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RESEARCH ARTICLE

Effect of land use and land cover change on soil erosion and the spatio-temporal variation in Liupan Mountain Region, southern Ningxia, China

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Abstract The Liupan Mountains are located in the southern Ningxia Hui Autonomous Region of China, that forms an important divide between landforms and biogeographic regions. The populated part of the Liupan Mountain Region has suffered tremendous ecological damage over time due to population pressure, excessive demand and inappropriate use of agricultural land resources. To present the relationship between land use/cover change and spatio-temporal variation of soil erosion, data sets of land use between the late 1980s and 2000 were obtained from Landsat Thematic Mapper (TM) imagery, and spatial models were used to characterize landscape and soil erosion conditions. Also, soil erosion in response to land use and land cover change were quantified and analyzed using data from geographical information systems and remote sensing. Soil erosion by water was the dominant mode of soil loss, while soil erosion by wind was only present on a relatively small area. The degree of soil erosion was classified into five severity classes: slight, light, moderate, severe, and very severe. Soil erosion in the Liupan Mountain Region increased between the late 1980s and 2000, both in terms of acreage and severity. Moderate, severe, and very severe eroded areas accounted for 54.86% of the total land area. The lightly eroded area decreased, while the moderately eroded area increased by 368817 ha (22%) followed by severe erosion with 146552 ha (8.8%), and very severe erosion by 97067.6 ha (5.8%). Soil loss on sloping cropland increased with slope gradients. About 90% of the cropland was located on slopes less than 15°. Most of the increase in soil erosion on cropland was due to conversion of steep slopes to cropland and degradation of grassland and increased activities. Soil erosion was severe on grassland with a moderate or low grass cover and on dry land. Human activities, cultivation on steep slopes, and overgrazing of pastures were the main reasons for the increase in erosion severity.

Keywords land use/land cover change, soil erosion, geographical information system, remote sensing, Liupan Mountain Region

1 Introduction

Land use and land cover change (LUCC) modifies surface albedo, sources and sinks of carbon, precipitation recycling, ecosystem services as well as vulnerability of places and people to natural hazards, social-economic and political perturbations [1–4]. In recent years, LUCC studies in China have made considerable progress [5–9]. Most of these studies have focused on the LUCC itself, and less attention was given to the relationships between the LUCC and its induced eco-environmental effects, in particular, between the LUCC and soil erosion [10]. In general, scientists attribute soil erosion mainly to inappropriate land use, which has an accelerating influence on the process of soil erosion [11]. Zhu and Ren [12] and Zhang et al. [13] concluded that while soil erosion is a natural geomorphic process, the severe soil erosion

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problem in China are primarily the result of improper land use by man. It is not clear, how the degree of human activities has impacted soil erosion in different parts of China and what the acceptable limits of human activities would not lead to irreversible land use changes. However, there has been a significant increase in research interest concerning the relationship between the LUCC and deteriorated ecological environment. A typical example of such a situation is found in the severely eroded and impoverished region of the Liupan Mountain in China. This region is a mountainous area located in the central western part of the Chinese Loess Plateau. The mountains form an important divide between three bio-geographic zones of China. The related studies have shown that soil erosion modulus is about 5000–8000 $t \cdot km^{-2} \cdot a^{-1}$ and the amount of long-term average sediment load in the Yellow River is 60×10^6 t in this region [14–16]. They represent a transition zone between the humid and arid region where different flora eco-systems exist with large biodiversities. It is a severely degraded area where the local population is very poor. The impoverishment of the area is thought to be closely related to LUCC and to the deterioration of the eco-environment [17–19]. In 2005, the Government of Ningxia Hui Autonomous Region designated the Liupan Mountain and surrounding areas to be the "Large Liupan Eco-Economic Circle" (LLEC). Green shelter belts would be established that will promote social and economic development. As a result, ecological problems that developed have created a demand for additional research resources for this region. To determine the future trends of economic development and the performance of the LLEC plan, this paper explores the land use/land cover changes and the spatio-temporal distribution of soil erosion for this region, and proposes suitable and comprehensive measures for a sustainable development. Not only will it be of interest to many researchers in many disciplines, but it also will be of major importance in the Liupan Mountain Region itself for providing a scientific basis for making decision of a land sustainable utilization.

