Response to Editor and Referee 1

Dear Editor and Referee 1,

We sincerely appreciate the editor's and referees' thorough evaluation and insightful comments on our manuscript (EGUSPHERE-2025-3510). These comments are very helpful for improving our paper. We have studied all the comments carefully and have revised the manuscript accordingly. Below is our point-by-point response to each suggestion.

Comment 1

Abstract: L16: Remove the word "mechanisms" since that wasn't investigated in this study.

Response Comment 1

We sincerely thank the referee for this precise and valuable comment. We fully agree that the term "mechanisms" was indeed imprecise, as this study solely focused on the spatial patterns of soil stoichiometric characteristics in the karst forest and their influencing factors, without investigating underlying biogeochemical processes or other intrinsic mechanisms. Accordingly, we have removed the term "mechanisms" and revised the sentence. The modified sentence now reads:

"**To quantitatively evaluate the stoichiometric characteristics of karst forest soils across complex microenvironments, this study systematically investigated the patterns of soil nutrients and their influencing factors at different microtopographic and microhabitat scales in the Maolan karst forest.**"

We believe this revision enhances the scientific rigor and clarity of our research statement. Thank you again for this constructive suggestion.

Comment 2

L19: Without first defining what moderate or high spatial variability is, it doesn't make sense to specify it in this way in the abstract. It should read more simply, "Soil nutrient contents exhibited strong spatial heterogeneity."

Response Comment 2

We sincerely thank the referee for their valuable suggestions regarding the rigor of expression in the abstract. We agree that using terms such as "moderate or higher" without prior definition in the abstract was ambiguous and could compromise clarity. Following your suggestion, we have simplified the sentence to directly state the core finding. The revised sentence now reads: "**Soil nutrient contents exhibited strong spatial heterogeneity across the study area.**"

We once again appreciate the referee's insightful guidance, which has significantly improved the accuracy of our abstract.

Comment 3

Introduction: L64-65: Recommend rewording to something more concise like "This knowledge gap limits our understanding of how soil and vegetation co-evolve in karst ecosystems." Then the next sentences can more clearly set up how the study addresses the knowledge gap by saying: "To address this gap, we examined soil-vegetation relationships across varied microhabitats and microtopographic positions in the Maolan karst area. By coupling systematic soil sampling with vegetation surveys of plant life forms, we characterized how soil stoichiometric properties vary with vegetation structure and topographic setting. Specifically, we address the following questions:"

Response Comment 3

We sincerely appreciate the referee's insightful suggestion to enhance the clarity and conciseness of our Introduction. In response, we have thoroughly revised the relevant sentences to directly link the identified knowledge gap with our research approach: the phrase "synergistic evolution mechanisms" was replaced with the more precise and accessible expression "**how soil and vegetation co-evolve**" to eliminate redundancy; the methodology section was rephrased to explicitly state that we "**examined soil-vegetation relationships across varied microhabitats and microtopographic positions**" and "**characterized how soil stoichiometric properties vary with vegetation structure and topographic setting**" through the

integration of systematic soil sampling and plant life form surveys; and the transition to the scientific questions was sharpened to ensure logical continuity. These revisions have significantly strengthened the narrative flow, clarified the study's contribution to addressing the knowledge gap, and aligned the text with concise academic writing standards. We are deeply grateful for your constructive guidance, which has substantially elevated the rigor and readability of our manuscript.

Comment 4

Methods section: Tables 1 and 2 can be moved to supplemental. The reference to Chinese Forestry Industry Standards is made three times and can instead be made once to apply to all soil and plant nutrient analyses.

Response Comment 4

We sincerely thank the referee for the insightful suggestions to enhance the conciseness and clarity of the Methods section. In full accordance with your recommendations, Tables 1 and 2 have been relocated to the Supplementary Materials as Supplementary Tables S1 and S2, respectively, with explicit references added in Sections 2.5 and 2.6 to direct readers to these detailed protocols. Furthermore, the previously repeated citations of the Chinese Forestry Industry Standards have been consolidated into a single authoritative statement at the conclusion of Section 2.6, which now comprehensively covers all soil and plant nutrient analyses: "All soil and plant nutrient analyses were conducted in strict accordance with the relevant *Chinese Forestry Industry Standard LY/T 1210-1999*." This revision eliminates redundancy while preserving full methodological transparency and traceability. Thank you again for your valuable guidance.

