

Supplementary materials for

Soil stoichiometric characteristics and influencing factors in karst forests under micro-topography and microhabitat scales

5 Yi Dang et al.

Correspondence to: Run Liu (18285115229@163.com) and Peng Wu (zuishaoxu@163.com)

Table S1. The correspondence between various factors and the number of sample plots.

Environmental factors	Class	Number of Plots
Slope position	Upslope	6
	Midslope	18
	Downslope	49
	Depression	13
	Flat slope	16
Slope degree	Gentle slope	12
	Tilted slope	14
	Steep slope	27
	Sharp slope	17
	Shady slope	6
Slope aspect	Semi-shady slope	22
	Flat land,	16
	Semi-sunny slope	19
	Sunny slope	23
	Stong gully	29
Microhabitat	Stong surface	29
	Soil surface	28
	Evergreen trees	32
Life forms	Deciduous trees	21
	Shrubs	21
	Herbs	12

Table S2. Characteristics of various types of nutrient content.

Statistical characteristics	Soil Organic Carbon /(g·kg ⁻¹)	Total Nitrogen /(g·kg ⁻¹)	Hydrolyzable Nitrogen /(mg·kg ⁻¹)	Total Phosphorus /(g·kg ⁻¹)	Available Phosphorus /(mg·kg ⁻¹)	Total Potassium /(g·kg ⁻¹)	Available Potassium /(mg·kg ⁻¹)	Total Calcium /(g·kg ⁻¹)	Exchangeable Calcium /(cmol·kg ⁻¹)	Total Magnesium /(g·kg ⁻¹)	Exchangeable Magnesium /(cmol·kg ⁻¹)	pH
Arithmetic mean	125.08	9.52	495.24	0.87	2.48	13.95	271.65	17.72	10.49	6.51	3.73	7.00
Geometric mean	103.10	11.20	575.80	0.99	3.88	14.45	322.83	22.91	12.43	7.14	4.28	6.98
Median	104.22	10.51	500.08	0.98	2.45	14.48	272.06	19.98	11.40	6.64	3.75	7.07
Standard deviation	78.45	6.21	292.87	0.47	3.71	3.79	191.09	16.44	8.63	3.16	2.44	0.42
Kurtosis	0.46	-0.40	-0.48	-1.09	0.77	1.45	0.02	3.36	8.15	1.42	2.23	2.82
Skewness	1.04	0.70	0.46	0.14	1.32	0.50	0.86	1.50	2.58	1.13	1.51	1.22
Minimum	21.30	2.45	112.70	0.19	0.27	7.21	84.17	2.83	3.87	1.99	1.21	5.40
Maximum	374.73	26.38	1326.12	2.11	15.39	27.55	943.74	94.78	48.69	16.90	13.03	7.92
$P_{(K,S)}$	0.00	0.01	0.00	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Coefficient of variation	0.62	0.55	0.50	0.47	0.95	0.26	0.59	0.71	0.69	0.44	0.56	0.06

Notes: $CV \leq 0.20$ for weak variability, $0.20 < CV < 0.50$ for moderate variability, and $CV \geq 0.50$ for strong variability;. Same as below.

Table S3. Characteristics of various types of nutrient content.

Statistical characteristics	SOC/TN	SOC/TP	SOC/TK	TN/TP	TN/TK	TP/TK	TCa/TMg	TN/TCa	TN/TMg
Arithmetic mean	10.98	143.00	10.11	12.48	0.91	0.08	3.34	0.60	1.80
Geometric mean	10.83	119.04	7.39	10.99	0.68	0.06	2.72	0.54	1.46
Median	10.80	113.02	6.94	9.94	0.67	0.07	2.78	0.58	1.38
Standard deviation	1.84	102.06	8.11	7.16	0.69	0.05	2.59	0.27	1.34
Kurtosis	1.05	3.98	0.82	3.55	0.42	1.11	15.18	-0.10	3.33
Skewness	0.82	2.03	1.22	1.81	1.16	1.16	3.18	0.53	1.91
Minimum	7.25	32.64	1.11	3.78	0.11	0.01	0.70	0.06	0.30
Maximum	17.05	520.43	35.12	42.69	2.73	0.23	18.76	1.31	6.46
$P_{(K,S)}$	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.20	0.00
Coefficient of variation	0.17	0.71	0.79	0.57	0.75	0.64	0.77	0.44	0.73

Notes: $CV \leq 0.20$ for weak variability, $0.20 < CV < 0.50$ for moderate variability, and $CV \geq 0.50$ for strong variability;. Same as below.