2 Materials and methods

2.1 Study area

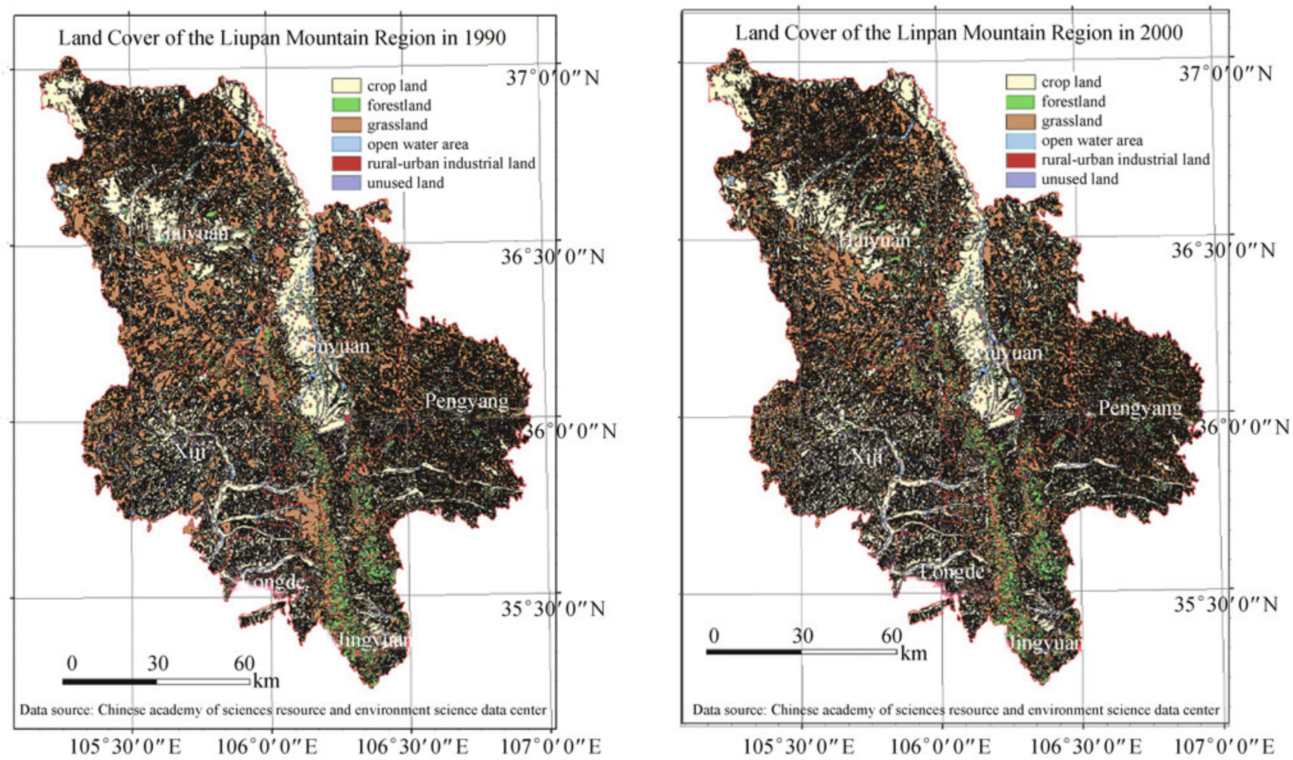
The Liupan Mountain Region (35°14′–37°04′N, 105°09′–106°58′E) is located in the southern part of the Ningxia Hui Autonomous Region, China, with an area of 16775 km^2, and consist of Guyuan, Jingyuan, Pengyang, Xiji, and Longde and Haiyuan Counties. These mountains form an important division between landforms and bio-geographic zones in China. This region has a temperate semi-humid climate in the south and a temperate semi-arid climate in the north. The mean annual temperature fluctuates between 5°C and 8°C, while the mean precipitation varies between 240 and 760 mm and decreases gradually from the south-east to the north-west. Because the region is situated in a transition zone between the humid and arid regions, there are different ecosystems and large biodiversities. Major crops are wheat, corn maize and potato. The *Bothriochloa ischemum* meadow steppe is a representative herbaceous community. *Stipa bungeana*, *Artemisia gmelinii* and *Artemisia giraldii* steppe are representative type of vegetation through the loess hills of this region [15]. Vegetation changes gradually from forest in the south-east to desert in the north-west. A large part of the deciduous broad-leaved forests extends in this mountain range making it one of the most important forested headwater conservation areas of the Loess Plateau. More than 60 rivers and streams make up the river system in this mountainous region [20]. In 2000, its population was 1868528 people and the net annual income per farmer was only 928 CNY, indicating that it was still difficult to provide sufficient food and fiber for the population[1)]. The implementation of LLEC will promote social and economic development in the future of southern Ningxia.

