Responses to the comments from the 3rd Reviewer

This manuscript describes the multi-elemental composition of soil collected in locations in different mountain regions across China. It also describes the associated environmental parameters in these locations using remote sensing data. The authors then used these environmental parameters, along with geospatial and climatic data, to explain the variations in the soil multi-elemental composition.

The database potentially contains important data which can be used for various applications as outlined by the authors in Sec. 4 of the manuscript. However, there are several important pieces of information that are missing in the manuscript, as well as serious concerns regarding data quality and completeness of the database, which I have described below.

Responses: We sincerely appreciate your recognition of the potential value of our dataset and also thank you for the constructive and professional comments and suggestions regarding data quality, completeness, and missing information. We have carefully considered the comments raised and made specific revisions to both the manuscript and the dataset documentation. Please see the point-by-point response and corresponding modifications below.

Database

It is better to store the database in a more open-access platform like Zenodo that does not prompt users of data to log-in.

Responses: Thank you very much for the helpful suggestion. Although the National Tibetan Plateau/Third Pole Environment Data Center suggests users to log in, data can be freely and directly downloaded via the DOI link without registration. The platform ensures open access and stable sharing through permanent DOI-based links, similar to Zenodo. Moreover, this data repository has been widely used in Earth System Science Data publications (e.g., Li et al., 2024; Jin et al., 2023; Ma et al., 2024), demonstrating its compatibility with the journal's data policy. Therefore, we retain our dataset on this platform and trust that this can also meet the journal's open-access requirements.

References:

Jin, Y., Wang, H., Xia, J., Ni, J., Li, K., Hou, Y., Hu, J., Wei, L., Wu, K., Xia, H., and Zhou, B.: TiP-Leaf: a dataset of leaf traits across vegetation types on the Tibetan Plateau, Earth Syst. Sci. Data 15, 25-39, https://doi.org/10.5194/essd-15-25-2023, 2023.

Li, X., Jin, H., Feng, Q., Wu, Q., Wang, H., He, R., Luo, D., Chang, X., Şerban, R.-D., and Zhan, T.: An integrated dataset of ground hydrothermal regimes and soil nutrients monitored in

some previously burned areas in hemiboreal forests in Northeast China during 2016-2022, Earth Syst. Sci. Data 16, 5009-5026, https://doi.org/10.5194/essd-16-5009-2024, 2024.

Ma, Y., Xie, Z., Chen, Y., Liu, S., Che, T., Xu, Z., Shang, L., He, X., Meng, X., Ma, W., Xu, B., Zhao, H., Wang, J., Wu, G., and Li, X.: Dataset of spatially extensive long-term quality-assured land–atmosphere interactions over the Tibetan Plateau, Earth Syst. Sci. Data 16, 3017-3043, https://doi.org/10.5194/essd-16-3017-2024, 2024.

The database lacks metadata that explains what the columns mean. The units are also not given. The authors stated that a "Description of the dataset.docx" document accompanies the dataset, but it is not included when I downloaded the database several times. All these render the data in the database practically useless.

Responses: We sincerely thank you for pointing out this important issue. This file was previously provided as a supplementary attachment under the Additional Information section on the data repository webpage, which may have caused it to be overlooked during download. In the revised version, all abbreviations and measurement units used in the dataset have been carefully documented in the file of "Description of the dataset.docx". To address this, we have uploaded the data description file together with the main dataset in a single compressed package, ensuring that all necessary metadata are conveniently available to users. A detailed explanation of the abbreviations and units can be found in the updated version, as illustrated in the table below.

Abbreviations	Full name	Unit
O	Organic horizon	-
A	Surface mineral horizon	-
C	Parent material horizon	-
BF	Broadleaf forest	-
CBF	Coniferous-broadleaf mixed forest	-
CF	Coniferous forest	-
MAP	Mean annual precipitation	mm
MAT	Mean annual temperature	°C
AI	Aridity index	-
N deposition	Atmospheric nitrogen deposition	kg N ha^{-1} yr^{-1}
NDVI	Normalized difference vegetation index	-

