

Chilean blind spots in soil biodiversity and ecosystem function research

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Abstract Soil harbour up to a quarter of the world's biodiversity, substantially contributing to many ecosystem functions and processes. It is significantly important to identify the distribution patterns of soil organisms and their ecosystem functions, to support their conservation efforts and to build policy around them. This has been recently analysed at macroecological scales, but analyses at national or local scales are scarce. Here, we identify and analyse the blind spots in soil taxa and ecosystem functions data in continental Chile. A Web of Science search (1945–2020) was conducted focusing on ten soil taxa and four ecosystem functions (nutrient cycling, decomposition, water infiltration and soil respiration). A total of 741 sampling sites were obtained from 239 articles: in 49.25% of these sites, soil biodiversity was studied alone, while this percentage was 32.65% for ecosystem functions. In 18.10% of the sites, both soil biodiversity and ecosystem functions were jointly studied, a surprisingly high percentage compared to global-scale studies. By far, bacteria/fungi and nutrient cycling were the most investigated taxa and function, respectively. Several soil taxa (Acari, Collembola, Nematoda, Formicoidea, Protista, Rotifera) were represented by just a few sampling sites concentrated in specific Chilean regions. Places like the central region (Metropolitan and Valparaíso administrative Regions), the Atacama Desert (north of the country) and the Valdivian temperate forests (La Araucanía, Los Ríos and Los Lagos administrative Regions) present the majority of studies on soil Fungi, Bacteria and nutrient cycling, reflecting the historical interests of well-established research groups. Based on this research, we are identifying the causes of the data blind spots and inviting the Chilean soil ecology community to propose ideas on how to fill them, especially targeting less studied soil taxa and ecosystem functions in neglected regions of Chile.

Key words: continental Chile, distribution patterns, ecosystem functions, soil ecology, soil fauna.

SOIL BIODIVERSITY AND ECOSYSTEM FUNCTIONS: FROM GLOBAL TO LOCAL TRENDS

Soil is a highly diverse habitat that contains a plethora of very different organisms, ranging from bacteria and fungi to nematodes, earthworms and moles. It is estimated that soil harbour up to a quarter of all living species on Earth and that one gram of healthy garden soil may contain one billion bacterial cells, up to one million individual fungi, about one million cells of protists and several hundred of nematodes (European Commission 2010). Soil biodiversity is an important factor driving several ecosystem functions and services, including nutrient cycling and plant acquisition, plant productivity, reduction of plant pathogens, control of antibiotic resistance genes, climate regulation and food production (Bardgett & van der Putten 2014; Delgado-Baquerizo *et al.* 2020).

Despite its importance, soil biodiversity has historically and largely been neglected. But progress has been made in recent years, for example with the launching of the first global report on the *State of knowledge of soil biodiversity* (FAO *et al.* 2020), with more than 300 scientists worldwide as co-authors. Nevertheless, one of the main questions in soil ecology remains (Eisenhauer *et al.* 2017): how to causally integrate soil biodiversity and ecosystem functioning at different spatiotemporal scales? Although over the last decade, global-scale studies have started to disentangle this causal relationship (Maestre *et al.* 2012, 2015; Delgado-Baquerizo *et al.* 2016, 2017, 2020; Pärtel *et al.* 2016; Soliveres *et al.* 2016; Song *et al.* 2017; Crowther *et al.* 2019), there is much work to be done compared with above-ground ecosystems, where the relationships between plant community attributes and productivity are better established (Flynn *et al.* 2011; Grace *et al.* 2016; Liang *et al.* 2016; Duffy *et al.* 2017). Some definitions are needed to determine causal relationships between soil microbial communities' attributes and ecosystem functions (Xu *et al.* 2020). Hall *et al.* (2018) define

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Accepted for publication August 2022.

three categories of microbial communities' attributes: microbial processes (i.e. nitrogen fixation), microbial community properties (i.e. biomass C:N ratio and functional gene abundance) and microbial membership (i.e. taxonomic and phylogenetic diversity, community structure and co-occurrence networks). In this conceptualisation, microbial processes are more directly related to a nutrient pool or flux, while the effects of community properties and microbial membership are more indirect, mediated by their concatenate effect on microbial processes. Besides soil microbes, this perspective also needs to include soil fauna, as in addition to regulating population size and resources of microorganisms (herbivory, bacterivory and fungivory), soil fauna also plays important roles in soil and litter transformation, having overall very significant effects on the energy flux, network structure and ecosystem multifunctionality of soil food webs (Potapov 2022).

