Influence of Check Dams on Flood and Erosion Dynamic Processes of a Small Watershed in the Loss Plateau



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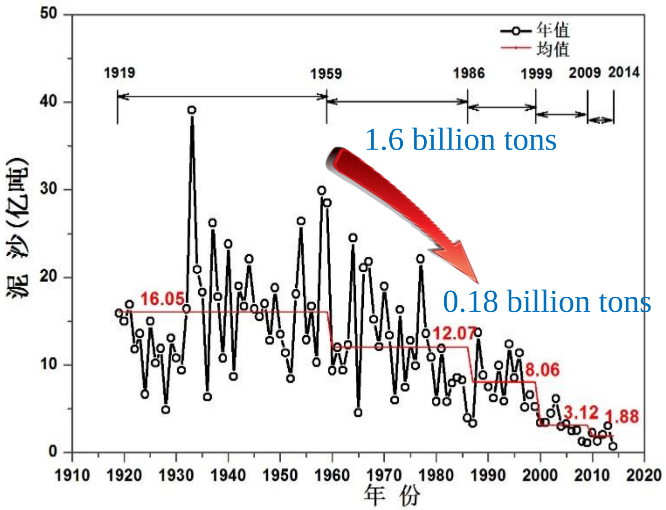
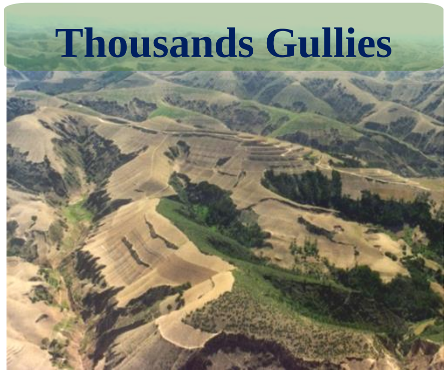
1 Introduction

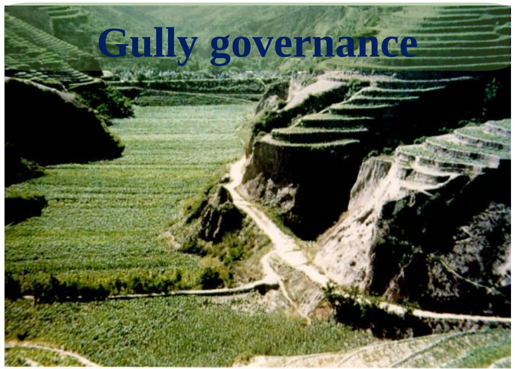
The Loess Plateau is the **main source area** of the Yellow River sediment, average contribution of 1.6 billion tons sediments per year, which of **more than 60%** are produced from the 6.67×10^5 eroded channels. Therefore, the channel governance is **vital** and **difficult**.

The check dam **intercept sediment** resulting in forming **dam farmland** at the same time, unifying the relationship between channel treatment and grain production, which is the **main measure for gully governance.**



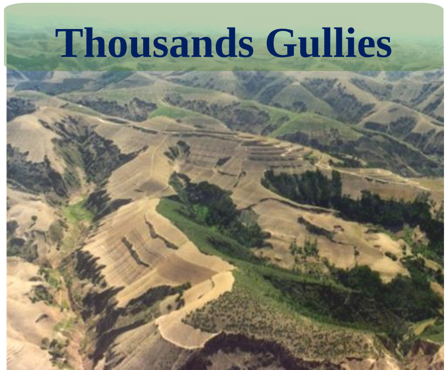
Variation of Yellow River sediments (Tongguan Hydrological station）

