Study on Soil and Water Erosion of Xiang Xi Watershed Based on 3S Dynamic Monitoring

Ying Jiang, Da Xiang Xiang, Zhe Li, Xiong Fei Wen, and Xi Chi Chen

***Abstract*—3S technology is the effective method to carry out the dynamic monitoring of soil and water erosion. The paper select XiangXi watershed as the study region. Firstly, extracting erosion factors like vegetation coverage, land-use types and slop information, then conducting spatial overlay analysis to extract distribution of soil erosion intensity. Finally, analysing the change tendency by using transfer matrix to provide basic data for soil and water conservation. Results suggested that the intensity of soil erosion was getting better from 2016 to 2017, the Micro-degree and Slight-degree were slightly increased, the Medium-degree and Dought-degree were slightly reduced, the Extrem-degree and Vigorous-degree were alleviated.**

***Index Terms*—Soil and water erosion, dynamic monitoring, 3S technology, transfer matrix.**

I. Introduction

Soil and water erosion is the principal factor for the decline of cropland productivity and the deterioration of ecological environment, which is closely related to the precipitation erosion, topographic and engineering excavation, land cover changes. Traditional monitoring method usually adopted artificial survey including statistical investigation and ground observation etc, which have high accuracy but time-consuming and low-automation, also cannot dynamic monitor for a wide range [1]. As the key technology in the global satellite monitoring system, 3S provide a new approach for soil erosion investigation, of which GPS have high precision and strong portability, RS have real-time performance, while GIS have powerful storage, calculate and analyze function. These unique advantages can effectively improve the accuracy of dynamic monitoring. 3S technology has been widely applied in engineering practices in recent years. Haboudane *et al* [2] combined the RS with GIS to reveal the erosion spatial distribution by establishing the degradation and soil erosion map of Guadalentin basin. Zhao PengXiang *et al* [3] proposed a solution on watershed returning farmland to forest based on 3S technology, which improved the efficiency of small watershed dynamic monitoring. Xu Feng *et al* [4] took Hydropower station as example to introduce the key steps of development and construct project monitoring by using 3S technology, results showed that the method can effectively obtain accurate erosion date and surface disturbance area.

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The authors are with Changjiang River Scientific Research Institute, Wuhan, China (e-mail: 496396225@qq.com).

Although 3S technology has become an effective measure to monitor the soil and water erosion, the efficiency interpretation and accuracy of erosion monitoring still need improvement in actual application.

II. Methodology

A. The Regional Overview

The paper select XiangXi watershed flowing through ZiGui country as study region,which occupied area above 99.92 km^2. It's the first tributary of the Three Gorges Dam, and belongs to subtropical zone continental monsoon climate, which summer longer than winter and abundant in natural resources. XiangXi watershed exist a series of ecological environment problems like soil and water erosion, flood disaster or environmental degradation in the process of economic development, it's necessary to carry out relevant relevant regulation measures. The location of XiangXi watershed is shown in Fig. 1.

Fig. 1. Geographic location of study region.

B. Technical Roadmap

The datasource including multi-temporal remote sensing images of GF1. Soil and water erosion factors such as vegetation coverage, land-use type, human-caused erosion. Topographic slope factor like 1:50 000 DEM provided by Geospatial Data Cloud Website [5].

The technical roadmap can be described as follows. Firstly, conducting spatial overlay analysis based on Arcgis to generate water and soil erosion intensity map of different temporal towards vegetation coverage, land-use type and slop data. Then calculating the erosion area by statistical function. Finally, constructing change transfer matrix to analyze the dynamic changes of various erosion area. The overall technical route is shown in Fig. 2.

III. Erosion Factor Extraction

A. Land-Use Information Extraction

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Classifying the land-use patters into 12 first-class and 57 second-class by adopting standard specifications of GB/T 21010-2007, SL592-2012 *et al*. Classification standard was shown in Table I.

