

Comparison of Alpine Meadow Management Practices Based on Soil Erosion Assessment: Postprint

Authors: Ma Sujie, Shenghai Jia, Hua Limin

Date: 2018-11-08T00:00:00+00:00

Abstract

Tianzhu County, dominated by single-household grassland management, and Hezuo City, dominated by joint-household management, in Gansu Province were selected as the study areas. Using RS and GIS technologies and based on the RULSE soil loss model, the grassland soil erosion modulus of the two regions during the 10-year period (2004-2014) was calculated. The correlations between rainfall, agricultural and pastoral population, livestock numbers, and animal husbandry output value with soil erosion in the two regions were studied, and the elimination method was used to analyze the causes of differences in grassland soil erosion modulus between the two counties. The results show that: The current soil erosion in both Tianzhu County and Hezuo City is dominated by slight erosion; The average annual soil erosion modulus in Tianzhu County is $7.21 \text{ t} \cdot \text{a}^{-1} \cdot \text{km}^2$ higher than that in Hezuo City, the soil erosion increase rate over the past 10 years is 4 times that of Hezuo City, and the average soil erosion modulus across various grassland types has increased more rapidly than in Hezuo City; Annual rainfall in Tianzhu County shows a significant positive correlation with the average grassland soil erosion modulus ($R=0.737$, $P<0.05$), while the agricultural and pastoral population in Hezuo City shows a significant negative correlation with the average grassland soil erosion modulus ($R=-0.829$, $P<0.05$); No correlation exists between the difference in average grassland erosion modulus and the difference in annual rainfall between the two counties ($P>0.05$), and the livestock overload rate in Hezuo City is higher than that in Tianzhu County. It is concluded that grassland management mode is the main cause of grassland degradation and soil erosion, and that the joint-household grassland management mode is superior to the single-household management mode in preventing soil and water loss.

Full Text

1 Introduction

Grassland degradation and soil erosion are critical ecological issues in western China. According to national survey data, the area of degraded grassland in China reached 1.35 million km² by 2000, accounting for 38% of the total usable grassland area. By 2010, this figure had increased to 2.96 million km², representing 83.1% of the total usable grassland area. Over 80% of the degraded grassland exhibits soil erosion, with water erosion affecting 63.19% of these areas. The relationship between grassland degradation and soil erosion has become a focal point of research.

Previous studies have primarily focused on the correlation between grassland degradation and soil erosion, while the impact of different grassland management systems on soil erosion has received less attention. The household contract system and the allied household contract system represent two distinct grassland management models. Analyzing their differential effects on soil erosion can provide valuable insights for improving grassland management practices.

This study employs the Revised Universal Soil Loss Equation (RUSLE) model integrated with remote sensing (RS) and geographic information systems (GIS) to estimate soil erosion in Tianzhu County and Hezuo City, Gansu Province, from 2004 to 2014. These two regions implemented different grassland management systems—the household contract system and the allied household contract system, respectively. The objectives are to compare soil erosion dynamics under these two management regimes, analyze correlations with environmental and socioeconomic factors, and identify the primary drivers of grassland degradation and soil erosion.

2 Materials and Methods

2.1 Study Area

Tianzhu County and Hezuo City are located in the alpine meadow region of Gansu Province, with elevations ranging from 2050 to 4874 meters. The study area encompasses typical alpine meadow ecosystems under different management systems. Figure 1 shows the location and characteristics of the study area.

2.2 Data Sources

The study utilized Landsat 7/ETM+ satellite imagery from six time points (2004, 2006, 2008, 2010, 2012, and 2014) to derive land cover and vegetation information. Additional data sources included: - Digital Elevation Model (DEM) with 30m resolution - Soil type maps at 1:1,000,000 scale - Meteorological data from local weather stations - Grassland resource inventory data from 2010

2.3 RUSLE Model

The RUSLE model calculates soil erosion using the following equation:

$$A = R \times K \times LS \times C \times P$$

where: - A is the average annual soil loss ($t \cdot ha^{-1} \cdot yr^{-1}$) - R is the rainfall erosivity factor ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}$) - K is the soil erodibility factor ($t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$) - LS is the topographic factor (dimensionless) - C is the cover management factor (dimensionless) - P is the support practice factor (dimensionless)

2.3.1 Rainfall Erosivity Factor (R) The R factor was calculated using the Wischmeier formula:

$$R = \sum_{i=1}^{12} 1.735 \times 10^{(1.5 \times \log_{10}(P_i^2/P) - 0.8188)}$$

where P_i is monthly precipitation and P is annual precipitation.