Comment 5

L236-237: Recommend removing this line ("these patterns preliminarily highlight…") since it's more analysis than results, and would therefore belong in discussion section.

Response Comment 5

We sincerely appreciate the referee's precise and valuable comments. We fully agree that the original sentence constituted interpretive analysis and properly belongs in the Discussion section. Accordingly, we have removed this sentence from the Results section. The revised paragraph now objectively describes the spatial distribution patterns of soil nutrients, retaining the reference to descriptive statistics to ensure transparency. We appreciate your rigorous and professional guidance.

Comment 6

L347-348: Recommend removing the line "The underlying driving mechanisms…" since this is an already expected part of the discussion section.

Response Comment 6

We sincerely appreciate the referee's valuable comments regarding the writing conventions of the Results section. We fully agree that the original sentence "*The underlying driving mechanisms will be thoroughly analyzed in the Discussion section*" constitutes a preview statement of the Discussion content and is inappropriate for the Results section. Accordingly, we have removed this sentence from the manuscript. The revised paragraph now objectively describes the observed correlation patterns and their statistical significance. We appreciate your professional guidance.

Comment 7

Discussion section: This section reads more like a literature review because of the number of citations (1-2 for almost every line). It could be improved by leading with the interpretation, then supporting with 1-2 key citations only where essential.

The section describing Ca effects (L428-442) could be trimmed down, since effects of Ca-mediated processes are currently described multiple different ways. The mechanism can be stated once, then move on to implications.

The slope-nutrient relationships are described twice, and should instead be combined into one description.

Response Comment 7

We sincerely thank the referee for the valuable comments on the Discussion

section of our manuscript. We have comprehensively revised the text according to your suggestions, as detailed below:

(1) Reducing citation density and strengthening self-interpretation: We fully agree that the original manuscript weakened the interpretation of our own results due to excessive citations. In the revised version, we restructured the Discussion to lead with comprehensive interpretations of our findings, consolidated previously scattered descriptions, and selectively cited key references only at critical points. This revision successfully shifted the focus from literature enumeration to in-depth data analysis, enhancing logical clarity.

(2) Streamlining and integrating Ca effects: We consolidated and streamlined the descriptions of Ca effects (originally dispersed across multiple subsections) to clarify the central role of calcium in coupling soil biogeochemical processes in karst systems, effectively eliminating redundant explanations.

(3) Unifying slope-nutrient relationships: We merged the duplicated descriptions of slope-nutrient interactions in the original manuscript to systematically explain how slope degree, as a key topographic factor, influences nutrient spatial patterns through regulating surface processes, ensuring a more focused and logically coherent argument.

The revised Discussion now more clearly highlights the innovative value of this study in advancing the understanding of soil stoichiometric characteristics in karst mountainous regions. We deeply appreciate your rigorous and insightful guidance.

Comment 8

L449-466: This Mg section can be drastically reduced into a couple sentences.

Response Comment 8

We sincerely thank the referee for the precise suggestion. In accordance with your advice, we have thoroughly condensed this section. The core finding has been highly summarized, with emphasis placed on its association with specific microtopography and the accompanying biogeochemical processes. All redundant data listings, excessive citations, and extended discussions on the physiological

functions of magnesium have been removed. We believe the revised presentation is now more concise and effectively enhances the clarity of the Discussion section. Once again, we appreciate your rigorous and constructive guidance.

Comment 9

L574: This is speculative since the present study did not directly measure depth of plant root penetration (at least according to the results presented). This section could be reworded to reflect its speculative nature or struck entirely to maintain the focus on main findings.