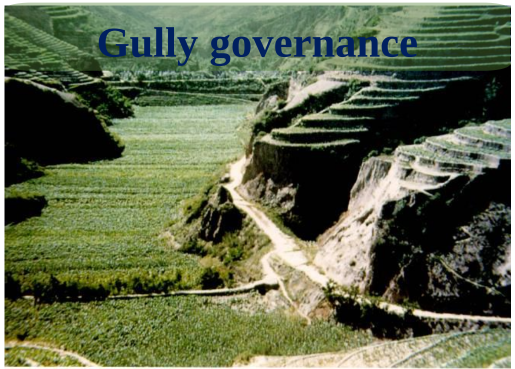




2 Objectives

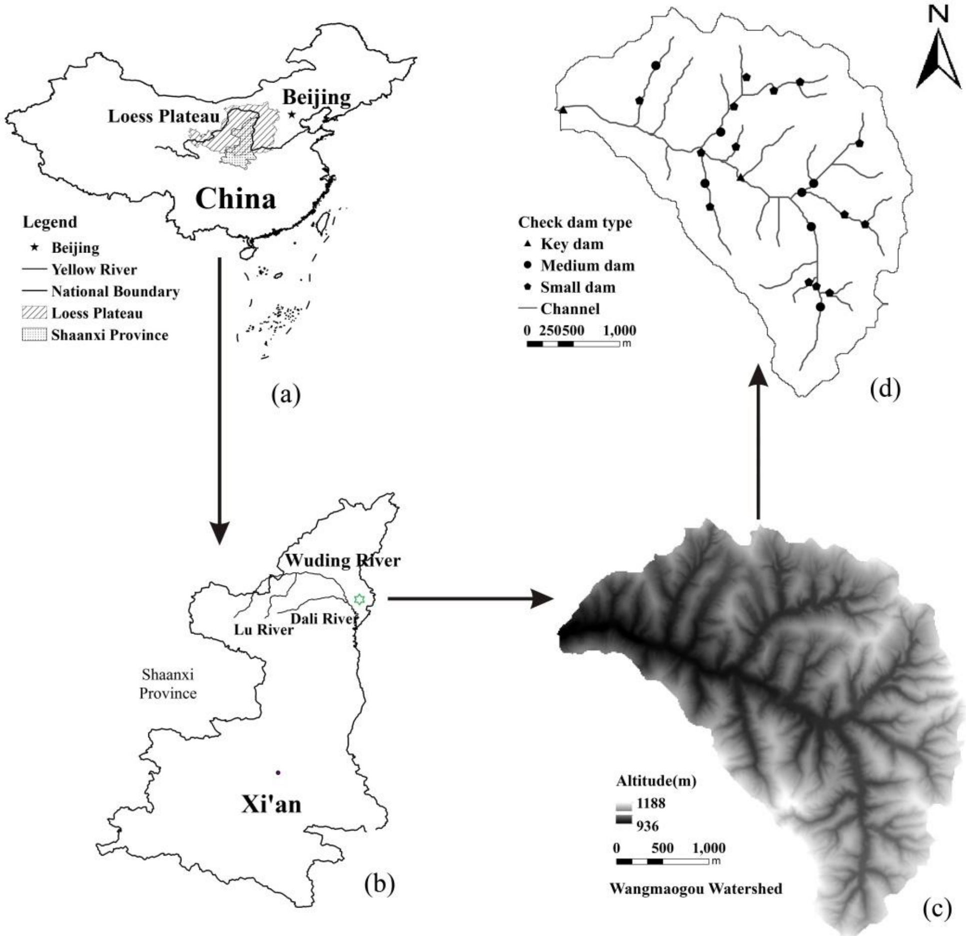
- Investigate the influence of different types of check dams and their combinations on the flood process of small watersheds;
- Explore the influence of different types of check dams and their combinations on the erosion dynamic processes in a small watershed;
- Calculate the sediment reduction benefit of different types of check dam combinations.





