Postprint of Remote Sensing Interpretation of Check Dams in the Wuding River Basin, Yulin Region, Shaanxi Province

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Abstract

Sediment check dams are one of the primary measures for soil and water loss control on the Loess Plateau, and clarifying important parameter information such as their distribution and scale is of great significance for watershed soil and water conservation research. Using remote sensing (RS) and geographic information system (GIS) technologies, combined with Gaofen-2 satellite imagery of the Wuding River basin in northern Shaanxi, field surveys, and collected data on sediment check dams in the study area, preprocessing was performed to obtain vector data, and interpretation criteria for sediment check dams were established through comparative analysis. Remote sensing interpretation was conducted for sediment check dams in the Wuding River basin of Yulin region, utilizing RS and GIS software to extract key information including dam number, dam location, water surface area, and control area, thereby obtaining the distribution status of sediment check dams across eight counties (districts): Dingbian, Jingbian, Mizhi, Suide, Hengshan, Yuyang, Zizhou, and Qingjian. The results show that a total of 1,257 suspected sediment check dam features were interpreted in the study area, including 60 in Yuyang District, 85 in Hengshan District, 65 in Dingbian County, 19 in Jingbian County, 470 in Mizhi County, 99 in Zizhou County, 316 in Suide County, and 143 in Qingjian County. This reveals that sediment check dams are mainly distributed in the gullies of four counties in the lower Wuding River region—Suide, Mizhi, Zizhou, and Qingjian—where farmland or water bodies commonly exist within the gullies. Comparative analysis between the distribution of sediment check dams and factors such as terrain, average annual rainfall, agricultural planting area, and geological hazards demonstrates that their distribution is correlated with these factors, manifesting as more sediment check dams in areas with dense gully networks, more sediment check dams in regions with smaller agricultural planting areas, and more sediment check dams in areas with larger ratios of average annual

rainfall to cultivated area. Consequently, the distribution patterns are summarized, providing important support for future maintenance and construction of sediment check dams.

Full Text

Remote Sensing Interpretation of Check Dams in the Wuding River Basin, Yulin Region, Shaanxi Province

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Abstract

Check dams represent a primary measure for soil erosion control on the Loess Plateau. Identifying their distribution, scale, and key parameters is essential for watershed conservation research. This study employs remote sensing (RS) and geographic information system (GIS) technologies, integrating GF-2 satellite imagery of the Wuding River Basin in northern Shaanxi with field surveys and collected data to preprocess and obtain vector data. Through comparative analysis, interpretation indicators for check dams were established. Remote sensing interpretation was conducted for check dams in the Wuding River Basin, Yulin region, extracting key information including dam count, location, water surface area, and control area across eight counties (districts): Dingbian, Jingbian, Mizhi, Suide, Hengshan, Yuyang, Zizhou, and Qingjian. The results identified 1,257 suspected check dam patches, distributed as follows: 60 in Yuyang District, 85 in Hengshan District, 65 in Dingbian County, 19 in Jingbian County, 470 in Mizhi County, 99 in Zizhou County, 316 in Suide County, and 143 in Qingjian County. Check dams are concentrated in the downstream reaches of the Wuding River within the gullies of Suide, Mizhi, Zizhou, and Qingjian counties, where cultivated land or water bodies commonly exist within the channels. Comparative analysis with topography, annual rainfall, agricultural planting area, and geological hazards reveals correlations: more check dams occur in deeply dissected areas, regions with less agricultural cultivation, and areas with higher ratios of rainfall to cultivated land. These distribution patterns provide important guidance for future check dam maintenance and construction.

Keywords: check dam; remote sensing interpretation; GF-2 satellite; Wuding River

Introduction

Check dams are hydraulic structures built across riverbeds or gullies in soil erosion areas, designed to control water flow and sediment transport while retaining sediment to create new land. With a history spanning over 400 years, their concept originated from ancient sedimentation ponds. Construction rapidly expanded from the mid-1950s to late 1970s alongside dam-building technological advances, and the Ministry of Water Resources' "Bright Spot Project" in 2003 further accelerated their deployment. During his 2015 inspection of Liangjiahe in northern Shaanxi, President Xi Jinping affirmed the significance of check dams for Loess Plateau management and agricultural development, noting they represent an effective watershed management approach that increases arable land while preventing soil erosion.

