Benefit Analysis of Soil and Water Conservation of Two Typical Economic Forests in Yuyao City

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Abstract. In this study, the typical economic forests (\textit{Phyllostachys pubescens} and \textit{Myrica rubra} forests) in Yuyao City, Zhejiang Province, were taken as research objects. Rainfall, runoff and soil loss data were collected from runoff plots with different measures. The differences of soil and water loss in different measure plots were studied by benefit analysis and regression analysis. The results showed that natural \textit{Phyllostachys pubescens} and \textit{Myrica rubra} forests had better soil and water conservation benefits. Human disturbance will increase the runoff by more than 19\% and soil loss by more than 55\%. There was a significant regression relationship between rainfall-runoff-soil loss in the two forest lands, but the regression curve type was affected by vegetation structure and soil properties.

1. Introduction

Liang \textsuperscript{[1]} attributed the occurrence of soil and water loss in economic forest land to the single vegetation structure and poor surface coverage quality; Chen \textsuperscript{[2]} and Hu \textsuperscript{[3]} analysed the causes of soil and water loss in mountain tea plantations and pointed out that the main causes were slope reclamation, extensive management and unreasonable cultivation. According to the study \textsuperscript{[4]}, the planting methods and planting density of \textit{Camellia sinensis} had a great impact on soil and water loss. The dominant factors causing soil and water loss were different under different environmental conditions. Because of the lack of effective soil and water conservation measures in some economic forests, erosion led to the deterioration of soil physical and chemical properties, which were closely related to soil erosion resistance. In the study of soil properties of artificial pure forest, it was found that soil nutrient loss was serious, organic matter and N, P, K content were low, soil pore condition was bad, sand content was high, which was not conducive to soil and water conservation \textsuperscript{[5,6]}. Yang \textsuperscript{[7]} studied the effects of soil and water conservation measures on soil structure and fertility in citrus orchards on red soil sloping land. The results showed that the soil physical and chemical properties of orchard grass planting measures were the best. In addition, the soil moisture and soil structure of economic forest land also had a certain impact on the growth and development of forest trees \textsuperscript{[8]}. It can be seen that a comprehensive understanding of the physical and chemical properties of soil of economic forest land had a certain guiding significance for the rational management of economic forest. Therefore, the study of soil physical and chemical properties of typical economic forest land can provide a basis for improving the management mode of forest land.
Most of the economic forests were planted in hilly areas. Without reasonable protection measures, soil erosion will be very serious. For example, the annual soil loss of the clear cultivated land in *Citrus reticulata Blanco* orchards can reach more than 4000 t/km², but after the implementation of grass belt control measures, there was no soil loss[9]. The loss of soil and organic matter was 1280 t/km² and 691 kg/km² in *Carya cathayensis* woodland. After planting *Amorpha fruticosa* and *Lolium perenne*, the soil loss was reduced to 256 t/km² and the loss of organic matter was lower than 50% of the control[10].

2. Materials and Methods

2.1. Experiment design and Data acquisition

In order to select typical sample plots as experimental observation sites, a field survey of *Phyllostachys pubescens* forest and *Myrica rubra* forest in the study area was conducted from March to April 2016. Four runoff plots (width was 5m, length was 20m) were established in two kinds of *Phyllostachys pubescens* forests (one was natural forest, with shrub and grass growing under the forest and no human disturbance; the other was pure forest with strong disturbance under the artificial forest). And six runoff plots were established in two kinds of *Myrica rubra* forests (including natural and disturbed)

The data collected included rainfall, runoff and soil loss. The rainfall was measured by a combination of telemetering rain gauge and manual simple rain gauge barrel device. Rainfall device was installed horizontally in open space, with built-in water storage equipment and indoor rain gauge cylinder. When rainfall occurred, recorded the beginning time of rainfall, and when ended, recorded the stopping time and the rainfall amount. The standard of runoff measurement and sampling were that the water depth in observation pool exceeded 10mm.

2.2. Division of Rainfall Intensity

Rainfall may be intermittent. From the point of view of hydrology, If the time interval of rainfall was short, it can be regarded as a rainfall process; if the time interval was long, it should be divided into different rainfall processes. Normally, the standard of dividing rainfall process by time interval of n hours (e.g. n is 6 hours). It was to say, if the rainfall value was not monitored for more than 6 hours in a row, it will be regarded as two rainfall processes; if the interval of rainfall was less than 6 hours, it will be the same rainfall. In this study, rainfall data were collected by telemetering rainfall gauge for 5 minutes. The precipitation data were export to excel, and the precipitation of each rainfall was divided and counted according to the 6-hour interval. The study was carried out according to the classification standard of precipitation intensity issued by the Chinese Meteorological Bureau, as detailed in Table 1.