3 Data and Methods

3.1 Study Area

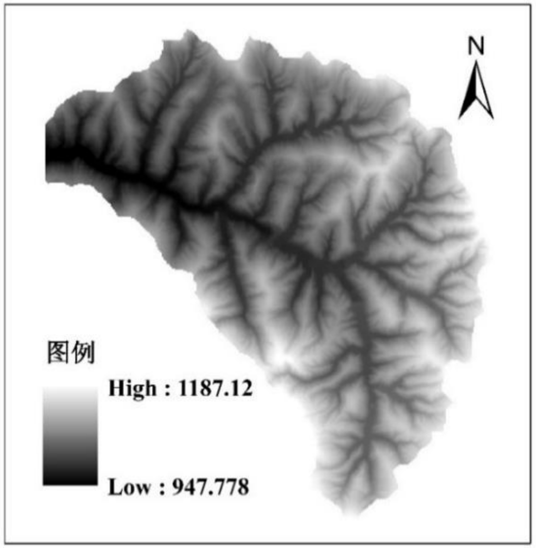


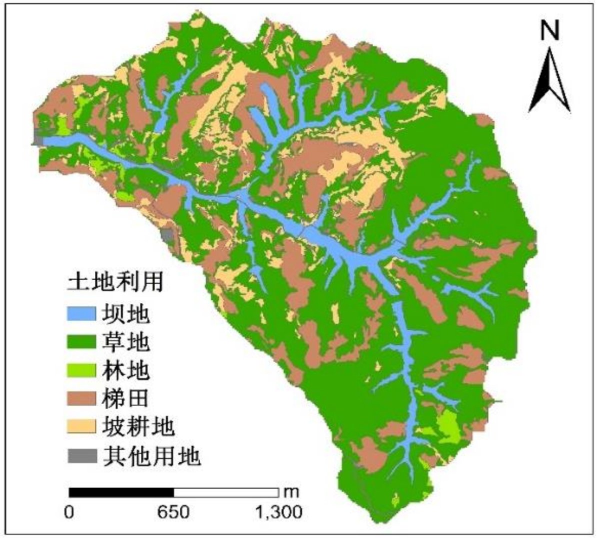
- The watershed covers an area of 5.97 km^2 . The main channel length is 3.75 km, and the average slope of the channel is 2.7% .
- The average annual temperature is 10.2 ° C and the mean annual precipitation is approximately 513 mm, more than 60% of which occurs between July and September.
- By the end of 2017, there were 23 normal check dams, including 2 key dams, 7 medium dams, and 14 small dams

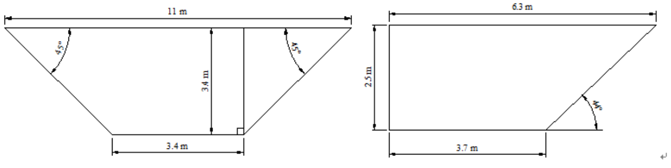
3 Data and Methods

3.2Data Sources

- The station monitor runoff and sediment data from 1962 to 1966, mainly including water level, discharge, sediment concentration, and sediment transport rate.
- The terrain data is obtained from the State Bureau of Surveying and Mapping. The geodetic reference is the 1980 Xi'an coordinate system, contour distance of which is 5 m.
- The land use data for the watershed was obtained from the land use survey of the Suide Supervision Bureau in 1960s.







