land

Article

Analysis of Influencing Factors of Soil Erosion Changes Based on Structural Equation Model

Ziwei Wang [1,2], Xiaohuan Yang [1,2,*] and Hongyan Cai [1,2]

[1] State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; wangzw.19s@igsnrr.ac.cn (Z.W.); caihy@igsnrr.ac.cn (H.C.)
[2] University of Chinese Academy of Sciences, Beijing 100049, China
* Correspondence: yangxh@lreis.ac.cn

Abstract: Soil erosion is a complex process influenced by both natural and human factors. Accurately assessing the temporal and spatial variations in soil erosion, along with thoroughly investigating the factors influencing these changes, is crucial for developing effective regional soil and water conservation strategies. Taking Jiangxi Province as the study area, this research employed the Chinese Soil Loss Equation model and structural equation modeling to evaluate the spatiotemporal variation in soil erosion and its influencing factors under the main land cover types from 2000 to 2020 (five-year intervals). It revealed the interaction paths among these factors and their direct and indirect effects on soil erosion. The findings indicate that soil erosion in Jiangxi Province initially decreased and then increased over the study period, with the rate of increase gradually slowing. Spatially, the region experienced overall improvement but with some local deterioration. The primary factors influencing soil erosion changes varied with land cover type and specific areas of change. For Jiangxi Province, changes in human activities were the predominant factor, followed by slope. These results provide a theoretical basis for formulating scientific soil and water conservation measures and optimizing land management strategies, thereby supporting regional environmental management and sustainable land use development.

Keywords: soil erosion change; structural equation models; CSLE model; influential factors; resource management; Jiangxi province

Academic Editor: Hanoch Lavee

Received: 18 December 2024
Revised: 16 January 2025
Accepted: 29 January 2025
Published: 1 February 2025

Citation: Wang, Z.; Yang, X.; Cai, H. Analysis of Influencing Factors of Soil Erosion Changes Based on Structural Equation Model. *Land* **2025**, *14*, 304. https://doi.org/10.3390/land14020304

1. Introduction

Soil erosion is one of the most prevalent and severe issues in China. Extensive soil erosion has caused significant damage to the ecological environment and poses a substantial threat to social and economic development as well as food security. Soil erosion directly impacts the sustainable use of natural resources and the health of ecosystems. It has become a critical factor limiting China's sustainable development. Soil erosion is a complex process influenced by multiple factors. Changes in these controlling conditions directly affect the erosion process [1]. Therefore, analyzing the spatiotemporal characteristics of soil erosion changes and their influencing factors, as well as clarifying the roles of various factors in the soil erosion process, can provide a scientific foundation for optimizing soil and water conservation strategies. It also supports decision-making for land management, ecological restoration, and sustainable resource development. This is essential for achieving a balanced approach to environmental protection and socio-economic development.

Soil erosion is influenced by a variety of natural and human factors, including rainfall, terrain characteristics, soil properties, vegetation cover, and land use and management practices [2–5]. In recent years, the impact of various factors on soil erosion has increasingly attracted attention. Early research often concentrated on the effects of natural factors such as climate, topography, and vegetation type [6–8]. Rainfall intensity and frequency directly influence the extent of soil erosion [9]. Meanwhile, slope affects runoff velocity and erosion rates [6]. Forest canopies and litter layers can mitigate the impact of precipitation on the soil surface, while increased vegetation cover can effectively reduce soil erosion [10]. Grassland root systems contribute to maintaining soil structure and significantly enhance the soil's resistance to erosion [11,12]. As the understanding of human activities has evolved, studies have begun to explore the influence of human factors, including agricultural practices and land use changes [13]. The more developed agricultural practices and mining activities on cultivated land have aggravated soil erosion [14,15], while the construction of terraces can effectively control soil erosion on slopes [16]. Affected by human intervention, soil erosion in forest areas has become increasingly serious, but with the implementation of the project of returning farmland to forests and grassland, forest soil erosion has been effectively controlled [17]. Contemporary research now tends to comprehensively analyze the combined effects of natural and human factors [18,19], aiming to provide a more comprehensive understanding of the soil erosion process. However, current studies often characterize human factors primarily by land use types [20–22] or administrative divisions. There is a need for more detailed explanations of how human activities impact soil erosion at finer grid scales. It is evident that the factors influencing soil erosion vary under different types of surface cover. Furthermore, the same factor can exert different effects on soil erosion. This indicates that studying soil erosion requires a comprehensive consideration of both natural and human factors and their interactions.

From the perspective of research methods, a variety of statistical analysis methods [23,24] and spatial analysis methods [25] have been employed to study the driving factors of soil erosion. These methods effectively quantify the relationship between soil erosion and individual or multiple natural factors, but they often fall short in capturing the spatial distribution characteristics of these influencing factors. To address this gap, geographic detectors [26,27] have been utilized. Geographic detectors not only quantitatively assess the dominant factors based on the spatial heterogeneity of influencing factors but also evaluate the impact of interactions between two factors on soil erosion. Current research provides a solid foundation for understanding soil erosion but often overlooks the specific pathways through which different factors interact. Recent studies have utilized structural equation modeling (SEM) to delve deeper into the impact of various factors on soil erosion, revealing both direct and indirect effects [28–30]. SEM allows for the simultaneous consideration of causal relationships and interaction pathways among multiple factors, thereby offering a more comprehensive exploration of the factors influencing soil erosion [31]. However, most studies primarily focus on cross-sectional analyses at specific time points [32,33] and lack investigations into the long-term dynamic changes in soil erosion. Furthermore, existing research has primarily focused on the Loess Plateau in northwest China [34–36]. In contrast, the southern red soil region exhibits significant differences in geography, climate, and soil characteristics. Studying the impact of soil erosion in this region remains a critical area requiring further attention.

Therefore, taking Jiangxi Province as an example, this study analyzed the influencing factors of the dynamic changes in soil erosion under different land cover types during the period from 2000 to 2020, aiming to reveal the interaction pathways among these factors under different surface covers and their direct and indirect impacts on soil erosion changes. This will provide a scientific basis and theoretical foundation for developing resource protection measures and land management strategies tailored to the different surface covers in the southern red soil region, and ensure the sustainable use of natural resources. In this study, the soil erosion mentioned refers to water erosion.

2. Material and Methods

2.1. Study Area

Jiangxi Province is situated in the southeastern part of China, on the southern bank of the middle and lower reaches of the Yangtze River (Figure 1). Its landforms are predominantly mountains and hills, with relatively large topographic undulations. The average altitude is approximately 240 m, and the average slope gradient is 10.5 degrees. In terms of soil types, the Quaternary red soil covers a large area in the province. This type of soil is sticky in texture, with tiny pores, resulting in poor water permeability. When it rains, surface runoff is easily formed. Moreover, the region experiences substantial and concentrated rainfall, often accompanied by heavy storms. These distinctive geographical traits render Jiangxi extremely prone to soil erosion [37], making it one of the most severely affected provinces in southern China. In recent years, effective control measures have significantly mitigated the soil erosion problem [38]. However, due to economic development demands and high land use intensity, the issue of soil erosion remains severe, posing challenges to ecological and socio-economic sustainability [39]. Therefore, this research centers on Jiangxi Province to analyze the factors influencing changes in soil erosion, providing valuable insights for future soil erosion management in the region.

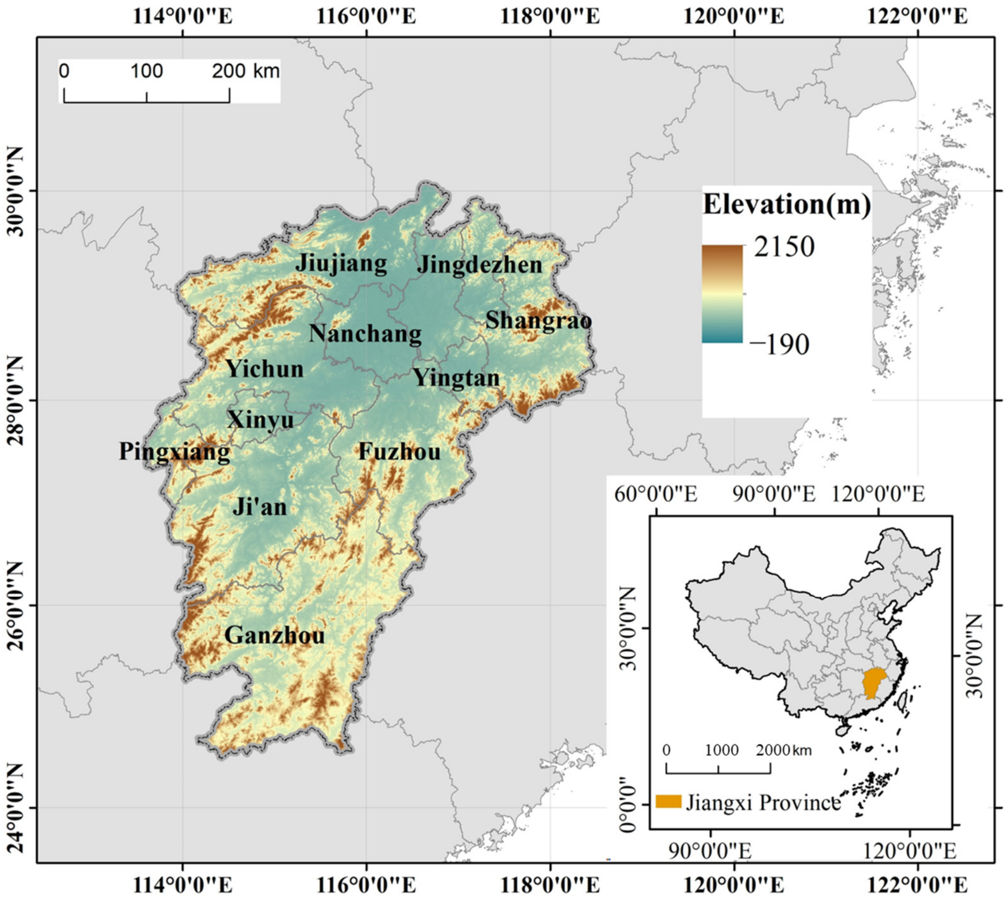

Figure 1. Geographical location of Jiangxi Province, China.