Response Comment 9

We sincerely thank the referee for the precise comment. We fully agree that, as this study did not directly measure root distribution, the speculative discussion regarding root behavior and its effects on soil stoichiometric characteristics in the original manuscript indeed extended beyond the scope of our empirical evidence. To maintain a strict focus on the main empirical findings of this study, we have followed your suggestion and completely removed this section. This revision ensures greater rigor and focus in the Discussion, effectively preventing non-empirical inferences from interfering with the core conclusions. We appreciate your rigorous and constructive guidance.

Response to Editor and Referee 3

Dear Editor and Referee 3,

We sincerely appreciate the editor's and referees' thorough evaluation and insightful comments on our manuscript (EGUSPHERE-2025-3510). These comments are very helpful for improving our paper. We have studied all the comments carefully and have revised the manuscript accordingly. Below is our point-by-point response to each suggestion.

Major concern 1

The Introduction devotes considerable space to highlighting the importance of studying soil stoichiometric characteristics and their responses to environmental factors. However, it does not address two key issues, which weakens the logical progression and justification for the subsequent work: (1) Which environmental factors influence soil stoichiometric characteristics, and by what mechanisms they do so; (2) What soil stoichiometric processes can be inferred from soil stoichiometric balance, and how environmental factors affect these processes. In addition, the second paragraph provides an extensive description of the uniqueness of the study area, but it does not clearly explain how these site-specific characteristics may shape soil stoichiometric characteristics and balance.

Response major concern 1

We sincerely thank the referee for the insightful and constructive comments, which were crucial for improving the logical framework of our study. We have carefully revised the Introduction following the suggestions to enhance its logical coherence and soundness. The specific revisions include:

First, we have supplemented key environmental factors (e.g., climate, topography, biological factors, and human disturbances) that influence soil stoichiometric characteristics and elaborated on the biogeochemical pathways through which they shape elemental balances.

Second, we further elucidate that analyzing soil stoichiometric characteristics can

effectively infer key processes such as organic matter decomposition, microbial nutrient limitation, and nutrient cycling efficiency. Moreover, environmental factors often drive the direction and rate of these processes by altering the supply of energy and nutrients.

Third, focusing on the uniqueness of the study area, we have elucidated the specific biogeochemical pathways driving the formation of the "patchy" distribution pattern of soil stoichiometric characteristics on karst slopes. Furthermore, we have supplemented the discussion with the profound impact of differences in hydrothermal conditions and material exchange efficiency among microenvironments on the soil stoichiometric balance.

We believe these revisions have established a mechanistic link from local characteristics to stoichiometric balance, significantly enhancing the logical rigor of the Introduction. We once again express our gratitude for the referee's guidance.

Major concern 2

Plant nutrient content is considered as a factor influencing soil stoichiometric characteristics only in the VPA analysis. It is therefore unclear why this variable was not included in other correlation analyses. In addition, the Introduction does not describe the relationship between plant nutrient content and soil stoichiometric characteristics or balance. The Results section also lacks a presentation of the data on plant nutrient contents. Together, these omissions make the inclusion of this factor in the VPA appear abrupt and insufficiently justified.

Response major concern 2

We sincerely thank the referee for the extremely valuable and insightful comments. Your remarks regarding the logical discussion and data presentation of the "plant nutrient content" variable are crucial for improving our manuscript. We fully agree with your suggestions and have carefully revised the paper to strengthen the justification for including this factor and to enrich its data presentation. The specific modifications are described below:

In the Introduction, we have added an explanation that, within the unique context

of karst regions characterized by fragmented topography and intense karst processes, litter is prone to relocation driven by wind or slope runoff. Consequently, its nutrients are not necessarily returned to the soil directly beneath the plant. Furthermore, to adapt to the shallow and discontinuous soil environment, plant roots often extend into rock fissures to absorb nutrients, meaning their nutrient sources are not limited solely to the basal soil. In the Results section, we have supplemented the statistical analysis of plant nutrient content. The results show that plant nutrient content itself exhibits moderate to strong variation and differs significantly among plant life forms. Even the same plant species, when occurring in different combinations of microhabitats and microtopographic settings, displays varied stoichiometric characteristics due to regulation by local microenvironmental conditions. Therefore, under the influence of the fragmented topography and heterogeneous microenvironments on karst slopes, plant nutrient status is not an independent intrinsic trait but is profoundly affected by its specific microenvironment. This leads to a weak spatial correspondence between plant stoichiometric characteristics and those of the basal soil, which explains why the plant nutrient factor showed the lowest independent explanatory power in the variance partitioning analysis (VPA).