Depth	Thickness of soil	cm
BD	Soil bulk density	g cm^{-3}
CIA	Chemical alteration index	-
SOC	Soil organic carbon	mg kg^{-1}
Al	Aluminum	mg kg^{-1}
Ba	Barium	mg kg^{-1}
Be	Beryllium	mg kg^{-1}
Ca	Calcium	mg kg^{-1}
Fe	Iron	mg kg^{-1}
K	Potassium	mg kg^{-1}
Mg	Magnesium	mg kg^{-1}
Mn	Manganese	mg kg^{-1}
Na	Sodium	mg kg^{-1}
Sr	Strontium	mg kg^{-1}
Ti	Titanium	mg kg^{-1}
V	Vanadium	mg kg^{-1}
Zn	Zinc	mg kg^{-1}
P	Phosphorus	mg kg^{-1}
Cr	Chromium	mg kg^{-1}
Co	Cobalt	mg kg^{-1}
Ni	Nickel	mg kg^{-1}
Cu	Copper	mg kg^{-1}
Mo	Molybdenum	mg kg^{-1}
Cd	Cadmium	mg kg^{-1}
Sb	Antimony	mg kg^{-1}
Tl	Thallium	mg kg^{-1}
Pb	Lead	mg kg^{-1}

There are unrealistic values in the database. For example, the bulk densities are too low even in the surface mineral soil. I would not expect the values to be below 0.5 g/cm^3, assuming this is the correct unit based on the data description paper. Another example is the moisture content which reaches up to over 200%. How were these values calculated? It would help if the authors explicitly state the measurement protocols and equations used.

Responses: Thank you for the careful review and pointing out the values of bulk density and moisture content. Our samples were collected along soil development profiles, including the organic horizon (O), surface mineral horizon (A), and parent material horizon. The relatively low bulk density values (e.g., <0.5 g/cm^3) are primarily concentrated in the surface layers, especially in the O horizon of the forest soils, which are rich in organic matter and characterized by loose, low-density materials. This phenomenon has been well documented in studies of forest soils. For example, Ostrowska et al. (2010) reported bulk density values ranging from 0.10 to 0.16 g/cm^3 in the O horizon of forest soils in Poland. Zhou et al. (2016) measured bulk density ranging between 0.15 and 0.24 g/cm^3 in the O horizon of Gongga Mountain. Furthermore, due to the thinness and high organic matter contents in the O and A horizons, it was not feasible to collect samples using traditional stainless-steel cutting rings. Instead, for these surface horizons, we used a volumetric excavation method: small pits with known volumes were excavated to collect the density samples. The pit volume was verified by refilling with water of known volume (e.g., Maynard & Curran, 2006). For the mineral horizons, bulk density was measured using the standard cylindrical core method with stainless-steel rings. This dual approach ensures accurate volume determination across diverse soil layers with different physical properties.

For the soil moisture content, we used the standard gravimetric method:

$$Moisture\ (\%) = \frac{Fresh\ weight - Dry\ weight}{Dry\ weight} \times 100\%$$

Based on this formula, values exceeding 100% are common in organic-rich surface soils with high water retention capacity, particularly in the O horizon. Such results are consistent with observations from many forest ecosystems and reflect the natural variability of organic surface soils. We have included a clearer explanation of the measurement protocols and calculation methods in the revised manuscript and the updated data description file to improve clarity for users (Lines 133-137, Lines 139-141).

References:

Maynard, D. G., and Curran, M. P.: Bulk density measurement in forest soils, Soil sampling and methods of analysis, 863-869, https://doi.org/10.1201/978142000527, 2007.

Ostrowska, A., Porebska, G., and Kanafa, M.: Carbon Accumulation and Distribution in Profiles of Forest Soils, Pol. J. Environ. Stud. 19(6), 1307-1315, 2010.

Zhou, J., Wu, Y., Bing, H., Yang, Z., Wang, J., Sun, H., Sun, S. and Luo, J.: Variations in soil phosphorus biogeochemistry across six vegetation types along an altitudinal gradient in SW China, Catena 142, 102-111, https://doi.org/10.1016/j.catena.2016.03.004, 2016.

What does depth mean in the database, and if I am right to assume that this represents the incremental depth, why are some organic layers lie below the surface mineral layer? Or does depth mean thickness here?