a.王茂沟 1 号坝溢洪道断面

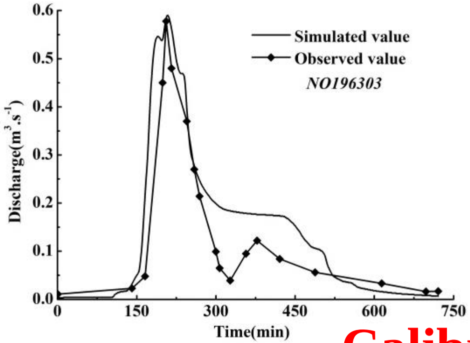
b.关帝沟 2 号坝溢洪道断面

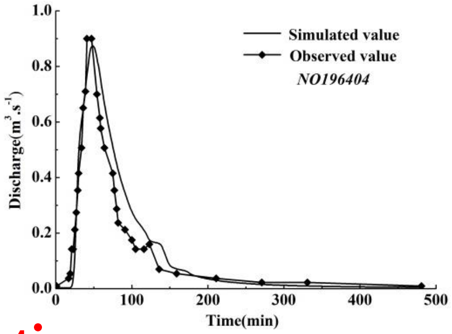
c.典型卧管示意图

d.典型竖井示意图

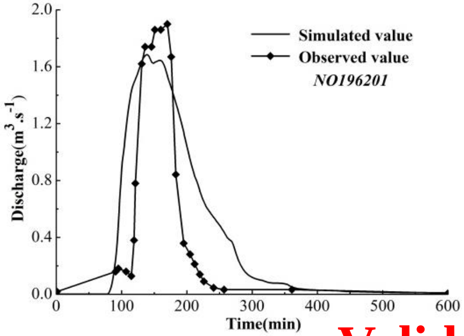
4 Results

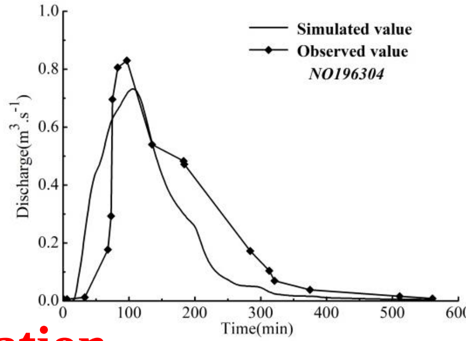
4.1 Model Effect Evaluation





Calibration





Validation

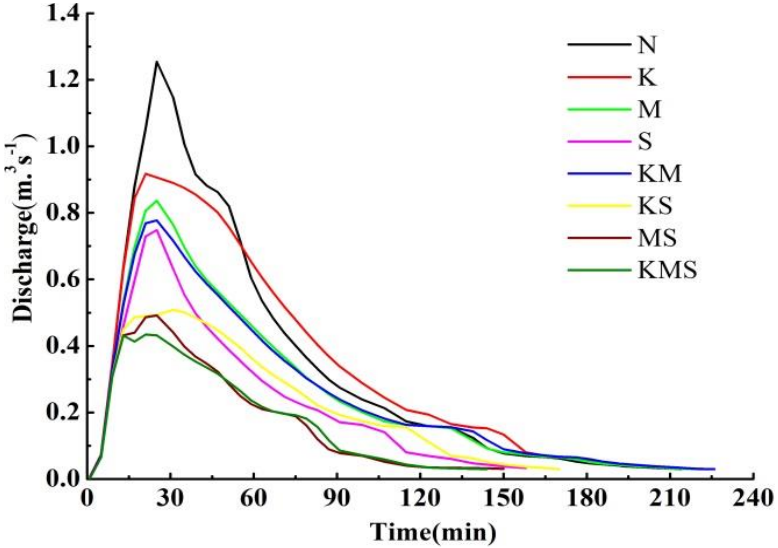
Stage	Flood number	Observed value ($m^3 s^{-1}$)	Simulated value($m^3 s^{-1}$)	Relative error/Re(%)	R^2	NSE
calibration	196303	0.58	0.59	1.72	0.90	0.80
	196404	0.90	0.87	3.33	0.88	0.85
validation	196201	1.90	1.69	11.05	0.72	0.60
	196304	0.83	0.73	12.05	0.72	0.71

The results showed that there is good agreement between the simulated runoff and the observed runoff in the calibration and validation periods. This model can be used to simulate the dynamic changes in the flood process.