2.2. Data Sources and Data Preprocessing

Table 1 shows the auxiliary data utilized in this study. All datasets were transformed into spatially consistent 30 m raster formats through projection, conversion, resampling, and other operations using ArcMap 10.8 [40]. Statistical data were standardized based on the 2020 administrative division data, resulting in long-term statistical datasets that align with administrative boundaries. Meteorological data were generated by interpolating site data using ANUSPLIN 4.37 [41], a process that incorporates the covariate Digital Elevation Model (DEM). For the long-term Normalized Difference Vegetation Index (NDVI[1]) and meteorological data covering the period from 1998 to 2020, in order to reduce random errors, better approximate the general characteristics of a certain stage, and enhance data stability, we used the multi-year average as the characteristic value for representative years [42]. Specifically, five-year averages were calculated to represent the intermediate years (2000, 2005, 2010, and 2015). The average from 2018 to 2020 was used to represent the year 2020. Regarding the land cover data, the underlying layer of impervious surfaces, such as construction land, is of a concrete structure, which possesses a certain degree of durability [43]. Thus, we assume that there is no soil erosion occurring on the construction land. Additionally, it can be posited that soil erosion in water bodies is negligible [44]. The area occupied by unused land is minimal and not a primary land use type. Therefore, this study focuses solely on analyzing soil erosion changes in cropland, forest, and grassland.

Table 1. Data information.

Data	Data Sources	Data Type	Spatial Resolution	Time Scale
Land use/land cover	Resource and Environmental Science and Data Center, Chinese Academy of Sciences	grid	30 m	2000/2005/2010/2015/2020
DEM	National Aeronautics and Space Administration	grid	30 m	
NDVI	Resource and Environmental Science and Data Center, Chinese Academy of Sciences	grid	30 m	1998–2020
Meteorology	National Meteorological Science Data Center	table	/	1998–2020
Statistical data	Jiangxi Province Statistical Yearbook [45]	table	/	2000/2005/2010/2015/2020

2.3. Methods

2.3.1. Soil Erosion Assessment

The soil erosion assessment method selected the Chinese Soil Loss Equation (CSLE) model of Liu et al. [46], and the formula is as follows:

$$SER = R \cdot K \cdot L \cdot S \cdot B \cdot E \cdot T \tag{1}$$

In the formula, SER represents the soil erosion rate, with the unit of $\text{t} \cdot \text{hm}^{-2}\text{a}^{-1}$. The unit of rainfall erosivity (R) is $\text{MJ} \cdot \text{hm}^{-2} \cdot \text{mm} \cdot \text{h}^{-1} \cdot \text{a}^{-1}$, and that of soil erodibility (K) is $\text{t} \cdot \text{hm}^{2} \cdot \text{MJ}^{-1} \cdot \text{hm}^{-2} \cdot \text{mm}^{-1} \cdot \text{h}$. The slope length factor (L) and slope steepness factor (S) are dimensionless. B, E, and T are dimensionless factors corresponding to biological-control, engineering-control, and tillage, respectively. The calculation and assignment methods of each factor refer to existing research [47,48].

2.3.2. Human Activity Index Simulation

The quantification and spatialization of the human activity are important prerequisites for studying the relationship between human activities and soil erosion rate (SER) changes at the grid scale. The study synthesizes socioeconomic data, land use data, and topographic data, with the Human Activity Index (*HAI*) serving as a comprehensive metric that gauges the overall extent of human impacts and interventions on the terrestrial surface [49,50]. The calculation formula is as follows:

$$HAI = CI \times CSA \times S \tag{2}$$

In the formula, CI is the conversion index of the construction land equivalent, and its value assignment refers to existing research [49,51]. The CI represents the coefficient obtained by converting different land use types according to the intensity of human activities, which can reflect the intensity of human activities in terms of land surface utilization, transformation, and development. The CSA is the comprehensive socioeconomic activity index, which represents the magnitude of human socioeconomic activity [49]. Based on the county statistical yearbook data, the principal component analysis of 12 socioeconomic indicators was performed to obtain the comprehensive principal component value as the comprehensive socioeconomic activity index. The socioeconomic indicators cover three main aspects: population level (including population density, urban population density, and rural population density), economic level (including per capita GDP, economic density, the proportion of tertiary industries, and the per capita net income of rural residents), and agricultural production (including per capita arable land area, per capita total grain production, per capita total meat production, grain yield per unit area, and per capita agricultural machinery power). S is the terrain correction coefficient, representing the restrictive effect of terrain on human activities. The logarithmic function was used to reflect the trend of human activity intensity changing with slope [50,52].

2.3.3. Structural Equation Modeling

Structural equation modeling (SEM) can not only quantify the direct impact of driving factors on target variables but it can also quantify their indirect impact on target variables through their effects on other driving factors [53,54].

Precipitation, DEM, slope, and the NDVI serve as the primary initial input data for the CSLE model and play a crucial role in the soil erosion process. Additionally, the impact of human activities on soil erosion cannot be overlooked. Therefore, this study uses terrain conditions (DEM and slope), changes in precipitation, the HAI, and vegetation cover (represented by the NDVI) as driving factors to construct the SEM of SER change (Figure 2). By performing linear regression on each SER pixel from 2000 to 2020, the slope of the function is used to represent the SER change trend during this period. A larger positive slope indicates a faster increase in the SER. Conversely, a larger negative slope (in absolute value) indicates a faster decrease in the SER. Similarly, the slopes of the linear regressions for precipitation change, vegetation cover change, and HAI change are calculated as their respective trends. To understand the differences in influencing factors of SER change across the main land cover types, we identified the pixels that have been cropland, forest, and grassland from 2000 to 2020 and constructed SEMs for each land cover type. The steps primarily include establishing a graphical conceptual model, model fitting, model evaluation, and correction.

It should be noted that the model we constructed is based on hypothesized relationships from previous studies rather than proven relationships and it is not necessarily consistent with actual physical processes. Based on the existing literature [20,31,55–58], the hypotheses of the conceptual model in this study are as follows: All factors directly affect soil erosion. Altitude and slope may indirectly influence soil erosion by affecting other factors. Human activities may indirectly affect soil erosion by influencing factors other than topography. Rainfall may indirectly affect soil erosion by influencing vegetation changes.

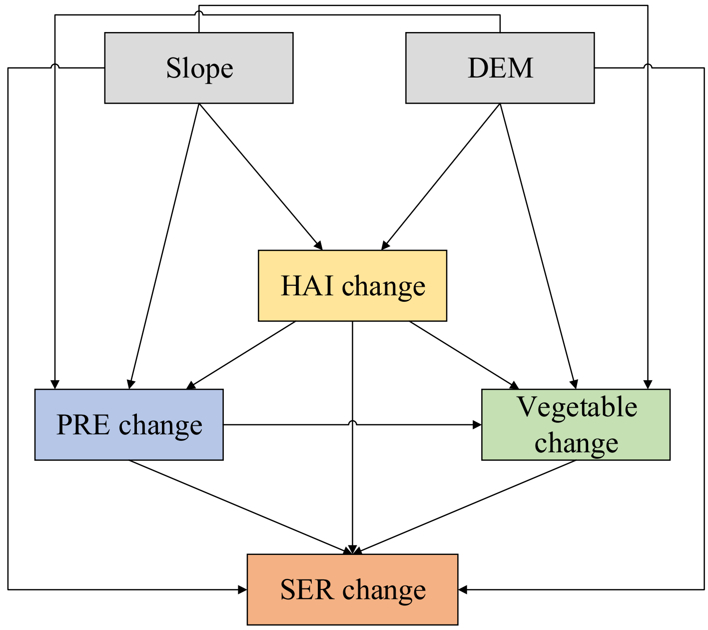

Figure 2. Graphical conceptual model of soil erosion rate (SER) changes in Jiangxi Province.

For target pixels of different land cover types, the changing trends in precipitation (PRE), the NDVI, the HAI, and the SER, as well as the values of DEM and slope, were extracted according to the graphical conceptual model to serve as the input data for SEM. Structural equation modeling was then performed using AMOS 24.0 software [59]. This study used the comparative fit index (CFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), root mean square error of approximation (RMSEA), standardized root means square residual (SRMR), chi-square/df ratio (CD_ratio), and the *p*-value of the *t*-test (*p*_value) to evaluate the model's goodness of fit. The model was modified and optimized by adjusting the relationships between variables until the goodness-of-fit evaluation met the required standards.

The standardized path coefficient is used to quantify the impact of each driving factor on SER change. A larger path coefficient indicates a greater impact. The total effect (TE) of a variable on SER change includes both direct and indirect effects [60]. The direct effect (DE) is the path coefficient of the arrow pointing directly from the variable to the SER change. The indirect effect (IE) is the product of the coefficient from the variable to the mediating variable and the coefficient from the mediating variable to the SER change. IE is the sum of the indirect coefficients of all paths between each driving factor and the SER change.

3. Result

3.1. Spatiotemporal Characteristics of Soil Erosion

The average SER of each year was 586.59 $t{\cdot}km^{-2}{\cdot}a^{-1}$ (2000), 489.09 $t{\cdot}km^{-2}{\cdot}a^{-1}$ (2005), 524.16 $t{\cdot}km^{-2}{\cdot}a^{-1}$ (2010), 549.93 $t{\cdot}km^{-2}{\cdot}a^{-1}$ (2015), and 551.05 $t{\cdot}km^{-2}{\cdot}a^{-1}$ (2020). These data suggest an initial downward trend, which is then followed by an upward one. Notably, the rate of increase tapers off gradually. In line with the soil erosion classification criteria formulated by the Ministry of Water Resources of China, the SER across these five periods was categorized, and the proportion of the area for each grade was calculated (Table 2). The findings indicated that slight soil erosion was dominant in the study area, accounting for over 80% of the area in each period. Next came light erosion, which accounted for 11–15% of the area. Meanwhile, the combined area of moderate and severe erosion did not exceed 6%.

