Vertical Variation Characteristics of Total Organic Carbon Flux in Vegetation-Hydrological Processes at Guilin Karst Experimental Site (Postprint)

Authors: Deng Yan, Jiang Zhongcheng, Guo Yiming, Xu Ye, Yue Xiangfei, Jiang Zhongcheng

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Abstract

This study takes two typical vegetation types (Toona sinensis forest and Caesalpinia decapetala shrubland) in the karst rocky mountainous area of Guilin, Guangxi as examples, and uses long-term field monitoring of TOC variation characteristics in rainfall, throughfall, stemflow, borehole water, and epikarst water to investigate the annual variation characteristics of TOC concentration and flux in the canopy layers of different vegetation types. The results show that during the process of rainfall passing through the atmosphere-vegetation-soil/rock system, the trend of TOC concentration change is: stemflow > throughfall > borehole water > spring water > atmospheric rainfall; the TOC concentrations in throughfall and stemflow exhibit a trend of being higher in the rainy season and lower in the dry season, while the monthly variation of TOC concentration in borehole water and spring water is relatively stable; the increase amplitude of TOC concentration differs, with the average increment and variation range of TOC concentration in throughfall and stemflow being greater than those in borehole water and spring water; the TOC concentration of stemflow in Toona sinensis forest shows a negative correlation with stemflow volume; the monthly average TOC flux is: Caesalpinia decapetala throughfall > Toona sinensis throughfall > rainfall > spring water > Toona sinensis stemflow > Caesalpinia decapetala stemflow; the TOC flux of rainfall in the Caesalpinia decapetala shrubland (204.86 kg · hm ^{2}) is 1.3 times that in the Toona sinensis forest (153.48 kg · hm ^{2}); during the observation period, the TOC flux input from atmospheric rainfall was 63.06 kg · hm ^{2}, the output from epikarst spring water was 48.29 kg · hm ^{2}, the difference between TOC input and output was 14.77 kg · hm ^{2}, and the system showed a positive TOC balance; when rainfall enters the interior of vegetation, the vegetation canopy acts as a "TOC active

pool" with a "source" effect of increasing TOC flux, while the soil/rock system in the epikarst zone acts as a "TOC inactive pool" with a "sink" effect of absorbing, filtering, and fixing TOC.

Full Text

Preamble

Vertical Variation Characteristics of Total Organic Carbon Flux in Vegetation Hydrological Processes at the Guilin Karst Experimental Site

DENG Yan[1],[2], JIANG Zhong-cheng[2]*, GUO Yi-ming[1], XU Ye[2], YUE Xiang-fei[2]

[1]School of Environmental Studies, China University of Geosciences (Wuhan), Wuhan 430074, China
[2]Institute of Karst Geology, Chinese Academy of Geological Sciences; Key Laboratory of Karst Ecosystem and Rocky Desertification Treatment, Ministry of Land and Resources, Guilin 541004, China

Abstract: This study examines two typical vegetation types (Toona sinensis forest and Caesalpinia decapetala shrubland) in the karst rocky mountain area of Guilin, Guangxi, using long-term field monitoring of rainfall, throughfall, stemflow, borehole water, and epikarst spring water to investigate the annual variation characteristics of total organic carbon (TOC) concentration and flux in different vegetation canopies. Results indicate that as rainfall passes through the atmosphere-vegetation-soil/rock profile, TOC concentration follows the trend: stemflow > throughfall > borehole water > spring water > atmospheric rainfall. TOC concentrations in throughfall and stemflow are higher in the rainy season and lower in the dry season, while monthly TOC concentrations in borehole water and spring water remain relatively stable. The magnitude of TOC concentration increase varies, with average increments and variation amplitudes in throughfall and stemflow being larger than those in borehole water and spring water. In the Toona sinensis forest, stemflow TOC concentration shows a negative correlation with stemflow volume. The monthly average TOC flux ranks as: Caesalpinia decapetala throughfall > Toona sinensis throughfall > rainfall > spring water > Toona sinensis stemflow > Caesalpinia decapetala stemflow. The TOC flux under shrubland rainfall (204.86 kg · hm ^{2}) is 1.3 times that of the forest (153.48 kg · hm ^{2}). During the observation period, atmospheric rainfall input a TOC flux of 63.06 kg · hm ^{2}, while epikarst spring output was 48.29 kg · hm ^{2}, resulting in a positive balance of 14.77 kg · hm ^{2}. When precipitation enters the vegetation system, the canopy acts as a "TOC live reservoir" that increases TOC flux (source function), whereas the soil/rock system in the epikarst zone serves as a "TOC dead reservoir" with sink functions of absorption, filtration, and fixation.