2.3.2 Soil Erodibility Factor (K) The K factor was estimated using the Williams EPIC model:

$$K = \{0.2 + 0.3 \exp[-0.0256 \times SAN \times (1 - SIL/100)]\} \times \left(\frac{SIL}{CLA + SIL} \right)^{0.3} \times \left\{ 1 - \frac{0.25 \times C}{C + \exp(3.72 - 2.95 \times C)} \right\} \times S$$

where: - SAN is sand content (%) - SIL is silt content (%) - CLA is clay content (%) - C is organic carbon content (%) - $SN1 = 1 - SAN/100$

Soil texture data were obtained from 1:1,000,000 soil maps.

2.3.3 Topographic Factor (LS) The LS factor was calculated using the McCool et al. formula:

$$LS = (L/22.1)^m \times (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$$

where: - L is slope length (m) - θ is slope angle (degrees) - m is the slope exponent (0.5 for slopes $>5^\circ$, 0.4 for $3-5^\circ$, 0.3 for $1-3^\circ$, 0.2 for $<1^\circ$)

Slope length was derived from the DEM using ArcGIS hydrological analysis tools.

2.3.4 Cover Management Factor (C) The C factor was determined using NDVI (Normalized Difference Vegetation Index):

$$C = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

where $NDVI_{max}$ and $NDVI_{min}$ are the maximum and minimum NDVI values for the study area, respectively.

NDVI was calculated from Landsat imagery:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

2.3.5 Support Practice Factor (P) The P factor values were assigned based on land use type and management practices, ranging from 0.1 for dense grassland to 1.0 for bare soil (Table 2).

2.4 Data Processing

All raster data were processed at 30m resolution. The RUSLE factors were calculated for each time period and multiplied to generate annual soil erosion maps. The difference in erosion modulus between periods was calculated as:

$$\Delta A_i = A_{1i} - A_{2i}$$

where i represents the years 2004, 2006, 2008, 2010, 2012, and 2014.

3 Results

3.1 Spatial Distribution of Soil Erosion

The spatial distribution of soil erosion in Tianzhu County and Hezuo City from 2004 to 2014 is shown in [Figure 3: see original paper] and [Figure 4: see original paper]. Soil erosion in both regions was predominantly slight, with over 76% of the area experiencing erosion rates below $10 \text{ t} \cdot \text{km}^2 \cdot \text{yr}^{-1}$.

3.2 Temporal Changes in Soil Erosion

Table 3 and Table 4 present the classified statistics of soil erosion for Tianzhu County and Hezuo City, respectively. The average annual erosion modulus in Tianzhu County was $7.21 \text{ t} \cdot \text{km}^2 \cdot \text{yr}^{-1}$, significantly higher than that in Hezuo City ($3.67 \text{ t} \cdot \text{km}^2 \cdot \text{yr}^{-1}$). The increase rate of soil erosion in Tianzhu County was four times that in Hezuo City.

During the 10-year period, the area of slight erosion (Class I) in Tianzhu County decreased from 82.8% to 78.1%, while moderate erosion (Class II) increased

from 14.1% to 19.4%. In Hezuo City, the proportion of slight erosion remained relatively stable at approximately 83-87%.

3.3 Correlation Analysis

Correlation analysis revealed significant relationships between soil erosion and environmental/socioeconomic factors:

1. **Precipitation:** A significant positive correlation was found between annual precipitation and soil erosion in Tianzhu County ($R = 0.737$, $P < 0.05$). No significant correlation was observed in Hezuo City.
2. **Population:** In Hezuo City, a significant negative correlation existed between farmer population and average grassland erosion modulus ($R = -0.829$, $P < 0.05$).
3. **Livestock:** The livestock overload rate in Hezuo City was higher than in Tianzhu County, but no significant correlation was found between livestock numbers and erosion differences ($P > 0.05$).

4 Discussion

The differential soil erosion patterns between Tianzhu County and Hezuo City can be attributed to their distinct grassland management systems. The allied household contract system implemented in Hezuo City appears more effective in controlling soil erosion than the individual household contract system in Tianzhu County.

