	6.69	2.06	3.83	0.00	0.00	3.61
Precipitation intensity (mm)	≥1	≥5	≥10	≥15	≥20	≥25	≥30	≥35	≥40	≥45	
Accumulating precipitation (mm)	112.57	74.60	43.20	24.60	18.99	11.15	8.73	4.24	4.24	4.24	
Percent to the total (%)	96.03	63.64	36.85	20.98	16.20	9.51	7.44	3.61	3.61	3.61	

perature in spring in desert area. These factors are attributed to the sensitive response of desert to global warming.

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References

Cao X M, Chen X, Bao A M, *et al*. 2011. Response of vegetation to temperature and precipitation in Xinjiang during the period of 1998–2009. Journal of Arid Land, 3(2): 94–103.

Chang Z F, Zhao M. 2006. Study on Desert Ecology in Minqin. Lanzhou: Gansu Science and Technology Press, 30–64.

China Vegetation Editorial Committee. 1995. Chinese Vegetation. Beijing: Science Press, 33–49.

Ding J M, Yan J P. 2007. An analysis on characteristics of climate change in Shan-Gan-Ning Region in recent 50 years. Journal of Arid Land Resources and Environment, 21(6): 124–129.

Ding Y H. 2002. Predict environmental changes in western China. In: Qin D H. Assessment of Environmental Evolution in Western China. Beijing: Science Press, 1–231.

Ding Z Y, Ma J Z, Zhang B J, *et al*. 2007. Analysis on the climate change in the Shiyang River basin since resent 50 years. Arid Zone Research, 24(6): 779–785.

Gao F, Sun C Q, Qu J S. 2002. New understanding of global climatic variation – the 3rd report on the IPCC weather assessment. Advance in Earth Sciences, 17(3): 314–319.

Hu R J, Fan Z L, Wang Y J, *et al*. 2001. Assessment about the impact of climate change on environment in Xinjiang since recent 50 years. Arid Land Geography, 24(2): 97–103.

Jin L Y, Fu J L, Chen F H. 2005. Spatial differences of precipitation over Northwest China during the last 44 years and its response to global warming. Geographica Scientia Sinica, 25(5): 567–572.

Kitoh A, Yukimoto S, Noda A, *et al*. 1997. Simulated changes in the Asian summer monsoon at times of increased atmospheric CO_2. Journal of the Meteorological Society of Japan, 75(6): 1019–1031.

Leng Z X, Ge L M, Haimid Y, *et al*. 2007. Changes of average air temperature and rainfall in Urumqi under background of global warming. Journal of Arid Land Resources and Environment, 21(4): 60–64.

Liu Y G, Miao Q L. 2004. Prediction on agricultural drought disasters in Northwest China. Arid Land Geography, 27(4): 564–569.

Lu Y. 2007. The 10 alarming aftermath from global warming. Geology Education, (3): 79.

Ma J Z, Li J J, Gao Q Z. 2002. Groundwater evolution and its influence on eco-environment under climatic change and under climatic change and human activity in the south of Tarim Basin. Arid Land Geography, 25(1): 16–23.

Qin D H, Din Y H, Wang S W, *et al*. 2002. Ecological and environmental change in west China and its response strategy. Advance in Earth Sciences, 17(3): 314–319.

Qin Y, Zhou Y Z, Shi Q D. 2007. The analysis on south Xinjiang climate change based on temperature and precipitation Changes. Journal of Arid Land Resources and Environment, 21(8): 48–53.

Ren Z X, Yang D Y. 2007. Impacts of climate change on agriculture in the arid region of Northwest China in recent 50 years. Journal of Arid Land Resources and Environment, 21(8): 48–53.

Sha W Y, Shao X M, Huang M. 2002. Climate warming and its impact on natural regional boundaries in China in the 1980s. Science in China: Series D, 32(4): 317–326.

Walter H, Leith H. 1960. Klimadiagramm-Weltatlas. Jena: Gustav Fischer Verlag.

Wang S W, Dong G R. 2002. Environmental characters and changes in west China. In: Qin D H. Evaluation of Environmental Changes in West China. Beijing: Sciences Press, 1–242.

Yan S H, Mu G J, Endo K, *et al*. 2003. Environmental evolution information from Aiby Lake since the last 2500a. Arid Land Geography, 26(3): 227–232.

Yang X B. 2007. People's activity is the main reason for global warming. Science Friends, (8): 35.

Zha X C. 2002. Study on the influence of global climatic warming and drying on the silt content in Hanjiang and Weihe Rivers in the southern and northern marginal zones of Qinling Mountain. Arid Zone Research, 19(3): 62–66.

Zhao C. 2007. Pledge to prevent Minqin from being the second Lop Depression: Premier Wen Jiabao's visit to Minqin. Gansu Daily, 2007-10-2 (1).

Zhao J, Wang N A. 2002. R/S analysis of urbanization effect on climate in Lanzhou. Arid Land Geography, 25(1): 90–95.