Table S4. Descriptive statistics of soil nutrients across different slope degrees.

Nutrient content	Flat slope	Gentle slope	Tilted slope	Steep slope	Sharp slope
Total Nitrogen/(g·kg ⁻¹)	13.11±6.13a	6.13±8.89c	8.89±6.18bc	6.18±8.91ac	8.91±5.67ab
Hydrolyzable Nitrogen/(mg·kg ⁻¹)	655.39±180.69a	180.69±577.32a	577.32±359.6a	359.6±589.37a	589.37±243.39a
Total Phosphorus/(g·kg ⁻¹)	1.19±0.5a	0.5±1ab	1±0.51ab	0.51±0.98a	0.98±0.44b
Available Phosphorus/(mg·kg ⁻¹)	3.1±4.06bc	4.06±2.04c	2.04±2.17a c	2.17±3.41a	3.41±3.63ab
Total Potassium/(g·kg ⁻¹)	14.55±2.24a	2.24±14.82a	14.82±3.27a	3.27±15.91a	15.91±3.15b
Available Potassium/(mg·kg ⁻¹)	476.29±168.5a	168.5±362.76ab	362.76±178.83bc	178.83±348.98bc	348.98±249.47c
Total Calcium/(g·kg ⁻¹)	28.85±22.56ab	22.56±21.42ab	21.42±18.07ab	18.07±22.38b	22.38±16.14a
Exchangeable Calcium/(cmol·kg ⁻¹)	11.78±3.18ab	3.18±11.15b	11.15±11.73b	11.73±8.89a	8.89±5.12ab
Total Magnesium/(g·kg ⁻¹)	7.84±3.78a	3.78±7.2ab	7.2±3.16a	3.16±7.32b	7.32±2.05a
Exchangeable Magnesium/(cmol·kg ⁻¹)	4.7±1.75a	1.75±3.28ab	3.28±1.12ab	1.12±5.18b	5.18±2.67ab
Soil Organic Carbon/(g·kg ⁻¹)	155.16±88.4a	88.4±99.33b	99.33±74.84b	74.84±95.67ab	95.67±64.58a

Notes: Data in the table are presented as mean ± standard deviation. Different lowercase letters within the same row indicate significant differences among different slope degrees ($P<0.05$).

Table S5. Descriptive statistics of soil nutrients across different slope aspects.

Nutrient content	Shady slope	Semi-shady slope	Flat land	Semi-sunny slope	Sunny slope
Total Nitrogen/(g·kg ⁻¹)	13.41±7.49ab	12.62±6.08a	13.11±6.13a	10.41±5.84ab	8.60±5.83b
Hydrolyzable Nitrogen/(mg·kg ⁻¹)	632.39±308.56a	591.21±298.03a	655.39±180.69a	530.63±300.81a	528.24±344.72a
Total Phosphorus/(g·kg ⁻¹)	1.17±0.59ab	1.02±0.45ab	1.19±0.50a	0.86±0.45b	0.88±0.42ab
Available Phosphorus/(mg·kg ⁻¹)	3.29±3.96a	4.67±3.60a	3.10±4.06a	2.62±2.18a	4.87±4.32a
Total Potassium/(g·kg ⁻¹)	13.32±4.21a	14.23±2.57a	14.55±2.24a	13.22±3.27a	15.90±5.41a
Available Potassium/(mg·kg ⁻¹)	412.14±256.59ab	340.19±203.48b	476.29±168.50a	223.71±121.80c	258.07±150.41bc
Total Calcium/(g·kg ⁻¹)	26.71±16.95ab	25.08±14.58a	28.85±22.56a	23.48±15.02ab	15.23±12.18b
Exchangeable Calcium/(cmol·kg ⁻¹)	13.07±1.93a	12.28±9.15a	11.78±3.18a	9.63±4.85a	15.15±12.87a
Total Magnesium/(g·kg ⁻¹)	9.05±3.92a	7.49±2.54a	7.84±3.78a	7.86±3.40a	5.22±2.00b
Exchangeable Magnesium/(cmol·kg ⁻¹)	5.08±2.99a	5.34±2.60a	4.70±1.75a	4.21±2.80a	2.83±1.53b
Soil Organic Carbon/(g·kg ⁻¹)	139.36±82.89ab	140.02±82.10a	155.16±88.40a	124.03±80.25ab	86.99±52.25b