2.2 Data source and land use classification system

The land use data was mainly obtained from the Chinese Resource and Environment Database, in which land use with scale of 1 : 100000 was determined from Landsat Thematic Mapper (TM/ETM) images of 1989/1990 and 1999/2000 from now on denoted as 1990 and 2000, respectively (Figs. 1 (a) and (b)). The classification accuracy of the two image data sets was 92.92% and 97.45%, respectively [21]. Soil erosion data for the two dates were obtained from the soil type and soil erosion severity maps of the Loess Plateau with a scale of 1∶500000 compiled in 1990 by the Committee of Resources and Environmental Remote Sensing and from the soil erosion map with a scale of 1∶100000 interpreted from the Landsat TM image of 2000, respectively. Also, other data were included such as DEMs (Digital Elevation Maps) and the boundaries of the administrative regions. The data were integrated in the same coordinate system. All spatial data were converted into a 30 m × 30 m grid.

Two classes were used in the land use data classification. The first class consisted of six subclasses and the second class was divided into 18 subclasses. Cropland (CL): paddy field (PF); dry land (DL); forestland (FL): forest (FT); shrubs (SL); sparse wood (SW); other woods (OW); grassland (GD): high cover grass (GH); moderate cover grass (GM); low cover grass (GL); open water area: river lake (RL); pond and reservoir (PR); beach (BH); rural-urban-industrial land (RL): urban town land (UT); rural residential land (RL); other build-up land (OL); and

1) Statistical bureau of Guyuan District. 2002. Statistical yearbook of Guyuan District (1993–2000), 348



(a) Land cover of the Liupan Mountain region in 1990 (b) Land cover of the Liupan Mountain region in 2000

Fig. 1 Land cover of the Liupan Mountain Region in 1990 (a) and 2000 (b)

unused land (UL): sand (SD); alkali-saline land (AS); and bare land (BL). The soil erosion data were classified according to the type of the geomorphic processes in action and severity of the erosion made, for which the Technical Specification of the National Survey on Soil Erosion (1999) were used as a guide*. Soil erosion was either by water (water erosion) or by wind (wind erosion) (Table 1). Soil erosion severity was classified on the basis of 5 subclasses or levels of soil loss with limits subjectively chosen by the authors: slight, light, moderate, severe, and very severe. The range of soil erosion severity for each subclass has been indicated in Tables 2 and 3 for water erosion and wind erosion, respectively, in terms of the amount of annual soil loss in tons/ha or mm of profile thickness.

Table 1 The classification system of soil erosion in Liupan Mountain Region

type	soil erosion intensity classification
1 water erosion	slight, light, moderate, severe, very severe
2 wind erosion	slight, light, moderate, severe, very severe

2.3 Models

Regional distribution of soil loss was determined by the soil loss rate model with following equation [22]:

$$K_e = \frac{C_i}{S_i} \times 100\%, \tag{1}$$

where K_e, a dimensionless parameter, is the percentage of an area i subject to soil erosion over and beyond a threshold value, that in practical terms can be referred to as the soil erosion tolerance and that here is defined as the upper limit of the slight soil erosion severity class; C_i is the sum of the areas in i with erosion severity classes: light, moderate, severe, and very severe; and S_i is the total area of i which equals the sum of the areas of all erosion severity classes.