Keywords: total organic carbon, flux, atmosphere-vegetation-soil/rock system,

karst rocky mountain area, hydrological processes

Introduction

Southwest China’ s karst region features exposed carbonate rocks with intense dissolution, highly developed fracture-conduit systems, and thin soils, forming a unique dual surface-subsurface spatial structure. This distinctive soil and water resource distribution pattern creates prominent ecological and environmental problems. Total organic carbon (TOC) refers to all organic carbon present in water in dissolved or suspended forms, including dissolved organic carbon (DOC) and particulate organic carbon (POC) (Greenberg, 1992), with DOC typically accounting for over 90% of TOC (Mattsson et al, 2003; Kortelainen et al, 2006). As an important component of the global carbon cycle, TOC serves as an energy source for aquatic microorganisms (Jansson et al, 2000), making its study crucial for analyzing carbon fluxes in aquatic systems and global carbon cycle research.

Global groundwater TOC export has shown a significant increasing trend in recent decades (Freeman et al, 2001; Erlandsson et al, 2008). Organic carbon transported from terrestrial ecosystems to oceans via rivers originates primarily from: (1) gaseous and particulate dry deposition (Wilcke et al, 2001); (2) vegetation, including direct litter input and leaching from living plants and litter; (3) soil, mainly from microbial metabolism, root exudates, and leaching and erosion of soil organic matter (Hope et al, 1994); and (4) formation of various organic carbon forms (POC and DOC) by aquatic plants in terrestrial aquatic ecosystems through consumption of dissolved inorganic carbon (DIC) (Zhang et al, 2013). Scholars have investigated TOC and DOC in precipitation, throughfall, stemflow, soil solution, and stream water in temperate and tropical forests (Currie et al, 1996; Inagaki et al, 1995; McDowell et al, 1998). Yang et al. (2014) demonstrated that TOC input flux carried by precipitation plays an important role in forest TOC input, with forest canopy leaching increasing TOC flux while soils significantly reduce TOC output flux. Research on the Guancun underground river in Guangxi (Wang et al, 2016) showed rapid fluctuations in TOC and DOC concentrations, with DOC diel variations potentially controlled by biological metabolic activity. Rainfall, discharge, and turbidity positively promote TOC export from karst underground rivers, while temperature and pH negatively affect TOC (Wang et al, 2016). Additionally, TOC significantly contributes to food chains in freshwater bodies like lakes and rivers, playing an important role in material element cycling. DOC composed of organic acids such as humic and fulvic acids plays a non-negligible role in neutralizing cations, decomposing heavy metal ions, mineral weathering, and desorption of acidic ions (Liechty et al, 1995). DOC is also associated with the migration of metal elements like Al and Hg (Driscoll et al, 1995). However, few studies have addressed TOC dynamics in the atmosphere-vegetation-soil/rock system in Southwest China’ s karst rocky mountain areas, and carbon fluxes through the vegetation ecosystem-epikarst zone remain unclear.

Therefore, this study focuses on Toona sinensis forest and Caesalpinia decapetala shrubland in the karst rocky mountain area of Guilin, Guangxi, using long-term field monitoring of TOC variation characteristics in throughfall, stemflow, borehole water, and epikarst water to investigate the annual variation characteristics of TOC concentration and flux in different vegetation canopies, providing a scientific basis for detailed characterization and quantitative evaluation of vegetation carbon and nutrient balance in biogeochemical cycles in Southwest China’ s karst rocky mountain areas.

