# Soil and Water Loss Characteristics of Different Forest Stands in Pingjiang

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**Abstract** In this paper, different stands in Xianzhong Nursery of Pingjiang were selected as the research object to study the runoff generation and soil loss characteristics of different stands. The results showed that the annual surface runoff of each model in Pingjiang was between 50.50 and 70.38 mm, and the annual surface runoff of each stand decreased with years. There was no significant difference in the annual runoff between each stand, nor between each stand and its control. There were significant differences in soil erosion modulus among the models, and the number ranged from 139.20 to 197.79 t/($km^2$ · y).

**Key words** Pingjiang; Forest stand; Surface runoff; Improving quality and efficiency

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Soil erosion is a global ecological and environmental problem, which seriously threatens ecological security and sustainable development[1–2]. As the main body of terrestrial ecosystem, forest plays an irreplaceable role in water conservation, soil and water conservation, *etc*[3–4]. However, due to the differences in structure, composition and function, there are also significant differences in the inhibition of soil and water loss by different forest stand types. Therefore, it is of great significance to study the characteristics of soil and water loss in different forest stand types for scientifically guiding forest management, optimizing forest structure and improving forest ecological benefits[5–7].

Pingjiang County is located in the northeast of Hunan Province, which belongs to the subtropical monsoon climate zone. The terrain is dominated by mountains and hills, and it is one of the areas with serious soil and water loss in Hunan Province. In recent years, with the implementation of ecological projects such as forest quality improvement and efficiency increase, the forest coverage in Pingjiang County has increased significantly, but the soil and water conservation functions of different forest stand types still need to be further evaluated. The purpose of this study is to provide a scientific basis for the sustainable management of local forest resources and the comprehensive management of soil and water loss through the comparative analysis on soil and water loss characteristics of different forest stand types in Pingjiang County.

## 1 Overview of the study area

**1.1 General situation** Xianzhong Nursery of Pingjiang is located in the northeast of Hunan Province, with a subtropical monsoon climate and four distinct seasons. The annual average temperature is about 16.8 ℃, hot in summer and mild in winter. The average annual precipitation is 1 358 mm, and most of the precipitation is concentrated in spring and summer. The climate is humid, and the light is sufficient, with simultaneous rain and heat, which is suitable for plant growth.

**1.2 Stand location** Pingjiang positioning monitoring point is located in Manaoling, Xianzhong Village, Jiayi Town, Xianchong Nursery, Pingjiang County. The young and middle-aged forest tending model (FY II, *Cunninghamia lanceolata* + *Liquidambar formosana* + *Camphora officinarum* + *Alnus cremastogyne*), precious tree species improved cultivation model (GP I, *C. lanceolata* + *Ginkgo biloba* + *Cinnamomum camphora* + *Sassafras tzumu* + *Liriodendron chinense*) and precious tree species afforestation model (XZ II, *L. chinense* + *Phoebe zhennan* + *G. biloba*) were selected as the objects for soil and water conservation monitoring (Table 1).

## 2 Materials and methods

**2.1 Rainfall observation** The data were collected continuously at rainfall observation field.

**2.2 Surface runoff observation** The surface runoff was monitored by the method of slope runoff plot location. Slope runoff plots were set up for forest stand type in each project area and each non project area for location monitoring, with 3 replicates.

**2.3 Determination and calculation method of soil water holding capacity** The soil profile was excavated in the sample plot, and the soil layer and the thickness were recorded. The ring knife was used to sample in layers, and it was taken back to the laboratory to determine the soil bulk density, capillary porosity, non capillary porosity, water content, and soil water holding ca-

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pacity. Meanwhile, the volume content of gravel was determined.

**2.4 Determination of soil erosion** Determination of suspended load: 500 ml of sediment mixed sample was collected and put into a marked plastic bottle, and the sediment content of surface runoff was calculated. Determination of bed load: the bed load in the launder and sediment sampling tank was collected after each rain, and sample was taken and dried to constant weight, to calculate the bed load loss.

