

Yonghuan Ma  
Shengyue Fan  
Lihua Zhou  
Zhaoyang Dong  
Kecun Zhang  
Jianmin Feng

## The temporal change of driving factors during the course of land desertification in arid region of North China: the case of Minqin County

Received: 25 December 2005  
Accepted: 6 June 2006  
Published online: 8 July 2006  
© Springer-Verlag 2006

Y. Ma (✉) · L. Zhou · Z. Dong  
K. Zhang · J. Feng  
Cold and Arid Regions Environmental  
and Engineering Research Institute,  
Chinese Academy of Sciences,  
320 West Donggang Road,  
Lanzhou 730000 Gansu Province, China  
E-mail: mayonghuan2000@sina.com.cn  
Tel.: +86-931-4967554

S. Fan  
Central University of Nationalities,  
Beijing 100081, China

Y. Ma  
Graduate School of Chinese Academy  
of Sciences, Beijing 100039, China

J. Feng  
Resource Environment and City Science  
Department, Xianyang Normal University,  
Xianyang 712000, China

**Abstract** Taking the key research area in the arid region of North China—Minqin County—as a case, this paper analyzes the main factors impacting land desertification. Based on factor analysis method and the collection of data in the last 50 years, this paper researches the spatial changes of driving factors during the course of land desertification in Minqin, Gansu Province. The results of factor analysis indicate that the driving force of human factor on land desertification accounted for 56.33% in 1956–2004 and for 66.19% in 1981–2004, the driving force of nature factor on land desertification accounted for 11.29% in 1956–2004 and 8.11% in 1981–2004, and the synthesis of driving forces of human and natural factors accounted for 11.19% in 1956–2004 and for 14.88% in 1981–2004. This indicated that human

driving force on land desertification was increasing in Minqin County gradually.

**Keywords** Minqin · Land desertification · Factor analysis · Driving factors · Spatial change

### Introduction

Land desertification of China is chiefly prevalent in 12 provinces (Autonomous Region) of North China (Fig. 1), namely Gansu Province, Ningxia Hui Autonomous Region, Inner Mongolia Autonomous Region, Qinghai Province, etc. (Wang et al. 2004). Owing to the rapid spread of land desertification, it has become the hot spot of academe (Wang et al. 2004; Brogaard and Zhao 2002; Ho 2000; Wu and Ci 2002). Currently, the cause of land desertification is the basic and most central problem considered in

research on the control of land desertification (Jia et al. 2003; Dong 2001a, b); however, the dispute of academe on the question is *relatively* obvious, which can be summed as human cause, natural cause, or synthesis of human and nature. In fact, the conclusion that the rapid spread of land desertification results from excess economic activity of humans is accepted by academe in the last 10 years (Fan and Gao 2000; Mortimore and Turner 2005; Zhao 1993; Zhao et al. 2005a, b; Wang and Zhu 2001). Because the driving factors of land desertification are diverse in different areas, a quantitative assessment standard has not yet

been agreed upon. Up to now, the research methods on driving factors of land desertification mainly indicate two aspects: one adopts the mathematical model from system dynamics (Fan and Yang 1989; Zhang and Sun 1999; Yang and Fan 1991), or fuzzy sets (Sasikala and Petrou 2001); because there are some limitations, this method is not widely used in practical research (Zhao 1993; Sasikala and Petrou 2001). Another method adopts principal component analysis based on collecting data on humans (Jia et al. 2003; Dong 2001a, b), such as area under cultivation, agricultural population, the number of livestock and so on, and meteorological data. Though the latter is widely used as it has a well-knit mathematical base, it lacks ample variables (Dong 2001b; Zhang 2000) and long-term data (Dong 2001a; Liu and Dong 2003), and is short of correlation test of factors selected and collinearity test of extracted factors (Li et al. 2004; Dong et al. 1994; Whap et al. 2004). More importantly, the method researches little on temporal change of driving factors of human and nature impacting on land desertification.

This paper takes Minqin County of Gansu Province, the key research area of land desertification in North China, as a case. On the basis of socioeconomic and meteorological data collected in the last 50 years, the driving forces of human and natural factors and their temporal changes are researched using factor analysis method during land desertification. In addition, the paper attempts to assess the driving forces of human and natural factors impacting land desertification, which could provide theoretical basis for the government to regulate human economic activity.

## Analyzing the driving factors impacting land desertification

### General survey of study area

As a key research area of land desertification in North China, Minqin County is located in the lower reaches of Shiyang River in Northwest China; except for a part of the southwest borders on Wuwei and Jinchang, others are surrounded by Badain Jaran Desert and Tengger Desert (Fig. 2). So Minqin is representative of a desert—oasis of semi-isolated inland. Desert and desertification land measures 1,520,000 hm<sup>2</sup>, accounting for 94.5% of total land area.