1. Study Area Overview

The study area is located near Yaji Village, approximately 8 km southeast of Guilin City (25°10 N, 110°15 E), at the junction between peak-cluster depressions and the Guilin peak forest plain, forming an independent karst hydrogeological system at the Yaji Experimental Site. The region has a subtropical monsoon climate with uneven seasonal rainfall distribution, dominated by the East Asian summer monsoon in summer and influenced by inland or local evaporation and winter monsoon in winter. According to meteorological data from Guilin Station (1951-2012), the multi-year average annual rainfall is 1,886 mm, with distinct rainy (April-August, accounting for 70% of annual rainfall) and dry seasons (September-March). The multi-year average temperature is 18.9°C.

The experimental area has uniform lithology, primarily exposing Upper Devonian Rongxian Formation limestone (D r) (Jiang and Zhang, 2011), composed of light gray to off-white pure medium-thick layered sparry grain limestone with dense structure and porosity of approximately 0.12%-3.29% (average 0.68%). Soils are thin and discontinuous, mainly fissure soils on slopes with thickness of 0-1 m, soil coverage of about 30%, and high rock exposure. Karst is well developed, with a fracture-conduit aquifer medium (Chang et al, 2012). The S31 epikarst spring watershed is the main sub-watershed of the experimental site, with tracer experiments indicating its recharge area consists of three small peak-cluster depressions covering approximately 1 km^2 (Chang et al, 2012; Yuan et al, 1996), dominated by conduit flow combined with diffuse fracture flow. The S31 spring is highly responsive to rainfall, with discharge varying from 0.1 to 7000 L • s ^{1}.

Since the 1980s, vegetation in the study area was extensively destroyed until protection measures were implemented after the experimental site’ s establishment. Currently, Caesalpinia decapetala shrubland accounts for about 70% of the site area, with sparse Toona sinensis forest covering approximately 30%. Detailed plot characteristics are shown in Table 1 . Representative plots were established: a 30 m × 30 m plot in Toona sinensis forest and a 20 m × 20 m plot in Caesalpinia decapetala shrubland. The Toona sinensis plantation had few understory shrubs and herbs, with stand age of about 15 years, canopy closure of 0.4, average DBH of 25.33 cm, average tree height of 7 m, and average crown width of 5 m. The shrub layer was dominated by Vitex negundo and Bauhinia championii (Benth.) Benth. with 65% coverage, while the herb layer mainly consisted of Nephrolepis auriculata (L.) Trimen with 20% coverage. In the Caesalpinia decapetala shrubland plot, average canopy height was 1.5 m, average crown width was 3.5 m, shrub layer coverage was 85% with dominant species including Caesalpinia decapetala, Vitex negundo, and Loropetalum chinnensis. The understory had abundant herbs with 30% coverage, mainly Miscanthus floridulus (Labnll.) Warb and Nephrolepis auriculata.

2. Research Methods

2.1 Data Collection

The experiment ran from May 2015 to April 2016. After each rainfall event, water samples of atmospheric rainfall, throughfall, stemflow, borehole water, and epikarst spring water were stored in freezers. A total of 42 rainfall events were sampled during the monitoring period.

To collect and monitor atmospheric rainfall, a tipping-bucket rain gauge with 1 mm precision was installed in an open area in Guilin City, 8 km from the study area, to measure rainfall amount and process. Additionally, three self-made rain gauges (20 cm inner diameter) were deployed, with water samples collected from all three gauges after each rainfall event and mixed to form a composite sample.

For throughfall collection, a mechanical layout method was used: 16 throughfall collectors were arranged in two rows (8 per row) in the Toona sinensis forest. In the Caesalpinia decapetala shrubland, 16 plastic buckets were placed extending east, south, west, and north from the base at radial distances of 5, 10, 15, and 20 cm. After each rainfall event, collected throughfall volume was measured using a 100 mL standard cylinder, with throughfall amount and water samples represented by the mean of all 16 collectors.