**Table 1 Information of each stand**

| No. | Model | Stand type | Small place name | Longitude and latitude |
|---|---|---|---|---|
| CK1 | Control | Barren mountain | Manaoling, Xianchong Nursery, Pingjiang | 113°50′40.47″ E, 28°37′49.88″ N |
| FY II | Young and middle-aged forest tending model | *C. lanceolata* + *L. formosana* + *C. officinarum* + *A. cremastogyne* | Manaoling, Xianchong Nursery, Pingjiang | 113°50′40.47″ E, 28°37′49.88″ N |
| GP I | Precious tree species improved cultivation model | *C. lanceolata* + *G. biloba* + *C. camphora* + *S. tzumu* + *L. chinense* | Manaoling, Xianchong Nursery, Pingjiang | 113°50′40.47″ E, 28°37′49.88″ N |
| XZ II | Precious tree species afforestation model | *L. chinense* + *P. zhennan* + *G. biloba* | Manaoling, Xianchong Nursery, Pingjiang | 113°50′40.47″ E, 28°37′49.88″ N |

**2.5 Data processing** In this paper, Excel 2010 was used for consolidated analysis and chart output of the observed statistical data.

Three models of precious tree species afforestation model (XZ II), precious tree species improved cultivation model (GP I) and young and middle-aged forest tending model (FY II) were used to monitor water and soil conservation in Xianzhong Nursery of Pingjiang County. The basic situation was investigated, including data collection of stand status, rainfall process, surface runoff, soil erosion and soil water capacity. The monitoring data of water and soil conservation capacity was collected, and the mid-term monitoring task of the project was fully completed.

## 3 Results

**3.1 Rainfall characteristics in Pingjiang monitoring point** According to the rainfall data of Pingjiang County monitoring point from 2022 to 2023, the total rainfall of Pingjiang was 1 477.3 mm in 2022 and 1 549.4 mm in 2023. According to the statistics of daily rainfall <10 mm, 10 – 20 mm, 20 – 30 mm, 30 – 40 mm, 40 – 50 mm and ≥ 50 mm (Table 2), the annual total rainfall of each interval varied greatly. The rainfall order in 2022 was (<10 mm) > 30 – 40 mm > 10 – 20 mm > (≥ 50 mm) > 20 – 30 mm > 40 – 50 mm, and the maximum interval rainfall was about 3.98 times of the minimum interval rainfall. In 2023, the rainfall order was (<10 mm) > 20 – 30 mm > (≥ 50 mm) > 10 – 20 mm > 30 – 40 mm > 40 – 50 mm, and the maximum interval rainfall was about 2.16 times of the minimum interval rainfall.

**3.2 Soil water storage** Seen from Table 3, the annual soil water storage of Pingjiang's various model plots was between 570.6 and 753.0 mm in 2022. Among the six rainfall ranges, there was a lot of soil water storage in the interval of ≥ 50 mm and 10 – 20 mm. The annual soil water storage was significantly different between FY II and GP I, XZ II and CK1, and between GP I, XZ II and CK1. The order of soil water storage in 2022 was FY II (768.5 mm) > GP I (655.6 mm) > XZ II (645.5 mm) > CK1 (570.6 mm). Compared with 2022, the annual soil water storage in 2023 increased, and the order was FY II (789.4 mm) > GP I (685.3 mm) > XZ II (675.3 mm) > CK1 (593.2 mm).

**Table 2 Rainfall characteristics in Pingjiang monitoring point from 2022 to 2023** mm

| Year | Rainfall interval | | | | | | Annual rainfall |
|---|---|---|---|---|---|---|---|
| | <10 | 10 – 20 | 20 – 30 | 30 – 40 | 40 – 50 | ≥50 | |
| 2022 | 328.9 | 268.6 | 239.7 | 294.7 | 82.6 | 262.8 | 1 477.3 |
| 2023 | 366.2 | 232.3 | 282.4 | 227.2 | 169.2 | 272.1 | 1 549.4 |