4 Results

4.2 Variation Characteristics of Flood under Different dam type combination

Working conditions	Coding	Different dam type combinations in watershed
1	N	No dams
2	K	Only key dams
3	M	Only medium dams
4	S	Only small dams
5	KM	Key and medium dam combination
6	KS	Key and small dam combination
7	MS	Medium and small dam combination
8	KMS	Key, medium, and small dam combination

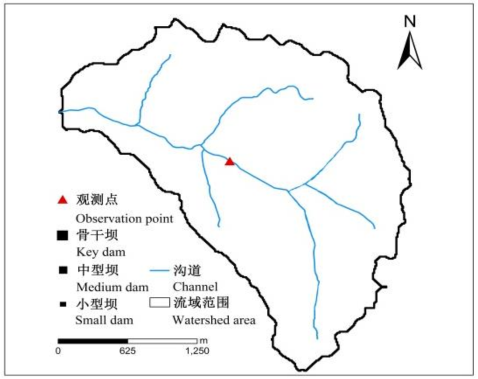


Flood characteristic parameters under different working conditions

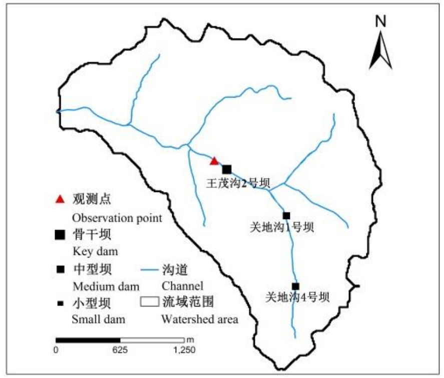
Working conditions	Flood peak discharge ($m^3\ s^{-1}$)	Flood peak reduction (%)	Flood volume (m^3)	Flood volume reduction (%)
N	1.26	-	4853.93	-
K	0.92	27.28	4828.87	2.18
M	0.84	33.39	3556.61	27.08
S	0.76	40.13	2541.04	44.89
KM	0.78	38.07	3532.24	27.37
KS	0.51	59.71	2518.06	45.15
MS	0.50	60.75	1802.36	58.42
KMS	0.44	65.34	1779.58	58.67

4 Results

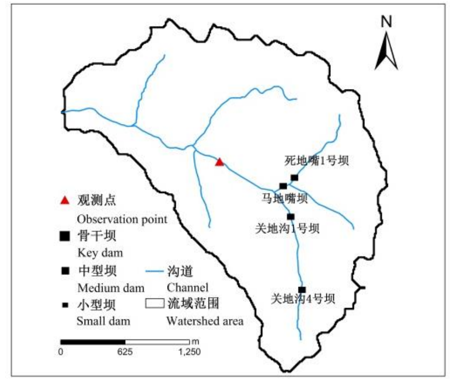
4.3 Variation Characteristics of Flood under different cascade