For stemflow measurement, three standard trees were selected in the Toona sinensis forest. Polyethylene tubes (2 cm diameter) were split longitudinally and wrapped spirally around the trunk starting 1 m above ground (with bark slightly scraped flat), fixed with thumbtacks and sealed with glass adhesive at joints. A 15 L plastic bucket was connected at the lower end, with water volume measured after each rainfall event. For shrubs, two standard shrubs were selected, with split polyethylene tubes (2 cm diameter) tied in a collar shape at 10 cm above the base, fixed with thumbtacks and sealed to prevent water leakage, connected to 15 L buckets for volume measurement and sample collection.

Borehole water and epikarst spring water were collected simultaneously with throughfall and stemflow measurements. A CTDP300 multi-parameter automatic recorder (Greenspan, Australia) was installed at the S31 epikarst spring to monitor five parameters (rainfall, water level, temperature, pH, and electrical conductivity) at 15-minute intervals.

2.2 Chemical Analysis

After field filtration with qualitative filter paper, TOC concentrations were measured using a Multi N/C 3100 multifunctional carbon-nitrogen analyzer (Analytik Jena AG, Germany) at the Institute of Karst Geology, Chinese Academy of Geological Sciences, with measurement precision of 0.1%-5%.

2.3 Data Analysis

The average TOC concentration of a given water type was calculated as a weighted value based on corresponding water volumes from each rainfall event:

$$C = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} = \frac{\sum_{i=1}^{n} C_i P_i}{P}$$

where C is the average TOC concentration of a water type (precipitation, throughfall, stemflow) ($\mathrm{mg} \cdot \mathrm{L}^{\ 1}$), C_i is the measured TOC concentration after a single rainfall event ($\mathrm{mg} \cdot \mathrm{L}^{\ 1}$), P_i is the water volume of a given type from a single rainfall event (mm), P is the total water volume of a given type (mm), and n is the number of rainfall events measured. Forest floor precipitation equals the sum of throughfall and stemflow volumes, with its average TOC concentration calculated as the volume-weighted average of separately measured throughfall and stemflow TOC concentrations.

This study simplified the complex karst ecosystem structure into two functional layers: the canopy layer (including canopy and herbaceous layers) and the soil/rock layer (litter layer and soil/rock layer). The TOC flux through each functional layer during rainfall passage was calculated as:

$$F = C \times P \times 10$$

where F is the TOC flux through a functional layer ($\mathrm{kg} \cdot \mathrm{hm}^{\ 2}$), C is the average TOC concentration ($\mathrm{mg} \cdot \mathrm{L}^{\ 1}$), and P is the total water volume passing through each layer (mm).

The change in TOC flux (ΔF) through a given layer (F_i) relative to the input TOC flux from the upper layer (F_j) was calculated according to formula (3):

$$\Delta F = F_i - F_j$$

3. Results

3.1 Rainfall Characteristics Analysis

During the experimental period (May 1, 2015–April 30, 2016), total rainfall was 3121.2 mm. Rainfall in the experimental area consisted mainly of short-duration showers. The rainy season began in April, dominated by small rainfall events (<10 mm) (Figure 1 [Figure 1: see original paper]). Rainfall amount, intensity, and duration peaked in May, with the highest number of rainfall days (22 days), including 12 small events (<10 mm) and 2 heavy storm events. Rainfall frequency, amount, and intensity decreased in June, July, and August.