Table 2. Area proportion of different levels of soil erosion intensity (%).

	SER ($t \cdot km^{-2} \cdot a^{-1}$)	2000	2005	2010	2015	2020
Slight	<500	80.12	83.83	82.31	81.82	81.53
Light	500–2500	14.32	11.62	12.59	12.83	13.12
Moderate	2500–5000	2.76	2.59	2.71	2.72	2.75
Intensive	5000–8000	1.48	1.26	1.36	1.47	1.47
Very intensive	8000–15,000	1.03	0.62	0.83	0.92	0.91
Severe	>15,000	0.29	0.08	0.20	0.23	0.22

Table 3 illustrates the variations in the SER across different land cover types. Cropland showed the highest SER, with grassland coming second. Over time, the SER of cropland initially decreased and then increased, with the rate of increase gradually slowing, mirroring the overall SER trend. The SER of forests and grasslands demonstrated a fluctuating downward trend.

Table 3. The SER of the main land cover types ($t \cdot km^{-2} \cdot a^{-1}$).

	2000	2005	2010	2015	2020
Cropland	1838.5	1500.0	1650.4	1738.2	1752.4
Grassland	657.7	556.3	564.4	596.4	591.1
Forest	84.0	74.1	76.8	78.7	78.0

From 2000 to 2020, there were varying degrees of transitions in and out of various erosion intensity levels (Table 4). These transitions were mainly characterized by shifts from high erosion intensity to low erosion intensity, and mutual transitions between slight erosion and light erosion.

Table 4. Transfer matrix of area proportion of different erosion intensity levels from 2000 to 2020 (%).

		2020						Total
		Slight	Light	Moderate	Intensive	Very Intensive	Severe	
2000	Slight	78.94	1.02	0.09	0.05	0.02	0.002	80.12
	Light	2.51	11.68	0.12	0.01	0.001	0	14.32
	Moderate	0.05	0.39	2.22	0.11	0.001	0	2.76
	Intensive	0.02	0.02	0.32	1.07	0.05	0	1.48
	Very intensive	0.01	0.01	0.01	0.23	0.76	0.02	1.03
	Severe	0.003	0	0.001	0.0004	0.08	0.20	0.29
Total		81.53	13.12	2.75	1.47	0.91	0.22	100.00

Notable spatial variation in the SER exists within the study area. Specifically, the northern region exhibits a higher SER compared to the southern part (Figure 3). Soil erosion is more severe in the Jiujiang, Shangrao, and Ganzhou cities. From 2000 to 2020, the spatial changes in soil erosion exhibited overall improvement with some local deterioration. Soil erosion has been alleviated in 61% of the areas in Jiangxi Province, primarily in the northern and eastern regions. Notably, soil erosion in low-altitude areas, such as the northwest of Jiujiang City, the west of Yichun City, the northeast of Ganzhou City, and the east of Shangrao City, has significantly decreased. These areas had a high SER in 2000, with reductions over the past 20 years exceeding 200 $t \cdot km^{-2} \cdot a^{-1}$. Conversely, the SER increased in 23.56% of the regions, mainly in the Ji'an, Pingxiang, and Ganzhou cities, as well as parts of the western Jiujiang City and central Fuzhou City, with increases of less than 100 $t \cdot km^{-2} \cdot a^{-1}$. The distribution of soil erosion across each period and the changes from 2000 to 2020 indicate that areas with more severe erosion initially experienced greater reductions in the annual average SER and a higher degree of soil erosion relief (Figure 3).

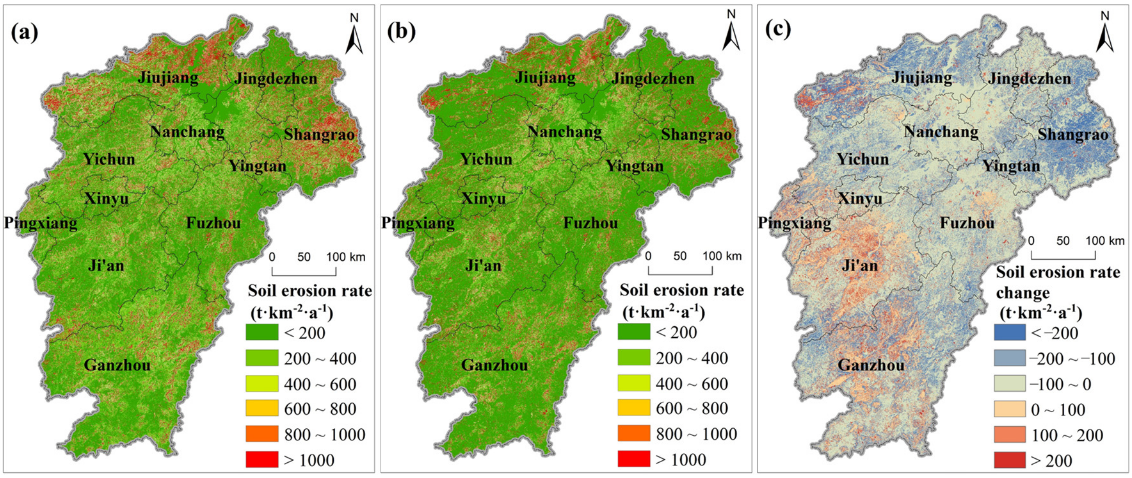

Figure 3. Distribution and change in the soil erosion rate from 2000 to 2020: (**a**) 2000; (**b**) 2020; (**c**) 2000–2020.

3.2. SEMs for Increased Soil Erosion

Figures 4 and 5 show the impacts of various factors on SER changes. Overall, the total effect of the HAI change on SER change in Jiangxi Province is the largest (TE = 0.125), followed by topography, NDVI change, and PRE change. The increase in the HAI will directly lead to a larger increase in the SER and will also indirectly positively affect the increasing trend in the SER through vegetation coverage (IE = 0.013). The indirect effect of DEM is relatively large (IE = −0.052), which indirectly negatively affects the SER through precipitation, vegetation cover, and human activities. Slope has a direct positive effect (DE = 0.111), but also has a small negative indirect effect (IE = −0.011). Vegetation cover change has only a direct negative effect on SER change (TE = DE = −0.061). Increased precipitation has a direct positive effect on SER change (DE = 0.052), and indirectly has an indirect positive effect on SER change by suppressing vegetation cover (DE = 0.003).

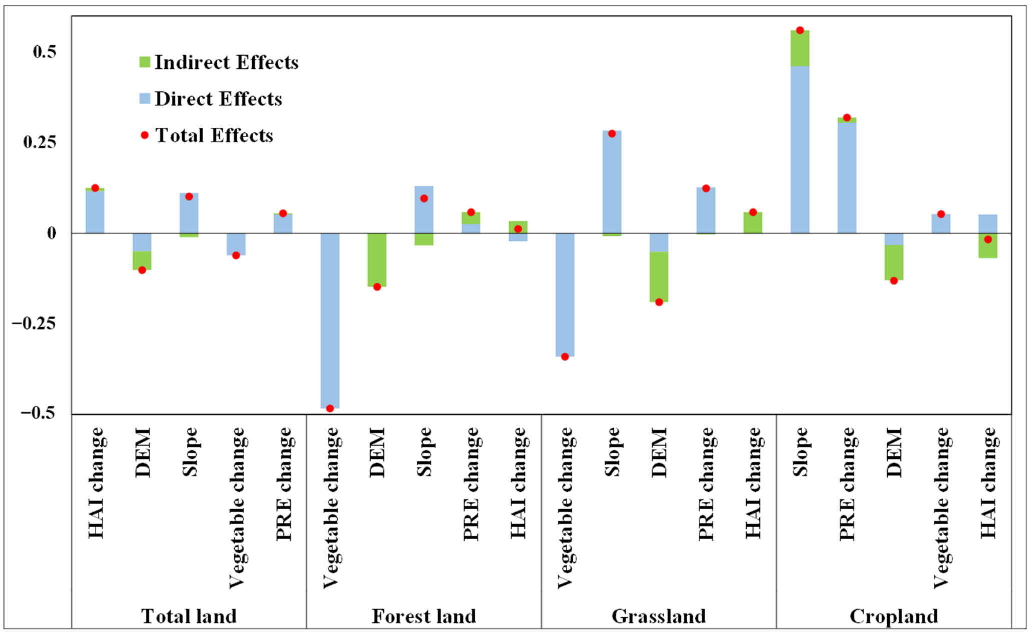

Figure 4. The total effect (TE), direct effect (DE), and indirect effect (IE) in areas with increased soil erosion.