The soil erosion degree was calculated by the relationship [23];

$$E_j = 100 \times \frac{\sum_{i=1}^{n} I_i A_i}{S_j'}, \tag{2}$$

where E_j, the regional soil erosion degree, represents a measure of the severity of soil erosion in a given area j, I_i is the amount of the soil erosion severity class in subarea i; A_i is the total area in the ith soil erosion severity class, n is the number of soil erosion severity classes present in area j, and S_j' is the total area of j. The different soil erosion severity classes were assigned quantitative values based on

Table 2 Soil erosion severity subclasses by water in Liupan Mountain Region

code	severity class	description
11	slight erosion	erosion amount < 1000 $t\cdot km^{-2}\cdot a^{-1}$ or lost soil layer thickness < 0.8 $mm\cdot a^{-1}$
12	light erosion	erosion amount is between 1000 and 2500 $t\cdot km^{-2}\cdot a$ or lost soil layer thickness is between 0.8 and 2 $mm\cdot a^{-1}$
13	moderate erosion	erosion amount is between 2500–5000 $t\cdot km^{-2}\cdot a^{-1}$ or lost soil layer thickness is between 2 and 4 $mm\cdot a^{-1}$
14	severe erosion	erosion amount is between 5000 and 8000 $t\cdot km^{-2}\cdot a^{-1}$ or lost soil layer thickness is between 4 and 6 $mm\cdot a^{-1}$
15	very severe erosion	erosion amount is between 8000 and 15000 $t\cdot km^{-2}\cdot a^{-1}$ or lost soil layer thickness is between 6 and 12 $mm\cdot a^{-1}$

Table 3 Soil erosion severity subclasses by wind in Liupan Mountain Region

code	severity class	wind erosion		surface configuration	vegetation coverage/%
		thickness/($mm\cdot a^{-1}$)	amount/($t\cdot km^{-2}\cdot a^{-1}$)		
21	slight erosion	< 2	< 200	fixed sand dune, sand land and bottomland	> 70
22	light erosion	2–10	200–2500	fixed sand dune, semi-fixed sand dune and sand land	70–50
23	moderate erosion	10–25	2500–5000	semi-fixed sand dune and sand land	50–30
24	severe erosion	25–50	5000–8000	semi-fixed sand dune, mobile sand dune and sand land	30–10
25	very Severe erosion	> 50	> 8000	mobile sand dune, sand land	< 10

their relative impact on the eco-environment. These values were 0, 2, 4, 6, and 8 for the soil erosion severity class: slight, light, moderate, severe, and very severe, respectively, irrespective of the type of soil erosion. For the sake of convenience in use, the result is multiplied by 100. Thus, E_j represents the effect of both acreage size and soil erosion severity.

Different land uses impact the soil erosion degree differently. Therefore a determination must be made of the relationship between the spatio-temporal distribution of soil erosion severity on one hand and the LUCC index on the other hand. The land use data were obtained from 1989/1990 and 2000, respectively, while the soil loss data were from 1986 and 2001, respectively. Since these data were obtained for different years, slight adjustments were made to the base year late 1980s and 2000 to permit meaningful comparisons. The methodology used consisted of overlaying land use data and soil erosion data using the grid module of software ArcGIS.

3 Results and analysis

3.1 Present soil erosion condition in the Liupan Mountain Region

The erosion affected area was 1260786.8 ha (75.22%) of the total area in the Liupan Mountain Region in 2000. Water erosion is the dominant soil loss mode while wind erosion area constituted only 2.16% of the total soil loss. The moderate, severe, and very severe water erosion areas accounted for 54.86% of the total eroded area. The estimated amount of soil loss was 50 × $10^6\,t\cdot a^{-1}$. Soil erosion in this region in the year 2000 may be characterized as serious and widespread (Fig. 2).