In prehistoric times, Minqin was covered with water; the geographical environment was everglade (Feng 1963). However, from the exploitation of Xihan dynasty to the reclamation of Ming and Qing dynasties, great changes had fundamentally occurred there, i.e. land desertification intensively spread. In the last 50 years, especially in the late 1970s, there was large-scale development in Shiyang River basin. Three well irrigation areas were built, namely Wuwei, Minqin, and Jinchuan-Changning, which provided 36% of foodstuff and supported 48% population in Hexi region. It became one of the most important barns of Gansu Province (Zhu and Chen 1994). Owing to the abundant irrigation of Wuwei oasis, located in the middle reaches of Shiyang River basin, the amount of water pouring into Minqin continued to reduce. In order to offset water resources, Minqin began to exploit groundwater in great force, forming three large-scale groundwater fillers, causing vegetation to perish, farmers to disperse, and the culti-

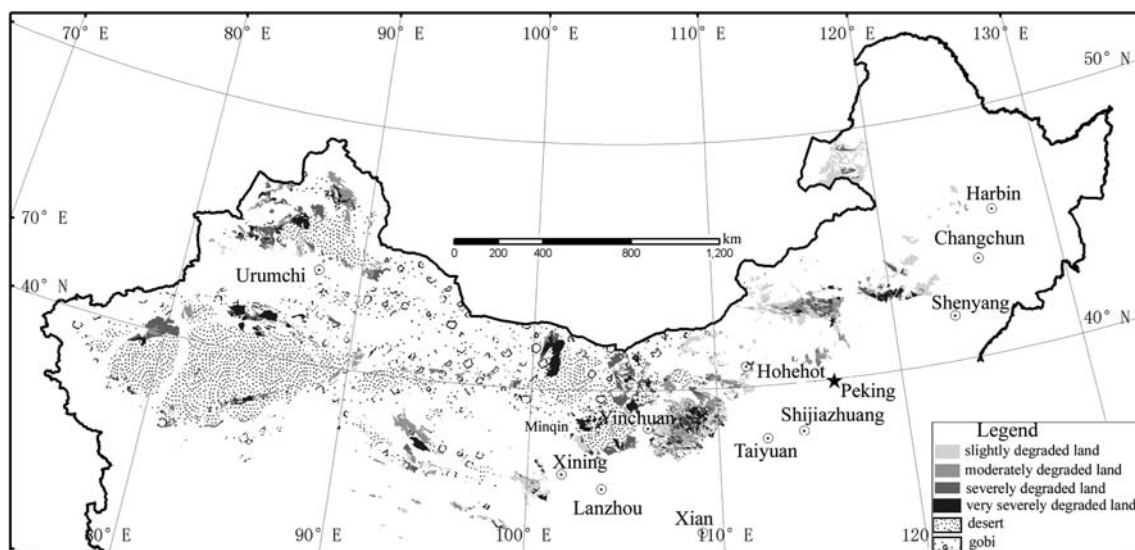
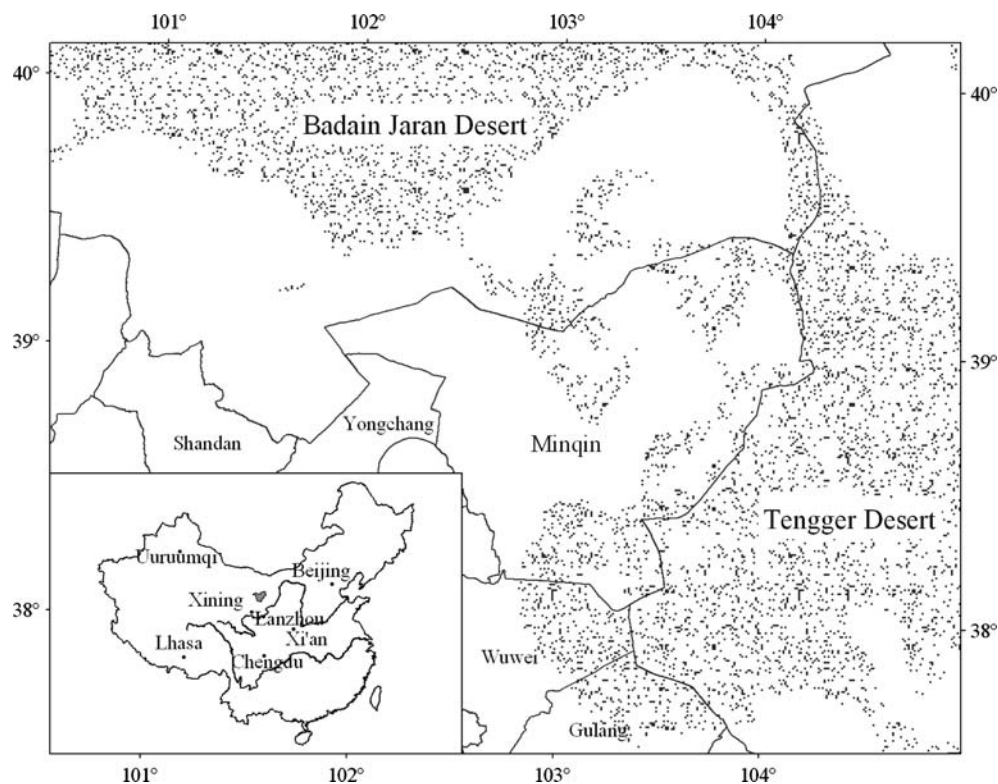


Fig. 1 The distribution map of land desertification in North China

Fig. 2 Location of Minqin



vated land to be abandoned. As a result, the fecund land that was once suitable for cultivation and fishery became a scene of “deserts occupying 90% of the area” and “no irrigation, no planting” (Xie et al. 2004).

