# Variation Characteristics of Vegetation Factors and Their Influencing Factors in the USLE/RUSLE Model (Postprint)

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## Abstract

The vegetation factor is the most critical influencing factor in the USLE/RUSLE models, and its numerical variation characteristics and influencing factors have attracted extensive attention. Based on observed data of runoff and sediment from individual rainfall events in runoff plots within the YuanKengShui small watershed, Wuhua County, Guangdong Province from 2011 to 2013, this study analyzed the temporal variation characteristics of C factor values in runoff plots and their responses to rainfall and vegetation types. The results indicate: (1) C values exhibit certain fluctuations across different time periods, with dry season values consistently exceeding those of the rainy season; summer and autumn values are relatively high and comparable. C values in all runoff plots generally peak in November, August, and July, and reach minima in June, May, and January. Herbaceous plant C values are significantly influenced by vegetation coverage. (2) Rainfall amount demonstrates a positive correlation with runoff plot C values. The correlation coefficients between C values of eucalyptus, pine, and molasses grass plots and individual rainfall amounts and average values across rainfall intervals are 0.360∗∗, 0.349∗∗, 0.291∗∗, and 0.912∗, 0.909∗, 0.822, respectively. Compared with herbaceous plants, woody plant C values are more substantially affected by rainfall, suggesting that relying solely on vegetation coverage to estimate C values warrants further scrutiny. (3) Relative to the bare soil plot, soil loss reductions in eucalyptus, pine, and molasses grass plots during 2011–2013 were 14.2%, 21.5%, and 23.2%, respectively, with corresponding C values of 0.814, 0.748, and 0.772. Among the three vegetation types, both molasses grass and pine exhibit relatively superior soil and water conservation benefits, while eucalyptus provides marginally inferior benefits.

# Full Text

## Preamble

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**Variations in Vegetation Cover Factors and Their Influence on USLE and RUSLE**

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**Abstract:** Vegetation factors are the most important influences in USLE/RUSLE models, and their variation characteristics and influencing factors have received widespread attention. Based on observed runoff and sediment yield data from field runoff plots in YuanKengShui, Wuhua County, Guangdong Province between 2011 and 2013, this study analyzed the variation characteristics of C values in runoff plots at different temporal scales and the impacts of rainfall and vegetation types. The results showed that: (1) C values fluctuated between seasons, with higher values in summer and fall than in spring and winter, and dry seasons showed higher values than wet seasons. Specifically, higher values were found in November, August, and July, while lower values were observed in June, May, and January. Herbaceous vegetation C values were significantly affected by vegetation coverage. (2) C values were positively correlated with rainfall volume, with correlation coefficients between C values and individual rainfall event volumes of 0.360, 0.349, and 0.291 for eucalyptus, pine trees, and *Melinis minutiflora* runoff plots, respectively. The correlation coefficients for average interval rainfall volume and C values were 0.912, 0.909, and 0.822 for the eucalyptus, pine trees, and *Melinis minutiflora* runoff plots, respectively. Rainfall volume had a much stronger influence on woody plants compared with herbaceous plants, suggesting that C values could not be determined by vegetation coverage alone. (3) A comparison with bare soil runoff plots showed that soil loss was reduced by 14.2%, 21.5%, and 23.2%, and the C values were 0.814, 0.748, and 0.772 for eucalyptus, pine trees, and *Melinis minutiflora* runoff plots, respectively. The results showed that *Melinis minutiflora* and pine trees were better at conserving soil and water than eucalyptus.

**Keywords:** vegetation factors; soil erosion; significant factors; temporal variation

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## Introduction

The C factor, or vegetation cover and management factor, quantitatively expresses the effect of vegetation on soil erosion in the Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE)—the most widely used soil loss equations today. The C factor value represents the ratio of soil loss from land with specific vegetation cover or management practices to that from clean-tilled fallow land under identical conditions. Larger C values indicate more severe soil erosion. Vegetation stems and leaves can weaken raindrop energy, while roots can dissipate the erosive energy of runoff, making vegetation cover critically important for reducing soil erosion.