As a soil and water conservation engineering measure for gully control, check dams store water, reduce flood peaks, mitigate erosion, trap sediment, and create farmland through sedimentation, directly reducing river sediment input and holding an irreplaceable position in erosion control. Accurate data on dam count, water surface area, control area (the area enclosed by the watershed divide and dam cross-section), location, and spatial distribution are fundamental for scientifically analyzing their erosion reduction and sediment retention functions and for future planning.

Traditional manual statistical methods suffer from low efficiency and accuracy due to subjective and objective limitations, and cannot capture spatial distribution or dynamic changes. Remote sensing technology overcomes these constraints through large-area synchronous observation and strong timeliness, playing a crucial role in information extraction. However, check dams have small image footprints, and some natural earth piles or field ridges exhibit similar spectral characteristics. High-precision, sub-meter resolution imagery reduces interpretation difficulty and improves accuracy. This study integrates GF-2 satellite data to explore technical methods for check dam information extraction using Chinese high-resolution satellite remote sensing and GIS technologies, providing support for extracting key dam parameters.

1. Study Area Overview

The Wuding River Basin (elevation 600–1800 m, 37°14 –39°35 N, 108°06 –110°45 E) lies in the transition zone between the Loess Plateau and Mu Us Desert [Figure 1: see original paper]. Originating at the northern foot of Baiyu Mountain in Dingbian County, the upper reaches are called Hongliu River. After passing through Xinqiao in Jingbian County, it becomes the Wuding River, flowing into Inner Mongolia before re-entering Shaanxi at Longwan in Yulin and eventually discharging into the Yellow River at Hekou Village in Qingjian County. The main stream extends 491.2 km with a drainage area of 30,261 km^2 and average channel gradient of 2.04‰. Within Shaanxi Province, the river length is approximately 217.4 km with a watershed area of 21,737.53 km^2, representing 71.84% of the total basin area. The river flows through Yuyang, Jingbian, Mizhi, Suide, Hengshan, Dingbian, Zizhou, and Qingjian counties (districts) in Yulin City [Figure 2: see original paper], covering 73.9% of the total basin area. As a first-order tributary of the Yellow River and Yulin' s largest river, the Wuding River significantly influences soil erosion in northern Shaanxi and sediment transport to the Yellow River.

2. Data Sources and Processing

This study utilized GF-2 satellite imagery covering the Wuding River Basin in Yulin. GF-2 is China' s first sub-meter resolution wide-swath civilian remote sensing satellite, featuring high spatial resolution, multispectral imaging, high radiometric and positioning accuracy, long operational life, and multi-angle imaging capabilities. The panchromatic band achieves 0.8 m resolution, while multispectral bands (blue: 0.45–0.52 m, green: 0.52–0.59 m, red: 0.63–0.69 m, near-infrared: 0.77–0.89 m) provide 3.2 m resolution. This high resolution enables precise identification of dam bodies, water areas, gullies, and slopes. With a 69-day revisit cycle and approximately 2-month coverage interval for the study area, the data provide rich multi-temporal information for seasonal feature comparison and improved extraction accuracy.

Original GF-2 data underwent orthorectification, fusion, clipping, mosaicking, and geometric correction before check dam extraction [Figure 2: see original paper]. All images had less than 5% cloud cover, as shadows complicate dam identification.

3. Results

3.1 Remote Sensing Interpretation of Check Dams

Establishing distinct interpretation indicators is crucial for rapid and accurate check dam information extraction. GF-2' s sub-meter resolution reveals clear ground object details. Through image interpretation and field verification, we identified different architectural characteristics and distribution patterns. Building on previous research, we established direct interpretation indicators by analyzing color, texture, pattern, size, morphology, image structure, and roughness of check dams in remote sensing imagery. Indirect indicators were developed by analyzing relationships between dam features and topography, environment, vegetation, and differences from natural or artificial slopes.