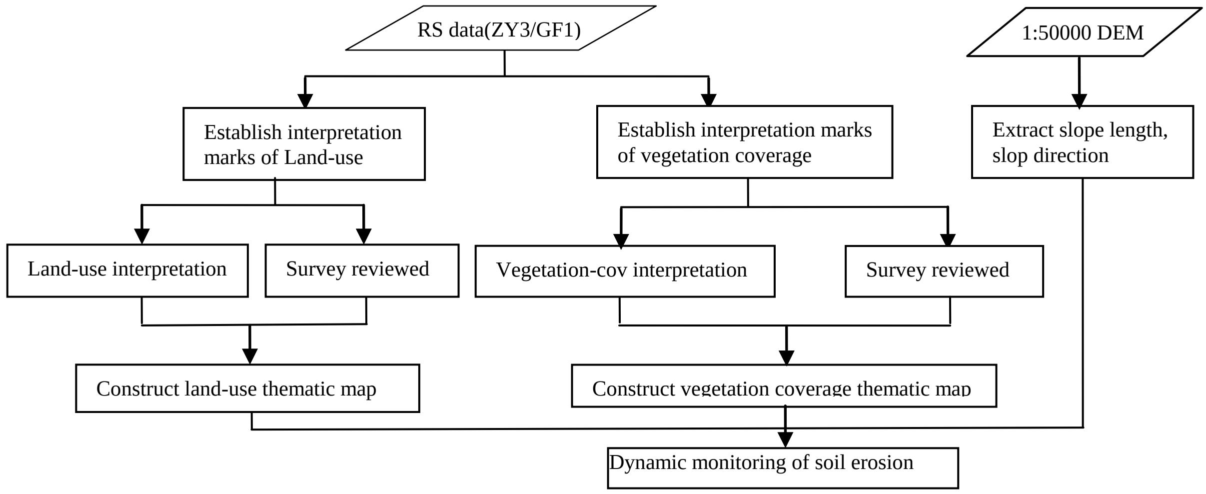

Fig. 2. Framework of Soil erosion dynamic monitoring.

TABLE I: CLASSIFICATION STANDARD OF LAND-USE

First-class	Second-class	BGF-code	Temp-code
Farmland	Paddyland	11	11
	Dryland	16	160
		17	17
Gardenland	Orchard or tea	23	211~235
Forestland	Forest	30	31~35
Grassland	Grass	40	41~45
	Shrub	90	91~95
Commercial- land	Settlement	52	52
	Industrialland	53	531,532
Transportation	Railway/road	60	61~66
Waters	River/reservoir	70	70~74
Other land	Bare land	80	84~88

The land-use types extraction results of 2016 to 2017 were shown in Fig. 3.

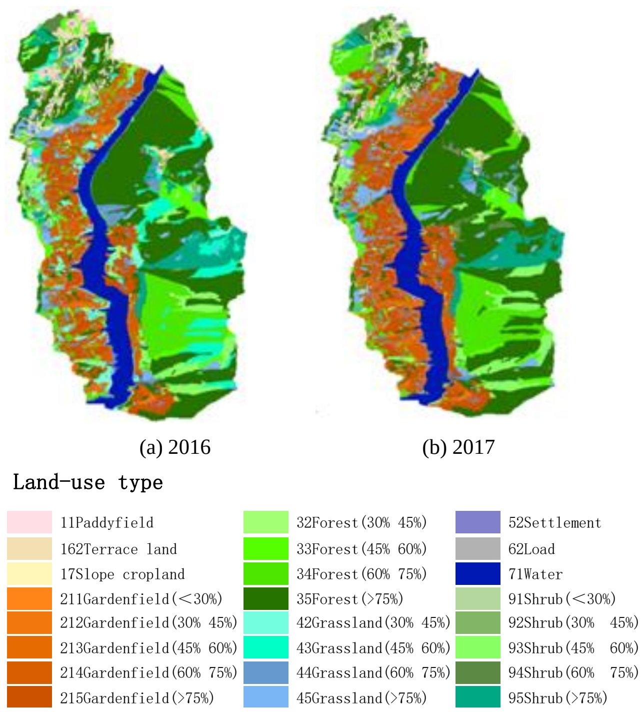

Fig. 3. Extraction results of Land-use type in 2016 and 2017.

The change results were shown in Table II. Statistical results shown that the land-use pattern was slightly structural adjustment from 2016 to 2017, the revegetated grassland was biggest decreasing magnitudes, which hold the line with the increasing magnitudes of forestland and gardenland. It reflected the tendency of reclamation and afforestation. Industrial and traffic land increased slightly, mainly derived from farmland conversion, while two periods of river and bareland kept flat, it was also consistent with the local water conservation measures and field reconnaissance.

TABLE Ⅱ: CHANGE AREA OF LAND USE TYPE IN THE STUDY REGION

Land use	BGF code	2016 Area	2017 Area	Change Percentage
Dryland	16	4.04	3.07	-0.98%
Slopeland	17	0.30	0.19	-0.11%
Garden	23	16.91	21.21	4.31%
Forest	30	41.97	44.89	2.92%
Grass	40	14.13	6.39	-7.74%
Shrub	90	11.50	12.48	0.98%
Settlement	52	1.11	1.28	0.17%
Indusland	53	0.19	0.22	0.03%
Road	60	0.80	1.13	0.33%
River	70	8.94	8.95	0.01%
Bareland	80	0.05	0.12	0.07%

B. *Vegetation Coverage Information Extraction*

Vegetation coverage is the main indicator to affect soil erosion [6]. Adopting interactive visual interpretation based on standard of SL 592-2012 [7] to extract vegetation coverage information, and to calculate variation of vegetation cover by using Arcgis. The extraction results of 2016 to 2017 were shown in Fig. 4.