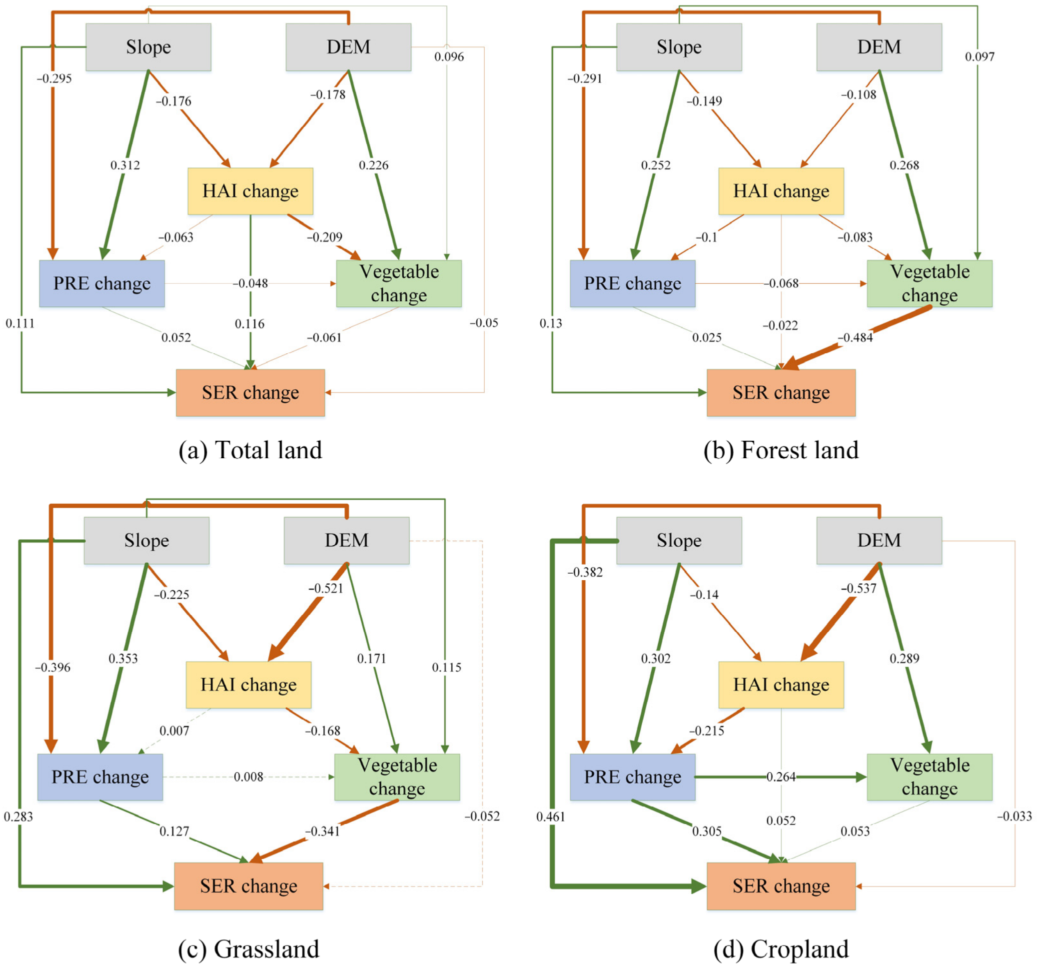

Figure 5. Path diagrams of the SEMs fitted for areas with increased soil erosion from 2000 to 2020 (The value on the arrow indicates the effect size. The thickness of an arrow corresponds to the magnitude of the effect size. Green lines denote positive paths, while red lines stand for negative paths. Solid lines signify that the relationship is significant ($p < 0.05$), and dashed lines indicate otherwise.): (**a**) Total land; (**b**) Forest land; (**c**) Grassland; (**d**) Cropland.

The impact of various factors on the SER increase area differed across different land cover types. Vegetation cover change had the greatest impact on SER change in forests and grasslands, with high vegetation cover directly slowing the increase in the SER (TE_forest = −0.484, TE_grass = −0.341). The total effect of slope on SER change was most pronounced in cropland (TE = 0.56), followed by grassland (TE = 0.275), with a direct impact as the main factor, which aggravated the increase in the SER. The indirect effect of slope varied among land cover types. In forest and grassland areas, the indirect effect of slope on SER change was negative, with a small portion of the SER increase trend being indirectly alleviated by increased vegetation cover (IE_forest = −0.047, IE_grass = −0.039). In cropland areas, the indirect effect of slope on SER change was positive, with the increase in the SER being indirectly promoted by increased precipitation (IE = 0.092). The direct positive effect of PRE change on SER change existed across all land cover types, and this effect was particularly evident in cropland (DE = 0.319). Additionally, the indirect effect of precipitation through vegetation cover was small and varied among land cover types: it was positive in grassland and cropland areas, and negative in forests. The impact of HAI change on SER changes was relatively minor and more complex in forests and cropland, showing both positive and negative effects. In grassland areas, HAI change mainly indirectly affected the SER through vegetation cover (IE = 0.057). With different types of land cover, elevation has a similar impact, mainly manifesting as an indirect negative effect.

3.3. SEMs for Reduced Soil Erosion

According to Figures 6 and 7, the influencing factors of SER reduction areas are relatively similar to those of SER increase areas, with generally low relative importance. HAI change has a notable impact on SER changes across Jiangxi Province (TE = −0.087). Increased human activities can negatively affect SER changes both directly and indirectly by enhancing vegetation cover. Slope primarily shows a direct negative impact (DE = −0.035), with a small positive indirect impact (IE = 0.019).

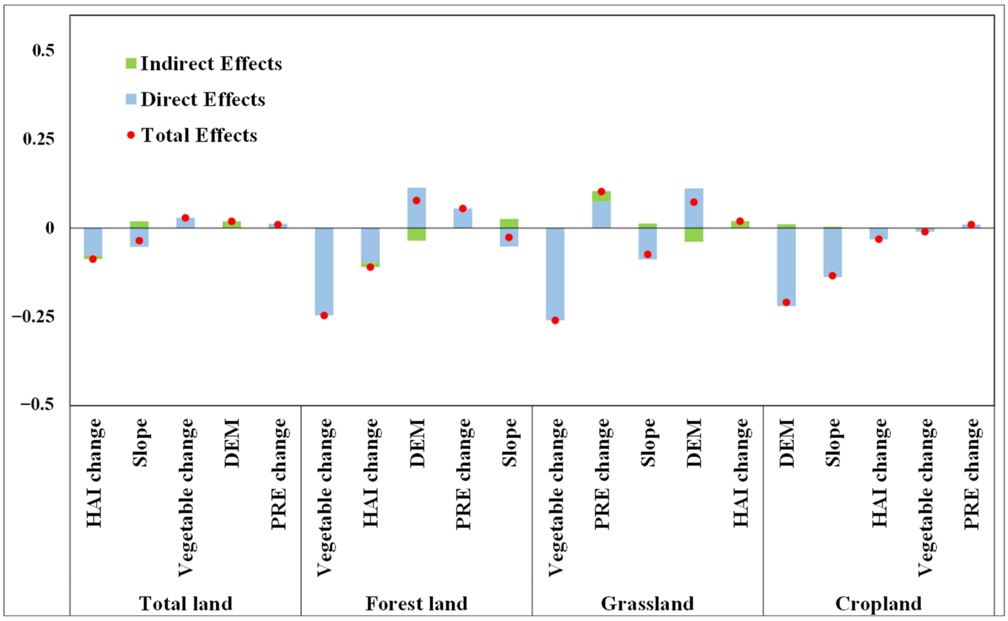

Figure 6. The total effect (TE), direct effect (DE) and indirect effect (IE) in areas with reduced soil erosion.

The effect of HAI change on SER change varies across different land cover types. In forest areas, the impact of HAI change is more pronounced, with both direct and indirect effects being negative. In cropland and grassland, HAI change has both positive and negative effects. The impact of slope on SER change is consistent across different land cover types, with a negative direct impact and a positive indirect impact. However, the mediating factors differ among land cover types. Vegetation cover change negatively affects SER change across all land cover types, with the most significant impacts observed in forest and grassland areas (TE_forest = −0.246, TE_grass = −0.26). This effect is less significant in cropland. The impact of PRE change on SER reduction in grassland areas is relatively greater (TE = 0.103). Besides its direct effects, PRE change can indirectly positively influence SER change by inhibiting vegetation cover (IE = 0.029). In forest areas, PRE change has a direct positive impact on SER change. Specifically, the greater the amount of precipitation, the less pronounced the decrease in soil erosion. The effect of PRE change on SER change in cropland is not significant. Altitude has the greatest impact on cropland (TE = −0.209). Increased altitude has a direct negative impact on SER change (DE = −0.22) and an indirect positive impact by influencing the HAI and PRE (IE = 0.011). The impact of altitude on SER change in forest and grassland areas is similar, with a direct positive impact and an indirect negative impact. In forests, the indirect factors are vegetation cover and human activities, while in grasslands, they are human activities and precipitation.