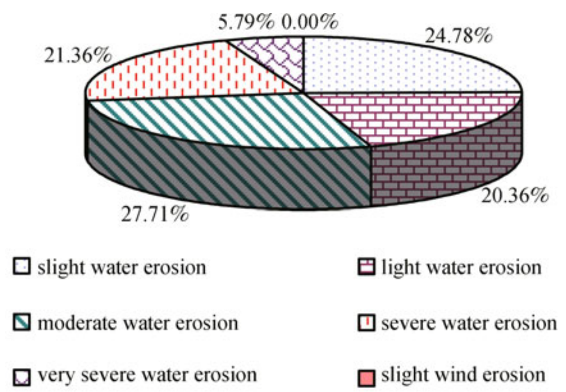


Fig. 2 Soil erosion status in Liupan Mountain Region in 2000

3.2 Characteristic of soil erosion and its change

Table 4 summarizes the percentage values for the various erosion severity classes in 1986 and 2000. In 2000, these percentages in the slight and light erosion class were 20.4% and 24.8%, respectively, while the area of moderate erosion had increased from 5.7% in 1986 to 27.7% in 2000 and that of severe erosion from 12.6% in 1986 to 21.4% in 2000, respectively. Also, no very severe erosion area was found in 1986, but this class represented only 5.8% of the total land area in 2000. So the lightly eroded area decreased, while the moderately eroded area increased by 368817 ha (22%) followed by severe erosion with 146552 ha (8.8%), and very severe erosion by 97067.6 ha (5.8%). In short, erosion severity by water had increased very substantially across the entire Liupan Mountain Region between 1986 and 2000.

Table 5 summarizes for the year 2000 the percentage

Table 4 Changes in soil erosion in Liupan Mountain Region

code	erosion type and intensity	area/ha		percentage/%	
		year 1986	year 2000	year 1986	year 2000
11	slight water erosion	514019.97	415329.84	30. 7	24. 8
12	light water erosion	827437.86	341196.93	49.4	20.4
13	moderate water erosion	95684.13	464500.98	5.7	27.7
14	severe water erosion	211468.95	358021.26	12.6	21.4
15	very severe water erosion	–	97067.61	–	5.8
21	slight wind erosion	221.04	0.63	0.01	0.00
23	moderate wind erosion	27288.54	–	1.6	–

area in each soil erosion severity classes for each county in the Liuipan Mountain Region, while Table 6 summarizes this information for 1986. The information was extracted from a map on a 30 m by 30 m grid basis. For the Jingyuan and Longde Counties, where land was covered by forest and grass, soil erosion was slight. Also, Longde County was well known for its terraces that promote and enhance soil and water conservation. In Jingyuan County, the area of severe erosion decreased with 6%, indicating a decrease in the erosion severity and a better eco-environment. In 2000, the area percentage of severe erosion in Xiji, Haiyuan, Guyuan, and Pengyang Counties were large while Jingyuan and Longde Counties had a very low percentage area with severe erosion (Table 5). In fact, the percentages of severe erosion in the aforementioned four counties increased while those for Jingyuan and Longde Counties decreased during this period. The reason for these different outcomes in the former counties is attributed to increases in the cultivated land area and an undeveloped economy that did not offer alternative employment for the local population, while for the latter two counties, no land was available that could be cultivated. In these two counties, forest and grass cover protected land from soil erosion. The area of very severe erosion was very small and no appreciable change in the very severely eroded area was observed.

3.3 Analysis of changes in soil erosion severity

According to the Eq. (1), soil loss rate in the Liupan Mountain Region increased by 5.9% during the period 1986 to 2000. Based on eco-environmental considerations soil loss as expressed by this model was divided into 5 grades or severity levels. Table 7 summarizes for both 1986 and 2000 the percentage distribution of each grade. The data indicate that 33.49% in 1986 and 0% in 2000 was in the first grade, with a soil loss severity of more than 90%, suggesting an appreciable reduction in the erosion