![Table 1. Criteria for Classification of rainfall Intensity grades](image)

3. Results and Analysis

3.1. Runoff analysis

Vegetation had the function of regulating rainfall. But the function was different because of the differences in vegetation structure and composition, coverage, rainfall conditions and so on. Table 2 showed the rainfall and runoff of *Phyllostachys pubescens* and *Myrica rubra* forests under different measures. From Table 2, it can be seen that 13 rainfall and runoff data had been observed in the
Phyllostachys pubescens
trees, with a total rainfall of 1399.5mm. Among the rainfall intensity of different grades, the times of heavy rain was the most, accounting for 30.8%, and the cumulative rainfall of extra torrential rain was the most, accounting for 40.4%.

The mean runoff depth of natural Phyllostachys pubescens forest plots was 47.40mm. The runoff depth of heavy rain and rainstorm accounted for 15% to 20% of total runoff depth, respectively. The highest proportion of runoff depth occurred in severe storm was 36.1%. And the proportion of runoff depth occurred in extra torrential rainfall was 28.7%. In terms of runoff coefficient, the mean runoff coefficient of natural Phyllostachys pubescens forest runoff plots was 0.034, of which the runoff coefficient of moderate rain was the smallest, while the runoff coefficients of heavy rain and rainstorm were larger. The mean runoff depth of disturbed Phyllostachys pubescens forest runoff plots was 76.21mm. The runoff of heavy rain and rainstorm accounted for 11% to 15% of total runoff, respectively. The proportion of runoff occurred in severe storm and extra torrential rain to total runoff was between 31% and 40%. The mean runoff coefficient of disturbed Phyllostachys pubescens forest runoff plots was 0.055. The runoff coefficients of moderate rain, severe storm and extra torrential rain were between 0.05 and 0.06. The runoff coefficients of heavy rain and rainstorm ranged from 0.06 to 0.07. Compared with disturbed Phyllostachys pubescens forest, natural Phyllostachys pubescens forest reduced runoff by 28.81 mm, and the benefit of reducing runoff was 37.8%.

Table 2. Runoff depth of different economic forest plots

| Rainfall intensity | Phyllostachys pubescens Forest | Myrica rubra Forest |
|-------------------|--------------------------------|---------------------|
|                   | Rainfall times | Rainfall mm | Natural mm | Disturbed mm | Rainfall times | Rainfall mm | Natural mm | Disturbed mm |
| Moderate rain     | 2              | 39.5        | 0.74       | 2.19        | 1              | 18.5        | 0.27       | 0.58        |
| Heavy rain        | 4              | 144.0       | 7.29       | 8.92        | 5              | 168.0       | 7.46       | 11.26       |
| Rainstorm         | 2              | 164.5       | 8.63       | 11.06       | 4              | 350.0       | 16.18      | 20.50       |
| Severe storm      | 3              | 486.0       | 17.13      | 24.24       | 4              | 526.5       | 28.41      | 30.77       |
| Extra torrential rain | 2            | 565.5       | 13.61      | 29.80       | 2              | 653.5       | 64.51      | 80.80       |

Table 2 also reflected the statistical results of rainfall runoff in different Myrica rubra forest runoff plots. A total of 16 rainfall and runoff data were observed in Myrica rubra forest runoff plots, with a total rainfall of 1716.5mm. Among the rainfall intensity of different grades, the times of heavy rain was the most, accounting for 31.3%, and the cumulative rainfall of extra-torrential rain was the most, accounting for 38.1%. The mean runoff depth of natural Myrica rubra forest runoff plots was 116.83mm, the proportion of rainstorm runoff, severe storm runoff, extra torrential rain runoff was 13.9%, 24.3%, and 55.2%, respectively. And the total ratio of moderate rain and heavy rain runoff was only 6.6%.