**Table 3 Soil water storage of each forest stand in Pingjiang** mm

| Rainfall interval | XZ II | | GP I | | FY II | | CK1 | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| <10 | 141.5 | 138.6 | 145.2 | 148.3 | 179.2 | 170.5 | 116.6 | 115.9 |
| 10 – 20 | 117.1 | 122.3 | 115.3 | 119.4 | 129.2 | 132.3 | 105.3 | 102.4 |
| 20 – 30 | 125.5 | 123.7 | 128.8 | 126.1 | 145.5 | 143.5 | 115.0 | 123.5 |
| 30 – 40 | 120.6 | 121.3 | 119.8 | 118.8 | 140.7 | 137.4 | 115.4 | 114.5 |
| 40 – 50 | 20.5 | 47.1 | 28.6 | 49.8 | 32.4 | 62.5 | 22.6 | 43.7 |
| ≥50 | 120.3 | 122.3 | 117.9 | 122.9 | 141.5 | 143.2 | 95.7 | 93.2 |
| Total | 645.5 | 675.3 | 655.6 | 685.3 | 768.5 | 789.4 | 570.6 | 593.2 |

**3.3 Surface runoff** From 2022 to 2023, the annual surface runoff of Pingjiang's various model plots was between 50.5 and 70.38 mm. The annual surface runoff of each stand decreased with the increase of years. The annual surface runoff of XZ II decreased from 63.66 mm in 2022 to 55.5 mm in 2023, and the annual surface runoff of GP I decreased from 59.74 to 52.97 mm. The annual surface runoff of FY II decreased from 55.59 to 50.5 mm, and the annual surface runoff of CK1 decreased from 70.38 to 64.2 mm. Among the six rainfall intervals, the runoff yield of each stand in each model was the lowest in the range of 0 – 10 mm, and there was more runoff in the intervals of 30 – 40 mm and ≥ 50 mm. The number of runoff generated in each interval ranged from 1 to 14, and each stand only generated runoff once in the interval of 30 – 40 mm in 2022. The number of runoff generated in the interval of 20 – 30 mm was the most among different forest stands in different years, with 8 times of runoff (minimum) generated in XZ II in 2022 and 14 times of runoff (maximum) generated in CK1 in 2023 (Table 4).

**Table 4 Interval distribution of annual runoff in each forest stand of Pingjiang** mm

| Rainfall interval | XZ II | | GP I | | FY II | | CK1 | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| <10 | 2.35 | 2.47 | 2.03 | 2.13 | 2.07 | 2.07 | 2.72 | 2.82 |
| 10 – 20 | 8.46 | 5.45 | 8.27 | 4.24 | 7.01 | 5.02 | 8.62 | 6.94 |
| 20 – 30 | 13.38 | 11.66 | 11.04 | 10.66 | 12.15 | 11.13 | 14.57 | 13.73 |
| 30 – 40 | 18.94 | 17.31 | 18.55 | 17.69 | 17.11 | 16.07 | 22.43 | 20.82 |
| 40 – 50 | 2.55 | 2.47 | 2.43 | 2.43 | 2.07 | 2.17 | 2.92 | 2.92 |
| ≥50 | 17.98 | 16.14 | 17.42 | 15.82 | 15.18 | 14.04 | 19.12 | 16.97 |
| Total | 63.66 | 55.50 | 59.74 | 52.97 | 55.59 | 50.50 | 70.38 | 64.20 |

**3.4 Characteristics of soil loss** Seen from Table 5, the order of each model of Pingjiang in soil erosion modulus in 2022 was CK1 > XZ II > GP I > FY II, and the number was between 139.2 and 197.79 t/($km^2$ · y), which had certain erosivity. The order of each model of Pingjiang in soil erosion modulus in 2023 was CK1 > XZ II > GP I > FY II, and the number ranged from 139.2 to 181.32 t/($km^2$ · y).

**Table 5 Changes of annual soil loss in various forest stands of Pingjiang** t/($km^2$ · y)

| Rainfall interval // mm | XZ II | | GP I | | FY II | | CK1 | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| <10 | 8.53 | 5.97 | 3.67 | 4.43 | 4.58 | 5.75 | 5.83 | 7.37 |
| 10 – 20 | 40.88 | 14.43 | 26.18 | 12.32 | 19.83 | 11.07 | 27.08 | 24.66 |
| 20 – 30 | 31.70 | 29.31 | 31.53 | 32.87 | 25.91 | 29.20 | 37.80 | 35.13 |
| 30 – 40 | 34.41 | 33.88 | 32.57 | 34.16 | 38.64 | 35.28 | 38.59 | 42.98 |
| 40 – 50 | 24.98 | 23.84 | 19.72 | 22.88 | 18.86 | 23.99 | 22.36 | 27.23 |
| ≥50 | 48.00 | 51.29 | 36.99 | 37.43 | 32.11 | 33.91 | 66.13 | 43.95 |
| Total | 188.50 | 158.72 | 150.66 | 144.09 | 139.93 | 139.20 | 197.79 | 181.32 |

The improved cultivation mode was carried out in the middle-aged forest, and the cultivation method was replanting under the forest, with little human interference. At the same time, there were other factors such as terrain and rainfall characteristics.