Responses: Thank you for your valuable comment. The values in this column represent soil layer thickness, not absolute or incremental depth. This was explained in the previous version of the data description file, but we acknowledge that the use of the term “depth” may have caused confusion. To improve clarity and avoid misinterpretation, we have revised the dataset to rename this column as “Thickness”, and we have clearly restated this definition in the revised data description file. We appreciate your helpful suggestion, which has enabled us to make this important clarification.

Why are some values missing for depth and bulk densities? This has to be explained by the authors.

Responses: Thank you for your careful review. The missing values for soil depth and bulk density primarily result from field and logistical limitations encountered during sampling and measurement. And we would like to clarify that the column "soil depth" in the dataset refers to horizon thickness. We have corrected its labeling in the revised dataset for improved clarity. Many of the sampling sites were located in high-elevation or steep-sloped areas with shallow, stony, or poorly developed soils, where it was difficult to clearly define the thickness of fragmented or discontinuous horizons. In such cases, rather than assigning potentially inaccurate or interpolated values, we retained these fields as missing to accurately reflect field conditions and ensure transparency in the dataset. Regarding bulk density, due to the extremely challenging and labor-intensive nature of soil sampling in remote mountain environments, we were only able to collect one bulk density sample per soil horizon at each site, without technical replicates. In our original dataset structure, the bulk density values were stored in the same table as other soil property data that did include replicates. This may have caused confusion or missing fields during data integration. To address this issue, we have now separated the bulk density measurements into a dedicated data file named "Soil bulk density", in which each row represents a unique sample per soil layer without replicated values. We have updated the metadata file and the dataset structure accordingly to make these details more explicit and user-friendly. The updated dataset is available at the following DOI:

https://doi.org/10.11888/Terre.tpdc.302620 or https://cstr.cn/18406.11.Terre.tpdc.302620.

It will also help if the authors include the soil type for each soil layer when available. This helps make sense of the elemental composition, CIA, and many other variables contained in the database.

Response: We appreciate your insightful suggestion regarding the inclusion of soil type information. In response, we have incorporated soil type data into our dataset to enhance its interpretability and usability. Specifically, we obtained soil classification data from the 1:1000000 Soil Map of the People's Republic of China, which was compiled and published by the National Soil Census Office in 1995. These data were accessed through the Resource and Environmental Science Data Center (http://www.resdc.cn). The updated dataset is available at the following DOI: https://doi.org/10.11888/Terre.tpdc.302620 or https://cstr.cn/18406.11.Terre.tpdc.302620.

The dataset does not contain the uncertainties of reported values.

Response: We sincerely thank you for this important point. In this dataset, we did not report measurement uncertainties primarily because all elemental and physicochemical analyses were conducted in certified laboratories following standardized national protocols, with strict quality assurance and quality control (QA/QC) procedures, including the use of blanks, standard reference materials, and analytical replicates. These procedures ensured high analytical precision and reproducibility. Moreover, we have provided detailed descriptions of the QA/QC protocols and the analytical precision of key measurements in the "Physicochemical analysis" section of the methods. For example, we reported the relative standard deviations (RSDs) and recovery rates of standard reference materials used in ICP-OES and ICP-MS measurements. We believe this additional information will help users better assess the reliability and quality of the dataset.

An existing dataset of soil properties has recently been published in ESSD (https://doi.org/10.5194/essd-17-517-2025). How does your dataset compare to this?

Responses: Thank you very much for pointing out the recently published dataset by Shi et al. (2025). We have carefully reviewed their study and would like to clarify the distinctions between our dataset and theirs in terms of data type, sampling strategy, element coverage, and research focus.

The dataset of Shi et al. is a model-derived product based on digital soil mapping techniques and machine learning, utilizing over 11,000 legacy soil profiles primarily from the 1970s-1980s. Their product provides gridded data (90 m resolution) for 23 soil physical and chemical properties across six fixed depth intervals (0-5 m, 5-15, 15-30, 30-60, 60-100, 100-200), focusing mainly on agricultural and land surface modeling applications. The dataset is based on standardized depth layers and primarily includes properties such as pH, bulk density, porosity, organic carbon, CEC, and major nutrients (N, P, K), but does not include concentrations of most soil elements (e.g., trace metals and micronutrients).

