The magnitude of soil erosion of small catchments with different land use patterns under an extreme rainstorm on the Northern Loess Plateau, China

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Research Background

The Loess Plateau is one of the most serious soil erosion areas in the world. Great efforts have been made in this area to reduce soil and water loss during the past decades. In particular, the Chinese government issued a policy named “Grain for Green (GFG)” in 1999. After more than 15 years of restoration and development, The land use over this area has been greatly changed. Soil erosion has been significantly weakened, and extensive dams are in the state of no soil to be deposited under non-storm rainfall conditions.

a.

b.

a. Vegetation coverage increased from 31.6 % in 1999 to 56.9 % in 2013

b. By the end of 2016, 59000 dams had been built on the Loess Plateau

Research Background

However

Whether the land use pattern in the catchment area can withstand the test of the extreme rainstorm ?

Is there any difference in the ability to resist rainstorm erosion between small catchments with different land use patterns?

We use this as a starting point

It chanced that, an extreme rainstorm event characterized by a short-duration and high-intensity occurred on July 26, 2017, in Wuding River of the northern Loess Plateau. The rainfall at Zizhou rainfall station (belong to Wuding River) was 206.6 mm, of which the maximum rainfall amount of 1 h (1:00-2:00 am on 26th) was 52.0 mm

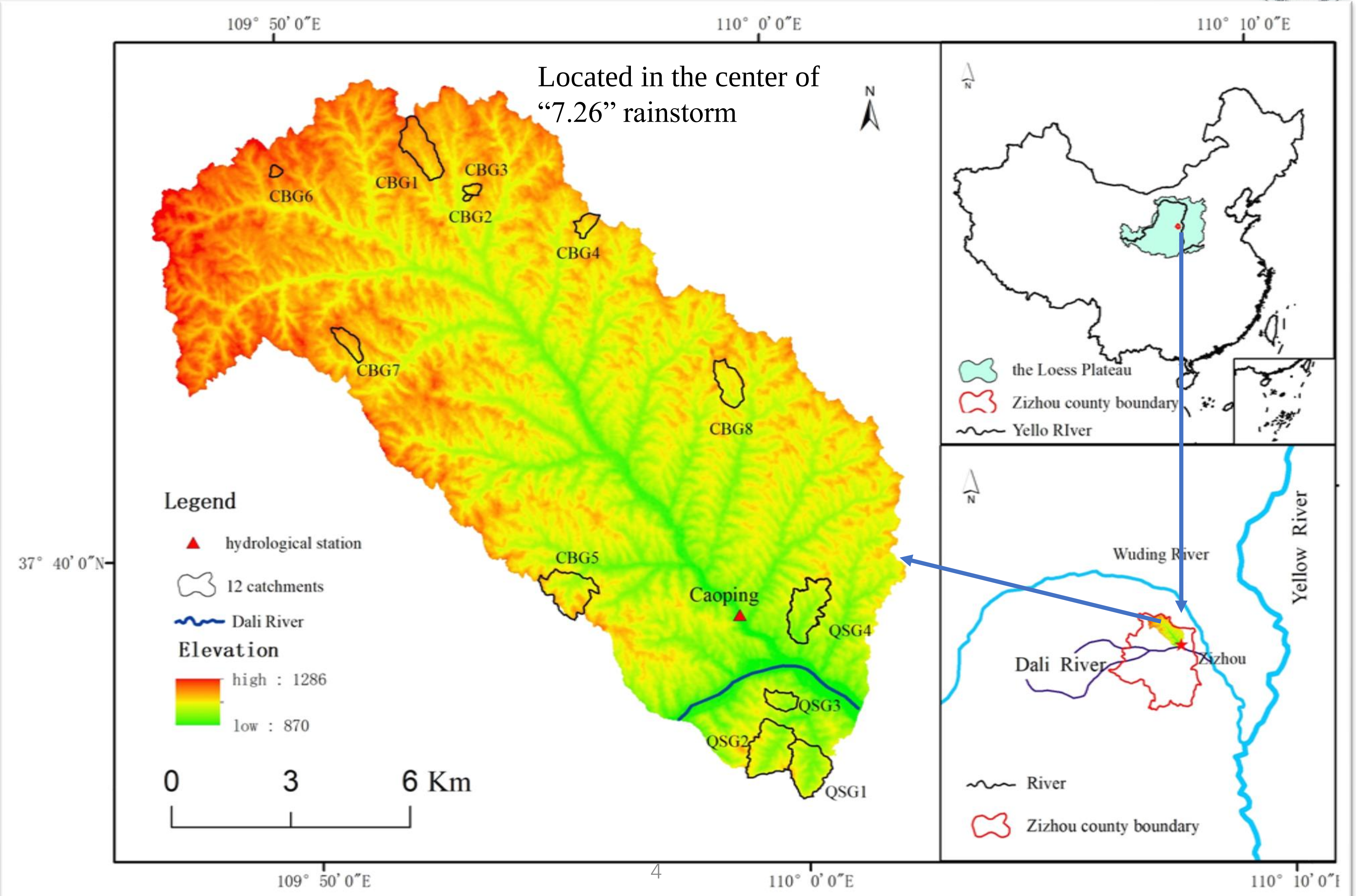
Study Area- Dam-controlled catchment

Selecting Principle：

1. Intact Dam body

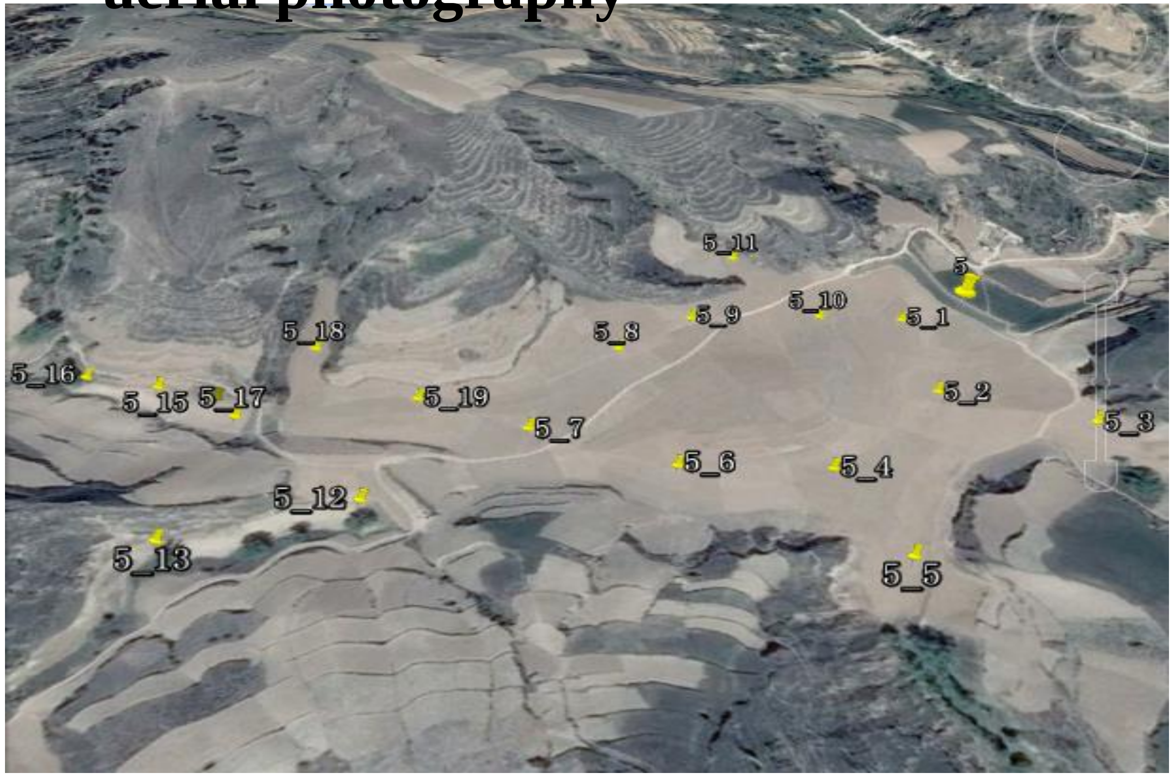
2. Land use patterns in the dam-controlled catchments vary

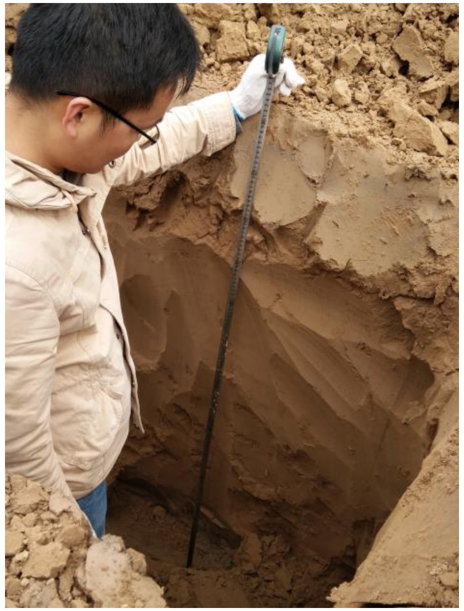
12 dam-controlled catchments were selected