Major concern 3

The Conclusions section is not written in an appropriate manner. It should briefly restate the study objectives and then concisely synthesize the key findings and overarching patterns derived from the Discussion, in direct correspondence with the scientific questions raised in the Introduction. At present, the Conclusions are overly long and the main points are difficult to identify.

Response major concern 3

We sincerely thank the referee for this critical and constructive suggestion. In accordance with your advice, we have thoroughly revised the Conclusion section to address the identified issues. The revision focused on enhancing the clarity of this section: we first explicitly restated the primary objective of the study in the opening sentence to establish a clear foundation. Subsequently, we synthesized the key

findings and overarching patterns derived from the Discussion, ensuring they correspond directly and logically to the scientific questions outlined in the Introduction. Through these modifications, we have streamlined the content by removing redundancies, ensuring that the core points are now prominent and easily discernible, thereby improving the overall impact and readability of the section. We believe the revised version now meets the journal's standards and are deeply grateful for the valuable guidance provided. The revised Conclusion section is presented below:

This study, based on systematic surveys of soils in the Maolan karst forest, reveals the spatial patterns of soil stoichiometric characteristics and identifies their primary driving factors. Results demonstrate that soil nutrients exhibit high spatial heterogeneity at the microenvironmental scale, a pattern closely linked to divergent elemental cycling strategies. Soil carbon and nitrogen cycling show strong synchrony, whereas phosphorus distribution is predominantly governed by microtopography-driven nutrient redistribution processes. As a critical linkage in biogeochemical processes, calcium-magnesium balance dynamics are tightly associated with microhabitat and plant life form factors. Notably, the spatial heterogeneity of soil nutrients in the Maolan karst forest is not randomly distributed but forms a "patchy" pattern shaped by key environmental drivers-microhabitat, microtopography, and plant life forms. Among these, microhabitat exerts the strongest influence on soil stoichiometric characteristics, directly governing the 'enrichment in stone surface microhabitats and depletion in soil surface microhabitats' pattern. Microtopography not only correlates significantly with nutrient patterns but also drives gradient distribution trends for certain elements. Although the influence of plant life forms is relatively weaker, their regulatory effects are often closely linked to microenvironmental factors such as microhabitat and microtopography. This multi-factor synergistic regulation profoundly influences the input, transport, accumulation, and loss of soil nutrients, serving as a key driving mechanism of nutrient cycling in karst forest soils. Collectively, these findings

enhance understanding of the co-adaptation mechanisms between soils and vegetation in fragile karst ecosystems and provide critical theoretical foundations for precise ecological restoration and management strategies in karst regions.

Other concerns 1

The Results section lacks key quantitative findings. Please provide the essential numerical results to strengthen this section.

Response other concerns 1

We sincerely thank the referee for the valuable suggestions. In accordance with your advice, we have supplemented the necessary core statistical results in the manuscript. Specifically, descriptive statistics (mean $\pm$ standard deviation) of soil stoichiometric characteristics across different slope degrees (Table S7), slope aspects (Table S9), slope positions (Table S11), microhabitats (Table S13), and plant life forms (Table S15) have been added, with between-group differences indicated based on statistical tests. These supplementary data systematically present the specific numerical ranges and patterns of significant differences in soil stoichiometric ratios across various environmental gradients. They provide direct quantitative support for the key conclusions described in the text and significantly enhance the objectivity and persuasiveness of the Results section.

Other concerns 2

Section 2.4. The classification criteria of microhabitat across the different categories appear to overlap, and some of the terminology is ambiguous. Especially, multiple terms are used repeatedly to describe "gully" (e.g., gully, solution gully, stone gully, and soil-dominated gully). However, the distinctions among these terms are not clearly defined, which may cause considerable confusion for readers. Besides, if the three types of microhabitat are defined using multiple indicators (e.g., bedrock exposure ratio, soil cover area, gully erosion depth), it would be clearer to present these criteria in a table. If possible, please also provide representative field photographs for each category to facilitate understanding.