## 4 Discussion

The reason for the runoff generated by the afforestation mode greater than that of the improved cultivation mode and tending mode is that the monitoring area of the afforestation mode is a newly planted forest, and the early cutting, burning, planting and other business activities have a greater disturbance on the soil, and the vegetation has been seriously damaged, which is not conducive to water and soil conservation. At the same time, the slope of project area in the afforestation mode is larger, which also aggravates the water and soil loss. The stands in the improved cultivation mode and tending mode are more mature, with more soil improvement. There are complete canopy layer, shrub grass layer and litter layer, which change the redistribution of rainfall and reduce the generation of surface runoff. The surface runoff of afforestation mode is decreasing year by year.

In the process of vegetation restoration, soil erosion modulus decreases rapidly. The effect of broad-leaved mixed forest on reducing soil erosion modulus is better than that of coniferous and broad-leaved mixed forest. From the monthly distribution of soil and water loss, it can be seen that the soil and water loss of each forest stand in the afforestation mode mainly occurs in April – July when the rainfall is relatively concentrated. Therefore, the forest tending and other business activities should avoid the rainy season. At the same time, the damage to the irrigation layer should be reduced as much as possible, as well as the disturbance to soil.

## References

[1] YUN HY, BI HX, WANG SS, *et al*. Soil physical and chemical characteristics of different forest types and their effects on soil infiltration process[J]. Journal of Soil and Water Conservation, 2021, 35(6): 183 – 189.

[2] LIANG Y, ZHANG B, PAN XZ, *et al*. Current status and comprehensive control strategies of soil erosion for hilly region in the Southern China[J]. Science of Soil and Water Conservation, 2008, 6(1): 22 – 27.

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unstable energy accumulated in the boundary layer. The *K* index of this process reached 42.7 ℃, which was relatively rare and worthy of attention.

## 4 Mesoscale characteristics of convective storm

Seen from the reflectivity factor and profile near Mochuan, Xing'an at 22:08 (Fig. 3), the strongest reflectivity factor of convective storm was 61 dBZ, and the precipitation echo above 45 dBZ was about 18 km long, which listed the effects to form short-term heavy rainfall. The extension height was lower, below 6 km, and it was a low centroid precipitation echo.

At 00:00 on April 20, an extreme wind speed of 26.5 m/s and a short-term heavy rainfall with an hourly rainfall intensity of 33.6 mm occurred in Xinlong, Baishou, Yongfu, which was caused by a heavy rainfall supercell. The maximum reflectivity factor of supercell (Fig. 4) was 71.5 dBZ, and the moving speed was 62 km/h. The reflectivity factor profile showed a low-level weak echo area, a middle and high-level echo hanging and a bounded weak echo area. The precipitation echo above 60 dBZ extended to 8 km, which was a high centroid precipitation echo. The mesocyclone has a diameter of about 8 km, a rotation speed of 20 m/s, a duration of about 30 min, and a distance of 60 km from the radar station. It was a mesocyclone with medium intensity. Obvious radial convergence in the middle layer can be seen on the velocity profile.

At 04:00 on April 20, the extreme wind speed of 23.6 m/s and the short-term heavy rainfall with an hourly rainfall intensity of 25.2 mm occurred at Yanshan National Weather Station. The strongest reflectivity factor of convective storm reached 71 dBZ, and the moving speed reached 71 km/h. There was a low-level weak echo area, and the precipitation echo above 60 dBZ extended to 7.5 km. The moving direction of convective storm was perpendicular to the radar radial direction, but there was still a large wind speed area behind it.