Over the last decade, there is a paramount of global soil ecology studies focusing on bacteria (Delgado-Baquerizo *et al.* 2018; Cano-Díaz *et al.* 2020), protists (Singer *et al.* 2019; Oliverio *et al.* 2020), fungi (Tedersoo *et al.* 2014; Egidi *et al.* 2019; Větrovský *et al.* 2020) including mycorrhizal fungi (Davison *et al.* 2015; Soudzilovskaia *et al.* 2015), invertebrates in general (Bastida *et al.* 2020), nematodes (van den Hoogen *et al.* 2019), earthworms (Briones & Schmidt 2017; Phillips *et al.* 2019), isopods (Sfenthourakis & Hornung 2018), ants (Bertelsmeier *et al.* 2017; Gibb *et al.* 2017), termites (Buczkowski & Bertelsmeier 2017), roots (Iversen *et al.* 2017) and the overall soil community (Fierer *et al.* 2009; Bahram *et al.* 2018; Cameron *et al.* 2019; Crowther *et al.* 2019; Delgado-Baquerizo *et al.* 2020; Guerra *et al.* 2020; Johnston & Sibly 2020; Luan *et al.* 2020). Despite these great advances in global soil ecology, major taxonomic, functional, geographic and temporal gaps still exist (Bueno *et al.* 2017; Cameron *et al.* 2019; Guerra *et al.* 2020). Filling these gaps is crucial for soil biodiversity conservation and governance. Furthermore, and unlike above-ground biodiversity, there is no monitoring of soil biodiversity; thus, as much of global soil biodiversity is yet to be described, we do not even know at what pace are these unknown species being lost. There is an urgent need for action.

Recently, when analysing 17 186 sampling sites at a global scale (from macro-ecological scale studies), Guerra *et al.* (2020) found that just in 0.3% of those sites, both soil biodiversity and ecosystem functions were studied at the same time. As both are so interdependent, much work needs to be done in order to integrate conceptually, causally and disciplinary (regarding different knowledge areas) soil biodiversity and its associated ecosystem functions. Guerra *et al.* (2020) found a lack of conjoint studies of soil

biodiversity and ecosystem functions at continental and global scales but would the same happen at national, regional or local scales? To find out, we conducted a similar analysis (through a Web of Science search and taxonomic and ecosystem function assignation to each site) restricted to the continental Chilean territory. Chile is the longest country in the World, and as such, it contains a variety of ecosystems, which could be reflected in its soil ecology: the driest desert (Atacama), high Andean ecosystems, Mediterranean climate areas, extremely rainy temperate forests and Patagonian forests and steppe. There is plenty of interest in the soil microbial biodiversity of the country, reflected, for example in the creation of The Chilean Network of Microbial Culture Collections (Santos *et al.* 2016), or more specifically with the Atacama (microbiome) Database (Contador *et al.* 2020).

This review aimed to identify the information blind spots in soil taxa and ecosystem functions in the continental Chilean territory, analysing their distribution patterns, as a baseline for future monitoring and conservation initiatives.

ANALYSES OF SOIL BIODIVERSITY AND ECOSYSTEM FUNCTIONS IN CHILE

Literature search and coordinates extraction

In January 2021, a Web of Science (<https://clarivate.com/webofsciencelibrary/solutions/web-of-science/>) search of articles published between 1945 to 2020 was conducted focusing on 10 soil taxa (Bacteria, Fungi, Archaea, Oligochaeta, Acari, Collembola, Nematoda, Formicoidea, Protista, Rotifera) and four ecosystem functions (nutrient cycling, decomposition, water infiltration and soil respiration) according to Guerra *et al.* (2020). The following keywords were used: (Chile* OR Arica) OR Parinacota OR Tarapacá OR Valparaíso OR O'Higgins OR Maule OR Ñuble OR Biobío OR Araucanía OR Aysén OR Magallanes OR Metropolitan OR Antofagasta OR (Northern AND Chile) OR (Central AND Chile) OR (Southern AND Chile) AND (soil* OR below-ground) AND (*function* OR *diversity OR organism* OR biota OR animal* OR invert* OR fauna*) AND distribution AND (*mycorrhizal* OR microb* OR nematodos* OR bacteria* OR ant* OR fung* OR invertebrate* OR earthworm* OR protist* OR eukaryot* OR collembola* OR rotifer* OR Archaea OR formic* OR mite* OR termite* OR arthropod* OR respiration OR decomposition OR nitrogen-cycling OR nutrient cycling OR water infiltration OR aggregate* OR bioturbation).