Notes: Data in the table are presented as mean ± standard deviation. Different lowercase letters within the same row indicate significant differences among different slope aspects ($P<0.05$).

Table S6. Descriptive statistics of soil nutrients across different slope positions.

Nutrient content	Upslope	Midslope	Downslope	Depression
Total Nitrogen/(g·kg ⁻¹)	13.59±5.53a	5.98±2.85b	12.36±6.31a	13.00±6.09a
Hydrolyzable Nitrogen/(mg·kg ⁻¹)	530.90±155.11a	276.70±121.69b	667.85±301.67a	663.68±185.38a
Total Phosphorus/(g·kg ⁻¹)	0.60±0.16b	0.46±0.18b	1.15±0.37a	1.32±0.46a
Available Phosphorus/(mg·kg ⁻¹)	4.77±2.39a	4.82±4.36a	3.62±3.39a	3.16±4.46a
Total Potassium/(g·kg ⁻¹)	12.73±2.29a	15.95±4.96a	13.94±3.69a	15.11±2.00a
Available Potassium/(mg·kg ⁻¹)	167.78±42.59c	224.6±152.83bc	322.56±184.03b	531.46±125.23a
Total Calcium/(g·kg ⁻¹)	34.80±16.59a	12.28±12.66b	23.66±13.47a	29.27±23.66a
Exchangeable Calcium/(cmol·kg ⁻¹)	11.92±3.57ab	8.39±4.78b	14.01±10.57a	12.27±2.69a
Total Magnesium/(g·kg ⁻¹)	12.52±4.38a	5.42±2.89b	6.98±2.41ab	7.61±2.91ab
Exchangeable Magnesium/(cmol·kg ⁻¹)	6.09±4.7a	3.05±2.38b	4.31±2.08a	5.04±1.73a
Soil Organic Carbon/(g·kg ⁻¹)	189.42±91.02a	69.65±33.87b	130.92±76.18a	150.09±88.34a

Notes: Data in the table are presented as mean ± standard deviation. Different lowercase letters within the same row indicate significant differences among different slope positions ($P<0.05$).

Table S7. Descriptive statistics of soil nutrients across different microhabitats.

