Research on the control of soil and water loss in the Yellow River Basin in the new era Based on GIS and RUSLE

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Abstract. The Loess Plateau is a typical ecologically fragile area in China. As early as 1952, it was clear that soil and water conservation is an important measure to control the Yellow River, but there are still some weak links and deficiencies. Based on the research and analysis of the Yellow River Basin, this paper takes a typical site in Fugu County as an example, uses Globalmapper and ArcGIS for scientific analysis, and uses the RUSLE calculation method to obtain the current soil erosion degree results. Suggestions for the prevention and control of soil and water loss in the Yellow River Basin in the new period are put forward from the aspects of ecological protection, agricultural technology, policies and regulations.

Keywords: erosion; RUSLE; scientific innovation; ecological restoration.

1. Introduction

1.1 Problem statement:

In the Yellow River basin the problem of soil erosion is prominent, being an ecologically fragile environment. At present, although results have been achieved in the Loess plateau to prevent soil degradation by erosion, but in the vast majority of the territory and specifically in certain areas, continues to be serious and the ecological environment system remains fragile (Yao, 2019).

Since some governance models cannot meet people's livelihood improvement needs, people are not very enthusiastic about the governance system. Therefore, there is an urgent need to change the ecology and life, and the situation of protection and local economic development should be in harmony.

1.2 Management. Chronology of this administration.

Territory management is the fundamental basis for obtaining soil and water conservation (Yao, 2019). Although much progress has been made in the construction of the infrastructure and the management and monitoring system for soil and water conservation in the Yellow River basin, there are still deficits to be filled. The main problem is that the monitoring system is not robust, especially in the sandy zone and coarse sand areas. For now, the coverage and representation of the network of soil erosion monitoring stations is insufficient, the index system is incomplete and imperfect, and there is a lack of real-time automation of erosion to obtain data that is comparable with other study and monitoring places in the same basin.

In addition, the construction of artificial vegetation on slopes has an impact on the supply-demand relationship and the sustainable use of water resources. It has not always been a success as dry soil layers have formed in some areas and many of the ancient trees have often died (Li, 2016). At the same time, large-scale conversion of agricultural land and urbanization of arable land have highlighted the problem of coordination between humans and land.

1.3 Current status. Of the problem and of the management. Pending issues.

"Less water, more sand, and insufficient water and sediment control capacity" are historical contradictions in the governance of the Yellow River. (Wang and Zhao, 2019). In the new era, there have been major changes in the contradiction of the governance of the Yellow River. Facing the ecological protection and high-quality development goals of the Yellow River basin, the idea of addressing the contradictions of the Yellow River is to increase water, reduce sediment, and improve the ability to control water and sediment.

The comprehensive stage of large-scale general governance of the past should lead to a new stage of governance concentrating on weak areas to fill: a) deficiencies, b) perfecting the large-scale protection system, c) strengthening supervision, and d) serving people's livelihood and improving the quality of life, for which they will face many challenges.

2. Regional overview

Due to the large area of the entire Yellow River basin, Fugu county, which is located in one of the most problematic areas of soil erosion in the Loess Plateau, has been chosen as the geographic data analysis area. Fugu belongs to Yulin City, Shaanxi Province, and is located in the northwest of the Loess Plateau, bordering Inner Mongolia to the north and close to the Mu Us Desert. Although the government has been implementing soil erosion control for many years, it has not achieved effective results (consistent with the results of the RUSLE analysis in the next section).

Fugu is in the zone 110°22'～111°14'E, 38°42'～39°35'N. The general relief is high in the northwest and low in the southeast, with an altitude between 779.5 and 1399.5 meters. Due to the influence of external geology and human activities over thousands of years, the area has sparse vegetation, severe soil erosion, barren land, fragmented terrain, and gullies, forming a unique loess-aeolian semi-arid landform.