TABLE III: RESULTS OF VEGETATION COVERAGE IN STUDY REGION

vegetation coverage	2016 Area	2017 Area	Changes	
			Variation	Percentage
High-cov	35.75	42.24	+6.49	+9.60%
Moderate-High	13.37	15.54	+2.17	+3.21%
Moderate-cov	13.04	8.23	-4.80	-7.11%
Low-Moderate	5.28	1.50	-3.79	-5.60%
Low-cov	0.16	0.09	-0.07	-0.10%

The vegetation coverage results of 2016 and 2017 were shown in Table III. Result shown that in 2017, High coverage increased 6.49 km^2 accounted for 9.6%, while Moderate-High coverage increased 2.17 km^2 accounted for 3.21% compared with 2016, which were mainly transformed from Moderate coverage and Low-Moderate coverage. It reflected the tendency of better ecologica environment.

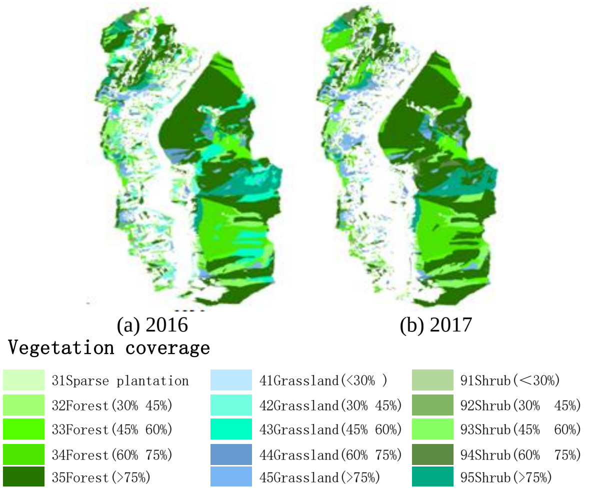

Fig. 4. Vegetation coverage results in 2016 and 2017.

C. Slope Information Extraction

Terrain is the basic natural geographical factor and can effect human production, which is mainly including slope length, slope shape and slope direction. In general, the more complex the terrain, the worse the water loss [8]. Slop is closely related to soil erosion, which is not only the main factor to affect soil erosion, but also the key determinant of slope surface erosion. The conventional method including percentage and degree method. The slope formula based on small watershed was shown as below.

$$S=\begin{cases}10.8\sin\theta+0.03 & \theta<0.5^{o}\\ 16.8\sin\theta-0.5 & 0.5^{o}\le\theta<10^{o}\\ 21.9\sin\theta-0.03 & \theta\ge10^{o}\end{cases} \quad (1)$$

Slop was divided into 6 level,including(0°5°],(5°8°],(8°15°],(15° 25°],(25° 35°], >35° according to the Technical Specification of Soil and Water Conservation. The slope classification was shown in Table IV.

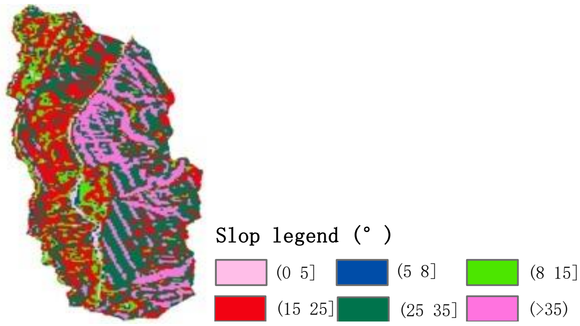

Fig. 5. Slop distribution results.

The paper generated slope map by using 1:50 000 DEM, then resampling to normalize scale. The result was shown in Fig. 5.

Statistics results of different slope was shown in Table V. The terrain were flat relatively, of which mainly belong to alpine foothills. Flat slope (0°5°] account for 2.10%, Gentle slope (5°8°] account for 2.34%, Continental slope(8°15°] account for 11.65%, Abrupt slope (15° 25°] account for 31.95%, Steep slope(25°35°] account for 34.03%, Slippery slope (>35°) account for 17.93%.