Daily rainfall amounts across six categories (<10, 10-25, 25-50, 50-100, 100-250, and >250 mm) were 418.8, 541.2, 830.8, 922.2, 408.2, and 0 mm, respectively, accounting for 13.42%, 17.34%, 26.62%, 29.55%, 13.08%, and 0% of total rainfall (Table 2). Small rain days (<10 mm) accounted for 63.16% of total rainfall days but only 13.42% of total rainfall, indicating minimal impact. Heavy rain events (50-100 mm) represented 7.37% of rainfall occurrences but contributed 29.55% of total rainfall, demonstrating significant influence. The minimum daily rainfall was 0.2 mm, with three heavy storm events recorded (169.4 mm on May 15, 2015; 107.2 mm on May 20, 2015; and 131.6 mm on June 13, 2015), and no extreme storm events.

[Figure 1: see original paper]

3.2 Monthly Dynamics of TOC Concentration in Vegetation Hydrological Processes in Karst Rocky Mountain Areas

TOC concentrations changed as rainfall passed through the atmosphere-vegetation-soil/rock profile. During the observation period, atmospheric precipitation had an average TOC concentration of 3.05 ± 2.12 mg · L ^{1}. Rainfall deposits carbon-containing particles from air suspension, leaching organic carbon adhered to plant surfaces, secreted by plants and attached microorganisms, and from small animal carcasses. In Toona sinensis forest, average TOC concentrations ranked as: stemflow (8.96 ± 3.77 mg · L ^{1}) > throughfall (6.40 ± 3.99 mg · L ^{1}) > CF18 (6.07 ± 2.17 mg · L ^{1}) > spring water (5.18 ± 1.56 mg · L ^{1}). In Caesalpinia decapetala shrubland, average TOC concentrations ranked as: stemflow (15.63 ± 6.11 mg · L ^{1}) > throughfall (15.03 ± 7.47 mg · L ^{1}) > CF16 (6.40 ± 1.96 mg · L ^{1}) > spring water (5.18 ± 1.56 mg ^{1}). After precipitation enters the forest, carbon concentration increases due to canopy leaching (McDowell & Likens, 1988) and dissolution (Turkey et al, 1970), making canopy structure and composition the primary factors affecting throughfall TOC concentration. As a pioneer species for vegetation restoration in Southwest China' s karst rocky mountain areas, Toona sinensis has a simple canopy structure, low closure, relatively simple secretions, and fewer organic particles deposited on leaf surfaces due to its deciduous nature. The higher leaching capacity of Caesalpinia decapetala shrubland results from dense foliage, high closure and leaf area index, cracked bark, rough and hairy leaves, and possibly secretion characteristics. After throughfall and stemflow enter the epikarst zone, TOC concentrations decrease through adsorption by fissure soils/rocks and microbial degradation, with spring water TOC concentrations continuing to decline after long-term water-rock interaction.

Monthly TOC concentration dynamics showed minimal variation in rainfall

TOC concentrations throughout the year, while both forest types exhibited substantial monthly variation in stemflow and throughfall TOC concentrations, generally higher in the rainy season than dry season (Figure 2 [Figure 2: see original paper]). Throughfall and stemflow TOC concentrations began increasing in June, peaked in September, and decreased by November as organic carbon particles accumulated on plant surfaces during the rainy season were flushed and leached, leaving fewer organic substances on bark and leaves. Borehole water and spring water TOC concentrations showed monthly variation patterns consistent with throughfall and stemflow.

[Figure 2: see original paper]

The magnitude of TOC concentration increase differed during rainfall passage through atmospheric-vegetation-soil/rock layers (Table 3), related to rainfall intensity, duration, canopy structure, and epikarst zone structure. During the observation period, average increments and variation amplitudes of TOC concentration in throughfall and stemflow were larger than those in borehole water and spring water, with shrubland showing the greatest average increment and variation amplitude.

3.3 Correlation between Organic Carbon Concentration and Water Volume in Toona sinensis Forest and Caesalpinia decapetala Shrubland

As shown in Figure 3 [Figure 3: see original paper], Toona sinensis forest stemflow TOC concentration showed a negative correlation with stemflow volume, while no significant correlation existed between Caesalpinia decapetala shrubland stemflow TOC concentration and stemflow volume. Neither Toona sinensis forest nor Caesalpinia decapetala shrubland showed significant correlations between throughfall TOC concentration and throughfall volume.