Based on these indicators, we conducted visual interpretation (direct interpretation and comprehensive analysis) combined with computer image processing to extract location, coordinates, area, latitude/longitude, water surface area, type, and scale of check dams in the Yulin county-level watersheds. After interpretation, 125 patches were randomly selected for field verification, representing 10% of the total. Verification confirmed 1028 check dam patches, yielding approximately 81.78% accuracy. Misinterpreted patches were primarily natural earth piles and field ridges with similar spectral characteristics.

A total of 1,257 suspected check dam patches were interpreted, covering 1,145.06 hm^2 in water area and 349.58 hm^2 in control area . Interpretation indicators were established for four types: bilateral sedimentation, unilateral sedimentation, unilateral water body, and bilateral mixed types . Check dams typically appear as dam-like structures in gullies, wider at the bottom than the top, with at least one side featuring sedimentation land, cultivated land, or water. Multiple dams may exist in a single gully, with regular, flat sedimentation land or water surfaces in the channel [Figure 3: see original paper].

3.2 Distribution Characteristics

Check dams were classified by area: large (>6.67 hm^2), medium (3.33-6.67 hm^2), and small (<3.33 hm^2). Interpretation identified 79 large dams (6%), 228 medium dams (18%), and 950 small dams (76%). Check dams are concentrated in downstream areas of Mizhi, Suide, and Qingjian counties [Figure 4: see original paper], totaling 1,028 patches (81.78%) and 233.84 hm^2 (73.88%). Large and medium dams are predominantly located in Mizhi County, with 48 large dams (60.76%) and 94 medium dams (41.23%).

Comparative analysis with annual rainfall, population, geological hazard monitoring points, and crop cultivation area reveals several patterns [FIGURE:5, FIGURE:6]: (1) Check dam distribution partially correlates with geological hazard monitoring points—counties with more monitoring points (Mizhi, Zizhou, Qingjian, Suide) have more check dams; (2) Distribution inversely correlates with population—less populated areas have more dams; (3) Distribution inversely correlates with crop cultivation area—areas with less cultivated land have more dams; (4) Distribution positively correlates with annual rainfall—higher rainfall areas have more dams; (5) Distribution positively correlates with the rainfall-to-cultivation area ratio—higher ratios indicate more dams.

These relationships reflect that: (1) In counties with extensive cultivated land, sufficient farmland reduces agricultural demand for check dams, whereas limited farmland increases demand; (2) Areas with high rainfall-to-cultivation ratios have greater precipitation, smaller per capita area, potentially rugged terrain, and higher flood risk, increasing dam demand; (3) Check dams provide geological hazard protection, so hazard-prone areas have more dams.

4. Conclusions

This study developed a technical framework for check dam interpretation in the Wuding River Basin using domestic GF-2 data. Key findings include:

1) Multiple check dams may exist along a main gully and its tributaries, converging in the main channel. Interpretation indicators show regular, flat cultivated land or water surfaces within gullies. Gullies without such features likely lack check dams. Future work should increase field verification samples and refine interpretation indicators based on ground features.

2) Check dam concentration in the Wuding River' s downstream relates to topography. Upstream areas in Dingbian and Jingbian counties have relatively flat terrain, including the southern edge of the Mu Us Desert, with fewer gullies and lower dam demand. Downstream areas in Mizhi

and Suide counties feature extensive loess hill-gully regions where human activities concentrate in gullies, necessitating numerous check dams for production and life safety protection.

3) Distribution correlates with agricultural development, climate, and geological hazards. Areas with less cultivated land, higher rainfall, and frequent geological hazards show greater check dam density, reflecting demand for agricultural land creation and disaster mitigation.

This research demonstrates that high-resolution GF-2 satellite imagery combined with GIS technology provides an effective method for large-scale check dam investigation, offering technical support for soil erosion control, geological disaster prevention, and agricultural development planning in the Loess Plateau.

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