3. Methodology

3.1 Read, analyze and compare

To complete this work, a large number of articles related to the subject of soil erosion in the study area have been consulted, as well as the human and natural geographical conditions of the study region, according to the problems and the steps taken to control them in the Yellow River over the years. Finally, an analysis is carried out and they are compared with other similar documented cases.

3.2 Analysis with GIS

Geographic Information System (GIS) is a visualization technology with powerful spatial analysis functions and data processing capabilities. The effective analysis of spatial data is particularly necessary in the process of understanding geographic information, environmental protection and territorial planning. In addition, the GlobeMapper program has been used as an auxiliary tool.

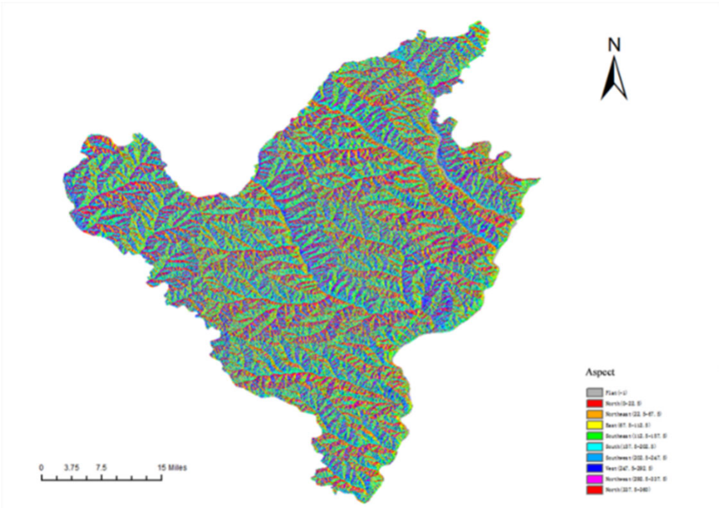

Figure 1. Fugu slope aspect. Source: self made.

Fugu has a complex distribution of slope aspect (figure 1) GlobeMapper has been used to generate the original tif data as demo. The same protocol has been followed for the slope analysis, mainly oriented to the southwest, south and southeast. Therefore, the available solar radiation here is large, the temperature is high, and the evaporation is large, which aggravated the drought in this area. As the vegetation cover here is low and the surface is bare, the temperature The daily temperature between day and night is highly contrasted at a thermal level and the annual temperature is very high, which intensifies physical weathering.

Most parts of Fugu have a slope of less than 25 degrees (figure 2), but there are some places where the slope is large and concentrated (red box), and there are varying degrees of topographic undulations in various parts of the county. The greater the slope, and the faster the flow of rainwater, which will cause soil erosion, the more damaging it is to the most fertile layer of the soil. That is, as the slope increases, the rate of soil erosion also increases. The contour map and the 3D topographic map show that the surface is very ridged. This is not only detrimental to the growth and restoration of vegetation, but also causes difficulties in production and the lives of the local population, and increases the risk of natural disasters.

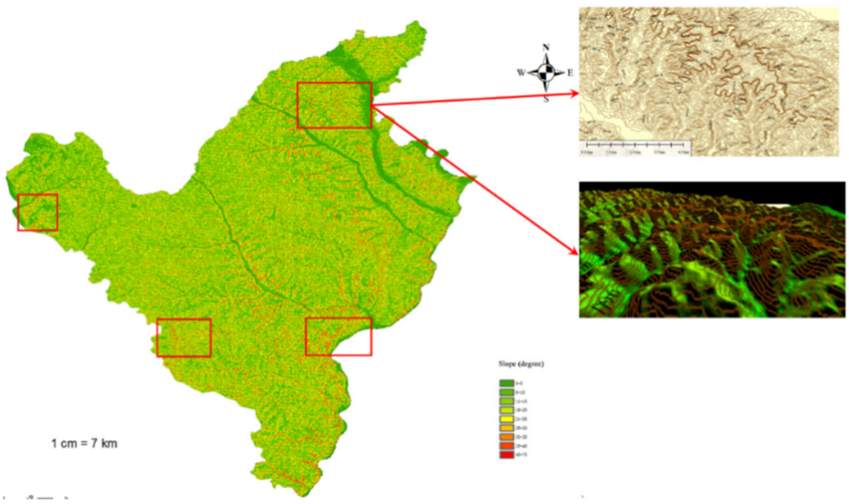

Figure 2. Fugu slope. Source: self made.