[Figure 3: see original paper]

3.4 TOC Flux in the Atmosphere-Vegetation-Soil/Rock System of Karst Rocky Mountain Areas

Leaching, adsorption, and absorption of TOC occur when precipitation contacts vegetation surfaces, litter, soil, and rocks, with water volume variations creating differences in TOC flux across functional layers. As shown in Figure 4 [Figure 4: see original paper], during the observation period, monthly average TOC flux ranked as: Caesalpinia decapetala throughfall (16.68 kg · hm ^{2}) > Toona sinensis throughfall (8.73 kg · hm ^{2}) > rainfall (5.25 kg · hm ^{2}) > spring water (4.02 kg · hm ^{2}) > Toona sinensis stemflow (0.59 kg · hm ^{2}) > Caesalpinia decapetala stemflow (0.38 kg · hm ^{2}).

[Figure 4: see original paper]

The difference between forest floor precipitation and open rainfall TOC flux indicates the degree of leaching from vegetation canopy and trunks. Both Toona sinensis forest and Caesalpinia decapetala shrubland showed increased annual TOC flux under forest floor precipitation relative to open rainfall, with increases of 48.75 kg · hm ^{2} and 170.67 kg · hm ^{2}, respectively (Table 4), demonstrating net TOC flux increase through canopy and trunk leaching. The difference between spring water and forest floor precipitation TOC flux indicates the role of the epikarst zone in processing TOC input from forest floors. Annual TOC flux carried by spring water (63.06 kg · hm ^{2}) was lower than that under forest floor precipitation in both vegetation types. After passing through the epikarst zone, spring water TOC flux (48.29 kg · hm ^{2}) decreased by 0.46 kg · hm ^{2} and 122.38 kg · hm ^{2} for Toona sinensis forest and Caesalpinia decapetala shrubland, respectively, indicating net adsorption or storage ("sink" function) of TOC in the epikarst zone.

4. Discussion

4.1 Analysis of TOC Concentration Differences in the Atmosphere-Vegetation-Soil/Rock System of Southwest Karst Rocky Areas

Atmospheric rainfall TOC input represents one source of TOC for the epikarst zone. In the karst atmosphere-plant-soil/rock system, TOC concentration follows the trend: stemflow > throughfall > borehole water > spring water > atmospheric rainfall. In Guilin, Guangxi, atmospheric precipitation TOC concentration (3.05 mg · L ^{1}) is higher than that in Dinghushan, Guangdong (2.4 mg · L ^{1}) (Luo et al, 2004; Yin et al, 2005) and some foreign temperate forest studies (1.0-2.9 mg · L ^{1}) (Currie et al, 1996; Inagaki et al, 1995; McDowell et al, 1998; Liu & Bor, 2003), but lower than in Liupanshan, Ningxia (7.34 mg · L ^{1}) (Yang et al, 2014) and Guandaosi, Taiwan (4.7 mg · L ^{1}) (Chiung et al, 2003), related to the quantity of suspended organic particles in local air. Through leaching and washing of leaves and trunks, TOC concentration increases significantly as precipitation transforms to throughfall and stemflow. In this study, stemflow showed the highest TOC concentration (0.11-45.56 mg · L ^{1}), lower than ranges reported elsewhere (4.1-56.89 mg · L ^{1}) (Currie et al, 1996; Inagaki et al, 1995; McDowell et al, 1998; Liu & Bor, 2003; Yang et al, 2014). Throughfall TOC concentration in the Yaji Experimental Site varied widely (0.02-51.89 mg · L ^{1}), showing greater variation than Dinghushan (12.9-14.6 mg · L ^{1}) (Yin et al, 2005), Liupanshan (11.05-21.92 mg · L ^{1}) (Yang et al, 2014), central Taiwan' s Guandaosi (7.0-9.9 mg · L ^{1}) (Liu & Bor, 2003), and other regions (3.1-33.9 mg · L ^{1}), primarily related to tree species, forest structure characteristics, and Guilin' s rainfall intensity/frequency patterns with distinct wet and dry seasons. The high TOC content in throughfall from Yaji' s Toona sinensis forest and Caesalpinia decapetala shrubland can provide substantial energy for understory microbial growth and enhance biochemical interactions between microorganisms and plants.