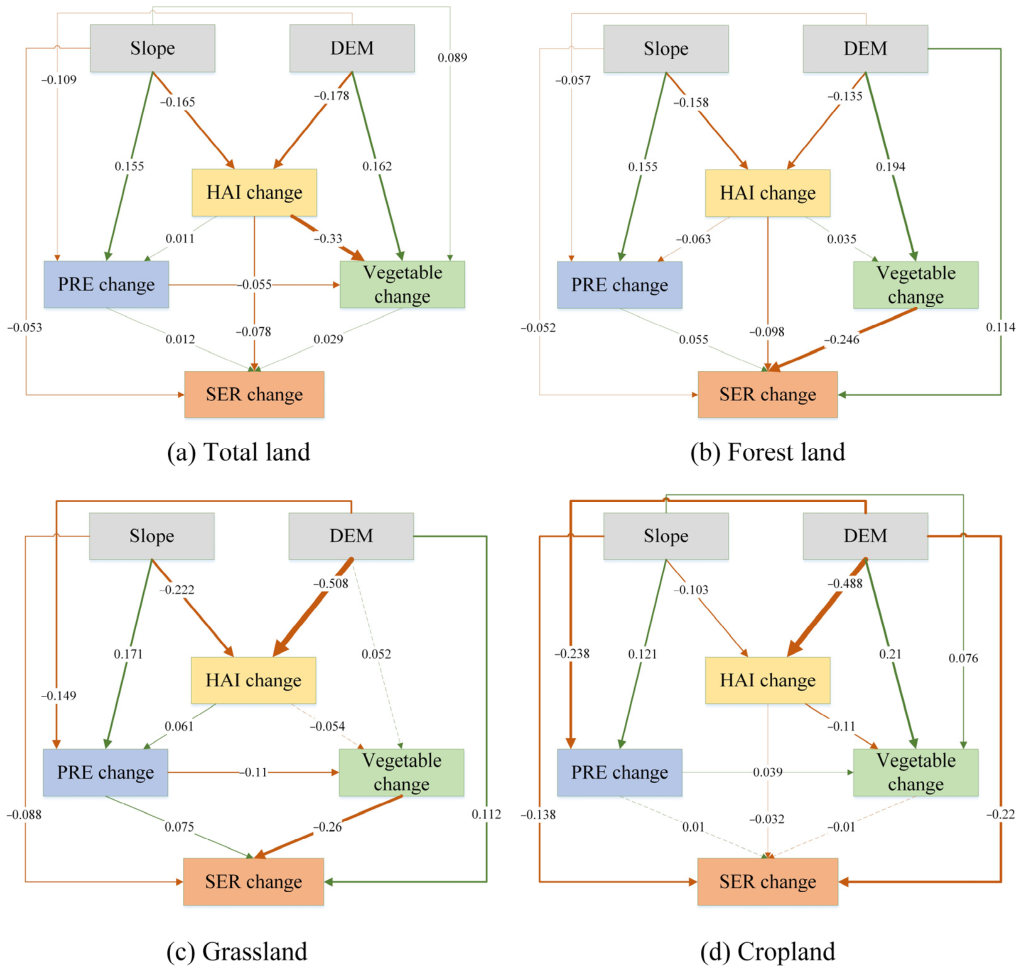

Figure 7. Path diagrams of the SEMs fitted for areas with reduced soil erosion from 2000 to 2020 (The value on the arrow indicates the effect size. The thickness of an arrow corresponds to the magnitude of the effect size. Green lines denote positive paths, while red lines stand for negative paths. Solid lines signify that the relationship is significant (p < 0.05), and dashed lines indicate otherwise.): (**a**) Total land; (**b**) Forest land; (**c**) Grassland; (**d**) Cropland.

4. Discussion

4.1. Accuracy of SEMs

The fitting accuracy evaluation index was used to assess the goodness of fit of the models for the total land, forest, grassland, and cropland. The results, as shown in Table 5, indicate that all indicators met the required standards, demonstrating that the model accurately described the data.

Table 5. Results of SEM precision fitting.

Fitting Index Threshold		CFI ≥0.9	GFI ≥0.9	AGFI ≥0.8	RMSEA <0.1	SRMR <0.1	CD_Ratio <3	*p*_Value >0.05
Areas with increased soil erosion	Total	1	1	1	0.003	0.028	2.428	0.119
	Forest	1	1	1	0.006	0.01	2.721	0.099
	Grassland	1	0.992	1	0.027	0	2.867	0.09
	Cropland	1	1	0.999	0.01	0.012	2.684	0.101
Areas with reduced soil erosion	Total	1	1	1	0.001	0.019	1.258	0.262
	Forest	0.999	1	0.995	0.025	0.04	2.882	0.083
	Grassland	1	0.998	1	0.013	0	2.025	0.132
	Cropland	1	0.999	1	0.008	0	2.689	0.102

4.2. Characteristics of Soil Erosion Change

The variations in the average SER within Jiangxi Province align with the discoveries made by Lang et al. [61]. The changes in average rainfall erosivity align closely with the changing trends in the SER, with values of 8674, 6676, 7772, 8140, and 8285 MJ·hm^{-2}·mm·h^{-1}·a^{-1}, respectively. This suggests that there has been a rise in both the frequency and intensity of extreme rainfall events. Such an increase gives rise to greater rainfall erosivity, which in turn aggravates the overall situation of the SER [9,62]. The variations in the SER for forest and grassland areas result from the combined effects of vegetation coverage and rainfall erosivity [63]. From 2000 to 2020, forest vegetation coverage increased from 75% to 85%, and grassland coverage rose from 71% to 80%. Despite the increase in rainfall erosivity, the growth in vegetation cover has effectively mitigated the SER [10,64]. This indicates that measures such as afforestation and grassland improvement, which enhance vegetation density, can significantly improve the soil's ability to resist erosion [18].

The transformation of land use types is detailed in Table 6. From 2000 to 2005, the predominant trend was the repurposing of cropland. Roughly 567 km^2 of cropland underwent conversion, primarily due to the urbanization [65] and the execution of the policy for converting cropland into forest and grassland [17,66]. This led to cropland being transformed into construction land, forests, and grassland. This transformation significantly alleviated the soil erosion. Additionally, the conversion of grassland to forests increased vegetation cover, which further reduced soil erosion. However, from 2005 to 2020, the primary trend reversed, with forest areas taking the brunt of conversion. Approximately 2021 km^2 of forests were repurposed. Rapid economic development, agricultural expansion, and infrastructure construction drove forests to be turned into construction land and cropland. This, in turn, diminished the vegetation cover and exacerbated soil erosion problems. This highlights the need to plan land use rationally while pursuing economic development, reduce excessive deforestation, and implement engineering measures such as terracing and soil and water conservation forests in erosion-prone areas to minimize surface runoff and soil erosion [67].

Table 6. Transfer matrix for land cover types (km^2).

		2005				Transferred Out in 2000
		Cropland	Forest	Grassland	Construction Land	
2000	Cropland		62	50	455	567
	Forest	247		48	102	397
	Grassland	56	178		8	242
	Construction land	8		2		10
		2020				**Transferred Out in 2000**
		Cropland	**Forest**	**Grassland**	**Construction Land**	
2005	Cropland		108	12	1583	1703
	Forest	418		594	1009	2021
	Grassland	75	436		162	673
	Construction land	183	19	5		207

From 2000 to 2020, the average annual precipitation in northern Jiangxi Province was higher than that in the southern part [68]. This disparity led to a higher likelihood of soil erosion in the north. Additionally, the low hills and plains in the northern region, which were marked by a dense population and a high intensity of human activities, further exacerbated soil erosion situation [61]. Although the overall degree of soil erosion in the southern region is relatively low, there are still some scattered areas with significant erosion, especially those dominated by cropland. This disparity can be attributed to variations in soil and water conservation measures implemented across the region. According to the

Jiangxi Provincial Soil and Water Conservation Plan (2016–2030) [69], the southern focus has been on enhancing forest quality and developing ecological forest networks to control soil erosion, with relatively less emphasis on protecting cropland. This might account for the relatively more prominent soil erosion witnessed in certain southern cropland areas.

Spatially, the transition from areas with high to low erosion intensity is primarily driven by several factors. Firstly, there has been a decline in rainfall erosivity. Secondly, vegetation cover has expanded. Thirdly, sloping cropland, especially that with a slope of around 15°, has been converted into forests and grassland. Conversely, the exacerbation of soil erosion in certain areas is mainly due to the intensification of rainfall erosivity [70]. Additionally, the scattered conversion of forests to construction land and cropland across the province has also played a part in fueling the increase in soil erosion [71]. To effectively manage and prevent soil erosion, it is essential to develop and implement scientifically based and regionally appropriate soil and water conservation strategies. These strategies should include enhancing vegetation protection and restoration, optimizing land use structures, and executing soil and water conservation projects tailored to the specific natural conditions and land use characteristics of different areas.

4.3. Direct and Indirect Effects of Soil Erosion Change

The SEM structures for different land cover types in Jiangxi Province are similar, but the direction and magnitude of the influence coefficients for each factor vary. In areas experiencing increased soil erosion, human activities such as excessive land development, unreasonable agricultural practices, and urban expansion have altered surface landforms [72], directly exacerbating soil erosion. Additionally, deforestation has accelerated the loss of surface vegetation [73], which in turn aggravates soil erosion indirectly. By contrast, in areas where soil erosion is on the decline, initiatives like afforestation, terrace construction, and soil and water conservation projects play a part in curbing erosion [16,20]. However, human activities have a more significant impact on areas with escalating soil erosion compared to those with decreasing erosion. This indicates that, currently, human activities predominantly exacerbate soil erosion, echoing the conclusions drawn by Lang et al. [61]. In areas with increased soil erosion, steep terrain leads to faster water flow, which directly enhances erosion. Additionally, steeper slopes often correlate with a lower intensity of human activities [52], which can mitigate vegetation damage and indirectly help reduce soil erosion. While steep slopes present challenges in areas with diminishing soil erosion, effective land management and vegetation restoration [74,75] can further decrease soil erosion.

For forests and grasslands, vegetation serves as a natural safeguard for the soil. Its root systems anchor the soil firmly, while the canopy intercepts raindrops, thus reducing direct erosion [76]. Enhanced vegetation cover at multiple levels and increased surface vegetation can further mitigate soil erosion. In high-altitude mountainous zones, where evergreen broad-leaved forests dominate [77], the dense branches and leaves provide substantial coverage, weakening the scouring impact of raindrops and alleviating the overall trend of rising amounts of soil erosion. With the implementation of policies like the Outline for Ecological Civilization Construction and the general advancement in environmental awareness and green sustainable development [78], human activities such as afforestation, urban greening, and returning farmland to forests have significantly boosted vegetation cover, effectively reducing soil erosion. However, in some areas, practices like overgrazing and reclamation persist, leading to the degradation of and reduction in grassland vegetation. This exposes the soil to rain erosion, consequently increasing soil erosion. Precipitation increases surface runoff and can also augment soil moisture, providing sufficient water for grassland plants, which is beneficial to plant root growth and nutrient absorption [79].

The roots then penetrate deep into the soil, strengthening its aggregate structure and stability [80]. However, excessive precipitation may trigger root hypoxia in plants [81], cause soil nutrient depletion, inhibit growth, and reduce vegetation cover, which inhibits the mitigation of soil erosion. Although more rainfall can mitigate some soil erosion, overall, the increased surface runoff brought about by heavier precipitation has a greater impact in exacerbating soil erosion.