Through the analysis of the above natural conditions, which are extremely harsh are the reason why it is easy to cause soil erosion, along with human overexploitation which harm the environment.

3.3 RUSLE

The empirical Revised Universal Soil Loss Equation (RUSLE) is a very popular model for estimating the annual potential rate of soil erosion due to rainfall (Renard et al., 1997). Although originally developed for agricultural applications, today the RUSLE is used as a general model to provide estimates also for non-agricultural land at different spatial scales, including continental scales (Panagos et al., 2015).

RUSLE estimates the annual potential soil erosion rate A [t / (hm2 · a)] through five parameters, which are the following:

$$A = R \times K \times LS \times C \times P \tag{1}$$

In the formula: A —— mean annual soil loss, t / (hm2 · a); R —— rain erosion factor, MJ mm / (hm2 h a); K—— soil erosion factor, t h / (MJ mm); L —— slope length factor; S —— slope factor; C —— coverage and management factor; P —— factor of soil and water conservation measures.

3.3.1 Estimation of the K factor of soil erodibility

Soil erodibility refers to the sensitivity of the soil to erosion and is an integral manifestation of the soil's ability to resist erosion by rainfall and runoff. In RUSLE, the soil erodibility factor is defined as the rate of soil loss caused by unit erosivity of rainfall on a standard plot.

$$K= 7.594(0.0034\ 0.0405\ \exp\{-0.5[\ (\log D_g+1.659)/0.7101]^2\}) \quad (2)$$

$$D_g = \exp(0.01\Sigma\ f_i\ \ln m_i\ ). \quad (3)$$

In the formula, Dg——Geometric diameter of soil particles, mm;

mk——Value of the lower limit of the component of level k, mm;

fk——Mass percentage of the granular component of level k, %.

The soil type of the basin is loessial soil, which belongs to the loessial soil subtype. According to formula (1), (2) and (3), and table 1, K=0.047.

Table 1. Size and mass fraction of soil particles in Fugu. Source: Research by Liu et al., 2003.

Particle size class / mm	＞0～＜0.002	0.002～＜0.01	0.01～＜0.02	0.02～2
Mass Score /%	21.37	26.12	30.95	21.56

Most of the formulas for calculating the K value require that the soil particle analysis standard be performed in the United States. However, the analysis of soil particles in the second soil census in China used the international system, so there is a problem of conversion from the international system to the American system. Through the conversion (Ka=Ki/0.1317), the value K = 0.35 t · h / (MJ · mm) is obtained.

3.3.2 Estimation of the precipitation erosion factor R

The rain erosivity factor reflects the dynamics of soil separation and transport caused by rain.

The magnitude of the force, that is, the potential capacity of rain to produce soil erosion. This study uses the empirical formula proposed by Wischmeier et al., (1971), which is more suitable for the Loess Plateau and is widely used.

$$R=.\sum_{i=1}^{12} \quad (1.735*101.5*\lg\frac{pi^2}{p}-0.8088) \quad (4)$$

In the formula, Pi——Precipitation in month i, mm;

P——Annual precipitation, mm.

Based on the monthly precipitation data for Fugu from 2010 to 2020 and calculated according to formula (4), the mean value of R from 2010 to 2020 is 1885.63.

3.3.3 Estimation of the length factor L and slope S (LS)

The slope factor represents the ratio of the amount of soil lost on a slope with a certain slope to the amount of soil lost on the typical slope of a standard runoff plot when other factors are equal.

