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DATA NOTE

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Drivers of soil biophysical processes along an elevational gradient at Pico de Orizaba volcano, Mexico

Guillermo Angeles[1*], Marycruz Álvarez-Jiménez[1], Fabien Anthelme[2], Isabelle Barois[1], José Luis Chaparro Carrillo[3], Nereyda Cruz-Maldonado[2], Thibaud Decaens[4], Martín de los Santos-Bailón[5], Stéphane Fourtier[2], Emmanuel García-Gutiérrez[6], David García-Segura[7], Rodrigo Gómez-Aguilar[8], Antonio Gómez-Anaya[5], Eduardo Hernández[8], Daniel Hernández-Cáceres[2], Leonor Jiménez[1], Beatriz E. Marín-Castro[9,10], Luis Merino-Martín[11], Marco A. Morales-Martínez[13], Edwin U. Monfil-León[12], René A. Palestina[14], Carlos Pimentel-Reyes[1], Ricardo Quiroz Reyes[15], Frédérique Reverchon[16], Hervé Rey[2], Catherine Roumet[4], Christina D. Siebe-Grabach[9], Katrin Sieron[13], Víctor Vázques Reyes[1], Monique Weemstra[2,4] and Alexia Stokes[2]

Abstract
Elevational gradients are characterized by major shifts in environmental conditions, reflected through changes in climatic and soil variables. These shifts strongly impact the composition, community structure and specific functional traits of vegetation. Vegetation, in turn, influences soil properties through litter input, root growth and the release of root exudates, thereby influencing soil microbial and faunal communities. Here, we report and briefly describe data of soil and underlying bedrock physical and chemical properties, climatic variables, plant community composition and species abundance, soil microbial diversity and macro and mesofaunal abundance and diversity. Data are provided for 6 elevations (3400–4600 m) ranging from pine forest to alpine prairie. We focused on soil biophysical properties beneath several keystone or community-structuring plant species with different growth forms: (1) tree (*Pinus hartwegii* Lindl.); shrub (*Oxylobus arbutifolius* (Kunth) A. Gray and *Chionolaena lavandulifolia* (Kunth ex Kunth) Benth. & Hook.f. ex B.D.Jacks.); and (3) herb (*Lupinus montanus* Kunth and *Senecio roseus* Sch.Bip.). These data are useful for understanding how shifts in abiotic conditions and vegetation communities along an elevational gradient affect soil ecosystem services such as water infiltration, soil aggregation and carbon (C) storage, and modify soil biodiversity. The collected data also provide useful information to understand how alpine vegetation, soil macro- and meso-fauna, and soil bacterial communities may shift under a climate change scenario.

Keywords Elevational gradient, Bulk soil and rhizosphere microbial communities, Carbon storage, High mountain ecosystem, Soil biodiversity, Soil hydrophysical properties, Soil macro and meso-fauna, Soil structure and soil moisture monitoring

*Correspondence:
Guillermo Angeles
guillermo.angeles@inecol.mx
Full list of author information is available at the end of the article

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Table 1 Overview of data files/data sets. Pico de Oizaba, Mexico

Label	Name of data file/dta set	File type (file extension)	Data repository and identifier (DOI)
Data file 1	Plots and map	MS Excel file (.xlsx)	10.6084/m9.figshare.22057106 https://figshare.com/s/d474da60e15dbb937251
Data file 2	Soil profile	MS Excel file (.xlsx)	10.6084/m9.figshare.22097993 https://figshare.com/s/4e917b031648148a7f87
Data file 3	Plot climate interpolated base	MS Excel file (.xlsx)	10.6084/m9.figshare.22057175 https://figshare.com/s/369a80465b62cfa15249
Data file 4	Soil moisture monitoring station	MS Excel file (.xlsx)	10.6084/m9.figshare.22102379 https://figshare.com/s/e9c605c45cea45b3a669
Data file 5	Floristic list	MS Excel file (.xlsx)	10.6084/m9.figshare.22010852 https://figshare.com/s/f64079ca0a9bf3ceebe7
Data file 6	Infiltration and field saturated hydraulic conductivity	MS Excel file (.xlsx)	10.6084/m9.figshare.22093580 https://figshare.com/s/f64079ca0a9bf3ceebe7
Data file 7	Monolith aggregate stability	MS Excel file (.xlsx)	10.6084/m9.figshare.22010849 https://figshare.com/s/ce7b2dcf96a58b848fdf
Data file 8	Monolith earthworms	MS Excel file (.xlsx)	10.6084/m9.figshare.22057160 https://figshare.com/s/629b3fcaafcd994bb5e5
Data file 9	Monolith soil analysis	MS Excel file (.xlsx)	10.6084/m9.figshare.22010846 https://figshare.com/s/dd175f66a054808a8c2b
Data file 10	Monolith vegetation	MS Excel file (.xlsx)	10.6084/m9.figshare.22105787 https://figshare.com/s/b15659ca007b50831440
Data file 11	Bulk soil and rhizosphere 16S amplicon sequences	MS Excel file (.xlsx)	10.6084/m9.figshare.22062104 https://figshare.com/s/4b0a2ae602909390c1b7
Data file 12	Monolith macrofauna	MS Excel file (.xlsx)	10.6084/m9.figshare.22065185 https://figshare.com/s/ea9cbf6b1d8708ea8674
Data file 13	Soil mesofauna	MS Excel file (.xlsx)	10.6084/m9.figshare.22065302 https://figshare.com/s/c9f291f23d0cf4b8cc2d