Response other concerns 1

We sincerely thank the referee for the valuable comments regarding the microhabitat classification criteria. In accordance with your suggestions, we have comprehensively revised Section "2.4 Microhabitat division." To eliminate terminological ambiguity and present the classification criteria more clearly and intuitively, we have consolidated and refined the originally descriptive, text-based criteria into a structured table (Table 1). This table clearly displays the quantitative classification standards for the three microhabitat types based on three core diagnostic indicators: bedrock exposure rate, gully depth, and the areal surface soil cover area. This revision effectively resolves potential ambiguity and overlap present in the original descriptive criteria, making the classification basis more explicit and operational. Additionally, we have provided schematic diagrams of the various microhabitat types (Figure S1) in the supplementary materials to facilitate readers' intuitive understanding. We believe this revision significantly enhances the clarity and rigor of this section. Once again, we deeply appreciate the Referee's meticulous guidance.

Table 1. Classification criteria for various types of microhabitats.

Microhabitat types	Bedrock exposure rate	Gully depth	Surface soil cover area
Stone surface microhabitat	>50%	≤30 cm	<1 m²
Stone gully microhabitat	>50%	>30 cm	<1 m²
Soil surface microhabitat	≤50%	≤30 cm	≥1 m²

a

Soil surface microhabitat

b

Stone surface microhabitat

c

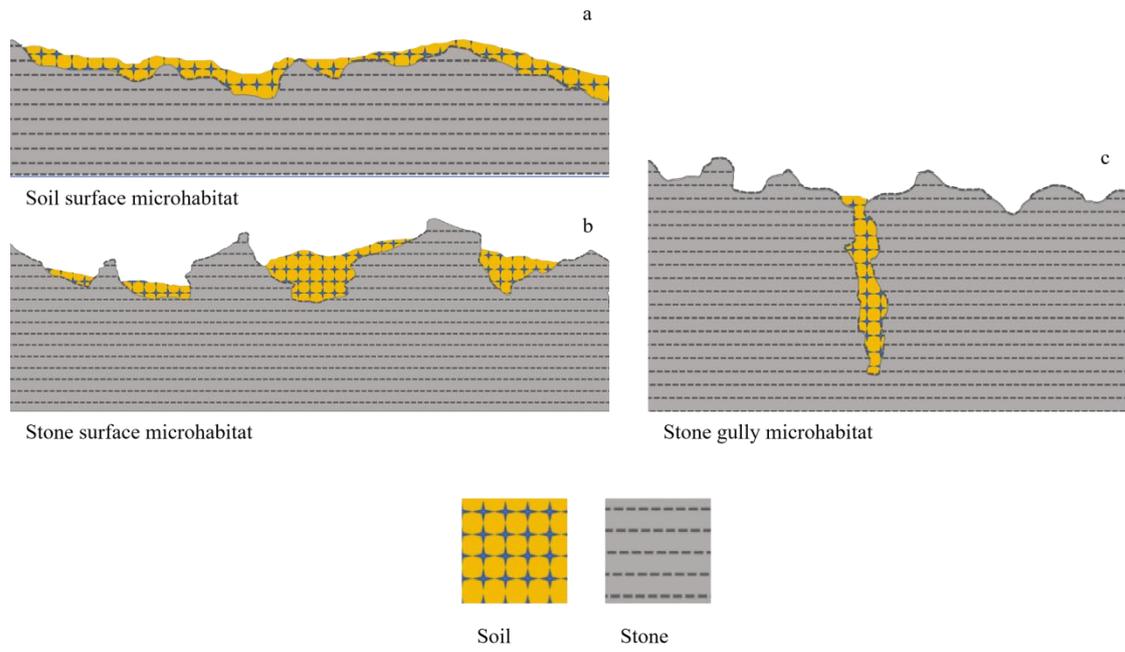Stone gully microhabitat

Soil   Stone

Figure S1. Schematic diagram of stone and soil distribution under different microhabitat types.