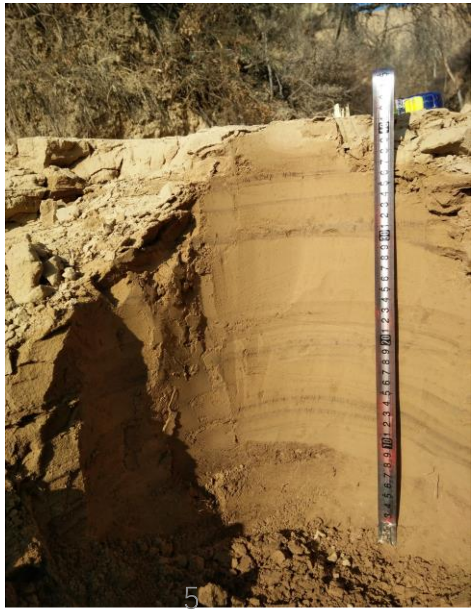


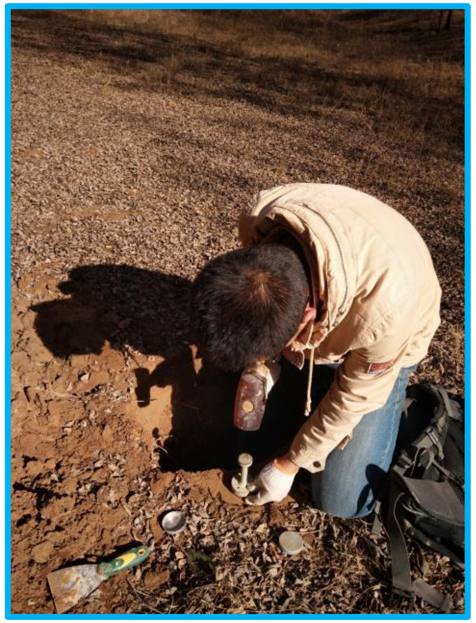
Field Work

1. Measurement of Sediment deposition depth
2. Measurement of Dam-land area
3. Unmanned Aerial Vehicle (UAV) aerial photography









Field Work

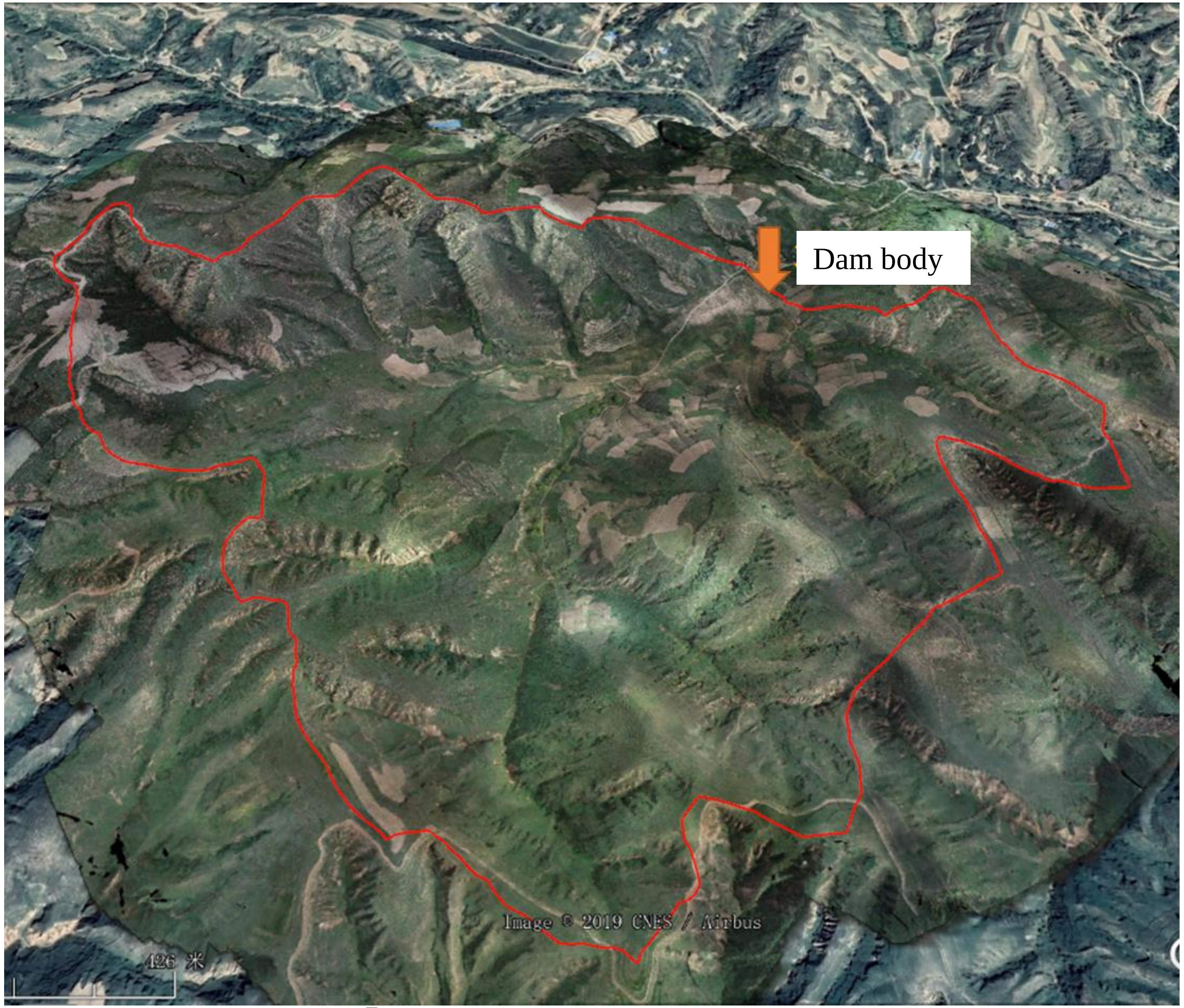
1. **Measurement of Sediment deposition depth**
2. **Measurement of Dam-land area**
3. **Unmanned Aerial Vehicle (UAV) aerial photography**