Background

Elevational gradients and the associated biotic and abiotic changes provide useful frameworks to elucidate the drivers behind species distribution and their response to climate change (Cruz-Maldonado et al. 2021; Fukami and Wardle 2005; McCain and Grytnes 2010). Environmental factors such as temperature, radiation, and precipitation shift with altitude and strongly influence soil biophysical properties, including soil structure and moisture. Plant communities also change along altitudinal gradients, further modifying soil properties through litter and root carbon (C) inputs, thereby affecting soil biodiversity. Here, we collected belowground and aboveground data to elucidate the mechanisms through which altitude and the associated shifts in climate and vegetation affect soil properties and ecosystem processes, at different elevations.

The ecosystem services provided by (sub)alpine soils, e.g., C sequestration, nutrient cycling, and water retention, are threatened by a changing climate and land use conversion, as high mountains are particularly fragile ecosystems (Mountain Research Initiative 2015). These ecosystem services depend on soil physicochemical properties, its biodiversity, as well as on plant species composition and community structure. Therefore, our dataset includes data on soil porosity and aggregate stability at different soil depths and altitudinal levels and measurements of soil water infiltration and retention, which will allow a better understanding of the water flow dynamics along this Neotropical altitudinal gradient. We also collected data on soil macro- and meso-fauna diversity, as well as on microbial communities at the bulk soil and rhizosphere level, thus allowing researchers to explore the biotic and abiotic drivers behind soil biodiversity, which is key in mediating soil biophysical processes (Collins et al. 2020; Hernández-Cáceres et al. 2022). This dataset complements the already published data from our twin study in France (Stokes et al. 2021) and represents the largest freely available collection of data on plant traits, soil physicochemical variables and soil biodiversity along a 1200 m elevational gradient in a Neotropical climate. Methods for data collection and analysis are provided in the data files and supplementary materials (Table 1).

Objectives

Our objective was to determine how changes in environmental conditions with altitude affect edaphic properties, vegetation, and soil microbial and faunal communities, by collecting data along a 1200 m long gradient between 3400 and 4600 m.a.s.l. on the North-East flank of the highest mountain of Mexico, Pico de Orizaba volcano. A twin study with the same objective was carried out at Massif de Belledonne, in the French Alps.

Methods

Data file 1 shows an aerial map of the whole protected area named "Área Natural Protegida Pico de Orizaba (ANPPO)", within which our study sites are located. Data file 1 also provides the names and numbers of each plot, with their respective coordinates and elevations. The studied elevational gradient lies on the North-East flank of Pico de Orizaba, the highest peak of Mexico. We hereby present data collected in 2017 and 2018, at six altitudes (elevational bands of 200 m each) along an elevational gradient ranging from 3400 to 4600 m.a.s.l. and from 3400 to 4400 m.a.s.l. for soil profile and soil moisture (Data files 2 and 4, respectively), at Pico de Orizaba volcano, Mexico. Climatic data (Data file 3) are also provided and were measured over 2 years (2018–2020).

The underlying bedrock is composed of intermediate to acid lavas and pyroclastic (volcaniclastic) material. Soil profiles were described for each altitudinal level (two soil profiles made per altitudinal band). Soil physico-chemical properties were analyzed from each identified soil horizon. The main soil units correspond to Endosilandic Andosols at Sleketic Regosol. The volumetric and tension soil moisture, as well as the soil surface temperature were monitored for one year, in six soil profiles distributed along the altitudinal gradient (Data file 4).