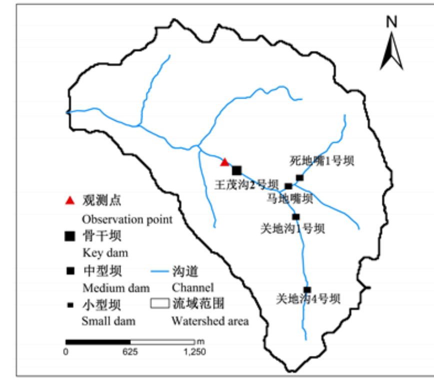
a. Not built dam



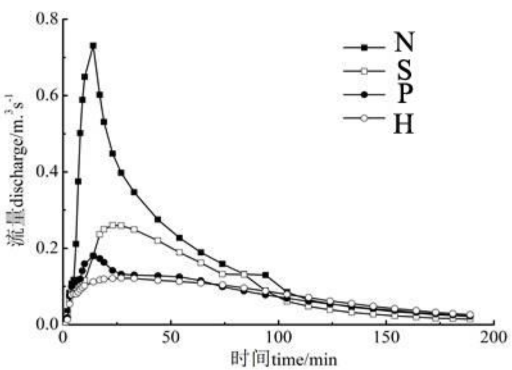
b. Series connection



c. Parallel connection



d. Hybrid connection

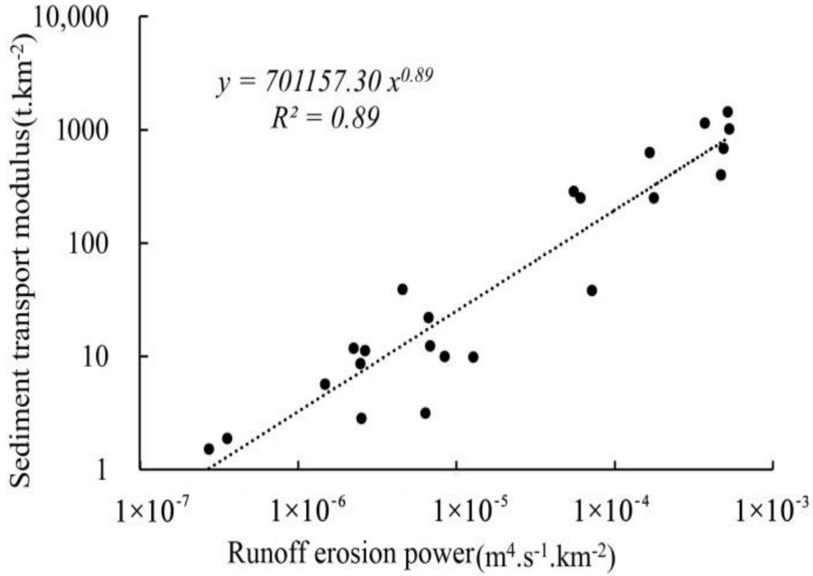


Working conditions	Flood peak discharge/$m^3 \cdot s^{-1}$	Flood peak reduction/%	Flood volume/m^3	Flood volume reduction/%
N	0.73	-	1882.89	-
S	0.26	64.30	1176.42	37.52
P	0.18	75.38	924.84	50.88
H	0.12	83.31	890.94	52.68

The flood peak and flood volume were significantly reduced under three cascading modes of series, parallel and hybrid connection of check dam system, in which the hybrid connection of dam system had the largest decrease amplitude, the parallel dam system took the second place and the series dam system was the last.

4 Results

4.4 Effect of Different Dam Type Combinations on Sediment Discharge



Working conditions	Runoff erosion power (m^4 s^{-1} km^{-2})	Sediment transport modulus (t .km^{-2})	Sediment transport modulus reduction (%)
N	1.72×10^{-4}	314.99	-
K	1.25×10^{-4}	237.07	24.74
M	8.38×10^{-5}	166.61	47.11
S	5.42×10^{-5}	113.04	64.11
KM	7.73×10^{-5}	155.03	50.78
KS	3.60×10^{-5}	78.65	75.03
MS	2.53×10^{-5}	57.41	81.78
KMS	2.20×10^{-5}	50.66	83.92

- **The sediment transport modulus of the watershed reached 314.99 t.km^{-2} under working condition N and 50.66 t/km^2 under working condition KMS, while the values of other working conditions fell between these. When compared to no dam construction, the sediment transport modulus was reduced by 83.92% after the dam system was completed.**
- **Compared with working condition N, working condition K, M, and S reduced the sediment transport modulus in the watershed by 24.74%, 47.11% ,and 64.11%, respectively, among which the sediment reduction benefit of small dams was the most obvious.**

5 Conclusions

- **The check dams reduced the flood peak and flood volume and mitigated the flood process, while different types of check dams played various roles in flood regulation. After the dam system was completed, the flood peak and flood volume were reduced by 65.34% and 58.67%, respectively.**

- **Check dam construction can effectively reduce the sediment transport capacity in the watershed. When compared with the absence of dams in the basin, the sediment transport modulus of the key, medium, and small dams was reduced by 24.74%, 47.11%, and 64.11%, respectively, with the largest amplitude reduction being observed for small dams. The benefits of sediment reduction are most obvious after the check dam system is completed, with the sediment discharge in the basin being reduced by 83.92%.**