In contrast, our dataset is based on newly collected soil samples from 166 sites across 30 mountain regions in China, with a total of over 1,300 samples. Importantly, sampling was conducted by pedogenic horizons (O, A, C), rather than fixed-depth increments, to better capture soil development processes in mountainous environments. Our dataset focuses on the measured concentrations of 24 elements, including macronutrients (e.g., K, Ca, Mg), micronutrients (e.g., Fe, Mn, Cu, Mo), and trace metals (e.g., Cd, Pb, Sb), which are currently underrepresented in national-scale datasets. Furthermore, while the dataset of Shi et al. aimed to support generalized land surface modeling, our dataset is designed to fill critical data gaps in mountain ecosystem studies, with a particular focus on elemental stratification, biogeochemical modeling, and responses to environmental gradients (e.g., climate, altitude, parent material).

Therefore, we believe our dataset offers original, fine-resolution, multi-element observational data in mountain soils. It fills a critical data gap for understanding element cycling and environmental responses and provides a valuable foundation for biogeochemical modeling, ecosystem assessments, and global change research in mountainous regions.

Manuscript

L1 – A more appropriate title would be “Multi-Element dataset of soil profiles across (diverse) climatic zones in China’s mountains” since the focus is on the soil.

Responses: Thank you very much for your valuable suggestion regarding the manuscript title. We agree that the revised title you proposed more accurately reflects the focus of our dataset on soil profiles. Accordingly, we have adopted your recommendation and revised the manuscript title to: “Multi-element dataset of soil profiles across climatic zones in China’s mountains.”

L17-19 – This has to be stated the other way around as this is a data description paper. Talk about how the dataset could contribute to the better understanding of China’s mountain ecosystems. Also, include a statement about how this is related to soil.

Responses: Thank you for the insightful suggestion. We agree that the sentence structure should better reflect the nature of a data descriptor paper. In response, we have revised the opening sentence of the abstract to emphasize the relevance and contribution of the dataset to mountain ecosystem studies, with a clear focus on soils. The revised version is as follows:

Datasets of soil multi-element concentrations are essential for advancing our understanding of ecological functioning and responses to global change in mountain regions. However, the paucity of such datasets represents a fundamental impediment to accurately assess and predict biogeochemical processes in these sensitive ecosystems.

L103 – The materials and methods lack the details needed especially in the analytical part. It also lacks a description of the statistical process that does not prepare readers about what to expect in the following parts of the paper.

Responses: We sincerely appreciate for your constructive comments. In the revised manuscript, we have improved the section of Materials and methods by providing details on sampling procedures and physicochemical analyses (Lines 116-121, Lines 126-130, Lines 133-137, Lines 139-143). Moreover, we add a subsection of Statistical analysis to clearly describe the methods used for data interpretation (Lines 175-186). These revisions aim to better understand the workflow of sample collection, laboratory analysis, and subsequent data processing. The revised Soil physical and chemical analyses and Statistical analysis sections are as follows:

Soil physical and chemical analyses

Soil moisture content was determined by oven-drying the soils at 105°C to constant mass, which was calculated using the following formula:

$$Moisture\ (\%) = \frac{Fresh\ weight - Dry\ weight}{Dry\ weight} \times 100\%$$

Soil pH was measured using a pH meter (Mettler-Toledo FE28, Switzerland) after shaking the soil samples with deionized water at a 1:2.5 soil-to-water ratio. Soil organic carbon (SOC) concentration was determined by a CE400 elemental analyzer (Elementar vario ISOTOPE cube, Germany), after removing carbonates with 5% HCl. Soil samples for element analysis were digested with concentrated HNO_3, HF, and $HClO_4$ (Bing et al., 2022). The concentrations of major elements (Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, Sr, Ti, V, and Zn) in the digests were determined using an inductively coupled plasma atomic emission spectrometry (ICP-AES, Optima 2000, USA), and the concentrations of trace elements (Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, and Tl) were determined using an inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7700x, USA), with SPEXTM serving as the standard solution. Quality control was ensured by analyzing replicates, blanks, and reference material (BW07405, China). The recovery of the reference material was routinely within the range of 95-105%, and the precision and accuracy of the analyses were < 5% (relative standard deviation).