1.S86 RTK GPS measurement system

2.Distance between measuring points is 5 ~ 10 meters

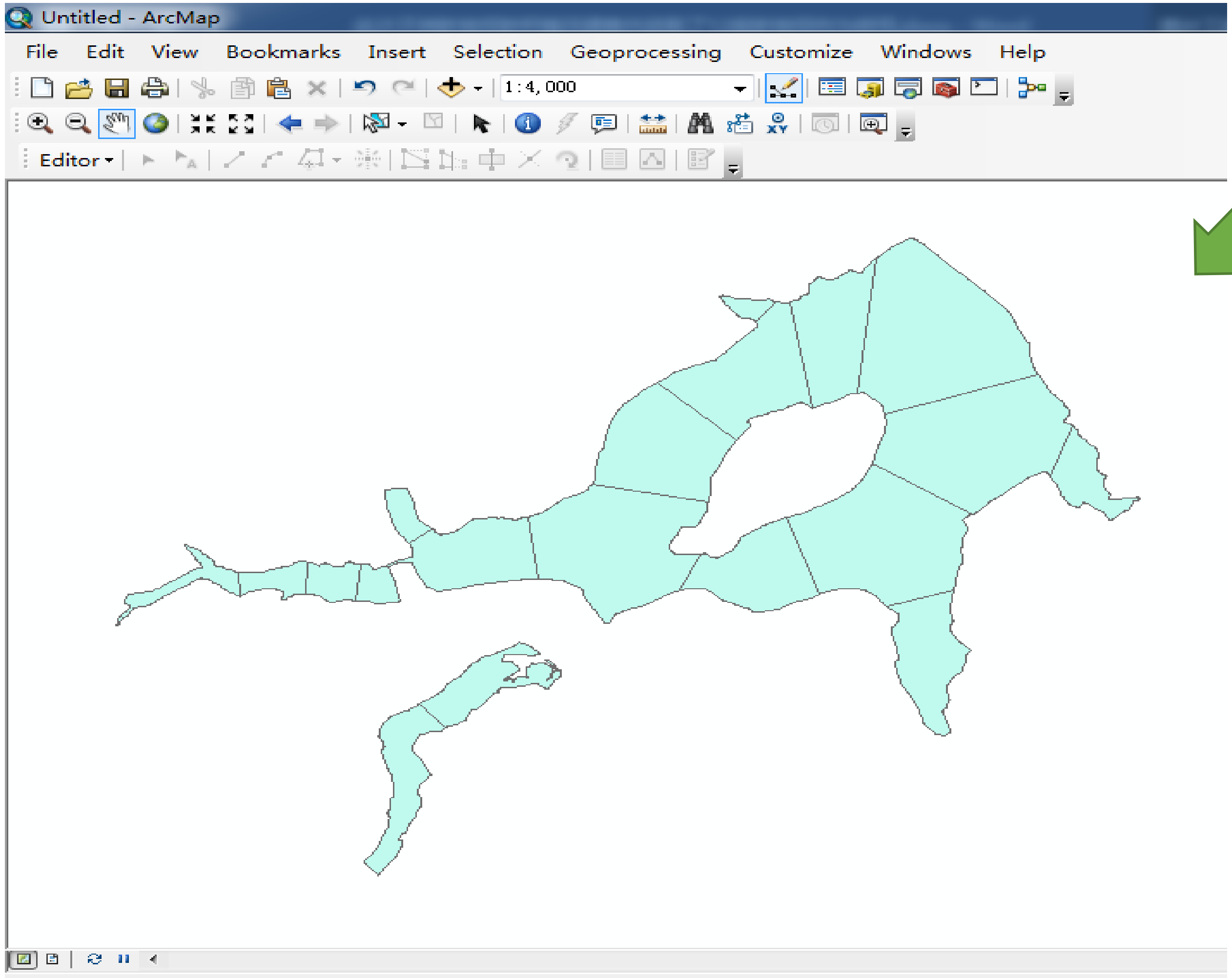
Field Work

1. **Measurement of Sediment deposition depth**
2. **Measurement of Dam-land area**
3. **Unmanned Aerial Vehicle (UAV) aerial photography**
   （DTM+DEM+DOM）



Data analysis and processing

Calculate the sedimentation amount in dam-land



$$M = \sum_{1}^{n} s_i \ \bar{h}_i \ \bar{\rho}b_i$$

Where M is the total amount of sediment deposition caused by "7.26" rainstorm in the dam-land (t), n is the number of section