For cropland areas, a steeper slope makes the soil more susceptible to gravity, increases the collection and flow velocity of precipitation on the surface [82], and enhances the erosive power of water flow, directly and indirectly aggravating soil erosion. Due to variations in precipitation patterns, high-altitude areas experience less intense rainfall [83], which reduces the direct scouring effect of rainwater on the soil. Additionally, high-altitude areas have fewer human activities and a lower intensity of land development, leading to a reduced impact on the soil. Furthermore, the advancement of the economy and technology, along with the implementation of engineering measures, crop rotation, and fallow practices, contributes to improved land management and soil structure [16,84]. Reasonable farming practices enhance soil permeability and stability [85], thereby reducing soil erosion.

4.4. Limitations and Prospects

This study employed the CLSE model and SEM to analyze the influencing factors of soil erosion changes. However, it has certain limitations. In terms of data sources, rainfall data obtained through interpolation from meteorological stations are affected by station distribution, and are prone to deviations from actual rainfall in sparsely covered areas. At the same time, land use data may have mixed pixel effects, which may lead to biased results. Future research could use higher-resolution remote sensing images along with detailed field monitoring to enhance overall accuracy.

As for influencing factors, soil is undoubtedly one of the key elements affecting soil erosion. As can be seen from Figure 8, during the period from 2000 to 2020, there were significant differences in the changes in soil erosion among different soil types in Jiangxi Province. The erosion of most soil types showed a downward trend, while only the soil erosion of yellow cinnamon soil and purple soil increased. Red soil, being the soil type with the largest coverage area in the province, had a reduction in soil erosion, with a decrease of approximately 50 $t \cdot km^{-2} \cdot a^{-1}$. This indicates that different soil types, due to differences in formation processes, environments, and other factors, have distinct physical and chemical properties, which may lead to variations in their anti-erosion capabilities. For example, factors such as soil particle size, porosity, and aggregate stability can affect the infiltration capacity and scouring resistance of the soil, directly influencing soil erosion. Additionally, differences in soil properties can also affect ecological factors such as surrounding vegetation types and hydrological conditions, indirectly influencing soil erosion [86]. Due to the inability of the structural equation model to effectively handle and reflect categorical variables, we did not incorporate soil types into the model construction process. In the future, it is expected that by combining more detailed soil property data, a more in-depth analysis of the driving mechanisms of soil erosion changes can be carried out, further exploring the specific impact mechanisms and processes of soil on soil erosion. This will provide a solid basis for formulating more precise soil and water conservation strategies.

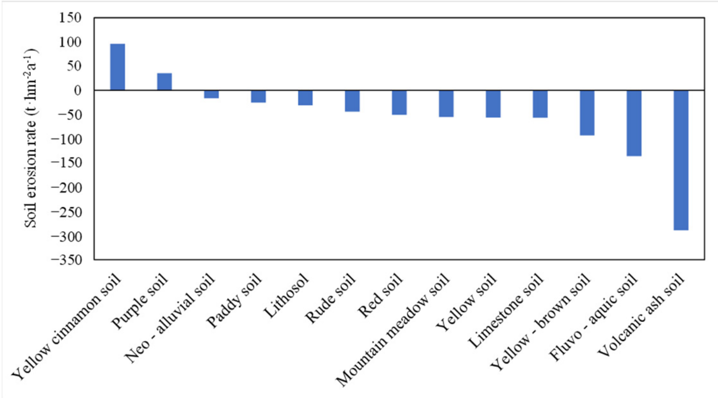

Figure 8. Mean changes in the soil erosion rate in different soil types from 2000 to 2020.

Furthermore, in this study, with the aim of more intuitively reflecting the dynamic changes in soil erosion conditions, we primarily focused on the change in the amount of soil erosion. However, it should be noted that when analyzing the influencing factors of soil erosion, the impact of the change rate might lead to deviations in the effects of different factors. For instance, in regions with a relatively high initial degree of erosion, their response to influencing factors could be more sensitive. To some extent, this may amplify the effects of these influencing factors. Therefore, in subsequent research, it would be advisable to further analyze the influencing factors of the change rate and to combine this analysis with that of the change amount. This approach will enable a more comprehensive understanding of the soil erosion mechanism, facilitating the formulation of more scientific and effective prevention and control strategies. Ultimately, this will contribute to the effective protection and sustainable utilization of soil resources.

5. Conclusions

This study utilized SEM to quantify the influencing factors of SER changes across the main land cover types in Jiangxi Province from 2000 to 2020. It elucidated the interaction pathways of changing human activities, vegetation, precipitation, and terrain conditions, as well as their direct and indirect effects on SER trends. The research results suggest that for areas with relatively severe erosion or large variation ranges, it is necessary to carry out protection and treatment work in a timely and precise manner, so as to minimize the disaster losses. From 2000 to 2020, the SER in Jiangxi Province initially decreased and then increased, with the rate of increase gradually slowing down. Soil erosion is predominantly classified as slight or light, with higher intensity observed in the northern regions. Spatially, soil erosion demonstrates a transition from high to low erosion intensity, as well as a shift between slight and light erosion. Significant variations in SER changes are observed across different land cover types. Cropland exhibits the highest SER, which increases over time, while the SER of forests and grasslands remains relatively low, showing a fluctuating downward trend over the years.

The factors influencing SER changes varied depending on land cover types and change areas. This suggests that relevant departments should formulate differentiated land use control policies for different land cover types. For the entire Jiangxi Province, changes in human activities are the predominant factor affecting SER changes, followed by slope. The direct impact of HAI change on SER changes is predominantly negative. Based on this, in the erosion-prone areas with frequent human activities, it is necessary to focus on standardizing the processes of engineering construction and the modes of farming and animal husbandry activities. At the same time, sufficient ecological buffer zones should be reserved to prevent the risk of aggravated erosion that may be brought about by construction activities. In forest and grassland areas, vegetation change is the primary direct factor influencing SER change. Therefore, it is necessary to increase the intensity of ecological compensation, fully mobilize the enthusiasm of all parties, encourage the long-term implementation of vegetation conservation and restoration actions, and stabilize the ecological barrier. In this region, the secondary factors influencing the SER change vary significantly, including topography (increased soil erosion areas), precipitation (reduced soil erosion in grassland areas), and human activities (reduced soil erosion in forest areas). In cropland, slope and precipitation changes were the main factors influencing increased soil erosion, while altitude and slope had a more significant impact on areas experiencing reduced soil erosion. For the areas with relatively severe erosion in cropland, new development projects should be strictly restricted, and the scale of sloping farmland reclamation should be controlled at the source to prevent the erosion situation from further deteriorating. These findings provide a scientific basis for understanding the dynamic changes in soil erosion in the southern red soil region and establish a foundation for developing scientifically sound and region-specific soil protection measures and land management strategies. This will improve the scientific foundation and effectiveness of soil protection efforts, thereby effectively reducing soil erosion, conserving soil resources, and advancing regional environmental management and sustainable land use development.

Author Contributions: Conceptualization, Z.W.; data curation, Z.W.; formal analysis, Z.W.; funding acquisition, X.Y.; investigation, Z.W.; methodology, Z.W.; project administration, X.Y.; resources, X.Y.; software, Z.W.; supervision, Z.W., X.Y. and H.C.; validation, Z.W.; visualization, Z.W.; writing—original draft, Z.W.; writing—review and editing, Z.W., X.Y. and H.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science & Technology Fundamental Resources Investigation Program, grant number 2023FY101001; and the National Natural Science Foundation of China, grant number 41771460.

Data Availability Statement: Data will be made available on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Note

1 The calculation formula for NDVI is NDVI = (NIR − R)/(NIR + R), among which, "NIR" represents the reflectance of the near-infrared band (Near-Infrared Radiation), and "R" represents the reflectance of the red light band (Red Light).

References

1. Food and Agriculture Organization of the United Nations (FAO). *Soil Erosion: The Greatest Challenge to Sustainable Soil Management*; FAO: Rome, Italy, 2019; 100p.
2. Bryan, R.B. Soil Erodibility and Processes of Water Erosion on Hillslope. *Geomorphology* **2000**, *32*, 385–415. [CrossRef]
3. Tang, K. *Soil and Water Conservation in China*; Science Press: Beijing, China, 2004.
4. Wen, X.; Deng, X. Current Soil Erosion Assessment in the Loess Plateau of China: A Mini-review. *J. Clean. Prod.* **2020**, *276*, 123091. [CrossRef]
5. Xu, C.; Yang, Z.; Qian, W.; Chen, S.; Liu, X.; Lin, W.; Xiong, D.; Jiang, M.; Chang, C.T.; Huang, J.C.; et al. Runoff and Soil Erosion Responses to Rainfall and Vegetation Cover under Various Afforestation Management Regimes in Subtropical Montane Forest. *Land Degrad. Dev.* **2019**, *30*, 1711–1724. [CrossRef]
6. Liu, Q.Q.; Chen, L.; Li, J.C. Influences of Slope Gradient on Soil Erosion. *Appl. Math. Mech.* **2001**, *22*, 510–519. [CrossRef]
7. Nearing, M.A.; Pruski, F.F.; O'Neal, M.R. Expected Climate Change Impacts on Soil Erosion Rates: A Review. *J. Soil Water Conserv.* **2004**, *59*, 43–50.
8. Yan, Z.; Liu, B.Y.; Zhang, Q.C.; Xie, Y. Effect of Different Vegetation Types on Soil Erosion by Water. *J. Integr. Plant Biol.* **2003**, *45*, 1204.
9. Li, S.; Li, B.; Zhang, J. Characteristics of Soil Erosion on the Loess Plateau under Different Rainfall Amounts. *J. Agro-Environ. Sci.* **2005**, *1*, 94–97.