This variety of keywords was used in order to capture the maximum number of published articles,

which often used very different expressions when referring to the Chilean administrative regions, soil taxa and ecosystem functions. Words like 'Los Ríos' and 'Los Lagos' referring to the administrative regions of Chile named that way, were excluded, as searching for them leads to studies conducted in rivers and lakes (as translated from Spanish). A second, more detailed search was necessary to focus on the soil of specific geographic regions and the taxa or function of interest, using (as an example) the following keywords: (Chile* OR Arica OR Parinacota OR Tarapacá OR Valparaíso OR O'Higgins OR Maule OR Nuble OR Biobío OR Araucanía OR Aysén OR Magallanes OR Metropolitan OR Antofagasta OR (Northern AND Chile) OR (Southern AND Chile) OR Atacama AND soil* AND mycorrhizal*).

Each article was checked individually, discarding those that did not imply soil extraction from continental Chile and that did not analyse at least one of the soil taxonomic groups or ecosystem functions defined. After compiling the articles, a database including coordinates (UTM system), citation, DOI identifier and soil taxa and ecosystem function investigated was constructed in an Excel file, available at: <https://figshare.com/s/c7b6dce6b12edfbc5e7d> (DOI: 10.6084/m9.figshare.14838804).

SPATIAL DATA PROCESSING AND ANALYSES

Data were georeferenced using Qgis 3.6 (QGIS.org 2021) to create three points layers projected in WGS84. These were used to elaborate four spatial distribution representation cartographies, also using a shape layer of regional administrative boundaries, extracted from the 'Infraestructura de datos Geoespaciales de Chile (IDE)' database (<http://www.geoportal.cl/visorgeoportal/>) and a shape layer of ecoregions extracted from the RESOLVE Ecoregions data set (<https://ecoregions.appspot.com/>).

The first cartography used three shape layers: The first one contained the sampling sites of soil biodiversity, the second one contained the sampling sites of soil ecosystem functions and the third one for sites containing both. For each layer, the parameters of points grouping (or cluster) were applied in Qgis 3.6 properties, assigning a tolerance distance of 50 km. For the second and third cartographies, the same tools and parameters were used, but applying 10 soil taxa shape layers (second cartography) and 4 soil ecosystem functions shape layers (third cartography). For the fourth cartography, the same three shape layers from the first cartography were used. For each layer, the Qgis 3.6 tool Heatmap (Core Density Estimation) was used, applying a 2 km radius to cover concentrations within that range. The colour gradient

was adapted to the design of previous cartographies, categorising from low density (only one point) to high density (over 10 sampling points). The RESOLVE Ecoregions shape layer (for continental Chile) was superimposed in this fourth cartography. This procedure allows showing in which Chilean ecoregions there is a concentration of sampling sites for soil biodiversity, soil ecosystem functions and both. All cartographies were projected in WGS84/ EPSG:4326.

To analyse the representativeness (coverage percentage and the number of sites) of soil taxa and ecosystem functions in the ecoregions, the ecoregions layer, the 10 soil taxa layers and the four ecosystem function layers were transformed to raster files with a 2 km resolution, assuming each sample point equals one pixel. For the ecoregions layer, a value of 1 to 7 was assigned to each pixel depending on which ecoregion it corresponds to (i.e. pixels with a value of 1 corresponding to the Atacama Desert; pixels with a value of 2 correspond to the Central Andean dry puna). For point layers, a value of 10 was given to each point. Using a raster calculator, the values were processed by multiplying: the Ecoregions raster X Point layer raster, for each taxon and function. The result was 10 raster layers for soil taxa and 4 raster layers for soil ecosystem functions with values from 1 to 7 and 10 to 70. Following the same example: all values of 10 correspond to the sampling points located in the Atacama Desert, and all values of 20 correspond to the sampling points located in the Central Andean dry puna. Using the Unique values report raster tool, a report was obtained for each layer showing the number of pixels for each value. These data were extracted and arranged in four Excel tables: two referring to the number of pixels for taxa and functions and the remaining referred to the percentage of representativeness of each taxa and function, according to each ecoregion. This analysis allows to establish, by each Chilean ecoregion, the number of sampling sites per soil taxa/ecosystem functions and how many of them were investigated on those sites (coverage percentage).