TABLE IV: CLASSIFICATION TABLE OF SLOPE

	Flat slope	Gentle slope	Continental slope	Abrupt slope	Steep slope	Slippery Slope
gradient (°)	(0 5]	(5 8]	(8 15]	(15 25]	(25 35]	>35

TABLE V: STATISTICAL RESULTS OF GRADIENT

Gradient(°)	(0 5]	(5 8]	(8 15]	(15 25]	(25 35]	(>35)
Area/km^2	2.05	2.29	11.41	31.29	33.33	17.56
Percentage (%)	2.10	2.34	11.65	31.95	34.03	17.93

IV. ANALYSIS OF SOIL EROSION

A. Soil Erosion Intensity and Spatial Distribution

The distribution of soil erosion intensity were divided into 6 categories, including Micro-degree, Light-degree,Medium-degree, Dought-degree, Extrem-degree, Vigorous-degree according to the Classification criteria of Soil Erosion (SL190-2007) [9] and basic research of Zhao Shanlun *et al* [10], Zhang Yubin *et al* [11]. The distribution were shown in Table VI and Table VII.

TABLE VI: SOIL EROSION CLASSIFICATION STANDARD

Forest coverage	Soil erosion degree of Different Gradient					
	(0°5°]	(5° 8°]	(8° 15°]	(15° 25°]	(25° 35°]	>35°
>75(%)	Micro	Micro	Micro	Micro	Micro	Micro
60-75(%)	Micro	Slight	Slight	Slight	Medium	Medium
45-60(%)	Micro	Slight	Slight	Medium	Medium	Dought
30-45(%)	Micro	Slight	Medium	Medium	Dought	Extrem
<30(%)	Micro	Medium	Medium	Dought	Extrem	Vigorous
cropland	Micro	Slight	Medium	Dought	Extrem	Vigorous

Overlaying the land-use, vegetation coverage and slop map to extract soil erosion intensity of XiangXi watershed during 2016 to 2017, the extraction results were shown in Fig. 6. Statistical results shown that the soil and water erosion was given priority to Micro-degree, Slight-degree, Medium-degree, of which Micro-degree occupied largest area, Slight-degree mainly distributed in the central depression area, Medium-degree mainly distributed in south-central. While Dought, Extrem and Vigorous-degree occupied less area, which mainly distributed in the steep mountains, the bareland.

TABLE VII: OTHER TYPES OF SOIL EROSION CLASSIFICATION STANDARD

Land-use type	Soil erosion degree of Different Gradient					
	(0 °5 °]	(5 ° 8 °]	(8 ° 15 °]	(15 °25 °]	(25 °35 °]	>35 °
Water/ Facilities	Micro	Slight	Slight	Slight	Medium	Medium
Terracing/Paddyfield	Micro	Slight	Slight	Medium	Medium	Dought
Settlement/ Transport	Micro	Slight	Medium	Medium	Dought	Dought
Construction/ Shoals	Micro	Slight	Medium	Dought	Dought	Extrem
Bare soil/ Bare rock	Slight	Slight	Medium	Dought	Extrem	Vigorous

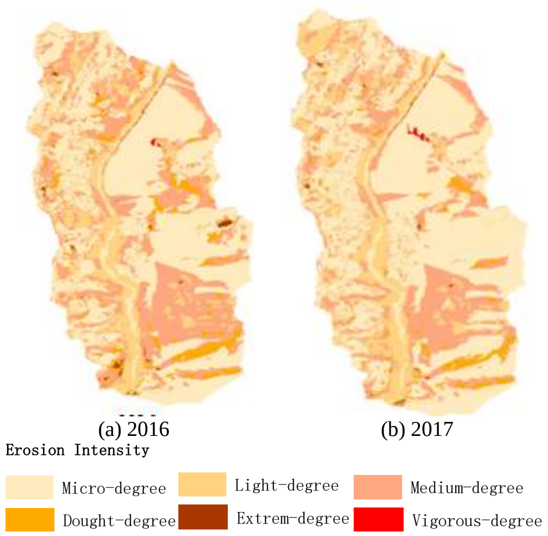

Fig. 6. Soil erosion scale of study region in 2016 and 2017.

B. Change Detection Analysis of Soil Erosion

Calculating soil erosion intensity and constructing the change transfer matrix which were shown in TABLE VIII. Statistical results shown that the tendency of soil and water erosion distribution was getting better from 2016 to 2017. Micro-degree area increased, mainly transfering from Slight-degree (2.07 km^2), Medium-degree (7.01 km^2) and Dought-degree (1.41 km^2). Slight-degree erosion area kept flat. Medium-degree was slightly declined, transferred partially to Micro-degree and Slight-degree. Dought-degree was transferred partially to Micro-degree. Extrem-degree and Vigorous-degree were also partially declined.