10. Zheng, F.-L. Effect of Vegetation Changes on Soil Erosion on the Loess Plateau. *Pedosphere* **2006**, *16*, 420–427. [CrossRef]
11. Le Bissonnais, Y. Aggregate Stability and Assessment of Soil Crustability and Erodibility: I. Theory and Methodology. *Eur. J. Soil Sci.* **2005**, *47*, 425–437. [CrossRef]
12. Liu, J.; Chen, H.; Zhang, W.; Shi, D. Study on Soil Permeability in Karst Depressions Using a Disk Infiltrometer Method. *Bull. Soil Water Conserv.* **2008**, *6*, 202–206.
13. García-Ruiz, J.M. The Effects of Land Uses on Soil Erosion in Spain: A Review. *Catena* **2010**, *81*, 1–11. [CrossRef]
14. Emadodin, I.; Bork, H.R. Degradation of Soils as a Result of Long-Term Human-Induced Transformation of the Environment in Iran: An Overview. *J. Land Use Sci.* **2012**, *7*, 203–219. [CrossRef]
15. Waltner, I.; Saeidi, S.; Grósz, J.; Centeri, C.; Laborczi, A.; Pásztor, L. Spatial Assessment of the Effects of Land Cover Change on Soil Erosion in Hungary from 1990 to 2018. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 667. [CrossRef]
16. Liu, S.L.; Dong, Y.H.; Li, D.; Liu, Q.; Wang, J.; Zhang, X.L. Effects of Different Terrace Protection Measures in a Sloping Land Consolidation Project Targeting Soil Erosion at the Slope Scale. *Ecol. Eng.* **2013**, *53*, 46–53. [CrossRef]
17. Wang, B.; Yang, Q.; Liu, Z. Effect of Conversion of Farmland to Forest or Grassland on Soil Erosion Intensity Changes in Yanhe River Basin, Loess Plateau of China. *Front. For. China* **2009**, *4*, 68–74. [CrossRef]
18. Ma, T.; Liu, B.; He, L.; Dong, L.; Yin, B.; Zhao, Y. Response of Soil Erosion to Vegetation and Terrace Changes in a Small Watershed on the Loess Plateau over the Past 85 Years. *Geoderma* **2024**, *443*, 116837. [CrossRef]
19. Xiao, X.; Yang, Y.; Guo, B.; Lu, Y.; Zhang, R.; Zhang, D.; Zhen, X.; Chen, S.; Wu, H.; Wei, C.; et al. Spatial–Temporal Evolution Patterns of Soil Erosion in the Yellow River Basin from 1990 to 2015: Impacts of Natural Factors and Land Use Change. *Geomat. Nat. Hazards Risk* **2020**, *12*, 103–122. [CrossRef]
20. Li, N.; Zhang, Y.; Wang, T.; Li, J.; Yang, J.; Luo, M. Have Anthropogenic Factors Mitigated or Intensified Soil Erosion over the Past Three Decades in South China? *J. Environ. Manag.* **2022**, *302 Pt B*, 114093. [CrossRef]
21. Xiao, L.; Yang, X.; Chen, S.; Cai, H. An Assessment of Erosivity Distribution and Its Influence on the Effectiveness of Land Use Conversion for Reducing Soil Erosion in Jiangxi, China. *Catena* **2015**, *125*, 50–60. [CrossRef]
22. Liu, X.Y.; Song, H.L.; Li, R.J.; Zhu, W.B. Spatio-Temporal Dynamic Changes of Soil Erosion in the Yellow River Basin of Qinghai from 2000 to 2020. *South-to-North Water Transf. Water Sci. Technol.* **2025**, *1*, 1–10.
23. Xiao, J.; Sun, Z.; Liu, Z.; Zheng, J.; Liu, Y.; Feng, L.; Bai, W. Effects of Rainfall Erosion Factor, Vegetation Type and Coverage on Soil Erosion of Sloping Farmland. *Trans. Chin. Soc. Agric. Eng.* **2017**, *33*, 159–166.
24. Yao, X.; Yu, J.; Jiang, H.; Sun, W.; Li, Z. Roles of Soil Erodibility, Rainfall Erosivity and Land Use in Affecting Soil Erosion at the Basin Scale. *Agric. Water Manag.* **2016**, *174*, 82–92. [CrossRef]
25. Guo, L.; Liu, R.; Men, C.; Wang, Q.; Miao, Y.; Shoaib, M.; Wang, Y.; Jiao, L.; Zhang, Y. Multiscale Spatiotemporal Characteristics of Landscape Patterns, Hotspots, and Influencing Factors for Soil Erosion. *Sci. Total Environ.* **2021**, *779*, 146474. [CrossRef]
26. Xu, E.; Zhang, H. Change Pathway and Intersection of Rainfall, Soil, and Land Use Influencing Water-Related Soil Erosion. *Ecol. Indic.* **2020**, *113*, 106281. [CrossRef]
27. Zhao, Y.; Liu, L.; Kang, S.; Ao, Y.; Han, L.; Ma, C. Quantitative Analysis of Factors Influencing Spatial Distribution of Soil Erosion Based on Geo-Detector Model under Diverse Geomorphological Types. *Land* **2021**, *10*, 604. [CrossRef]
28. Cao, Y.; Hua, L.; Peng, D.; Liu, Y.; Jiang, L.; Tang, Q.; Cai, C. Decoupling the Effects of Air Temperature Change on Soil Erosion in Northeast China. *J. Environ. Manag.* **2024**, *351*, 119626. [CrossRef] [PubMed]
29. Wang, B.; Zeng, Y.; Li, M.; Chen, D.; Wang, H.; Wang, Y.; Ni, L.; Fang, N. Evaluation of the Driving Effects of Socio-Economic Development on Soil Erosion from the Perspective of Prefecture-Level. *Front. Environ. Sci.* **2022**, *10*, 1066889. [CrossRef]
30. Yu, S.; Wang, L.; Zhao, J.; Shi, Z. Using Structural Equation Modelling to Identify Regional Socio-Economic Driving Forces of Soil Erosion: A Case Study of Jiangxi Province, Southern China. *J. Environ. Manag.* **2021**, *279*, 111616. [CrossRef] [PubMed]
31. Shen, F.; Yang, L.; Zhang, L.; Guo, M.; Huang, H.; Zhou, C. Quantifying the Direct Effects of Long-Term Dynamic Land Use Intensity on Vegetation Change and Its Interacted Effects with Economic Development and Climate Change in Jiangsu, China. *J. Environ. Manag.* **2023**, *325 Pt B*, 116562. [CrossRef]
32. Yin, Z.; Chang, J.; Huang, Y. Multiscale Spatiotemporal Characteristics of Soil Erosion and Its Influencing Factors in the Yellow River Basin. *Water* **2022**, *14*, 2658. [CrossRef]
33. Xu, C.A.; Wang, N.J. Spatio-Temporal Differentiation and Quantitative Attribution of Soil Erosion in Southern Anhui Based on RUSLE and Geodetector. *Res. Soil Water Conserv.* **2025**, *32*, 21–29.
34. Tian, T.; Yang, Z.; Guo, J.; Zhang, T.; Wang, Z.; Miao, P. Spatio-Temporal Evolution of Soil Erosion and Its Driving Mechanism in the Mongolian Section of the Yellow River Basin. *Land* **2023**, *12*, 801. [CrossRef]
35. Wang, K.; Zhou, J.; Tan, M.L.; Lu, P.; Xue, Z.; Liu, M.; Wang, X. Impacts of Vegetation Restoration on Soil Erosion in the Yellow River Basin, China. *Catena* **2024**, *234*, 107547. [CrossRef]
36. Wang, N.; Yue, B.J.; Dang, T.M.; Zeng, L.Q.; Liu, W.W. Analysis of Influencing Factors of Soil and Water Loss in Typical Counties in the Farming-Pastoral Ecotone of the Loess Plateau. *Yellow River* **2024**, *46*, 90–91+93.