Research on the C factor originated in the United States in the 1960s, while Chinese studies began in the 1980s. Previous work has extensively investigated relationships between vegetation coverage and C factor values, C factor variations under different crops and management practices, and relationships between C factor values and remote sensing image bands. However, most studies have focused on how vegetation coverage differences during different crop growth stages affect C factors. In the red soil region of South China, where seasonal vegetation coverage changes are relatively small but throughfall splash erosion remains strong under forests, research on C value variations for natural vegetation and their dominant influencing factors—particularly rainfall effects on C values—is still limited. Previous studies have typically calculated C values based on the C factor definition while ignoring differences in soil K factors under different vegetation or cultivation conditions. Currently, the interactive effects of vegetation types, rainfall, and soil on C factor variation in the South China red soil region remain unclear. This study investigated C value variations and influencing factors for several common plant species in this region to provide references for comprehensive evaluation of plant benefits for soil and water conservation.

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## 1 Study Area

The study area is located in Wuhua County, Guangdong Province, in the upper reaches of the Han River. The region has a subtropical maritime monsoon climate with abundant and concentrated rainfall, with an average annual precipitation of 1,450 mm (1,016 mm during the rainy season). The average annual temperature is 20.5°C, with 1,969 hours of sunshine and 315 frost-free days. The topography is dominated by low mountains and hills with complex and diverse terrain, generally ranging from 50–200 m in elevation. Deeply weathered granite is widespread throughout the region. The soil is primarily subtropical red soil developed from granite weathering, with high sand content, loose structure, and poor erosion resistance. Surface vegetation is mainly Masson pine (*Pinus massoniana*) and eucalyptus, with *Schima superba* and *Cinnamomum camphora* distributed in valleys and other well-watered locations. Vegetation coverage is generally low, though it can reach 60–80% on some shady slopes.

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## 2 Methods

### 2.1 Runoff and Sediment Measurement

Active gully erosion and generally steep slopes characterize the study area. The Wuhua Soil and Water Conservation Experiment and Extension Station established soil and water conservation experimental runoff plots with 15° slopes in the YuanKengShui small watershed of Wuhua County. The bare soil slope had only sporadic weeds with vegetation coverage below 5%. Eucalyptus and pine plots had vegetation coverage of 60%, while *Schima superba* had 60% coverage. The *Melinis minutiflora* plot was dominated by molasses grass coverage (hereafter referred to as the molasses grass plot). Runoff and sediment from each plot were collected using cement-fixed runoff tanks. After each rainfall event, the water-sediment volume in each tank was recorded. The water-sediment mixture was thoroughly stirred with a shovel, and 500 ml plastic bottles were used to collect well-mixed samples from each tank. Samples were weighed in the laboratory, clear supernatant was removed, and sediment was transferred to aluminum boxes and dried at 105°C for 6–8 hours. The sediment weight in each sample was used to calculate total sediment yield per rainfall event for each plot. The monitoring period for runoff plots was from June 2011 to August 2013.

Runoff plot characteristics

### 2.2 K Factor Determination

Although soil K factors on the same slope might be considered consistent initially, they may change after several years of vegetation growth. Therefore, this study accounted for soil K factor differences when calculating C values. We used the soil erodibility factor K estimation method from the EPIC (Erosion-Productivity Impact Calculator) model developed by Williams:

$$K = [0.2+0.3\times e^{-0.0256\times Sa\times(1-Si/100)}]\times\left(\frac{Si}{Cl+Si}\right)^{0.3}\times\left[1-\left(\frac{0.25\times C}{C+e^{3.72-2.95\times C}}\right)\right]\times\left[1-\left(\frac{0.7\times Sn}{Sn+e^{-5.51+22.9\times Sn}}\right)\right.$$

Where:
K = soil erodibility factor
Sa = sand content (%) (2–0.05 mm)
Si = silt content (%) (0.05–0.002 mm)

Cl = clay content (%) (<0.002 mm)
C = organic carbon content (%)
Sn = 1 - Sa/100

All parameters were determined through field measurements.