3.3.3.1 Calculation of the slope factor S

To obtain the slope factor S, it is based on the Loess Plateau steep slope calculation formula proposed by Liu in 1994. The formula is as follows:

$$S=10.8\ \sin\theta +0.03,\ \theta <5°$$
$$S =16.8\ \sin\theta -0.50,\ 5°\leq\theta <10° \quad (5)$$
$$S = 21.91\ \sin\theta -0.96,\ \theta\geq 10°$$

In the formula, θ—— slope, °.

The "Raster Calculator" tool has been used by loading the Fugu slope data previously obtained in ArcGIS, according to formula (5), calculate the result of factor S.

3.3.3.2 Calculation of the factor L of the length of the slope

According to Kong (2008) the length of the slope can be defined as the projection length of the maximum distance to the ground from a point on the ground along the direction of the water flow to its initial point in the horizontal plane.

The slope length factor formula is proposed as:

$$L=(\lambda/22.13)^m$$
$$\lambda= flowacc * cell\ size$$
$$m=\beta/(\beta+1)$$
$$\beta=(\sin\theta/0.0896)/(3.0\sin\hat{}0.8\theta+0.56) \quad (6)$$

In this formula, m——slope length index; flowacc——flow calculation results in Arcgis; β——the ratio between the amount of erosion of the streams and the amount of erosion between the erosion of the streams; θ ——slope, (°).

The hydrologic analysis tool in ArcGIS has been used to analyze water fill, flow direction, and order flow. The following has obtained the value of the pixel size in the properties of the flow layer (x,y): 0.0001230825, 0.0001230825.

The raster calculator and the formula “Flowacc*0.0001230825” have been used, and λ has been obtained.

The raster calculator and the formula “(Sin("Slope_FG") / 0.0896) / (3 * Power(Sin("Slope_FG"),0.8)+0.56)” have been used, and β has been obtained.

" β" / ("β" + 1) " have been entered into the raster calculator, and m have been obtained.

"Power("λ" / 22.13,"m ")" have been entered, the result of the factor L.

Finally, the S and L grids have been superimposed to calculate the LS factor (figure 2):

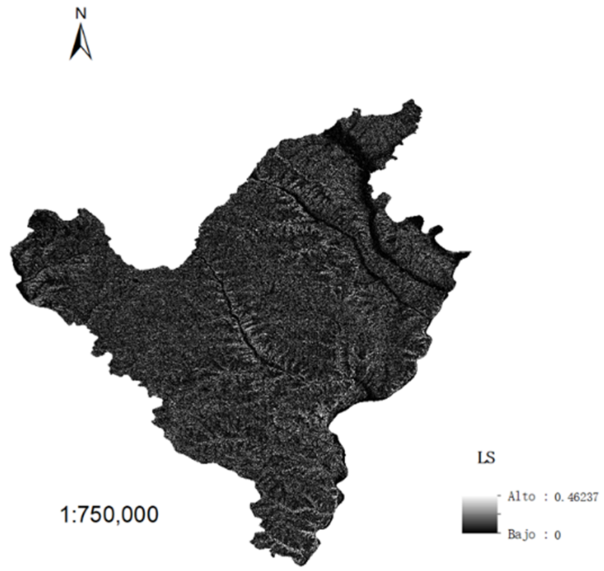

Figure 3. Result of the LS topography factor. Source: self made.

3.3.4. Estimation of the P factor of the soil and water conservation measures.

In RUSLE, the soil and water conservation measure factor is defined as the ratio of the amount of soil lost on land with specific measures to the amount of soil lost by planting downhill, which ranges from 0 to 1.

Studies have shown that horizontal fish scale terraces reduce slope erosion on average by 91.6% and 81.3% (Wu et al., 2004), thus the P-factors for horizontal terraces and fish scale site preparation are determined to be 0.084 and 0.187, respectively. The value of the P factor of land use types without water and soil conservation measures is 1.

3.3.5. Estimation of the coverage and management factor C

Factor C is determined by factors such as vegetation type, cover, height, leaf area index, etc. The values of C range from 0 to 1.