TABLE VIII: TRANSFER MATRIX OF SOIL EROSION

2017 / 2016	Micro	Slight	Medium	Dought	Extrem	Vigorous	Total
Micro	44.8	2.0	1.2	0.2	0.0	0.1	48.3
Slight	2.1	13.4	0.3	0.0	0.0	0.0	15.8
Medium	7.0	1.2	19.7	0.1	0.0	0.0	28.0
Dought	1.4	0.0	0.7	3.2	0.0	0.0	5.4
Extrem	0.3	0.0	0.0	0.0	0.2	0.0	0.5
Vigorous	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Total	55.5	16.6	21.9	3.5	0.2	0.2	98.0

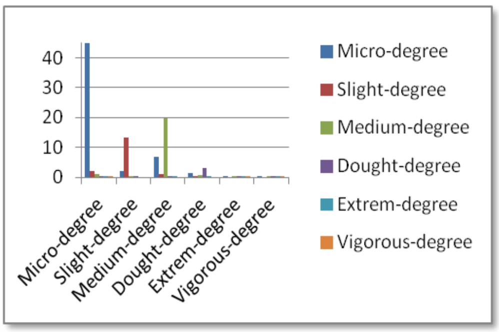

Fig. 7. Graph of soil erosion scale of study region.

Results suggested that soil and water erosion of XiangXi watershed was getting better from 2016 to 2017, the land-use pattern of study region had experienced structural adjustment, mainly reflected in that slope gravity erosion got improvement and vegetation measures such as Returning Farmland to Forest got efficiency. The erosion disturbance caused by engineering excavation was relatively small compared to the local water conservation engineering measures. Combining the water protection measures provided by local experts with the actual field investigation, XiangXi watershed adopted comprehensive management of Interception Irrigation and complementary scientific prevention mode of Horizontal Terraces-Economic Forest during 2016 to 2017, it had governed slope cropland 2.03 km^2, including stone terracing of sloping land 0.41 km^2, ridge terracing of sloping land 0.12 km^2, repaired cross wall terraces 1.5 km^2. In the meanwhile, supported the slope drainage engineering including the drain 3720 m, the sand basin 31 th, the field road 20.1 km. Several typical water conservation projects were shown in Fig. 7, which verified the reliability of results proposed in the paper.


(a) Navel orange gardens (b) Terracing economic forest
Fig. 7. Soil and water conservation project.

V. CONCLUSION

The paper combined remote sensing monitoring with GPS investigation based on GF1 images of multiple time-phase, and extracted the major factors affecting soil erosion like vegetation coverage, land-use type and slop data to overlap analyze soil erosion intensity and constructed change matrix to analyze dynamic changes. Results showed that the land-use patterns of XiangXi watershed from 2016 to 2017 had experienced structural adjustment ,the distribution of soil erosion were getting better, of which mainly reflected in comprehensive improvement of slope gravity erosion and efficiency of vegetation measures. It has positive connection with the local slope control engineering such as Terracing of Sloping land and Slope drainage, and also plant measures such as Returning Farmland to Forest and Planting Navel orange gardens.

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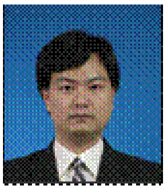
Ying Jiang was born in 1990 in Hunan province of China. She had the master degree of photogrammetry and remote sensing at the Wuhan University in 2016. She is an engineer in Changjiang River Scientific Research Institute, Wuhan, China, and mainly engaged in application of water conservancy informatization, especially in the soil erosion and ecological environment dynamic monitorring.

Daxiang Xiang was born in 1984 in Hubei province of China. He had the PhD degree of photogrammetry and remote sensing at the Wuhan University in 2011. He is a senior engineer in Changjiang River Scientific Research Institute, Wuhan, China, and mainly engaged in remote sensing analysis of meteorological drought.



Zhe Li was born in 1980 in Hubei province of China. He had the PhD degree of earth and Space sciences at the Peking University in 2009. He is a senior engineer and chief officer in Changjiang River Scientific Research Institute, Wuhan, China, and mainly engaged in digital watershed space-time information organization and transmission system research.

Xiong Fei Wen was born in 1984 in Hubei province of China. He had the PhD degree of photogrammetry and remote sensing at the Wuhan University in 2011. He is a Senior engineer in Changjiang River Scientific Research Institute, Wuhan, China, and mainly engaged in application of Water conservancy informatization.

Xichi Chen was born in 1990 in Hubei province of China. She had the master degree of Marine engineering at the Wuhan Technology University in 2015. She is an engineer in Changjiang River Scientific Research Institute, Wuhan, China, and mainly engaged in application of Water conservancy informatization.