Research (An and Ding 2000) indicates that land desertification of Minqin County accelerated spread in the last 30 years. The area of land desertification (including desert) was 1,487,620.45 hm<sup>2</sup> in 1977 and 1,496,391.03 hm<sup>2</sup> in 1993, increasing by 8,770.58 hm<sup>2</sup>. It further became 1,525,528.3 hm<sup>2</sup> in 1998, the area of land desertification increasing by 9,137.27 hm<sup>2</sup>, compared to 1993.

## Human driving factors

### *The impact of population pressure*

Population increase results in more demand for farmland and food, which has an impact on the spread of land desertification (Ci and Liu 2000). This mainly manifests as excess reclamation, overgrazing, and water overdraft. Though the ecological condition of Minqin County was fragile, the population increased to 307,200 in 2004, increasing by 107,468 compared to 1949. At the same time, farm population increased from 193,209 to 248,600 (Fig. 3). More farm population meant more demands, which resulted in the continuing increase of

farmland. There were two large-scale reclamations of wasteland. The first happened in the end of 1950s and early 1960s. The farmland increased by 2,253 hm<sup>2</sup>. Another excess reclamation happened when the price of seed melon began to rise in the mid-1990s. The farmland increased by 1,700 hm<sup>2</sup>. The grain output had increased due to the increasing farmland, e.g. it was 31,000 t in 1949 and 167,600 t in 2004 (Fig. 4), increasing by 2,484 t per year.

In order to supply the irrigation demand of grain and commercial crop, farmers had to pump groundwater because the demand for irrigation water for agriculture far exceeded the amount of water supplied from the

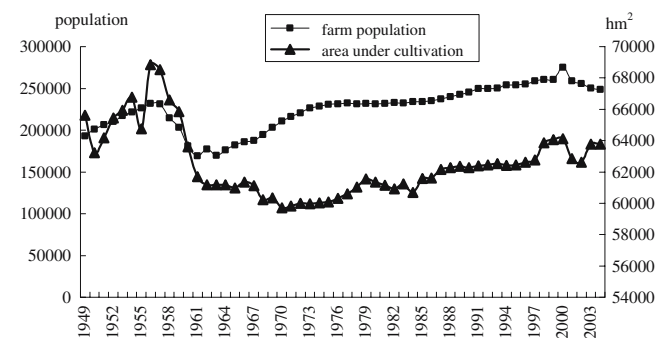
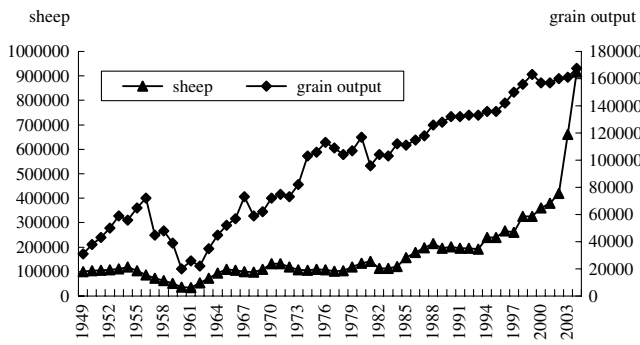


Fig. 3 The changes in farm population and area under cultivation



**Fig. 4** The change in sheep numbers and grain output

upper reaches of Shiyang River. By the end of 2003, the number of motored wells had added up to 16,000 in Minqin. About 9,649 motored wells were still used at that time. The amount of groundwater overexploited was 270,000,000 m<sup>3</sup> every year. Water level descended by 0.5 m and the degree of mineralization ascended by 0.04 g/l per year (Li et al. 2005). In Easthu village and Zhongqu village, farmers pumped groundwater from a depth of 300 m. This activity led to the death of shrubbery and arbor. Till 1999, Minqin had planted 17,000 hm<sup>2</sup> Eurasian trees and 27,000 hm<sup>2</sup> shrubbery, but 6,000 hm<sup>2</sup> Eurasian trees and 8,000 hm<sup>2</sup> shrubbery died due to water overdraft (Shen et al. 2005).

*The impact of overgrazing*

There are 1,360,500 hm<sup>2</sup> desert steppe and semi-desert steppe in Minqin, including 850,000 hm<sup>2</sup> of available grassland, accounting for 62.5% of the total area of the steppe (Li 1995). The number of livestock, especially the number of sheep, increased rapidly since the 1980s. It was 916,098 in 2004, while it was 133,677 in

1980 (Fig. 4). The amount of precipitation also decreased gradually at the same time, which led to the decrease in productivity of grassland. In such circumstances, the grazing capacity was far beyond the bearing capacity of grassland. According to our investigation, the number of sheep grazing was 200% more than the bearing capacity of grassland in dry years. Overgrazing was one of the most important factors that led to the desertification of grassland (Zhao et al. 2005a, b).

*The management of water resources*

Water resources are devoid of centralized management in Shiyang River basin. Upper and middle reaches of the river are misused and overused, which induces industries to seize the water needed by environment. Hence, the water utilization is out of balance (Table 1). In the last two decades, the amount of water reduced in large scale from top reaches to Minqin, e.g. from 542,000,000 m<sup>3</sup> in 1950s to 116,900,000 m<sup>3</sup> in 2003. It was dangerously less, only 65,000,000 m<sup>3</sup>, in 2004 (Fig. 5). Owing to decrease of water input, on the one hand, the soil salinity increased every year under the condition of intense evaporation, the area unceasingly expanded, the land productivity dropped, and land degeneration started to occur. On the other hand, some farmland was abandoned to culture when irrigation water was insufficient. According to our investigation in 2003, because of less availability of water, the area of abandoned farmland was 466.67 hm<sup>2</sup> in Weijie Village of Minqin County (Table 2), which equals as much as 82.35% farmland under cultivation. The activity resulted in the spread of land desertification.