in the dam-land, s_i is the area of section i (m^2), $\bar{h}_i$ is the average deposition thickness of section i (m) $\bar{\rho}b_i$ is the bulk density of section i ($t \cdot m^{-3}$) (t/m^3)

Data analysis and processing

-Land use type and distribution extraction

DOM (July 2018)

《Land use status Classification》(GB/T 21010-2017)

field investigation

Grassland ;

Forestland ;

Terrace;

Slope cropland ;

Cement road;

(5)

\+

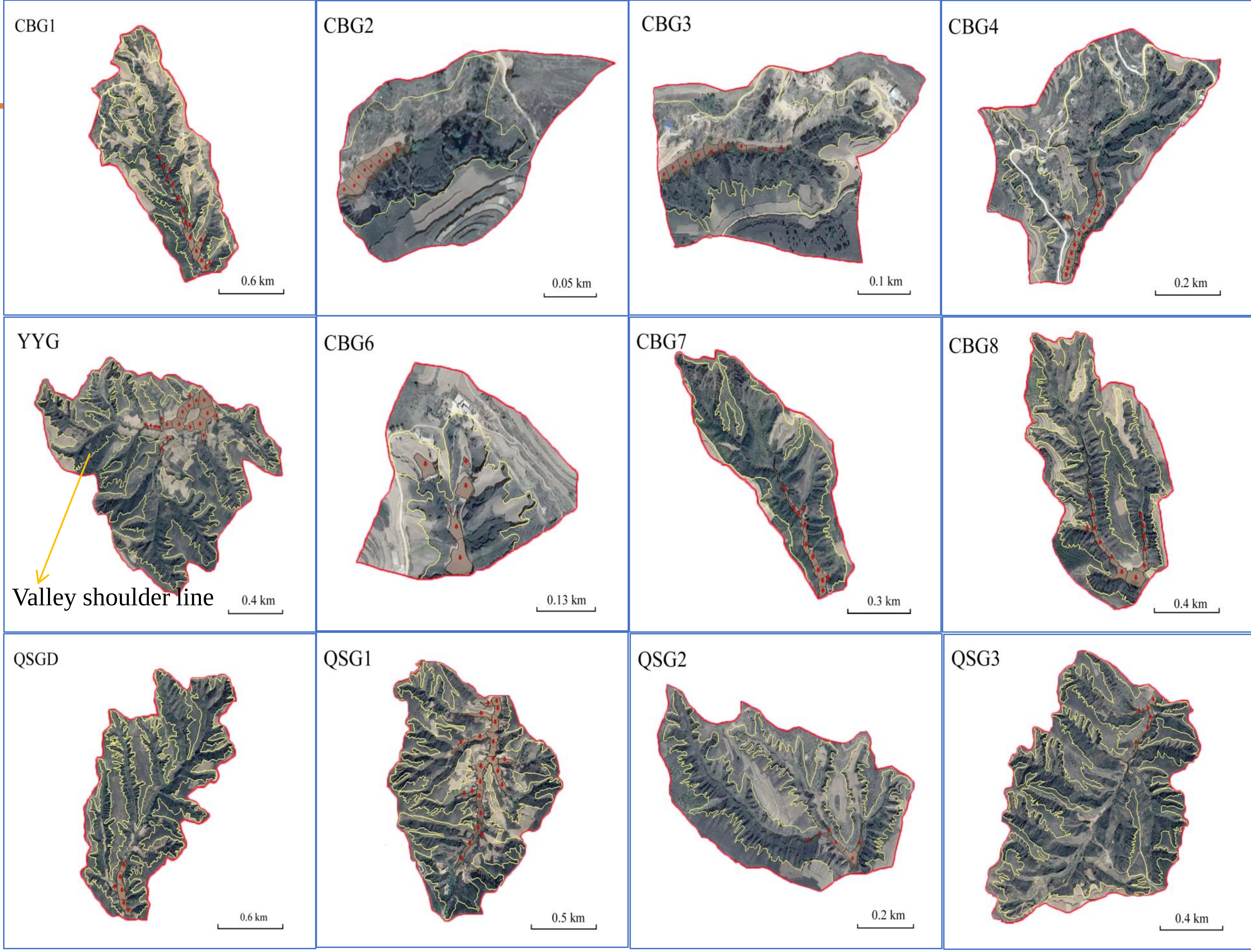
Land upper the valley shoulder lines;
Land lower the valley shoulder lines;