To obtain the floristic list of our study site, five 20×20 m plots were established at each altitude (every 200 m along our 1000 m long elevational gradient) up to 4000 m of elevation, to include keystone and community-structuring species with different growth forms: *Pinus hartwegii* (tree), *Oxylobus arbutifolius* and *Chionolaena lavandulifolia* (shrubs), and *Lupinus montanus* and *Senecio roseus* (herbs). From 4200 m.a.s.l. and above, the distance between our plots had to be reduced to 5 m for space availability reasons (mountain tapering). A botanical survey was performed inside each plot (Data file 5) and one adult individual of each structuring species was selected per plot. At the limit of the individual's canopy on the downslope side, infiltration tests were performed to estimate water flow through soil and hydraulic conductivity of the quasi-steady phase was calculated (Data file 6). Aggregate stability measurements were made from soil blocks ($10 \times 10 \times 15$ cm depth) taken beside the monoliths (Data file 7). An earthworm survey was made on soil monoliths of $0.25 \times 0.\ 25 \times 0.15$ m in the field to link the abundance of these ecosystem engineers with soil processes (Data file 8). To investigate the relationships between soil biophysical properties and vegetation, plant community composition was described in a 1 m^2 subplot within each plot, which was established near each structuring species (Data file 10). Soil texture, bulk and real density, cationic exchange capacity, pH, electric conductivity, organic C, nitrogen (N) content, nitrate and ammonium concentrations, total and available phosphorus (P), and macronutrients (Ca, Mg, K, Na) concentrations were determined on pooled soil samples harvested within each monolith (Data file 9). A soil monolith (0.25 m $\times$ 0.25 m $\times$ 0.15 m depth) was excavated within each subplot ($n = 83$). Above the monolith, litter layer thickness and aboveground biomass per species were measured (Data file 10). Soil samples were collected from the monolith and from rhizospheric soil attached to fine roots of the three structuring plant species. DNA was extracted from these soil samples and 16S rDNA amplicon sequences were obtained to determine the changes in bacterial communities at the bulk soil and at the rhizosphere level along the elevational gradient (Data file 11). Soil mesofauna was collected beside each monolith from litter and soil with a cylinder (5 cm diameter and 10 cm high) and then extracted with a Berlese funnel in the laboratory. All the organisms were kept in 70% alcohol and identified at order taxonomical level, except for Collembola for which identification was made at the family level (Data file 12). Soil macroinvertebrates were hand-sorted from each monolith and fixed in 70% ethanol, except earthworms, which were fixed in 96% ethanol for the DNA barcoding. Macroinvertebrates were identified at the order level, except for earthworms for which morphological diagnoses were combined with DNA barcoding to obtain species level assignations. Invertebrates within each taxon were counted and weighed (Data file 13).

Limitations

Although this dataset comprises a large number of field and laboratory data collected from 83 monoliths in 30 plots, it was not always possible to include all structuring species within the same plot. At higher altitudinal levels (4000–4400 m.a.s.l.), additional shrub and herbaceous species were sometimes included (*S. roseus* and *C. lavandulifolia*) to complement the data when *L. montanus* and *O. arbutifolius* were not present. Moreover, our focus on some keystone/structuring plant species does not allow generalization of rhizosphere processes under other species. Finally, our datasets do not provide information on plant functional traits nor on soil microbial functional diversity (i.e., enzymatic activities or microbial gene transcripts), the latter being a key factor to understand soil functioning as microorganisms are main contributors to soil biophysical processes.

Conclusion

Our data allow researchers to elucidate the changes in soil ecosystem services and their link with soil biodiversity along an altitudinal gradient in the Neotropical region, where high mountain ecosystems have been poorly studied. Under a climate change context, these data are particularly useful to improve our predictions of possible shifts in vegetation and soil organisms.

Abbreviation

m Meters above sea level

Author contributions

All authors contributed to data collection and writing of the paper. All authors read and approved the final manuscript.

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Availability of data and materials

The data described in this Data note can be freely and openly accessed on https://figshare.com/. Please see Table 1 for details and links to the data.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Red de Ecología Funcional, Instituto de Ecología, A.C., Xalapa, Veracruz, Mexico. [2]AMAP, Univ Montpellier, INRAE, IRD, CIRAD, CNRS, 34000 Montpellier, France. [3]Facultad de Ciencias, Universidad Autónoma de México, Ciudad de México, Mexico. [4]CEFE, Univ Montpellier, CNRS, EPHE, IRD, Montpellier, France. [5]Red de Biodiversidad y Sistemática, Instituto de Ecología, A.C., Xalapa, Veracruz, Mexico. [6]Posgrado en Ciencias Biológicas, Facultad de Ciencias, Universidad Nacional Autónoma de México, Ciudad de México, Mexico. [7]Biorefinery Group, Food Research Department, School of Chemistry, Autonomous University of Coahuila, Saltillo, Coahuila México, Mexico. [8]Facultad de Ciencias Agrícolas, Universidad Veracruzana, Xalapa, México. [9]Laboratorio de Edafología Ambiental, Instituto de Geología, Universidad Nacional Autónoma de México, Mexico, Mexico City. [10]Laboratorio de análisis químicos de suelo, agua y plantas, Secretaría Técnica, Instituto de Ecología A.C., Xalapa, México. [11]Departamento de Biología y Geología, Física y Química inorgánica, ESCET, Universidad Rey Juan Carlos, C/Tulipán s/n, Móstoles, C.P. 28933 Madrid, Spain. [12]Maestría en Gestión de Riesgos y Cambio Climático, Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutiérrez, Mexico. [13]Centro de Ciencias de La Tierra, Universidad Veracruzana, 91090 Xalapa, Veracruz, Mexico. [14]Instituto de Biotecnología y Ecología Aplicada (INBIOTECA), Campus para la Cultura, las Artes y el Deporte, Xalapa, México. [15]Independent profesional, Doylestown, USA. [16]Red de Estudios Moleculares Avanzados, Centro Regional del Bajío, Instituto de Ecología, A.C., Pátzcuaro, Michoacán, Mexico.

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