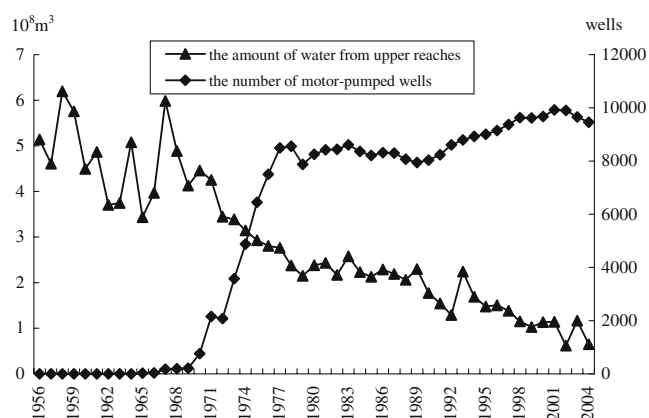
*Natural driving factors*

The fact that serious drought begets land desertification becomes a cause for concern in arid region (Nicholson et al.1998). Hence, climatic factor is commonly taken as the most important natural driving force on land desertification. Land desertification of Minqin is not an exception. The annual precipitation is 110 mm, but the annual evaporation is 2,644 mm; the latter is 24 times as much as the former. Minqin is one of the most arid regions in China (Li et al. 2000). Annual precipitation and annual evaporation are the important factors driving land desertification. In addition, some research studies indicated that mean annual temperature, the number of days with sand-storm, and the number of days with strong wind per year were influential factors for land desertification (Yang et al. 2005; Sun and Li 2002).

**Table 1** The annual runoff of Shiyang River and the amount pouring into Minqin

Year	Annual runoff (×10 <sup>8</sup> m <sup>3</sup> )	The amount of water pouring into Minqin	
		(×10 <sup>8</sup> m <sup>3</sup> )	Proportion (%)
1957	13.31	4.64	34.5
1969	13.05	3.94	30.2
1976	14.04	2.68	19.1
1980	13.00	2.21	17.0
1990	14.09	1.70	12.1
2000	13.03	0.98	7.2

Data source: Institute of Survey and Design of Water Conservancy and Hydroelectric Power Research, Qinghua University, 2005. Planning for short-term regulation, 33



**Fig. 5** The changes in the amount of water from upper reaches and the number of motor-pumped wells

**Table 2** The situation of abandoned farmland in Donghu Town of Minqin County, in 2003

Village	The area of abandoned farmland (hm <sup>2</sup> )	Area under cultivation (hm <sup>2</sup> )	The proportion between abandoned farmland and farmland area (%)
Weijie	466.67	566.67	82.35
Xiarun	313.33	400	78.33

## Method

### Data sources

Data sources of investigation include: (1) social economic data, from 1956 to 2004, obtained from compilation of statistics about national economy and social development from Minqin Statistical Bureau; (2) data of natural factors such as annual precipitation and evaporation, obtained from Minqin weather bureau.

Limited by the source of information, the impact of policy factor on land desertification is difficult to be quantified. In addition, as Minqin was selected as a key county of Shelter forest in the three northern areas of China in 1978, the economic reformation, household contract responsibility system with remuneration linked to output, was implemented in 1981. Hence the research period was divided into two periods: 1956–2004 and 1981–2004.

### The variables selected and research methods

#### *Selected influential factor variables of land desertification*

In the last 30 years, the research field of land degradation in North China indicated desertification due to sand

blown by the wind activity as the main factor caused by the man–land relationship out of line, which happened in arid, semi-arid, and some semi-humid regions (Wang et al. 2004). Hence the choice of influential factors of land desertification needs to consider both human and natural factors. Similarly, the synthesis of the nature and human needs to be considered too. According to the way of human activity impacting land desertification and the possible impact of natural conditions on the land desertification, considering long-term data collected and the correlation among data, 14 variables impacting land desertification were selected, in which the human factor included nine variables, i.e. size of farm population ( $P_1$ ), natural growth rate of population ( $P_2$ ), area under cultivation ( $P_3$ ), sheep size ( $P_4$ ), large livestock size ( $P_5$ ), the amount of water from upper reaches ( $P_6$ ), total grain output ( $P_7$ ), planting area ( $P_8$ ), and the number of motor-pumped wells ( $P_9$ ). The natural factors included five variables, i.e. the number of days with strong wind ( $P_{10}$ ), the number of days with sandstorm ( $P_{11}$ ), mean annual temperature ( $P_{12}$ ), annual precipitation ( $P_{13}$ ), and annual evaporation ( $P_{14}$ ).