(2)

DTM

Slope gradient

length of flow concentration routes



Data analysis and processing

−Attempted to establish an index named land use distribution index (W)

W was used to indicate the relative distribution of a type of land use in the catchment (including area and location). A total of 10 W was obtained for each catchment.

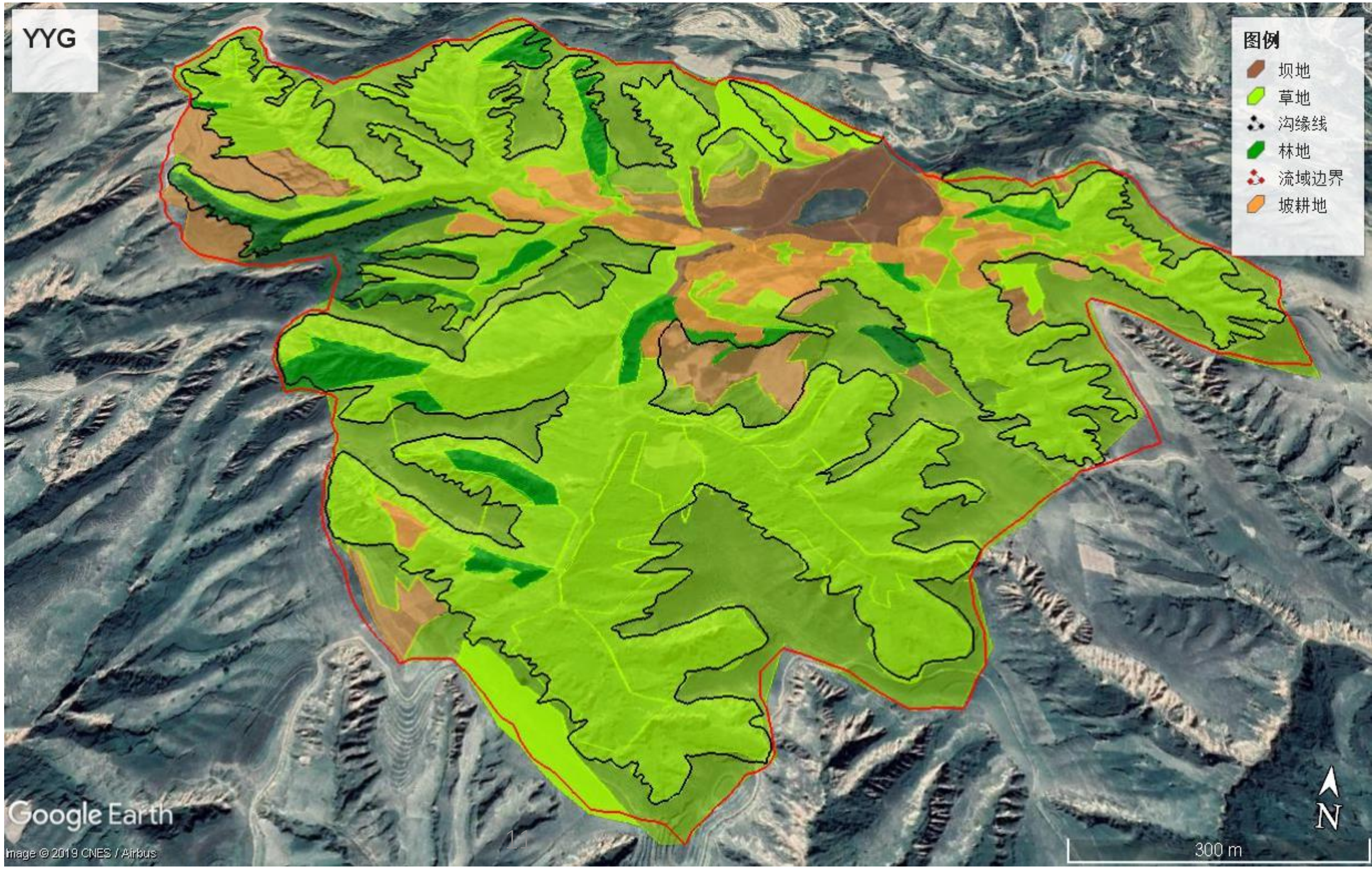
Land use distribution index W：

$$W_{x\text{-}y}=\sum_{i=1}^{n} P_i \times S_i \times 1/F_i$$

$$S_x = 10.8\sin\theta + 0.03 \qquad (\theta < 5^\circ)$$

$$S_x = 16.8\sin\theta - 0.5 \qquad (5^\circ \le \theta < 10^\circ)$$

$$S_x = 21.91\sin\theta - 0.96 \qquad (\theta \ge 10^\circ)$$



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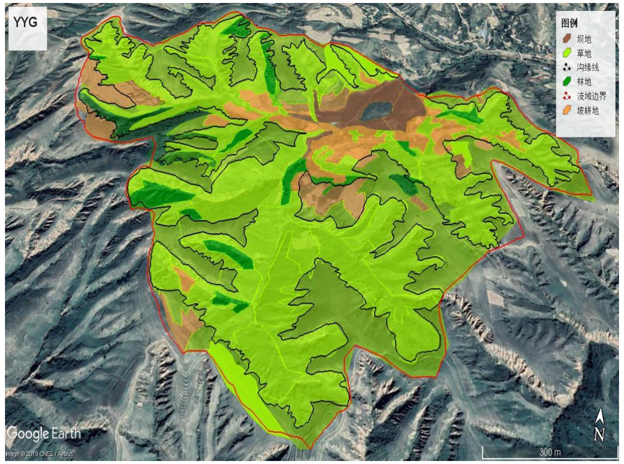


Where: x-y can take values of u-g, u-f, u-t, u-s, u-c, l-g, l-f, l-t, l-s, l-c.

u-g means the grassland in the upper part of the valleys shoulder line;

u-f means the forestland in the upper part of the valleys shoulder line;

u-t means the terrace land in the upper part of the valleys shoulder line;

u-s means the slope cropland in the upper part of the valleys shoulder line;

u-c means the cement road land in the upper part of the valleys shoulder line;