The agricultural lands of the basin are dry hills, most of which are planted with millet (Setaria italica), maize (Zea mays), soybean (Glycine max) and potato (Solanum tuberosum). The proportion of planting area is about 10% for millet; 20% for corn; 20% for soybeans and 60% for potatoes.

According to Zhang et al., (2001), the C factors of millet, maize, soybean and potatoes in the Loess Plateau were 0.53, 0.28, 0.51 and 0.47. The average value of the C factor of the lands in this area was 0.44 on a weighted average according to the proportion of crops area.

At the same time, the forest land in the basin is built mainly through the project of returning agricultural land to forests. Pergola forests are mostly small-leaved poplar, black locust, mountain apricot, etc. mainly pure sea buckthorn forests. Thus, C-factors of forest land, shrubland and sparse forest land were determined as 0.004, 0.083, 0.144 (Zhang et al., 2003).

Construction sites, such as oil wells and roads, are bare and the factor C is 1.

4. Results

According to the statistics and the results of the RUSLE calculations, the estimated value for the study area is approximately:

A= 3661.78 t/km2/year

According to the document Soil Erosion Classification Standard of the People's Republic of China (2008), the soil erosion level of the study area belongs to severe and intense erosion.

Based on decades of experience in the governance of the Yellow River basin and the analysis of current social and economic conditions, the following recommendations are drawn as the main measures for the governance of the Yellow River in the new period:

4.1 Implement comprehensive management of small hydrographic basins to reduce water and soil erosion.

The control and integral development of small hydrographic basins must be implemented. The governance of a small basin is based on the specific conditions of a certain basin according to the principle of optimized combination, and the above-mentioned individual water and soil erosion prevention technologies are scientifically configured in a certain structure to form a comprehensive system within the basin.

4.2 Make a scientific design.

A step-by-step implementation plan should be developed. Upper reaches of small watersheds should be closed for reforestation, and steep slopes should be gradually changed to terraces or converted to forest.

Cities, densely populated villages and areas where large tracts of agricultural land are protected will be renewed first. The second is according to the formation, convergence and development of the basin economy. Third, implement the technical approach of coordinating the allocation of small-scale soil and water conservation engineering measures, biological measures, and agricultural methods of water and soil conservation.

5. Conclusions

The ecological environment of the Yellow River basin is still very fragile and soil erosion in some typical or special areas has not been effectively controlled.

The water and sediment situation in the Yellow River Basin in the new period shows that the "excess sand" has been largely controlled, and the "insufficient water and sediment control capacity" has also been somewhat alleviated. The idea of solving the miscoordination of water and sediment in the Yellow River Basin in the new era lies in "increasing water, reducing sediment, and improving the regulation capacity of water and sediment."

In order to promote the ecological protection and high-quality development of the Yellow River basin, scientific and technological innovation is needed to systematically reveal the law of water and sediment changes in the basin and its effects. The conservation of water resources and their intensive use should be studied, flood control, sediment load regulation, and restoration technologies and protection of ecological corridors should be promoted.

References

[1] Hu Chunhong, Zhang Xiaoming. Control of soil erosion on the Loess Plateau and changes in water and sediment in the Yellow River [J]. Water resources and hydroelectric technology, 2020,51 (01): 1-11.

[2] Fu Guobin, Chen Shulin, McCool D K. Modeling the impacts of no-till practice on soil erosion and sediment yield with RUSLE, SEDD, and ArcView GIS[J]. Soil & Tillage Research, 2006, 85(1/2): 38-49.

[3] Beskow, S., Mello, C. R., Norton, L. D., Curi, N., Viola, M. R., & Avanzi, J. C. (2009). Soil erosion prediction in the Grande River Basin, Brazil using distributed modeling. Catena, 79(1), 49-59.

[4] Ouyang, W., Hao, F., Skidmore, A. K., & Toxopeus, A. G. (2010). Soil erosion and sediment yield and their relationships with vegetation cover in upper stream of the Yellow River. Science of the Total Environment, 409(2), 396-403.