Table 5 Percentage of the surface in the different soil erosion severity classes in each county of the Liupan Mountain Region in 2000/%

county	slight	light	moderate	severe	very severe
Pengyang	15	8	29	33	15
Xiji	13	30	35	15	7
Haiyuan	23	17	39	17	4
Guyuan	34	22	6	33	5
Longde	37	24	27	11	0
Jingyuan	49	33	18	0	0

Table 6 Change in the percentage of the surface area of the soil erosion severity classes for each county in the Liupan Mountain Region between 1986 and 2000 /%

county	slight	light	moderate	severe	very severe
Pengyang	7	–64	19	23	15
Xiji	7	–55	35	7	7
Haiyuan	–10	–24	25	5	4
Guyuan	–13	–6	1	13	5
Longde	–6	–23	27	0	0
Jingyuan	–42	30	18	–6	0

severity at this grade level. On the other hand, substantial changes in grades 2 and 3 were observed between 1986 and 2000, indicating increases in the soil and water loss severity for those areas. Also, the lowest soil loss rates in 1986 (grades 4 and 5) had appreciable decreased by 2000, indicating a more severe soil erosion condition.

Changes in the soil loss for the various counties of the Liupan Mountain Region are shown in Fig. 3. The data show a decrease in the soil loss for Pengyang and Xiji County and an increase for the other four counties during 1986 and 2000. The decrease in soil loss for Pengyang and Xiji Counties was partly attributed to ecology protective measures and partly to the adoption of soil conservation practices.

The 1986 and 2000 distributions of the soil erosion degree for the Liupan Mountain Region are summarized in Table 8 on a county basis. These data show that the largest value for this soil erosion degree was obtained for Pengyang and Xiji Counties and the smallest value for Jingyuan and Longde Counties in both 1986 and 2000. The data of Table 8 with its high index values in 2000, also suggests that soil erosion became a more serious problem during this period. Similar observations were made for other parts of the Loess Plateau [24]. Although soil erosion was already a serious problem in 1986, the situation has steadily worsened. Therefore, there is an urgent need for more and more effective soil conservation measures.

3.4 Analysis of the relationship between soil erosion and land use change

The change in the spatio-temporal soil erosion severity between the 1980s and 2000 as a function of land use change in the Liupan Mountain Region has been summarized in Table 9. The data show that among the different types of land use, grassland with low (GL) and moderate (GM) cover had the first and third highest soil erosion degree value (490 and 340), respectively, indicating that these two types of land use were appreciably impacted by man-induced activities and management practices. Also dryland (DL) showed an increase in the soil erosion degree from 257 to 272 between the late 1980s and 2000, due to cultivation practices and desertification, while that for unused land (UL) decreased from 400 to 347. On the other hand, the soil erosion degree of paddy fields, forest land, shrubs, and other forests decreased, the latter decreased very substantially. Different reasons may be given for the decline in the soil erosion degree for each of these types of land use. The construction of terraces for small paddy fields made it possible to reduce soil erosion to negligible proportions. Aforestation policy contributed to the decrease in the soil erosion degree of forest land. Population growth, soil productivity, and cultivation of sloping fields increased the soil erosion degree of dryland [25]. The main reason for the increase in the soil erosion degree for grassland is over-grazing by livestock that reduced the stand and quality of grasses [26]. Therefore, more attention needs to be paid to the management of grassland. As a matter of general policy, the return of land from farming to forestry and grassland should be encouraged to reduce soil erosion. However, the conversion of land to grassland should be conditioned on the use of proper management practices.

3.5 Spatio-temporal changes of soil erosion on sloping cropland

The relationship between slope-gradient and changes in the soil erosion degree for cropland between the late 1980s and 2000 has been summarized in Table 10. The data was obtained by overlaying maps of slope gradient and cropland soil erosion data. The data in Table 10 indicate that the soil erosion severity on cropland gradually decreased in the late 1980s, while those of 2000 increased with increasing slope gradient. The reason for this anomalous result is that in the late 1980s, cropland cultivation was mainly on land with low or gentle slopes, while the steeper slopes were basically covered by forest and grasses. As the population increased, the steeper slopes were reclaimed for crop production, which explains the gradual increase in the soil erosion degree with increasing slope steepness in 2000. Chen et al. [27] reported that soil loss increased with slope steepness between 0 and 25° while between 25° and 28° soil loss decreased. The data in Table 10 are consistent with the values reported in the literature [27] above. Soil erosion severity on cropland with steep slope gradients is greater than in small slope gradients, but the area of sloping cropland below 15° accounted for approximately 90% of the total area in the late 1980s or 2000 (Table 10). Given the large percentage