### Research method

This paper adopted the factor analysis method using SPSS (Statistical Package for the Social Sciences) software, Version 11.5. During the course of land desertification of Minqin, the driving forces of natural factor, human factor and the synthesis of forces of natural and human factors were quantified by factor analysis. First, we judged whether selected variables were suitable for carrying out factor analysis according to Bartlett test of sphericity and Kaiser–Meyer–Olkin. Secondly, factors were extracted according to the scree spot and the initial solution of factor analysis, and then the correlation of extracted factors was tested by the variance matrix of variables; the design object of factor analysis was verified. Lastly, according to the component matrix and factors explaining the population variance of the original variables, human factor, natural factor, and the synthesis of nature and human, impacting on land desertification, were summed up H, N, and S, respectively. If the driving forces of human factor, natural factor, and the synthesis of nature and human are, respectively, denoted as DH, DN, and DS, the impact of human factor, natural factor, and the synthesis of nature and human impacting land desertification could be expressed as:

$$DH = \sum_{i=1}^m \lambda_i; \quad DN = \sum_{j=1}^q \lambda_j; \quad CN = \sum_{h=1}^p \lambda_h \quad (1)$$

where  $n$  stands for extracted component,  $m$  and  $q$  are the components of the human and natural factors ( $m < n$ ,

$q < n$ ),  $\lambda_i$  ( $i = 1, 2, \dots, m$ ) and  $\lambda_j$  ( $j = 1, 2, \dots, q$ ) are the driving forces of  $m$  human factors and  $q$  natural factors separately,  $p$  ( $p < n$ ;  $m + q + p = n$ ) is the component of synthesis of human and nature,  $\lambda_h$  ( $h = 1, 2, \dots, h$ ) is the driving force of synthesis of human and nature.

## The results: output and analysis

The driving factors of land desertification analysis

### The correlation test of original variables and factors extracted

Factor analysis should be adopted where there is a certain linear relation among the original variables. This paper examined the applicability of factor analysis through KMO (Kaiser–Meyer–Olkin) test and Bartlett test of sphericity (Table 3).

Table 3 shows the measured values of Bartlett test of sphericity in two periods, 1956–2004 and 1981–2004, are 741.26 and 332.074; accordingly, the probability values were close to 0, smaller than the significance level  $\alpha$  ( $\alpha = 0.05$ ). The null hypothesis should be refused, and the correlation is considerably significant. Synchronously, the KMO values of the periods were 0.807 and 0.812, according to Kaiser test standard (Xue 2004). So the original variables were suitable for carrying on factor analysis.

According to the coefficient correlation matrix of the original variables, the principal component analysis was adopted to extract factors, and latent roots were chosen bigger than 1 (Table 4). The second and third ranks of Table 4 are the initial solutions of factor analysis appointed to extract four latent roots in the period 1956–2004. The third rank indicated that the common degrees were relatively high for all variables; each variable lost less information. The fourth and fifth ranks of Table 4 are the initial solutions of factor analysis appointed to extract five latent roots in the period 1981–2004. The fifth rank indicated the common degrees were relatively high for all variables; each variable lost less information. Consequently, the overall result is that the extracted factors were relatively ideal in these two periods.

In order to prove the validity of the extracted factors, the covariance matrices were adopted to test the linear

**Table 3** KMO and Bartlett's tests

Test index	1956–2004	1981–2004
KMO	0.807	0.812
Bartlett's test of sphericity		
Approx. Chi-square	741.26	332.074
<i>df</i>	91	91
Sig.	0.000	0.000

correlation of the extracted factors. Table 5 and 6 indicate that the covariance of extracting factors was 0 in the two periods, 1956–2004, and 1981–2004. We could conclude there was no linear correlation among these extracted factors in the two periods; thus the aim of factor analysis was realized.

### Calculation and analysis

In order to make the factors explanatory, the quartimax method was adopted to practice orthogonal rotation to the component matrixes. Component matrixes for the two periods were extracted for analysis (Table 7). For some original variables, size of farm population ( $P_1$ ), the amount of water from upper reaches ( $P_6$ ), total grain output ( $P_7$ ), planting area ( $P_8$ ), and the number of motor-pumped wells ( $P_9$ ), there was a higher load on the first principal component, which mainly explained the variables of human factor. For some original variables, mean annual temperature ( $P_{12}$ ), annual precipitation ( $P_{13}$ ), and annual evaporation ( $P_{14}$ ), there was a higher load on the second principal component, which mainly explained the variables of natural factor. For some original variables, natural growth rate of population ( $P_2$ ), number of days with strong wind per year ( $P_{10}$ ), and number of days with sandstorm per year ( $P_{11}$ ), there was a higher load on the third principal component, including human and natural factors, which mainly explained the variables of human and natural factors. For some original variables, area under cultivation ( $P_3$ ), sheep size ( $P_4$ ), there was a higher load on the fourth principal component, which mainly explained the variables of human factor. The period for which the above were analyzed was 1956–2004.

Table 8 displays the component matrix for 1981–2004. For some original variables, size of farm popula-

**Table 4** Communalities

Influential factor	1956–2004		1981–2004	
	Initial	Extraction	Initial	Extraction
$P_1$	1.000	0.885	1.000	0.841
$P_2$	1.000	0.879	1.000	0.831
$P_3$	1.000	0.955	1.000	0.924
$P_4$	1.000	0.898	1.000	0.933
$P_5$	1.000	0.768	1.000	0.940
$P_6$	1.000	0.868	1.000	0.899
$P_7$	1.000	0.956	1.000	0.974
$P_8$	1.000	0.969	1.000	0.930
$P_9$	1.000	0.897	1.000	0.926
$P_{10}$	1.000	0.856	1.000	0.819
$P_{11}$	1.000	0.853	1.000	0.867
$P_{12}$	1.000	0.934	1.000	0.820
$P_{13}$	1.000	0.802	1.000	0.870
$P_{14}$	1.000	0.858	1.000	0.911