## 5 Conclusions

(1) During the night of April 19, 2025, the types of severe convection in Guilin were complex, with only short-term heavy rainfall in some areas, accompanied by thunderstorm and gale in some areas. It had the characteristics of large accumulated rainfall, concentrated precipitation periods, mainly short-term heavy rainfall, and mixed severe convection.

(2) This was a strong convective weather process in the warm region. On the south side of warm shear line, with the south branch fluctuation moving eastward, strong convection occurred near the surface convergence line. With the establishment of low-level jet at night, the organized development of convective system was obtained.

(3) Before the convection, Guilin was located on the left side of the low-level jet, between the low-level shear line and the boundary layer shear line, and in the upper dry cold and lower warm wet environment in front of the significant southerly airflow. Unstable stratification and inversion layer were conducive to the occurrence of severe convective weather. Small convective effective potential energy and large *K* value were conducive to the occurrence of short-term heavy rainfall, and strong wind shear and low-level inverted V-shaped structure were conducive to the occurrence of thunderstorm and gale.

(4) The convective storm that only produced short-term heavy rainfall presented as low centroid precipitation echo, and listed the effects to form short-term heavy rainfall. The mixed convection in Xinlong, Baishou, Yongfu was caused by the heavy rainfall supercell, showing high centroid precipitation echo, with weak echo area and bounded weak echo area. The mesocyclone in the supercell was a mesocyclone with medium intensity.

## References

[1] GAO XM, YU XD, WANG LJ, *et al.* Characteristics of environmental parameters for classified severe convective weather in central area of Shandong Province[J]. Acta Meteorologica Sinica, 2018, 76(2): 196-212.

[2] WANG J, YU XD, TAI QG, *et al.* Analysis on the three-dimensional structure and formation mechanism of a severe hailstorm with single- and dual-Doppler radar data[J]. Chinese Journal of Atmospheric Sciences, 2021, 35(2): 247-285.

[3] ZHANG W, CHEN L, HUANG HR, *et al.* Meso-scale structure analysis of an elevated thunderstorm in southwest Fujian[J]. Journal of Tropical Meteorology, 2023, 39(1): 55-65.

[4] ZHANG YP, YU XD, WANG D, *et al.* The formation of typical dry lines in Hetao and its role in triggering convection[J]. Acta Meteorologica Sinica, 2022, 80(1): 39-53.

[5] WANG J, LI XH, WANG YL. Mesoscale characteristic analysis of extreme gale weather in Lingui, Guangxi[J]. Journal of Meteorological Research and Application, 2020, 41(2): 84-88.

[6] WANG YL, WANG J, WU J, *et al.* Comparative analysis of characteristics of "3.21" extreme gale and "4.24" hailstorm in Guilin in 2019[J]. Journal of Tropical Meteorology, 2021, 37(2): 175-185.

[7] WANG T, TANG QY, WANG J, *et al.* Temporal and spatial distribution of short-time severe rainfall in Guilin[J]. Journal of Meteorological Research and Application, 2023, 44(3): 57-61.

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[3] XU YB. Study on soil and water loss process under *Pinus massoniana* forest in red soil hilly region of South China[D]. Fuzhou: Fujian Normal University, 2012.

[4] XIAO SS, WANG C, GUO LP, *et al.* Progress of researches on enhancing soil erosion control and ecological services in red soil hilly region of South China: A case study at Tangbei River watershed of Xingguo County, Jiangxi Province[J]. Bulletin of Soil and Water Conservation, 2019, 39(6): 289-294.

[5] YI K, WANG SY, WANG X, *et al.* The characteristics of spatial-temporal differentiation of soil erosion based on RUSLE model: A case study of Chaoyang City, Liaoning Province[J]. Scientia Geographica Sinica, 2015, 35(3): 365-372.

[6] LAI CY, ZUO SZ, REN Y. Impacts of different ecological restoration measures and environmental factors on water and soil conservation of the slope in the pure coniferous forest of the subtropical red soil area[J]. Acta Ecologica Sinica, 2021, 41(12): 4913-4922.

[7] XU J. Study on soil and water conservation effect of different forest stands in Hengdong sandy shale red soil area[D]. Changsha: Central South University of Forestry and Technology, 2016.