Statistical analysis

All statistical analyses were conducted using R (version 4.3.1). To test differences in element concentrations among soil horizons, we employed linear mixed-effect models using the “lmer” function from the “lme4” package, where soil horizon was treated as a fixed factor and sampling site as a random factor. Regression analyses were conducted to examine the spatial distribution characteristics of each element. To explore the compositional differences in elemental assemblages across soil horizons and to assess the influence of environmental variables on soil element variation, redundancy analysis (RDA) was conducted using the “rda” function in the “vegan” package. Correlation analyses were conducted separately for each soil horizon to identify horizon-specific relationships between elemental concentrations and environmental drivers. Furthermore, simple linear regression was employed to quantify the individual explanatory power (R^2) of each environmental variable for each element. The cumulative explanatory power of all environmental factors was also calculated to evaluate their combined influence on element variation.

L106 – This figure includes a disputed territory which is not relevant to the data because the authors did not sample in these areas. The authors are therefore advised to either remove the disputed territory from the map or include a statement regarding this in the figure caption. Make sure that it is aligned with ESSD's policy on neutrality regarding jurisdictional claims. I leave it to the journal editors to decide on this.

Response: We sincerely thank you for pointing this out. In accordance with the editor’s suggestion and the journal’s policy on neutrality regarding jurisdictional claims, we have revised the figure to focus only on the regions where sampling was actually conducted. The revised Figure is as follows:

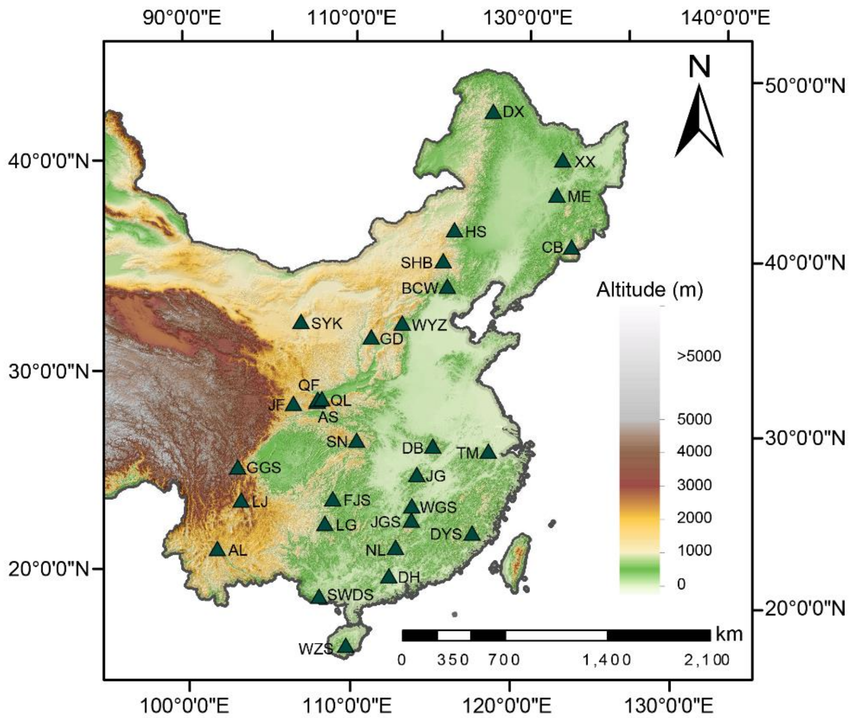

Fig. 1 Geographic distribution of the 30 China's mountains. AL, Mt. Ailao; AS, Mt. Ao; BCW, Mt. Baicaowa; CB, Mt. Changbai; DB, Mt. Dabie; DH, Mt. Dinghu; DX, Mt. Daxinganling; DYS, Mt. Daiyun; FJS, Mt. Fanjing; GD, Mt. Guandi; GGS, Mt. Gongga; HS, Mt. Han; JF, Mt. Jifeng; JG, Mt. Jiugong; JGS, Mt. Jinggang; LJ, Mt. Luoji; LG, Mt. Leigong; LJ, Mt. Luoji; ME, Mt. Maoer; NL, Mt. Nanling; QF, Mt. Qingfengxia; QL, Mt. Qinling; SHB, Mt. Saihanba; SN, Mt. Shennongjia; SWDS, Mt. Shiwandashan; SYK, Mt. Suyukou; TM, Mt. Tianmu; WGS, Mt. Wugong; WYZ, Mt. Wuyuezhai; WZS, Mt. Wuzhi; XX, Mt. Xiaoxinganling.