Method of extraction: the principal components analysis

**Table 5** Component score covariance matrix (in 1956–2004)

Component	I	II	III	IV
I	1.000	0.000	0.000	0.000
II	0.000	1.000	0.000	0.000
III	0.000	0.000	1.000	0.000
IV	0.000	0.000	0.000	1.000

**Table 6** Component score covariance matrix (in 1981–2004)

Component	I	II	III	IV	V
I	1.000	0.000	0.000	0.000	0.000
II	0.000	1.000	0.000	0.000	0.000
III	0.000	0.000	1.000	0.000	0.000
IV	0.000	0.000	0.000	1.000	0.000
V	0.000	0.000	0.000	0.000	1.000

tion ( $P_1$ ), sheep size ( $P_4$ ), the amount of water from upper reaches ( $P_6$ ), total grain output ( $P_7$ ), planting area ( $P_8$ ), and the number of motor-pumped wells ( $P_9$ ), there was a higher load on the first principal component, which mainly explained the variables of human factor. For area under cultivation ( $P_3$ ) and annual evaporation ( $P_{14}$ ), there was a higher load on the second principal component, which mainly explained the variables of human and natural factors. For the natural growth rate of population ( $P_2$ ), there was a higher load on the third principal component, which mainly explained the variables of human factors. As to annual precipitation ( $P_{13}$ ), there was a higher load on the fourth principal component, which mainly explained the variable of natural factor. There was a higher load on the fifth principal component as to large livestock size ( $P_5$ ), which mainly explained the variable of human factor.

**Table 7** Rotated component matrix (in 1956–2004)

Factors	Component I	Component II	Component III	Component IV
$P_1$	0.903	0.162	0.189	-0.083
$P_2$	-0.329	0.380	-0.649	-0.072
$P_3$	0.195	0.033	0.032	0.956
$P_4$	0.723	-0.017	-0.110	0.601
$P_5$	0.362	0.150	-0.118	0.000
$P_6$	-0.927	0.089	0.013	0.002
$P_7$	0.970	0.112	-0.030	0.038
$P_8$	0.970	0.007	-0.097	0.135
$P_9$	0.930	0.050	0.149	-0.082
$P_{10}$	-0.402	0.060	0.830	-0.042
$P_{11}$	-0.668	0.100	0.539	-0.082
$P_{12}$	0.647	-0.542	0.107	0.101
$P_{13}$	-0.218	-0.766	0.233	-0.412
$P_{14}$	0.142	0.685	0.072	-0.091

From the information of the principal components (Tables 9, 10), four components could explain the total proportion of information accounting for 45.13, 11.29, 11.19, and 10.80% in 1956–2004 (Table 9), and five components could explain the total proportion of information accounting for 48.29, 14.88, 10.32, 8.11, and 7.58% in 1981–2004 (Table 10). In light of the formula (1), the contribution rate of human factor, natural factor, and the synthesis of nature and human in the two periods could be calculated to find their impact on land desertification (Table 11).

The results indicated the driving force of human factor on land desertification accounted for 55.93% in 1956–2004 and for 66.19% in 1981–2004. The results of factor analysis indicated that the impact of human factor on land desertification was complicated, mainly manifesting as follows: size of farm population, area under cultivation, sheep size, the amount of water from upper reaches, total grain output, planting area, and the number of motor-pumped wells. Our research finds human activity strengthened constantly, e.g. a fast growth of farm population, sheep, and large livestock every year. In addition, since the household contract responsibility system with remuneration linked to output was implemented in Minqin in 1981, in the case of amount of water from the upper reaches reducing constantly, a large number of motor-pumped wells were exploited to guarantee the constant increase of total grain output and income of cash crop, which were the important driving factors impacting land desertification in Minqin (Figs. 3, 4). The driving force of natural factor on land desertification accounted for 11.29% in 1956–2004 and for 8.11% in 1981–2004. The results of factor analysis also indicated that the natural factors mainly impacting land desertification were annual precipitation and annual evaporation. On the basis of analyzing meteorological data, we also find that it mainly resulted from increase in annual precipitation, reduction in annual evaporation, and reduction of strong winds since 1981 (Fig. 6). The synthesis of nature and human impacting land desertification accounted for 11.19% in 1956–2004 and for 14.88% in 1981–2004; it weakened too, reducing by 3.69%. The temporal variation of driving factors, as mentioned above, confirmed the viewpoint that excessive human economic activity is the main cause of land desertification (Zhu 1998; Ma et al. 2003; Sheey 1992).