During transformation of forest floor precipitation to borehole water in the karst soil/rock system, TOC concentration changes relate to soil thickness, litter quantity/composition, and rock porosity. Borehole water TOC concentration at the Guilin experimental site ranged 0.01-12.77 mg · L ^{1}, lower than litter leachate in Liupanshan (22.29-28.55 mg · L ^{1}) (Yang et al, 2014) and Dinghushan (28.5 mg · L ^{1}) (Yin et al, 2005), but similar to soil leachate in Dinghushan (5.4-12.1 mg · L ^{1}) (Yin et al, 2005) and Guandaosi (7.7-11.0 mg · L ^{1}) (Chiung et al, 2003), mainly due to low litter quantity, thin soils, and low soil organic matter content at the Yaji site. Epikarst spring water TOC concentration (0.34-11.73 mg · L ^{1}) was similar to borehole water but significantly lower than all conversion stages from open to forest floor precipitation, indicating non-negligible adsorption and interception of TOC by the epikarst soil/rock system.

4.2 TOC Flux in the Atmosphere-Vegetation-Soil/Rock System of Southwest Karst Rocky Mountain Areas

As precipitation passes through the atmosphere-vegetation-soil/rock system, leaching, adsorption, and absorption of TOC occur in different tree species and media, with water volume variations creating differences in TOC flux across functional layers. Compared to open rainfall TOC flux (63.06 kg · hm ^{2}), forest floor precipitation TOC flux (throughfall + stemflow) increased in both forest plots, indicating net TOC leaching from vegetation canopies, consistent with other studies. Overall, forest floor precipitation TOC flux in Yaji' s Toona sinensis forest (153.48 kg · hm ^{2}) and Caesalpinia decapetala shrubland (204.86 kg · hm ^{2}) exceeded that in five forest types (63.01-132.28 kg · hm ^{2}) and one shrubland (79.49 kg · hm ^{2}) in Liupanshan, Ningxia, with shrubland showing the greatest net TOC leaching. This may result from rough, hairy leaves in shrubland more effectively intercepting and storing dry deposition, with dense foliage also promoting insect reproduction and growth; field sampling clearly observed numerous insect residues on Caesalpinia decapetala leaves.

In this study, Yaji epikarst spring water TOC flux was 48.29 kg · hm ^{2}, lower than Picea armandii forest soil leachate in Liupanshan (66.33 kg · hm ^{2}) (Yang et al, 2014) and far lower than litter leachate TOC flux, demonstrating the important "sink" function of absorption, filtration, and fixation in the epikarst zone. TOC flux changes in the atmosphere-vegetation-soil/rock system reflect carbon transfer processes accompanying water transformation within vegetation and the epikarst zone. Under Guilin's subtropical monsoon climate and exposed karst geological background, the canopy layer shows net increase (leaching and washing) of TOC flux from open precipitation input, while the epikarst soil/rock system significantly reduces forest floor precipitation TOC flux, demonstrating net fixation.

In summary, atmospheric rainfall inputs a certain amount of TOC into the karst ecosystem ("source" function). When rainfall enters vegetation, the canopy acts as a "TOC live reservoir" with a "source" function of increasing TOC flux, while the soil/rock system serves as a "TOC dead reservoir" with a "sink" function of fixing TOC. Therefore, when estimating carbon transfer in karst areas, the net increase effect of vegetation systems on TOC flux must be fully considered; models considering only atmospheric rainfall and spring water TOC input-output would substantially underestimate the fixation capacity of soil-carbonate rock systems for TOC.

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