In terms of runoff coefficient, the mean runoff coefficient of natural Myrica rubra forest runoff plots was 0.068, of which the runoff coefficient of moderate rain was the smallest, the runoff coefficient of heavy rain and rainstorm was 0.045, severe storm was 0.054, and extra torrential rain was 0.099. The mean runoff depth of disturbed Myrica rubra forest runoff plots was 143.91mm, the proportion of rainstorm runoff was 14.2%, severe storm runoff accounted for 21.4%, extra torrential rain runoff was 56.2%, and the total proportion of moderate rain and heavy rain runoff was only 8.2%. In terms of runoff coefficient, the mean runoff coefficient of disturbed Myrica rubra forest runoff plots was 0.084, of which the runoff coefficient of moderate rain was the smallest, the coefficients of heavy rain, rainstorm and severe storm were between 0.06 and 0.07, and the coefficient of extra torrential rain was 0.12. By comparing the two types of Myrica rubra forests, it can be concluded that the runoff of natural Myrica rubra forest was 27.08mm less than that of disturbed Myrica rubra forest, and the benefit of reducing runoff was 18.8%.

3.2. Soil loss amount analysis

According to the statistics of the observation results (Table 3), natural Phyllostachys pubescens forest runoff plots produced 39.42t/km² of soil loss during 13 rainfalls. Among them, 24.1% of the total soil
loss amount was caused by severe storm, 67.3% by extra torrential rain, 3.8% to 4.3% by heavy rain and rainstorm, and very little by moderate rain. The soil loss amount of disturbed Phyllostachys pubescens forest was 103.07 t/km²; the proportion of severe storm soil loss to total soil loss was 32.1%, the highest proportion of extra torrential rain soil loss was 60.6%, the proportion of heavy rain and rainstorm soil loss to total soil loss was between 3.1% and 3.7%. And the amount of moderate rain soil loss was very small. Compared with disturbed Phyllostachys pubescens, natural Phyllostachys pubescens forest reduced soil loss amount by 63.65 t/km², and soil conservation benefit was 61.8%.

| Rainfall intensity grades | Phyllostachys pubescens Forest | Myrica rubra Forest |
|--------------------------|-------------------------------|-------------------|
|                          | Rainfall times | Rainfall mm | Natural t·km⁻² | Disturbed t·km⁻² | Rainfall times | Rainfall mm | Natural t·km⁻² | Disturbed t·km⁻² |
| Moderate rain             | 2              | 39.5       | 0.20           | 0.61             | 1              | 18.5       | 0.09           | 0.19             |
| Heavy rain                | 4              | 144.0      | 1.51           | 3.18             | 5              | 168.0      | 1.56           | 2.49             |
| Rainstorm                 | 2              | 164.5      | 1.69           | 3.78             | 4              | 350.0      | 4.89           | 6.08             |
| Severe storm              | 3              | 486.0      | 9.51           | 33.07            | 4              | 526.5      | 7.83           | 9.37             |
| Extra torrential rain     | 2              | 565.5      | 26.51          | 62.43            | 2              | 653.5      | 25.07          | 69.41            |

From the statistical results in Table 3, it can be known that the natural Myrica rubra forest runoff plot produced 39.44t/km² of soil loss in 16 rainfalls. The proportion of soil loss in rainstorm and severe storm ranged from 12.4% to 19.9%. The highest proportion of soil loss in extra torrential rain was 63.6%, and the proportion of soil loss in heavy rain was 4.0%. The amount of soil loss from moderate rain was very small. The soil loss amount of disturbed Myrica rubra forest runoff plot was 87.54 t/km². The proportion of rainstorm and severe storm soil loss was between 5.9% to 9.1%. The proportion of extra torrential rain soil loss was 67.3%. The proportion of heavy rain soil loss was 2.4%. The amount of moderate rain in soil loss was very small. Compared with disturbed Myrica rubra forest, natural Myrica rubra forest reduced soil loss amount by 48.1 t/km², and soil conservation benefit was 54.9%.

Comparing two different types of economic forests, it can be concluded that the total rainfall of Phyllostachys pubescens forest was 317mm less than that of Myrica rubra forest, and the soil loss amount of natural Phyllostachys pubescens forest and natural Myrica rubra forest was almost the same. While the soil loss amount of disturbed Phyllostachys pubescens forest was 15.53t/km² higher than that of disturbed Myrica rubra forest, that was to say, disturbed Phyllostachys pubescens forest was more prone to soil loss, especially under severe storm rainfall conditions.