## Conclusions and discussion

Land desertification is the worst ecological and environmental problem in the arid region of North China. The causes of occurrence and spread are problems in which scholars are interested and need to solve. The conclusions of this study are as follows:

**Table 8** Component matrix (in 1981–2004)

Factors	Component I	Component II	Component III	Component IV	Component V
$P_1$	0.818	-0.390	0.007	0.128	0.059
$P_2$	-0.540	-0.347	-0.636	0.095	-0.074
$P_3$	0.418	0.788	-0.232	-0.273	0.012
$P_4$	0.830	0.470	0.001	-0.150	-0.006
$P_5$	0.275	-0.106	-0.247	0.191	0.869
$P_6$	-0.942	0.052	-0.032	0.078	-0.049
$P_7$	0.979	-0.104	-0.044	-0.033	-0.032
$P_8$	0.962	0.036	-0.053	0.003	-0.021
$P_9$	0.848	-0.035	0.420	0.080	0.152
$P_{10}$	-0.585	0.356	0.471	0.153	0.323
$P_{11}$	-0.758	0.281	0.400	-0.225	0.051
$P_{12}$	0.748	-0.304	0.181	-0.339	-0.143
$P_{13}$	0.296	0.043	0.291	0.783	-0.288
$P_{14}$	-0.308	-0.728	0.391	-0.351	0.100

**Table 9** Total variance explained (in 1956–2004)

Component	Total	% of variance	Cumulative %
Component I	6.32	45.13	45.13
Component II	1.58	11.29	56.42
Component III	1.57	11.19	67.61
Component IV	1.51	10.80	78.41

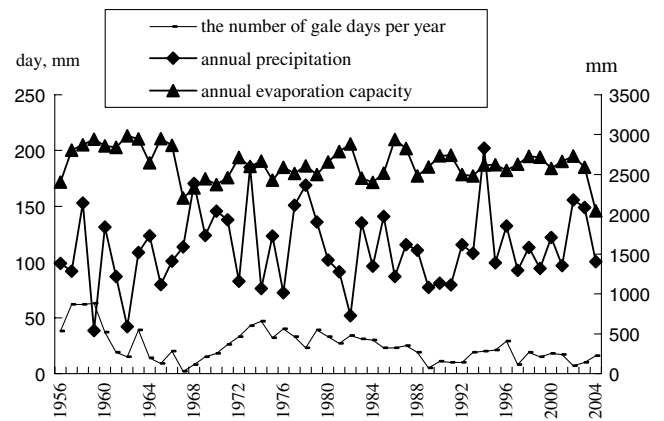
**Table 10** Total variance explained (in 1981–2004)

Component	Total	% of variance	Cumulative %
Component I	6.76	48.29	48.29
Component II	2.08	14.88	63.17
Component III	1.45	10.32	73.49
Component IV	1.14	8.11	81.60
Component V	1.06	7.58	89.18

**Table 11** Dynamic nature of driving factors of land desertification in Minqin (%)

Influential factors	Periods		Rate of change ( $\pm$ )
	1956–2004	1981–2004	
Human	55.93	66.19	+ 10.26
Nature	11.29	8.11	-3.18
Synthesis	11.19	14.88	+ 3.69

(1) On the basis of analyzing the driving forces of human and natural factors, this paper selected 14 variables impacting land desertification of Minqin County, including 9 human factors and 5 natural factors. The result of factor analysis indicated the contribution rates of human factor, natural factor, and the synthesis of nature and human on land desertification accounted for 55.93, 11.29, and 11.19%, respectively, in 1956–2004. Nevertheless,



**Fig. 6** The temporal changes in natural factors

their contribution rates accounted for 66.19, 8.11, and 14.88%, respectively, in 1981–2004.

(2) Restricted by availability of data, though this paper analyzes the temporal change of driving factors impacting land desertification by factor analysis, it fails to analyze spatial change. The population pressure in all villages and towns is not quantified either. Hence the quantization standard on shifting rural redundant labor force is not proposed. When this paper analyzes the driving force of human activity impacting land desertification, though policy factor is referred to, it is not separated from the human activity; the policy role of planting forestry and protecting environment is not quantified. And the impact of the household contract responsibility system with remuneration linked to output on land desertification is not appraised, while it promotes development of agriculture.

(3) Because natural conditions and social economic factors are complicated in land desertification areas, the same index could be not adopted to quantify the driving forces of human and nature factors on land

desertification. So the same kind of method could not be adopted to explain the driving factors on land desertification in different desertification areas.

- (4) Rural redundant farm population of Minqin plays a very heavy driving force on land desertification (Ma and Fan 2006; Ma et al. 2003); the pressure of population on the land is still the main factor impacting land desertification. Therefore, the means for the control of land desertification is releasing the pressure of population on land; this deserves research in advancing rural industrialization, improving the added value of the agricultural byproducts,

increasing per capita net income of farmers, and reducing ecological destruction by reducing the claim of farmers to land step by step.

**Acknowledgments** This research work is supported by the project of National Natural Science Fund of China (40501070) and the “Western Light” project of Chinese Academy of Sciences. The authors are grateful to one anonymous reviewer for good comments in improving the manuscript, and also to Dr Wanquan Ta of CAREERI for his help with the guidance and Dr Hailing Zhong of CAREERI for providing meteorological data.