Table 7 The 1986 and 2000 distribution of soil erosion grades in Liupan Mountain Region

grade	soil loss/%	percentage in 1986/%	percentage in 2000/%	change
1	⩾90	33.49	0	−33.49
2	80–90	0	33.49	+ 33.49
3	60–80	32.91	62.02	+ 29.11
4	20–60	29.11	4.49	−24.62
5	< 20	4.49	0	−4.49

Note: 1 represents for the largest soil loss area; 2 for larger soil loss area; 3 for large soil loss area; 4 for moderate soil loss area; 5 for small soil loss area in this region

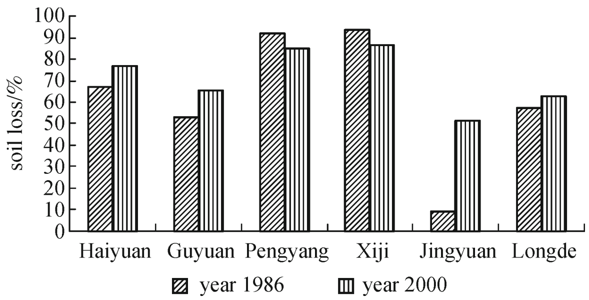


Fig. 3 Changes in soil loss severity for the different counties in the Liupan Mountain Region from 1986 to 2000

Table 8 Soil erosion degree and its changes between 1986 and 2000 for the Liupan Mountain Region

county	1986	2000	change
Pengyang	243	449	206
Xiji	221	343	122
Haiyuan	212	321	109
Guyuan	198	302	104
Longde	157	227	70
Jingyuan	41	139	98

of cropland area on low and moderate (< 15°) slopes, most of the resources available for controlling soil loss should be directed to cropland with slopes less than 15°. The low soil erosion degree for cropland with slope gradients less than 5 decreased, indicating that soil erosion conservation practices on those slopes were very successful. On the other hand, the soil erosion degree of cropland at higher slope gradients increased between the late 1980s and 2000, indicating the need for more comprehensive soil erosion control programs.

3.6 Relationship between soil loss and land use change

Land use changes during the late 1980s to 2000 period mainly consisted of conversions from one type to another type among cropland, forest land, grassland, and water bodies [28]. The effect of these changes in land use on spatial and temporal soil erosion can be well determined by overlapping digital maps of the land use change and the soil erosion degree (Fig. 4). When cropland is converted into other land use types, the soil erosion degree decreased (Fig. 4(a)). This observation supports the policy of "returning land to non-farming uses." Figure 4(a) suggests that the erosion degree on grassland following conversion from cropland increased slightly. It was hypothesized that in this case the soil of the converted cropland was still unstable and that its structure could readily be developed due to over grazing and trafficking by animals. The soil erosion degree decreased in forest land, grassland, and cropland reclaimed from water bodies in the Liupan Mountain Region between the late 1980s and 2000, which suggest that to some extent the overland flow processes is an important factor that causes soil loss (Fig. 4(b)).

4 Conclusions

Remote sensing and geo-information tools were used to quantify the interaction between soil erosion changes and its spatio-temporal distribution in the Liupan Mountain Region of southern Ningxia as a result of changes in land use. Soil erosion increased in the Liupan Mountain Region between the late 1980s and 2000 both in terms of acreage and severity. Limited progress has been made to address and prevent soil erosion. Soil erosion severity increased appreciable on grassland with a moderate and low grass cover land or dry land. Soil loss on sloping cropland