3.3. Regression analysis between rainfall and soil loss

According to the regression analysis (Figure 1 and Figure 2), it can be found that there was a significant relationship between runoff depth and rainfall (the determinant coefficient R² of fitting curve was above 0.98), but this relationship varied with vegetation structure and soil characteristics. The relationship between runoff depth and rainfall of the two types of Phyllostachys pubescens forest showed a growth curve with a decreasing slope. However, due to the different vegetation structure, the disturbed Phyllostachys pubescens forest was a quadratic curve and the natural Phyllostachys pubescens forest was a logarithmic curve. The relationship between runoff depth and rainfall of the two Myrica rubra forests was basically the same, showing a quadratic curve with an increasing slope.

From the analysis of runoff difference of different rainfall intensity, the difference of runoff between natural Phyllostachys pubescens forest and disturbed Phyllostachys pubescens forest was mainly over 100mm rainfall, especially under severe storm and extra torrential rain conditions. The runoff reduction benefit of natural Phyllostachys pubescens forest was the greatest in moderate rain, which can reach more than 65%. From heavy rain to extra torrential rain, the runoff reduction benefit gradually increased from 18% to 55%. The difference of runoff between natural bayberry forest and disturbed Myrica rubra forest was obvious over 250mm rainfall. The maximum benefit of reducing runoff of natural Myrica rubra forest was 53% in moderate rain. From heavy rain to severe storm, the
benefit of reducing runoff gradually decreased from 34% to 8%, and the benefit of reducing runoff in extra torrential rain was 20%.

From Figures 3 and 4, it can be seen that there was a significant quadratic relationship between soil loss and rainfall (the curve determinant coefficient $R^2$ was above 0.99), and the slope of the curve increased, which meant that the rate of soil loss increased with the increasing of rainfall.

From the analysis of the difference of soil loss in different rainfall intensity, the difference of soil loss between natural $Phyllostachys pubescens$ forest and disturbed $Phyllostachys pubescens$ forest was mainly over 100mm rainfall, especially under severe storm and extra torrential rain. The soil conservation benefit of natural $Phyllostachys pubescens$ forest was 67% in moderate rain. While from heavy rain to severe storm, the soil conservation benefit increased gradually from 53% to 71%. And the benefit of soil conservation during extra torrential rain was 58%. The difference of soil loss between natural $Myrica rubra$ forest and disturbed $Myrica rubra$ forest was obvious over 200mm rainfall. The maximum soil conservation benefit of natural $Myrica rubra$ forest was 53% in moderate rain. From heavy rain to severe storm, the benefit of soil conservation gradually decreased from 37% to 16%, and the soil conservation benefit was 64% in extreme torrential rain.

4. Conclusion
Based on the knowledge of statistics, meteorology, soil and water conservation and other related disciplines, and taking the oil and water conservation benefit, regression analysis as the key content, the data of rainfall, runoff and sediment in different economic forest types was collected. The soil and
water conservation benefit and differences of water-sediment relationship in different types of economic forests were analysed and compared. The main conclusions were as follows:

1) According to the classification standard of precipitation intensity of China Meteorological Administration, the composition and difference of soil and water loss of different types of economic forests under different rainfall conditions were studied and compared. Severe storm and extra torrential rain were the main rainfall that produced runoff and soil loss. Runoff and soil loss generated by the two rainfall types accounted for 20%~55% and 20%~67%. The runoff reduction benefits of natural Phyllostachys pubescens forest and Myrica rubra forest were 37.8% and 18.8%, and the soil conservation benefits were 61.8% and 54.9%, respectively.

2) By integrating rainfall, runoff and soil loss data of the same type of plots, the relationship and difference between rainfall-runoff-soil loss in different types of plots were analysed and compared. There was a significant curve relationship between rainfall-runoff-soil loss, and the determination coefficient \( R^2 \) of fitting curve was above 0.98. Rainfall-runoff relationship of Phyllostachys pubescens forest was quadratic curve with slope decreasing (disturbed type) and logarithmic curve (natural type). While the relationship between Rainfall and soil loss of Myrica rubra forest was quadratic curve (natural type and disturbance type) with slope increasing. The water and soil conservation benefits of natural Phyllostachys pubescens forest decreased with the increase of rainfall intensity, while the soil conservation benefits increased. The water and soil conservation benefits of natural Myrica rubra forest decreased with the increase of rainfall intensity.

Acknowledgments
This work is supported by the Science and Technology Planning Project of Zhejiang Province, China (Under Grant No. 2018F10030), and also supported by the Hydraulic Technological Program of Zhejiang Province (Under Grant No. RB1609).

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