Soil particle composition and K factor values of runoff plots

### 2.3 C Value Calculation

By definition, the C factor is the ratio of soil loss from vegetated or managed land to that from clean-tilled fallow land under identical conditions. However, due to differences in vegetation cover and management practices, soil K factor values may vary among runoff plots. Therefore, this study employed a model ratio method. Additionally, R factors were approximately consistent for all plots at the same location during the same period. All plots had identical topographic factors (SL). For the bare soil slope runoff plot, its C_{bare} value could be approximated as 1. By substituting the monitored soil loss data for different periods and K factor values into the equation, C values for different time scales could be calculated.

$$C_{\text{plant}} = \frac{A_{\text{plant}} \times K_{\text{bare}}}{A_{\text{bare}} \times K_{\text{plant}}}$$

Where:
A = soil loss amount
R = rainfall and runoff erosion factor
K = soil erodibility factor
SL = topographic factor
C = vegetation cover and management factor
P = conservation practice factor

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## 3 Results and Analysis

### 3.1 Seasonal Variation of C Values

C values were calculated for spring (March-May), summer (June-August), fall (September-November), and winter (December-February), as well as for rainy (April-October) and dry (November-March) seasons.

Seasonal variation of Factor C values in runoff plots

C values varied seasonally across all runoff plots. Woody plants showed C_{summer} > C_{spring} > C_{winter} > C_{fall}, while the molasses grass plot showed C_{summer} > C_{fall} > C_{spring} > C_{winter}. Variation amplitudes between rainy and dry seasons were 3.63%, 8.03%, and

8.92% for eucalyptus, pine, and molasses grass plots, respectively, with eucalyptus showing the smallest variation and molasses grass the largest. C_{summer} and C_{fall} values were similar across all plots, while woody plant C values in spring and winter were more stable than herbaceous plants, likely due to vegetation coverage changes. The small variation in eucalyptus plot C values between rainy and dry seasons indicates eucalyptus has certain drought-flood resistance, making its soil and water conservation benefits less affected by dry-wet alternation and potentially suitable for erosion control in drought-flood prone areas. The key factor causing increased C values in the molasses grass plot during winter was withering. In winter, C_{{{molasses}}*{{grass}}}* > *C*{eucalyptus} > C_{pine}, demonstrating that evergreen woody plants have better soil and water conservation benefits than herbaceous plants in winter.

### 3.2 Monthly Variation of C Factor

Monthly mean C values for each plant runoff plot showed consistent trends: higher values in November, August, July, and April, and lower values in June, May, and January. Inter-monthly variation coefficients were 0.07, 0.10, and 0.14 for eucalyptus, pine, and molasses grass plots, respectively. Woody plants, especially pine, showed minimal vegetation coverage changes throughout the year, resulting in the most stable C values. The dense, thick canopy and scattered needles on the ground surface effectively reduced raindrop splash erosion, indicating pine is a plant species with good and relatively stable soil and water conservation benefits in the South China red soil region.

[Figure 1: see original paper] Monthly mean of factor C value

In winter, C values differed significantly among plants, with variation coefficients of 0.11, 0.10, and 0.14. The maximum C value plots were pine in January-April and December, eucalyptus in July and September-October, and molasses grass in May-June and August-November. May-June represents the period when molasses grass transitions from withering to sprouting, with minimal vegetation coverage and maximum C values. The monthly variation in C values may be related to monthly vegetation coverage changes among different plants. The consistent trend of C values across plots suggests that in addition to vegetation type and rainfall effects, herbaceous plant C values are more strongly affected by vegetation coverage.

### 3.3 Relationship Between C Factor and Rainfall

Rainfall is the primary external force of soil erosion and has important effects on C values. Correlation analysis between individual rainfall events and C values for eucalyptus, pine, and molasses grass plots showed positive relationships with correlation coefficients of 0.360, 0.349, and 0.291 (n = 131), respectively. At the individual rainfall event scale, C factor values are significantly affected by vegetation coverage and other factors, resulting in large differences. Therefore, rainfall events were divided into intervals: 10-20, 20-30, 30-40, 40-50, and >50 mm (the minimum rainfall for runoff generation was 10 mm). Average rainfall for each interval was calculated, and C values for each vegetation plot increased with rainfall intervals.