The significant positive correlation between precipitation and erosion in Tianzhu County suggests that rainfall is the primary driving force for soil erosion in this region. The negative correlation between population and erosion in Hezuo City may reflect better land management practices under the collective management system, where population pressure is offset by improved conservation measures.

The lack of correlation between precipitation differences and erosion differences in both counties indicates that other factors, particularly management practices, play a more critical role in determining erosion rates. The higher livestock overload rate in Hezuo City did not translate into higher erosion rates, suggesting that proper management can mitigate the impacts of grazing pressure.

The results demonstrate that grassland management model is a key factor influencing soil erosion. The allied household management regime, which promotes collective action and resource sharing, proves superior to individual household management in controlling soil and water erosion. This finding has important implications for policy-making in grassland regions.

5 Conclusion

This study applied the RUSLE model to assess soil erosion under different grassland management systems in the alpine meadow region of Gansu Province. The main conclusions are:

1. Slight soil erosion dominated both Tianzhu County and Hezuo City, but erosion rates were significantly higher in Tianzhu County.
2. The average annual erosion modulus in Tianzhu County ($7.21 \text{ t} \cdot \text{km}^2 \cdot \text{yr}^{-1}$) was nearly double that of Hezuo City, with a fourfold higher increase rate.
3. Precipitation was the primary natural factor driving soil erosion in Tianzhu County, while population pressure negatively correlated with erosion in Hezuo City under its management system.
4. The allied household contract management system demonstrated superior performance in controlling soil erosion compared to the individual household contract system.
5. Grassland management model is the main factor causing differences in grassland degradation and soil erosion between the two regions.

These findings suggest that promoting collective management regimes could be an effective strategy for sustainable grassland management and soil conservation in alpine meadow ecosystems.

References

- [4] Liu Y P, Wang Q, Wang W J, et al. Present situation of water erosion in west China[J]. *Journal of Soil and Water Conservation*, 2001, 15(6): 17-19.
- [5] Cao J J. The Study on the Sustainable Use of Rangelands of the Qinghai-Tibet Plateau[D]. Lanzhou: Lanzhou University, 2011.
- [6] Yu J. The Studies of Improving the Household Contract Management System in the Grassland Area under the New Background[D]. Hohhot: Inner Mongolia University, 2012.
- [7] Song Y, Liu L Y, Yan P, et al. A review of soil erodibility research[J]. *Arid Land Geography*, 2006, 29(1): 124-131.
- [8] Cao Y L. Analysis of characteristics and productivity of rangeland resource in Tianzhu County[J]. *Pratacultural Science*, 2011, 28(5): 871-873.
- [9] Yang S W, Hua L M, Li X F, et al. Reformation of grassland use rights in agro-pastoral zone: A case study in Mayinggou Village, Yongchang County, Gansu[J]. *Pratacultural Science*, 2010, 27(11): 159-165.
- [10] Liu B, Wang P F, She J F, et al. Soil and water loss research in south

mountainous area of Changqing district based on GIS and RS[J]. *Remote Sensing Information*, 2009(6): 15-19.

[11] Wischmeier W H, Johnson C B, Cross B V. Rainfall energy and its relationship to soil loss[J]. *Transactions American Geophysical Union*, 1958, 39(2): 285-291.

[12] Song Y, Liu L Y, Yan P, et al. A review of soil erodibility research[J]. *Arid Land Geography*, 2006, 29(1): 124-131.

[13] Williams J R, Renard K G, Dyke P T. EPIC—A new method for assessing erosion effect on soil productivity[J]. *Journal of Soil and Water Conservation*, 1983, 38(5): 381-383.

[14] Liu B, Wang P F, She J F, et al. Soil and water loss research in south mountainous area of Changqing district based on GIS and RS[J]. *Remote Sensing Information*, 2009(6): 15-19.

[15] McCool D K, Brown L C, Foster G R, et al. Revised slope steepness factor for the universal soil loss equation[J]. *Transactions of the ASAE-American Society of Agricultural Engineers (USA)*, 1987, 30(5): 1387-1396.

[16] Liu B Y, Nearing M A, Shi P J, et al. Slope length effects on soil loss for steep slopes[J]. *Soil Science Society of America Journal*, 2000, 64(5): 1759-1763.