l-g means the grassland in the lower part of the valleys shoulder line;

l-f means the forestland in the lower part of the valleys shoulder line;

l-t means the terrace land in the lower part of the valleys shoulder line;

l-s means the slope cropland in the lower part of the valleys shoulder line;

l-c means the cement road land in the lower part of the valleys shoulder line;

n is the number of patches of a certain land use type in the catchment; P_i is proportion of patch i area to catchment area; S_i is average slope value of the patch i; F_i is mean distance from the patch i to the edge of the dam-land along flow direction.

Results

1. Sediment deposition in dam-lands

Sediment deposition in the dam-land

Dams	Catchment Area（km^2）	Deposition Thickness （m）			Dam-land Area (m^2)	The amount of sediment (t)
		Max	Min	Average		
CBG1	1.29	0.9	0.05	0.35	46563	21684
CBG2	0.04	0.29	0.05	0.16	1818	437
CBG3	0.14	0.27	0.04	0.17	5224	1343
CBG4	0.3	0.44	0.05	0.27	10639	3288
CBG6	1.54	0.59	0.03	0.33	5274	2398
CBG7	0.1	0.65	0.06	0.3	15633	6527
CBG8	0.44	0.8	0.05	0.51	32835	22883
QSG1	0.84	1.2	0.17	0.49	106080	76094
QSG2	1.53	2.26	0.15	1.67	6344	13262
QSG5	0.46	2.04	1.1	1.09	16145	24423
QSGD	1.83	0.93	0.35	0.76	30706	31790
YYG	1.57	2.4	0.05	0.83	67242	73192