DATA GAPS OF SOIL BIODIVERSITY AND ECOSYSTEM FUNCTIONS IN CONTINENTAL CHILE

A total of 239 Web of Science articles were obtained for continental Chile, from which 111 deal with soil biodiversity, 89 with soil ecosystem functions and 39 investigated both. From these articles, 741 sampling points were obtained (Fig. 1), showing a greater number of soil biodiversity sites on the administrative regions of Antofagasta (north) and Los Ríos (south) (Fig. 1a) and focused in Bacteria and Fungi

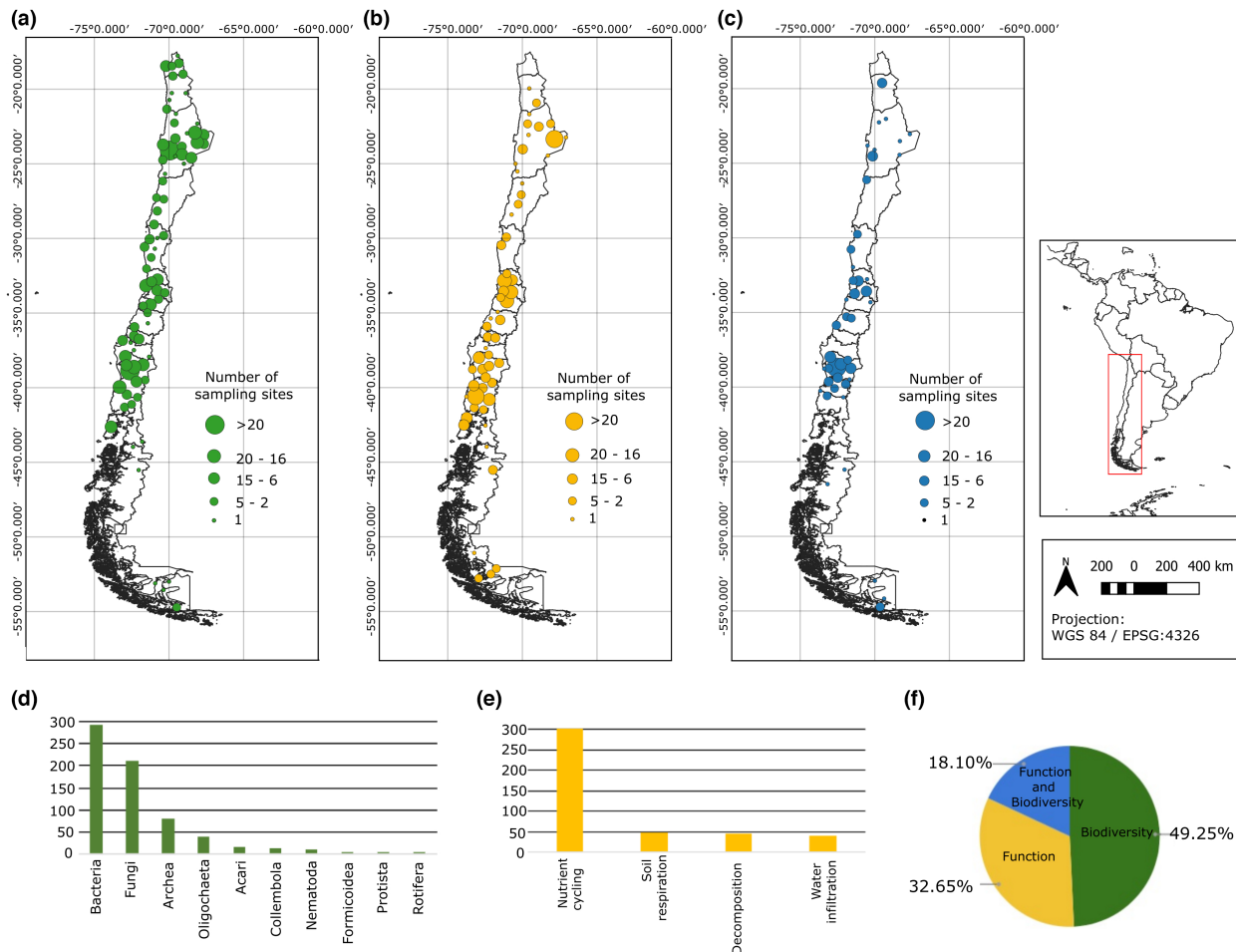


Fig. 1. Distribution of sampling sites for soil taxa and ecosystem functions in continental Chile. (a) Soil biodiversity sampling sites. (b) Soil ecosystem functions sampling sites. (c) Sampling sites where both soil biodiversity and ecosystem functions were conjointly studied. (d) Number of sampling sites per soil taxa. (e) Number of sampling sites per soil ecosystem function. (f) Percentages of sampling sites investigating soil biodiversity, ecosystem functions and both. The size of the circles is based on a 50 km grid.

(Appendix S1). The Andean part of the Coquimbo region and the regions of Aysén and Magallanes showed the least soil biodiversity sampling points (Fig. 1a), while taxa like Formicoidea, Protista and Rotifera did not surpass five studies and had scattered sampling points in specific regions. The central zone of Chile and the regions of Antofagasta and Los Lagos showed a greater number of soil ecosystem functions sites (Fig. 1b), with nutrient cycling being the most studied function with 300 sampling sites, while the remaining functions did not surpass 50 sampling sites (Fig. 1e) and had a scattered distribution across the country (Appendix S2). La Araucanía region had the highest number of sites where soil biodiversity and ecosystem functions were jointly studied (Fig. 1c).

When doing a 2 km radius heatmap analysis, two sampling hotspots in soil biodiversity were found: one in the south of the Atacama Desert and one in

the Chilean Matorral, which is also a sampling hotspot for soil biodiversity and ecosystem functions when studied together (Fig. 2c). Some parts of the Central Andean dry puna presented a medium sampling density of soil biodiversity (Fig. 2a); this ecoregion also showed a sampling hotspot for soil ecosystem functions (Fig. 2b). The Valdivian temperate forests had medium density regarding soil ecosystem functions sampling (Fig. 2b). Ecoregions like the Magellanic subpolar forests and the Patagonian steppe had the highest sampling gaps (Fig. 2).

Regarding the representativeness of the 10 soil taxa and of the four ecosystem functions in the ecoregions, it was found that in all ecoregions, at least five soil taxonomic groups had a percentage coverage of less than 5% (Fig. 3a), with less than 10 sampling sites (Fig. 3b). For soil ecosystem functions, overall, greater variability in percentage coverage (Fig. 3a) and the number of sampling sites (Fig. 3b) was