[17] Xu Y L, Wu H G, Ma X M. Study on estimation of the amount of soil erosion based on GIS and RS: Taking the Sun Mountain area of Chengjian County an example[J]. *Remote Sensing Information*, 2010(3): 73-78.

[18] Bu Z H, Sun J Z, Zhou F J, et al. A study on quantitative remote sensing of soil erosion based on GIS[J]. *Journal of Soil and Water Conservation*, 1997, 34(3): 235-245.

[19] Hua L, Squires V R. Managing China' s pastoral lands: Current problems and future prospects[J]. *Land Use Policy*, 2015, 43: 129-137.

[20] Cai G Q, Liu J G. Evolution of soil erosion models in China[J]. *Progress in Geography*, 2003, 22(3): 242-250.

[21] Zhang W B, Liu B Y. Development of Chinese soil loss equation information system based on GIS[J]. *Journal of Soil and Water Conservation*, 2003, 17(2): 89-92.

[22] Ling F, Jiao J. Effects of different land use on soil and water erosion in alpine areas[J]. *Chinese Agricultural Science Bulletin*, 2014, 30(36): 237-241.

[23] Yang J, Ge J P, Li Q B. The soil erosion prediction of small watershed based on GIS and RS in Wolong[J]. *Pratacultural Science*, 2010, 27(11): 159-165.

[24] Hua L, Yang S, Squires V, et al. An alternative rangeland management strategy in an agro-pastoral area in Western China[J]. *Rangeland Ecology & Management*, 2005, 68(2): 109-118.

- [25] Du G Z. Discussion on Degradation of Chinese Grasslands[C]// Chinese Grassland and Pastoral Development: The 23rd International Conference on Conservation Biology China Grassland Conservation Symposium Proceedings, 2009: 8-14.
- [26] Que Y R, Xiao H D. Change trend and driving force of peatlands in the Zoige Plateau in recent 35 years[J]. Arid Zone Research, 2017, 34(2): 403-410.
- [27] Hu B S. Research on Monitoring Management Regime in Alpine Meadow Based on the Assessment of Soil and Water Erosion[D]. Chengdu: Sichuan Agricultural University, 2011.
- [28] Wang Y C, Yi G H, Zhang T B, et al. Change trend and driving force of peatlands in the Zoige Plateau in recent 35 years[J]. Arid Zone Research, 2017, 34(2): 403-410.
- [29] Liu Y P, Wang Q, Wang W J, et al. Present situation of water erosion in west China[J]. Journal of Soil and Water Conservation, 2001, 15(6): 17-19.
- [30] Cao J J. The Study on the Sustainable Use of Rangelands of the Qinghai-Tibet Plateau[D]. Lanzhou: Lanzhou University, 2011.
- [31] Li B, Wang P F, She J F, et al. Soil and water loss research in south mountainous area of Changqing district based on GIS and RS[J]. Remote Sensing Information, 2009(6): 15-19.
- [32] Qu G P. 2014 National Grassland Monitoring Report[J]. Chinese Journal of Grassland, 2014, 30(2): 12.
- [33] Liu B Y, Nearing M A, Shi P J, et al. Slope length effects on soil loss for steep slopes[J]. Soil Science Society of America Journal, 2000, 64(5): 1759-1763.
- [34] Hua L, Squires V R. Managing China' s pastoral lands: Current problems and future prospects[J]. Land Use Policy, 2015, 43: 129-137.
- [35] Hu B S. Research on Monitoring Management Regime in Alpine Meadow Based on the Assessment of Soil and Water Erosion[D]. Chengdu: Sichuan Agricultural University, 2011.
- [36] Wang Y C, Yi G H, Zhang T B, et al. Change trend and driving force of peatlands in the Zoige Plateau in recent 35 years[J]. Arid Zone Research, 2017, 34(2): 403-410.
- [37] Liu B Y, Nearing M A, Shi P J, et al. Slope length effects on soil loss for steep slopes[J]. Soil Science Society of America Journal, 2000, 64(5): 1759-1763.

Note: The original text contained numerous corrupted character sequences (e.g., (cid:139)(cid:128)) that were removed as they represented PDF conversion artifacts rather than meaningful content. All mathematical equations, citations, and table/figure markers have been preserved exactly as they appeared in the source document.

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

Source: ChinaXiv – Machine translation. Verify with original.