Table 9 Changes in soil erosion degree in relation to LUCC between the late 1980s and 2000

land use type[a)]	area in late 1980s/km^2	percentage in late 1980s/%	area in 2000/km^2	percentage in 2000/%	erosion degree in late 1980s	erosion degree in 2000
PF	0.92	0.01	0.51	0.00	600	0
DL	7082.09	42.25	7524.50	44.89	257	272
FL	41.89	0.25	42.98	0.26	49	19
SB	380.50	2.27	419.20	2.50	69	37
TL	332.54	1.98	367.19	2.19	98	101
OL	52.54	0.31	68.02	0.41	454	24
GH	370.88	2.21	387.17	2.31	22	9
GM	2645.56	15.78	2457.04	14.66	146	340
GL	5497.72	32.80	5129.64	30.60	179	490
RL	213.55	1.27	229.05	1.37	347	24
UL	5.79	0.03	6.03	0.04	400	347

Note: a) PF-paddy field; DL-dry land; FL-forest land; SB-shrubbery; TL-thin forest land; OL-other forest land; GH-grass land with high degree of coverage; GM-grass land with moderate degree of coverage; GL-grass land with low degree of coverage; RL-rural-urban industrial land and UL-unused land

Table 10 Soil erosion degree on sloping cropland in the late 1980s and 2000 as a function of slope gradient

sloping field type	area in late 1980s/km^2	percentage in late 1980s/%	area in 2000/km^2	percentage in 2000/%	erosion intensity index in late 1980s	erosion intensity index in 2000
0°–5°	4901.05	69.20	5148.20	68.42	282	242
5°–8°	369.75	5.22	390.82	5.19	250	257
8°–15°	1149.33	16.23	1252.63	16.65	194	346
15°–25°	580.67	8.20	640.78	8.52	174	371
25°–35°	73.66	1.04	82.96	1.10	160	376
＞35°	8.45	0.12	9.49	0.13	158	368

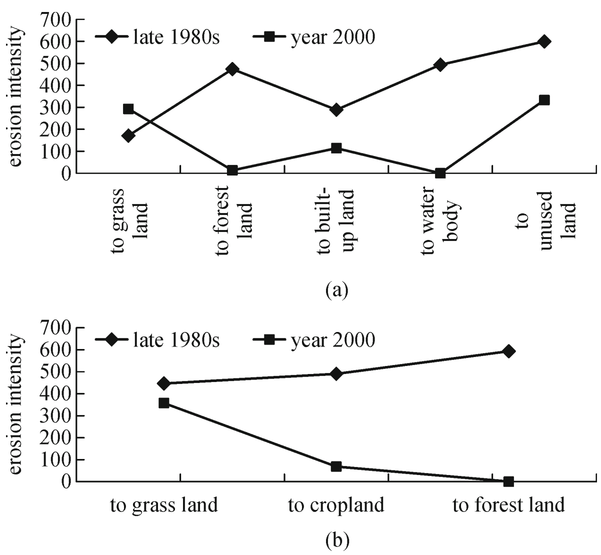


Fig. 4 Statistics of soil erosion degree change under the different land use. (a) Cropland was converted into other land uses; (b) water body was converted into other land uses

increased with slope gradients. About 90% of the cropland was located on slopes less than 15°. Most of the increase in soil erosion on cropland was due to conversion of steep slopes to cropland and degradation of grassland and increased activities. To reduce or even prevent soil erosion, conversion of sloping land to cropland and deforestation should be discouraged, while grassland should be protected from excessive grazing. In this regard the Chinese strategy: "Retain all rain water by increasing rain infiltration on-site and surface storage off-site; by limiting grain production to valley land areas and on high plateaus, by growing trees and fruit trees on gentle and moderately gullied slopes; and by planting grasses and shrubs on steep slopes" is very appropriate and desirable. Only then can the ecological environment of the Liupan Mountain Region be improved and restored, and an environmentally, sustainable agriculture be maintained. The present subsidy for returning land for cropland to forest and grass land is a very favorable regulation in this regards, which could promote the agricultural labors to seek for alternative livelihood means. To improve the eco-economic conditions in this hot-spot region, population control, urbanization and development of an ecological friendly agriculture were suggested.

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