[Figure 2: see original paper] Factor C variation with different rainfall range

Molasses grass C values showed good positive correlation with average rainfall within intervals, with correlation coefficients of 0.912, 0.909, and 0.822 ($n = 5$). At different rainfall intervals, the influence of vegetation coverage and other factors was more balanced than at the individual rainfall scale, resulting in smaller differences. The correlation between rainfall and C values was stronger than at the individual storm scale. Woody plant C values were more affected by rainfall than herbaceous plants, likely due to plant height. The greater drop height of raindrops under forest canopies results in larger splash erosion forces, making woody plant C values more rainfall-dependent.

### 3.4 Relationship Between C Factor and Vegetation Type

Generally, as plants grow older, biomass increases and vegetation coverage improves, leading to decreased C values. However, the data showed that C values did not consistently decrease over time. Eucalyptus C values showed the opposite trend to vegetation coverage changes but aligned with rainfall variation patterns, indicating rainfall may have greater influence than vegetation coverage for eucalyptus. This may be related to eucalyptus understory conditions—fewer weeds under eucalyptus stands result in poor energy dissipation for rainfall and runoff, allowing throughfall to directly impact the surface with strong splash erosion forces. As eucalyptus age and height increase, throughfall splash erosion intensifies, enhancing rainfall' s influence on C values.

Analysis of C value variation between rainfall events showed coefficients of variation of 0.18 (pine), 0.23 (molasses grass), and 0.30 (eucalyptus). Since plant C value changes are mainly affected by rainfall and vegetation coverage, and woody plants are more affected by rainfall than herbaceous plants, the larger C value variation in herbaceous plants is likely due to seasonal vegetation coverage changes. In 2011, C values showed eucalyptus > molasses grass > pine, while 2012 showed molasses grass > eucalyptus > pine.

Using 2011-2013 erosion modulus and K values, C values for eucalyptus, pine, and molasses grass plots were 0.814, 0.748, and 0.772, respectively. Although molasses grass plot C values were greater than pine plot values in all three years, erosion modulus showed A_{eucalyptus} > A_{{{molasses}}{{grass}}} > A{pine}. Soil loss reduction compared to bare soil was 14.2%, 21.5%, and 23.2% for eucalyptus, pine, and molasses grass, respectively. This discrepancy may be due to K_{eucalyptus} > K_{pine} > K_{{{molasses}}_{{grass}}}, demonstrating that vegetation effects on soil erosion include not only rainfall interception but also impacts on soil physical properties.

Annual variability of factor C value and erosion modulus

## 4 Conclusions

C values varied seasonally across runoff plots, all showing C_{{{dry}}{{season}}} > C{{{wet}}{{season}}}. Woody plants showed C{summer} > C_{spring} > C_{winter}, while herbaceous plants showed C_{summer} > C_{fall} > C_{spring} > C_{winter}. Maximum C value plots were pine in January-April and December, eucalyptus in July and September-October, and molasses grass in May-June and August-November. Higher C values occurred in November, August, July, and April, while lower values appeared in June, May, and January. Herbaceous plant C values were more strongly affected by vegetation coverage than woody plants.

Rainfall significantly affected C values. All vegetation plots showed good linear relationships between C factor values and rainfall intervals. Due to taller woody plant canopies, throughfall splash erosion remained strong, making woody plant C values more affected by rainfall than herbaceous plants.

Molasses grass and pine had relatively good soil and water conservation benefits. C values were 0.814, 0.748, and 0.772 for eucalyptus, pine, and molasses grass, respectively. However, because K_{eucalyptus} > K_{pine} > K_{{{molasses}}{{grass}}}, erosion amounts still showed A{eucalyptus} > A_{{{molasses}}{{grass}}} > A{pine}. Pine demonstrated relatively better soil and water conservation benefits. Vegetation effects on soil erosion include both rainfall interception and impacts on soil physical properties, suggesting that using vegetation coverage alone to determine C values requires further consideration, and understory vegetation protection and restoration in eucalyptus forests should be strengthened.

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