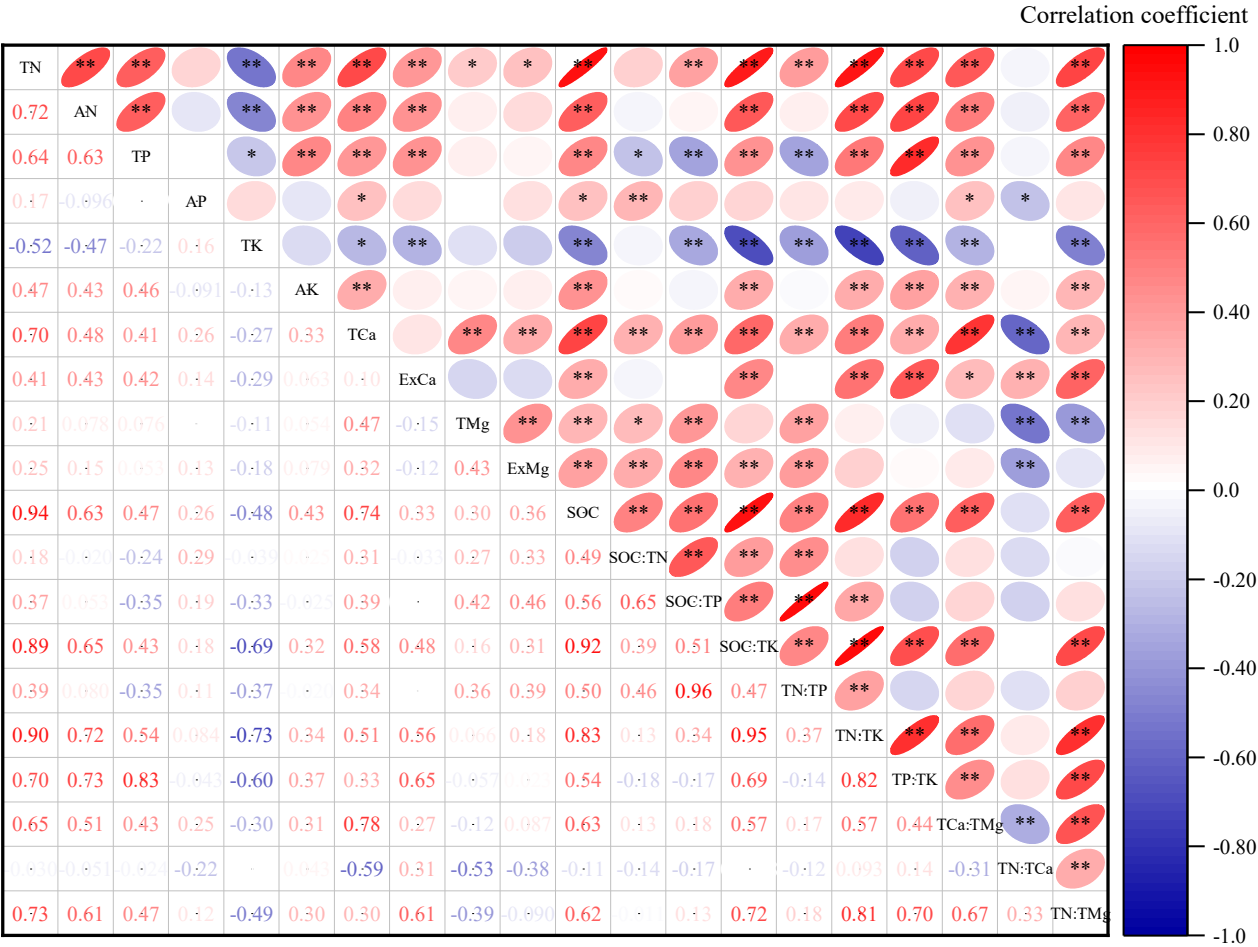
Nutrient content	Soil surface	Stone surface	Stone gully
Total Nitrogen/(g·kg ⁻¹)	7.34±3.71b	14.55±6.58a	14.55±6.58a
Hydrolyzable Nitrogen/(mg·kg ⁻¹)	468.94±250.35b	681.92±282.46a	681.92±282.46ab
Total Phosphorus/(g·kg ⁻¹)	0.85±0.44b	1.15±0.52a	1.15±0.52ab
Available Phosphorus/(mg·kg ⁻¹)	2.63±3.19b	4.59±3.84a	4.59±3.84a
Total Potassium/(g·kg ⁻¹)	15.61±3.65a	13.15±3.2b	13.15±3.2ab
Available Potassium/(mg·kg ⁻¹)	278.87±173.36b	393.87±221.63a	393.87±221.63ab
Total Calcium/(g·kg ⁻¹)	13.4±8.51c	32.21±18.68a	32.21±18.68b
Exchangeable Calcium/(cmol·kg ⁻¹)	9.52±7.07b	14.93±9.49a	14.93±9.49a
Total Magnesium/(g·kg ⁻¹)	6±2.14b	8.86±4.07a	8.86±4.07b
Exchangeable Magnesium/(cmol·kg ⁻¹)	3.78±1.99b	4.95±2.61a	4.95±2.61ab
Soil Organic Carbon/(g·kg ⁻¹)	79.79±41.53b	171.19±94.45a	171.19±94.45a

Notes: Data in the table are presented as mean ± standard deviation. Different lowercase letters within the same row indicate significant differences among different microhabitats ($P<0.05$).

45 **Table S8.** Descriptive statistics of soil nutrients across different plant life forms.