37. Tang, S. Evaluating the Effect of Wepp Predictions of Runoff and Soil Losses in the Loess Plateau Region of China. *Pak. J. Agric. Sci.* **2019**, *56*, 774–779.
38. Zhang, L.; Wang, N. Analysis of the Current Situation of Soil and Water Conservation and Countermeasures in Jiangxi Province. *Innov. Tech. Soil Water Conserv.* **2015**, *6*, 42–46.
39. Wang, G.; Zhang, Q.; Zheng, H.; Yang, J.; Xiao, R. Analysis of Soil Erosion Trends and Socio-Economic Driving Forces in Jiangxi Province from 1987 to 2013. *Ecol. Sci.* **2017**, *3*, 115–120.
40. *ArcMap*, Ver. 10.8; Software for Geographical Information System (GIS) Mapping; Esri: Redlands, CA, USA, 2020.
41. *ANUSPLIN*, Ver. 4.37; Software for Spatial Interpolation; Hutchinson, M. F.: Canberra, Australia, 2007.
42. Zhang, X.C. Discussion on Some Problems in Estimating Soil Erosion Using 137Cs Tracer Technique. *Bull. Soil Water Conserv.* **2013**, *37*, 342–346.
43. Li, P.R.; Wang, B.Z.; He, J. Research on Cement Soil under the Influence of Erosion Environment. *Pioneer. Sci. Tech. Mon.* **2012**, *25*, 150–151.
44. Zhou, P.; Meng, J.J. The Relationship between Spatio-Temporal Changes of Soil Hydraulic Erosion and Land Use in Ordos City from 1988 to 2000. *J. Nat. Resour.* **2009**, *24*, 1706–1717.
45. Jiangxi Provincial Bureau of Statistics, Jiangxi Survey Team of the National Bureau of Statistics. *Jiangxi Statistical Yearbook 2023*; China Statistics Press: Beijing, China, 2023.
46. Liu, B.; Zhang, K.; Xie, Y. An Empirical Soil Loss Equation Proceedings-Process of Soil Erosion and Its Environment Effect. In Proceedings of the 12th International Soil Conservation, Beijing, China, 26–31 May 2002; pp. 21–25.
47. Wang, Z.; Yang, X.; Cai, H. Optimizing Key Parameters (Biological-Control Factor) of Soil Erosion Simulation Models at a Regional Scale—The Case of Jiangxi Province, China. *Catena* **2024**, *247*, 108488. [CrossRef]
48. Soil and Water Conservation Department, Ministry of Water Resources. Technical Regulations for Dynamic Monitoring of Soil and Water Loss in the Region. 2018. Available online: https://max.book118.com/html/2019/0605/5211212333002042.shtm (accessed on 24 December 2024).
49. Xiao, Z.; Tian, X.; Li, Y. Study on Regional Soil Erosion Changes and Their Relationship with Human Activities Based on Remote Sensing and GIS: A Case Study of Jiangxi Province. *Remote Sens. Technol. Appl.* **2022**, *4*, 971–981.
50. Zheng, W.; Zou, J.; Tian, Y.; Deng, Y. Spatial Simulation of Regional Human Activity Intensity Based on RS and GIS. *Trop. Geogr.* **2011**, *1*, 77–81.
51. Xu, Y.; Xu, X.; Tang, Q. Human Activity Intensity of Land Surface: Concept, Methods and Application in China. *J. Geogr. Sci.* **2016**, *26*, 1349–1361. [CrossRef]
52. Hu, Z.; He, X.; Li, Y.; Zhu, J.; Li, X. Human Activity Intensity and Its Characteristics in the Upper Minjiang River Basin. *J. Ecol.* **2007**, *4*, 539–543.
53. Pearl, J. Graphs, Causality, and Structural Equation Models. *Sociol. Methods Res.* **1998**, *27*, 226–284. [CrossRef]
54. Hou, D.; Al-Tabbaa, A.; Chen, H.; Mamic, I. Factor Analysis and Structural Equation Modelling of Sustainable Behaviour in Contaminated Land Remediation. *J. Clean. Prod.* **2014**, *84*, 439–449. [CrossRef]
55. Zhou, Y.; Yi, Y.; Liu, H.; Tang, C.; Zhang, S. Spatio-Temporal Dynamic of Soil Erosion and the Key Factors Impact Processes over Semi-Arid Catchments in Southwest China. *Ecol. Eng.* **2024**, *201*, 107217. [CrossRef]
56. Adnan, S.; Aldefae, A.H.; Humaish, W.H. Soil Erosion and the Influenced Factors: A Review Article. *IOP Conf. Ser. Mater. Sci. Eng.* **2021**, *1058*, 012041. [CrossRef]
57. Liu, L.; Wang, Y.; Wang, Z.; Li, D.; Zhang, Y.; Qin, D.; Li, S. Elevation-Dependent Decline in Vegetation Greening Rate Driven by Increasing Dryness Based on Three Satellite NDVI Datasets on the Tibetan Plateau. *Ecol. Indic.* **2019**, *107*, 105569. [CrossRef]
58. Wei, S.; Zhang, K.; Liu, C.; Cen, Y.; Xia, J. Effects of Different Vegetation Components on Soil Erosion and Response to Rainfall Intensity under Simulated Rainfall. *Catena* **2024**, *235*, 107652. [CrossRef]
59. *Amos*, Ver. 24.0. Software for Statistical Analysis. IBM SPSS: Armonk, NY, USA, 2017.
60. Grace, J.B.; Anderson, T.M.; Seabloom, E.W.; Borer, E.T.; Adler, P.B.; Harpole, W.S.; Hautier, Y.; Hillebrand, H.; Lind, E.M.; Pärtel, M.; et al. Integrative modeling reveals mechanisms linking productivity and plant species richness. *Nature* **2016**, *529*, 390–393.
61. Lang, Y.; Yang, X.; Cai, H. Quantifying Anthropogenic Soil Erosion at a Regional Scale—The Case of Jiangxi Province, China. *Catena* **2023**, *226*, 107081. [CrossRef]
62. Ziadat, F.M.; Taimeh, A.Y. Effect of Rainfall Intensity, Slope, Land Use and Antecedent Soil Moisture on Soil Erosion in an Arid Environment. *Land Degrad. Dev.* **2013**, *24*, 582–590. [CrossRef]
63. Zhang, X.W.; Wu, B.F. Analysis of the Influence of the Coupling Relationship between Rainfall and Vegetation on soil erosion: A case study of the upper reaches of Miyun Reservoir. *J. Ecol. Environ* **2010**, *19*, 1290–1294.
64. Wang, J.H.; Lv, G.; Li, H.; Li, K.H.; Liang, Q.Z. Response of Soil Erosion Characteristics on the Slope of the Waste Dump to Rainfall Intensity and Vegetation Coverage. *Irrig. Drain.* **2021**, *40*, 36–39+49.
65. Liu, T.; Liu, H.; Qi, Y. Construction land expansion and cultivated land protection in urbanizing China: Insights from national land surveys, 1996–2006. *Habitat Int.* **2015**, *46*, 13–22. [CrossRef]

66. Zinda, J.A.; Trac, C.J.; Zhai, D.; Harrell, S. Dual-function forests in the returning farmland to forest program and the flexibility of environmental policy in China. *Geoforum* **2017**, *78*, 119–132. [CrossRef]
67. Liu, X.N. Soil and water conservation measures in farmland water conservancy construction. *Water Resour. Electr. Power Technol. Appl.* **2024**, *6*, 146–148.
68. Xin, J.J.; Zhao, G.N.; Huang, Z.L.; Luo, S.H. Spatio-temporal distribution characteristics of meteorological drought in Jiangxi Province from 1961 to 2021. *Meteorol. Disaster Reduct. Res.* **2023**, *46*, 9–17.
69. Provincial Department of Water Resources of Jiangxi. Jiangxi Soil and Water Conservation Plan (2016–2030). 2016. Available online: http://www.hfzf.gov.cn/hfzf/zcjdt/202202/0905786e724e4ae9a604f5c09fd921a7/files/8a4bd06057344ceead7ababedf5b0422.pdf (accessed on 24 December 2024).
70. Wen, T.F.; Zhang, F.P.; Hu, J.M.; Liu, Z.J. Spatio-temporal variation characteristics of rainfall erosivity in the Ganjiang River Basin from 1958 to 2014. *Res. Soil Water Conserv.* **2020**, *27*, 7–14+20.
71. Qi, S.J.; Zhang, X.N.; Xia, D.Z.; Liu, Y.Y.; Liu, B.J. Analysis of land use/cover change characteristics and their driving forces in the Jialing River Basin. *J. Yangtze River Sci. Res. Inst.* **2013**, *30*, 1–7.
72. Cui, J.; Kong, X.; Chen, J.; Sun, J.; Zhu, Y. Spatially Explicit Evaluation and Driving Factor Identification of Land Use Conflict in Yangtze River Economic Belt. *Land* **2021**, *10*, 43. [CrossRef]
73. Barbero, M.; Bonin, G.; Loisel, R.; Quzel, P. Changes and disturbances of forest ecosystems caused by human activities in the western part of the Mediterranean basin. *Vegetatio* **1990**, *87*, 151–173. [CrossRef]
74. Liao, H.; Wei, W.; Shi, Y. Spatiotemporal evolution characteristics and driving mechanisms of soil erosion in typical watersheds of the Loess Plateau: A case study of the Zuli River. *Environ. Sci. Ecotechnol.* **2024**, *6*, 908–918.
75. Lu, L. Issues in the development and utilization of arid land resources in Xinjiang. *Arid Land Res. Manag.* **1989**, *1*, 57–62.
76. Zuazo, V.H.D.; Pleguezuelo, C.R.R. Soil-erosion and runoff prevention by plant covers: A review. *Sustain. Agric.* **2009**, *28*, 785–811.
77. Liu, Y.; Shen, H.; Ge, G.; Xing, A.; Tang, Z.; Fang, J. Classification and distribution of evergreen broad-leaved forests in Jiangxi, East China. *J. Plant Ecol.* **2023**, *16*, rtac059. [CrossRef]
78. Gürcan, E.C. On the development of China's environmental policies towards an ecological civilization. *BRIQ Belt Road Initiat. Q.* **2021**, *2*, 7–25.
79. Ritchie, J.T. Atmospheric and soil water influences on the plant water balance. *Agric. Meteorol.* **1974**, *14*, 183–198. [CrossRef]
80. Bodner, G.; Mentler, A.; Keiblinger, K. Plant roots for sustainable soil structure management in cropping systems. *Root Syst. Sustain. Agric. Intensif.* **2021**, 45–90.
81. Armstrong, W.; Drew, M.C. Root growth and metabolism under oxygen deficiency. In *Plant Roots*; CRC Press: Boca Raton, FL, USA, 2002; pp. 1139–1187.
82. Jiang, F.-S.; Huang, Y.-H.; Wang, M.-K.; Lin, J.-S.; Zhao, G.; Ge, H.-L. Effects of Rainfall Intensity and Slope Gradient on Steep Colluvial Deposit Erosion in Southeast China. *Soil Sci. Soc. Am. J.* **2014**, *78*, 1741–1752. [CrossRef]
83. Cao, J.C.; Wu, H.; Yang, J.B.; Liu, J.Z. Optimizing the layout of meteorological stations and integrating rural revitalization to enhance meteorological service precision. *Chin. Agric. Sci. Bull.* **2021**, *4*, 91–97.
84. Lu, Z.R.; Li, Y.M.; Yang, C.H.; Xia, Z.T.; Cheng, W.W.; Wang, Z.L.; Zhao, J.X.; Fan, M.P. Effects of Continuous Annual Crop Rotation and Fallow on Soil Aggregate Stability and Organic Carbon. *Huan Jing Ke Xue* **2024**, *45*, 1644–1654. [PubMed]
85. Song, G.; Shi, D.M.; Zhu, H.Y.; Jin, H.F.; Zhang, Q.; Lou, Y.B. Effects of different tillage practices on the quality of the plow layer in red soil sloping fields. *Soil Sci.* **2020**, *3*, 610–622.
86. Dai, Z. *Study on the Improvement Effect and Biochemical Mechanism of Biochar on Acidified Soil*; Zhejiang University: Hangzhou, China, 2017.