L113 – Provide the dates when the sampling was done.

Response: Thank you for your feedback. The soil sampling was conducted from July 2012 to March 2013. This information has been clearly incorporated into the main text to improve clarity.

L135 – How much soil was used in the analyses and how many replicates?

Response: We appreciate for your great comments. For each soil horizon at every sampling site, we collected three replicate samples. Each replicate was a composite sample, thoroughly mixed from subsamples taken in each horizon. In total, 1,314 soil samples were collected and sent to the laboratory for analysis. During laboratory procedures, all replicates were analyzed separately rather than being pooled, ensuring the reliability of the data. We have revised the manuscript to include a more detailed description of the sampling procedure to enhance clarity (Lines 118-121, Lines 126-130).

L156 – It is not clear how the oxide values were obtained from the elemental analysis. We're certain ratios used? If so, it has to be clearly stated in the manuscript.

Response: Thank you very much for the professional comment. In our study, the CIA was calculated based on the molar proportion of oxides estimated from the total elemental concentrations using the widely accepted formula proposed by Nesbitt & Young (1982):

$$CIA = \frac{Al_2O_3}{(Al_2O_3 + Na_2O + K_2O + CaO^*)} \times 100$$

Specifically, oxide contents were derived by converting elemental concentrations to their corresponding oxide forms using standard molecular weights, a common practice in many studies (e.g., Ochoa-Hueso et al., 2021). Regarding CaO*, we acknowledge that calcium can be present in multiple forms, including silicates, carbonates, phosphates, and exchangeable forms. To ensure that the CIA reflects only the contribution from silicate weathering, we applied the correction method proposed by McLennan (1993), which has been widely adopted in geochemical studies. This method estimates CaO* as follows: If the measured CaO concentration is less than or equal to Na_2O, CaO* is assumed to be equal to the measured CaO. If CaO > Na_2O, CaO* is set equal to Na_2O. This approach helps to minimize the influence of non-silicate calcium on the CIA calculation and thus improves the reliability of the weathering index. We have revised the Methods section accordingly to clarify this procedure (Lines 168-173).

It is also worth noting that CIA is not a central focus of this dataset. Our primary aim is to provide a comprehensive multi-element concentration dataset across vertically stratified soil horizons in mountain regions, which can support a wide range of research, including but not limited to weathering assessments. Nevertheless, we included the CIA to offer a useful reference for users interested in assessing the degree of chemical weathering.

References:

Nesbitt, H. W., and Young, G. M.: Early Proterozoic climates and plate motions inferred from major element chemistry of lutites, Nature 299, 715-717, https://doi.org/10.1038/299715a0, 1982.

McLennan, S. M.: Weathering and Global Denudation, J. Geol. 101, 295-303, https://doi.org/10.1086/648222, 1993.

Ochoa-Hueso, R., Plaza, C., Moreno-Jimenez, E., Delgado-Baquerizo, M.: Soil element coupling is driven by ecological context and atomic mass, Ecol. Lett. 24, 319-326., https://doi.org/10.1111/ele.13648, 2021.

L173-177 – This doesn't mean anything and is already given information for almost all soil types.

Response: We appreciate for your comment and understand that elemental abundance patterns are generally consistent across most soil types. However, our intention in presenting the concentration ranges and mass ratios is to provide a comprehensive overview of the relative abundance and variability of the 24 elements specifically within mountain soils across diverse climatic and geological settings. While such information may seem well-established for common soil types, it remains underreported for high-resolution, multi-element datasets derived from standardized profiles in mountainous ecosystems.

L246 – How can you have explanation by environmental factors exceeding 100%?

Response: Thank you for raising this important point. In Fig. 6, the y-axis represents the cumulative explanatory power of all environmental variables for each individual element. Therefore, the total explanatory value exceeding 100% is mathematically possible. To avoid confusion, we have clarified this aspect in the "Statistical analysis" section of the revised manuscript and have also updated the figure legend accordingly.