## References

- An F, Ding F (2000) Development trend and control of land desertification in Minqin County of Gansu Province. *J Arid Land Resour Environ* 14:41–47
- Brogaard S, Zhao X (2002) Rural reforms and changes in land management and attitudes: a case study from Inner Mongolia, China. *Ambio* 31:219–225
- Ci L, Liu Y (2000) Driving action of population increase on desertification. *J Arid Land Resour Environ* 14:28–33
- Dong Y (2001a) Driving mechanism and status of sandy desertification in the northern Tibet plateau. *J Mt Sci* 19:385–391
- Dong Y (2001b) Quantitative identification of driving factors of contemporary sandy desertification in semi-arid zone in China. *J Desert Res* 21:412–417
- Dong G, Dong Y, Jin J, Jin H, Liu Y (1994) Study on the cause and development trend of desertification in the midstream region of Yarlung Zangbo river Tibet. *J Desert Res* 14:9–17
- Fan S, Gao X (2000) The pattern controlled and system innovation of desertification in China. *J China Soc Sci* 6:37–44
- Fan S, Yang G (1989) The mathematical models in land desertification. *J For Sci* 8:93–100
- Feng S (1963) The water system evolution of Minqin oasis. *Acta Geogr Sin* 29:241–249
- Ho P (2000) China's rangelands under stress: a comparative study of pasture commons in the Ningxia Hui Autonomous Region. *Dev Change* 31:385–412
- Jia B, Ci L, Gao Z, Zhang H (2003) The quantitative analysis of effect factors on sandy desertification in Ordos plateau. *J For Sci* 36:15–20
- Li F (1995) Natural grassland and its management and utilization Minqin. *Pratacult Sci* 12:37–38
- Li S, Harazono Y, Oikawa T, Zhao H, He Z, Chang X (2000) Grassland desertification by grazing and the resulting micrometeorological changes in Inner Mongolia. *Agric For Meteorol* 102:125–137
- Li X, Yang J, Wang L (2004) Quantitative analysis on driving role of human activity on the land desertification in arid area: the case of Tarim River basin. *Resour Sci* 26:30–37
- Li X, Song D, Xiao D (2005) The variability of groundwater mineralization in Minqin oasis. *Acta Geogr Sin* 60:319–327
- Liu Y, Dong Y (2003) Driving factors of sandy desertification change in the middle reaches of Yarlung zangbo river and its two tributaries in Xizang. *J Desert Res* 23:355–360
- Ma Y, Fan S (2006) The protection policy of eco-environment in desertification areas of northern China: contradictions and countermeasures. *Ambio* 35:132–133
- Ma Y, Fan S, Jiang D, Zhang M, Zhang C (2003) Study on the land desertification causes and the grass industry in North China. *Arid Zone Res* 20:217–220
- Mortimore M, Turner B (2005) Does the Sahelian smallholder's management of woodland, farm trees, rangeland support the hypothesis of human-induced desertification? *J Arid Environ* 63:567–595
- Nicholson S, Tucker C, Ba M (1998) Desertification, drought, and surface vegetation: an example from the west African Sahel. *Bull Am Meteorol Soc* 79:815–829
- Sasikala KR, Petrou M (2001) Generalised fuzzy aggregation in estimating the risk of desertification of a burned forest. *Fuzzy Sets Syst* 118:121–137
- Sheey DP (1992) A perspective on desertification of grazing land ecosystems in north China. *Ambio* 21:303–307
- Shen D, Cui L, Jiang S (2005) Institutional and countermeasures for water problems in shiyang river basin. *J Nat Resour* 20:293–299
- Sun W, Li B (2002) The relation between coupling among the principal components of desertification factors and desertification in rear hills of Bashang since 1950. *Geogr Res* 21:392–397
- Wang T, Zhu Z (2001) Some problems of desertification in northern China. *Quaternary Sci* 21:56–65
- Wang T, Wu W, Xue X, Sun Q, Zhang W, Han Z (2004) Spatial-temporal changes of sandy desertified land during last 5 decades in north China. *Acta Geogr Sin* 59:203–212
- Whap H, Hamid Y, Tashpulat T (2004) Tendency and driving forces of cultivated land use change in Qira oases: the case of Qira oases in south of Tarim basin. *Acta Geogr Sin* 59:608–614
- Wu B, Ci L (2002) Landscape change and desertification development in the Mu Us Sandland, Northern China. *J Arid Environ* 50:429–444
- Xie Y, Chen F, Wang N (2004) Spatial change of Minqin oasis in Gansu over the last 2000 years. *Acta Geogr Sin* 59:662–670
- Xue W (2004) Statistical analytical method and application of SPSS. Publishing House of Electronics Industry, Beijing, pp 331
- Yang G, Fan S (1991) Quantitative analysis of the land desertification influence factor of sand blown by the wind district in the north of loess highlands. *Arid Zone Res* 8:42–47
- Yang X, Zhang K, Jia B, Ci L (2005) Desertification assessment in China: an overview. *J Arid Environ* 63:517–531
- Zhang D (2000) Quantitative analysis of influential factors on land desertification in Qinghai Gonghe Basin. *J Desert Res* 20:59–62

- 
- Zhang H, Sun B (1999) Impact of land reclamation on desertification in arid and semi-arid areas of China: taking Minqin county of Gansu and Ejin horo banner of Inner Mongolia as case studies. *Resour Sci* 21:71–75
- Zhao J (1993) The brief analysis on the weak point of model quantitative analysis from influences human activity to the desertification. *J Arid Geogr* 16:80–82
- Zhao H, Zhao X, Zhou R, Zhang T, Drake S (2005a) Desertification processes due to heavy grazing in sandy rangeland, Inner Mongolia. *J Arid Environ* 62:309–319
- Zhao W, Xiao H, Liu Z, Li J (2005b) Soil degradation and restoration as affected by land use change in the semiarid Bashang area, northern China. *CATENA* 59:173–186
- Zhu Z (1998) Concept, cause and control of desertification in China. *Quaternary Res* 2:145–155
- Zhu Z, Chen G (1994) The sandy desertification of Chinese land. Science, Beijing, pp 201