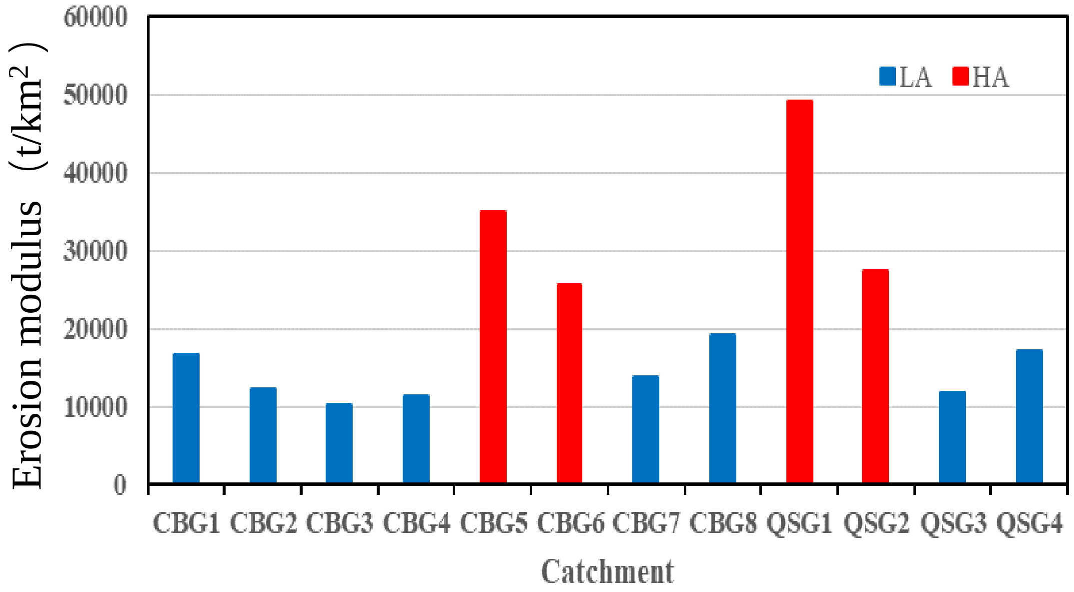
Average deposition thickness:

＜0.5 m	7 dam-lands
0.5 m~1.0 m	3 dam-lands
＞1 m	2 dam-lands

The average deposition thickness of sediment intercepted by 12 dams during “7.26” rainstorm was 0.48 m with soil bulk density 1.47 g·cm^{-3}.

Results

2. Soil erosion in dam-controlled catchments



The soil erosion modulus of the 12 catchments caused by “7.26” rainstorm was between 10295 t·km^{-2} ~ 49227 t·km^{-2} and the average erosion modulus was 20807.5 t·km^{-2}. Soil erosion caused by this rainstorm was 10~50 times of the soil loss tolerance on the Loess Plateau (1000 t km^{-2} year^{-1}) issued by Ministry of Water Resource of the People’s Republic of China (MWR).

Sediment deposition amount ÷ Catchment area= Erosion modulus (caused by “7.26” rainstorm)

Results

3. Influence of land use pattern on soil erosion at catchment scale

13 factors： 10 land use distribution index (W_{x-y}) + shape coefficient of catchment (K) + proportion of land area below valleys shoulder line in the catchment (P_l) + proportion of vegetation area in the catchment (P_v)

stepwise regression

$$E = -4378.15 + 60875.59\,K - 77183858.4\,W_{u\text{-}c} + 10512340.85\,W_{l\text{-}s}$$

Where E was the erosion intensity of the catchment in “7.26” rainstorm; K is the shape coefficient of catchment;

$W_{u\text{-}c}$ is the land use distribution index of cement road distributed above the valleys shoulder line;

$W_{l\text{-}s}$ is the land use distribution index of sloping farmland below the valleys shoulder line.

The result of stepwise regression shows that erosion modulus caused by “7.26” rainstorm was significant related with three variables, namely $W_{u\text{-}c}$, $W_{l\text{-}s}$, and K. (R^2=0.78, sig=0.005)

Conclusions

（1）The present land use pattern situation on northern Shaanxi province can’t effectively resist extreme rainstorm erosion.

（2） Slope cropland should be located on the inter-gully land of the catchment and the cultivation on the steep slopes below the valleys shoulder line should be forbidden. As well, it is the most suitable for the cement road with a drainage ditch to be located near the valleys shoulder line.

（3）Optimizing the distribution of land use types in catchments should be a focus for soil erosion control

Thank you!