Nutrient content	Evergreen trees	Deciduous trees	Shrubs	Herbs
Total Nitrogen/(g·kg ⁻¹)	10.31±6.22b	9.34±5.84b	12.27±5.76	14.99±6.34a
Hydrolyzable Nitrogen/(mg·kg ⁻¹)	455.25±254.84c	512.46±251.33bc	643.79±264.59	889.1±267.92a
Total Phosphorus/(g·kg ⁻¹)	0.91±0.51bc	0.78±0.37c	1.15±0.41	1.31±0.37a
Available Phosphorus/(mg·kg ⁻¹)	4.05±3.8a	4.97±4.62a	2.4±1.79	4.14±3.83a
Total Potassium/(g·kg ⁻¹)	15.38±3.57a	16.16±3.63a	12.77±2.98	11.93±3.84b
Available Potassium/(mg·kg ⁻¹)	289.82±158.41a	345.42±218.77a	319.77±189.84	376.73±227.08a
Total Calcium/(g·kg ⁻¹)	19.2±14.13b	20.06±16.34ab	28.38±19.01	28.2±15.49a
Exchangeable Calcium/(cmol·kg ⁻¹)	11.58±5.33a	11.57±4.05a	10.42±4.54	19.71±18.94a
Total Magnesium/(g·kg ⁻¹)	7.09±3.79a	7.42±3.06a	7.61±2.37	5.94±2.71a
Exchangeable Magnesium/(cmol·kg ⁻¹)	3.04±1.24b	5.43±3.28a	4.05±1.44	5.95±2.85a
Soil Organic Carbon/(g·kg ⁻¹)	107.3±64.47b	116.62±92.52b	138.34±77.38	164.09±79.62a

Notes: Data in the table are presented as mean ± standard deviation. Different lowercase letters within the same row indicate significant differences among different plant life forms ($P<0.05$).



* $p < 0.05$ ** $p < 0.01$

Figure S1.Heatmap of Pearson correlation matrix for soil elemental contents and stoichiometric ratios. Ellipses in the lower triangular matrix represent correlation coefficients (r): Color gradient indicates direction (red: positive correlation; blue: negative correlation); Saturation and eccentricity indicate strength (proportional to |r|); Additionally, "*" denotes significant correlation ($P < 0.05$); "***" denotes highly significant correlation ($P < 0.01$) Color scale ranges from -1.0 to 1.0 ("Correlation coefficient").

Table S9. Spearman's rank correlation coefficients between soil stoichiometric characteristics and environmental factors

Stoichiometry	Correlation coefficient with each factors				
	Microhabitat	Slope position	Slope aspect	Slope degree	Life forms
TN	0.470**	0.038	-0.328**	0.241*	0.266*
HN	0.296**	-0.221*	-0.169	0.386**	0.451**
TP	0.253*	-0.235*	-0.188	0.604**	0.330**
AP	0.259*	0.301**	0.031	-0.215*	-0.027
TK	-0.264*	-0.202	0.092	0.028	-0.387**
AK	0.245*	-0.451**	-0.283**	0.522**	0.113
TCa	0.508**	-0.02	-0.306**	0.19	0.317**
ExCa	0.350**	0.095	-0.022	0.184	0.053
TMg	0.339**	-0.04	-0.344**	-0.026	-0.02
ExMg	0.216*	-0.019	-0.440**	0.18	0.366**
SOC	0.456**	0.039	-0.306**	0.142	0.258*
SOC:TN	0.082	0.012	0.02	-0.332**	0.04
SOC:TP	0.283**	0.266*	-0.18	-0.416**	-0.03
SOC:TK	0.450**	0.102	-0.254*	0.096	0.339**
TN:TP	0.310**	0.312**	-0.223*	-0.384**	-0.051
TN:TK	0.436**	0.117	-0.21	0.145	0.347**
TP:TK	0.278**	-0.072	-0.125	0.423**	0.452**
TCa:TMg	0.373**	-0.006	-0.121	0.253*	0.390**
TN:TCa	-0.227*	0.067	0.152	-0.031	-0.184
TN:TMg	0.233*	0.078	-0.044	0.233*	0.270*