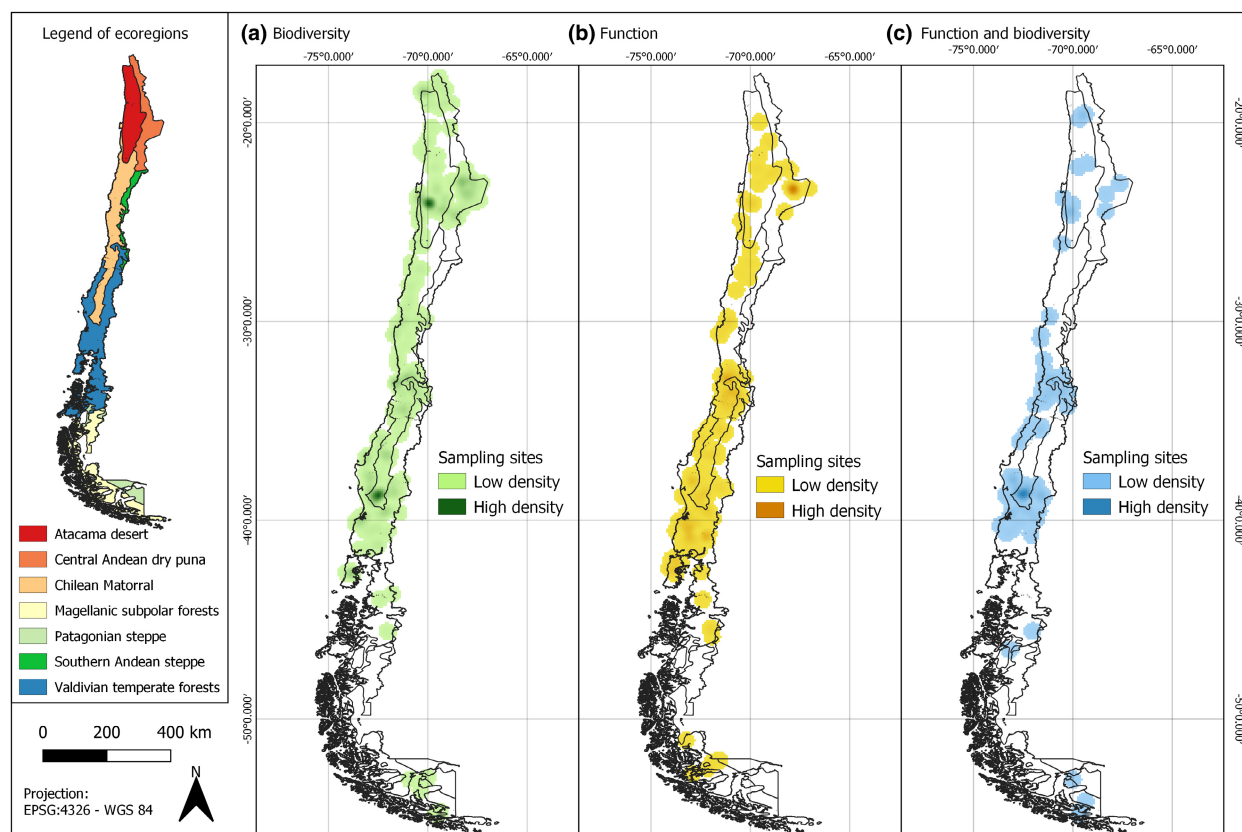


Fig. 2. Heatmap of sampling distribution across continental Chile ecoregions (2 km grid). (a) Soil biodiversity sampling sites. (b) Soil ecosystem functions sampling sites. (c) Soil biodiversity and ecosystem functions sampling sites.

found compared to soil biodiversity. The number of sampling sites for soil ecosystem functions was generally low in at least five of the seven ecoregions and did not surpass five sites for two ecosystem functions (Fig. 3b). Ecoregions like the Chilean Matorral and the Valdivian temperate forests had the highest soil ecosystem functions coverage percentage and number of sampling sites (Fig. 3). The Magellanic subpolar forests, the Patagonian steppe and the Southern Andean steppe presented extremely low numbers of sampling sites (Fig. 3b). Finally, historically, there is a steady increase in Chilean studies dealing with soil biodiversity, ecosystem functions and both (Fig. 4), especially during the last decade.

POSSIBLE EXPLANATIONS OF THE GAPS FOUND

In our analyses of soil biodiversity and ecosystem functions research in Chile, we overall found several types of biases: geographic, towards the Atacama Desert, the central zone of Chile and the Valdivian temperate forests; taxonomic, towards bacteria and fungi; and functional, towards nutrient cycling. Over

the last decades, the Atacama Desert, given its extreme conditions, has attracted plenty of national and international researchers interested in studying microbial life and communities under such conditions (Bull *et al.* 2018). Dry tephra of Atacama volcanoes (above 6000 m.a.s.l.) is the most similar terrestrial ecosystem to the surface of Mars, as these 'soils' are extremely acidic, oligotrophic and exposed to a thin atmosphere and have high UV fluxes and high temperature fluctuations (Schmidt *et al.* 2018). These conditions are perfect for the field of astrobiology, which also has proliferated in the Atacama Desert. There are now important established Chilean research groups studying the Atacama soil microbial life (Bull *et al.* 2016, 2018; Gómez-Silva & Batista-García 2022); in our analysis, the Antofagasta region, which had most Atacama Desert-based studies, had a total of 152 sampling sites. The central zone of Chile, around the Metropolitan (49 sampling sites) and the Valparaíso (59 sampling sites) regions, concentrates most of the population (52%), the most traditional and prominent universities and the most crop productive area. This partially could explain the concentration of sampling sites around that zone. Finally, there was also a significant number of sampling sites (for soil biodiversity,

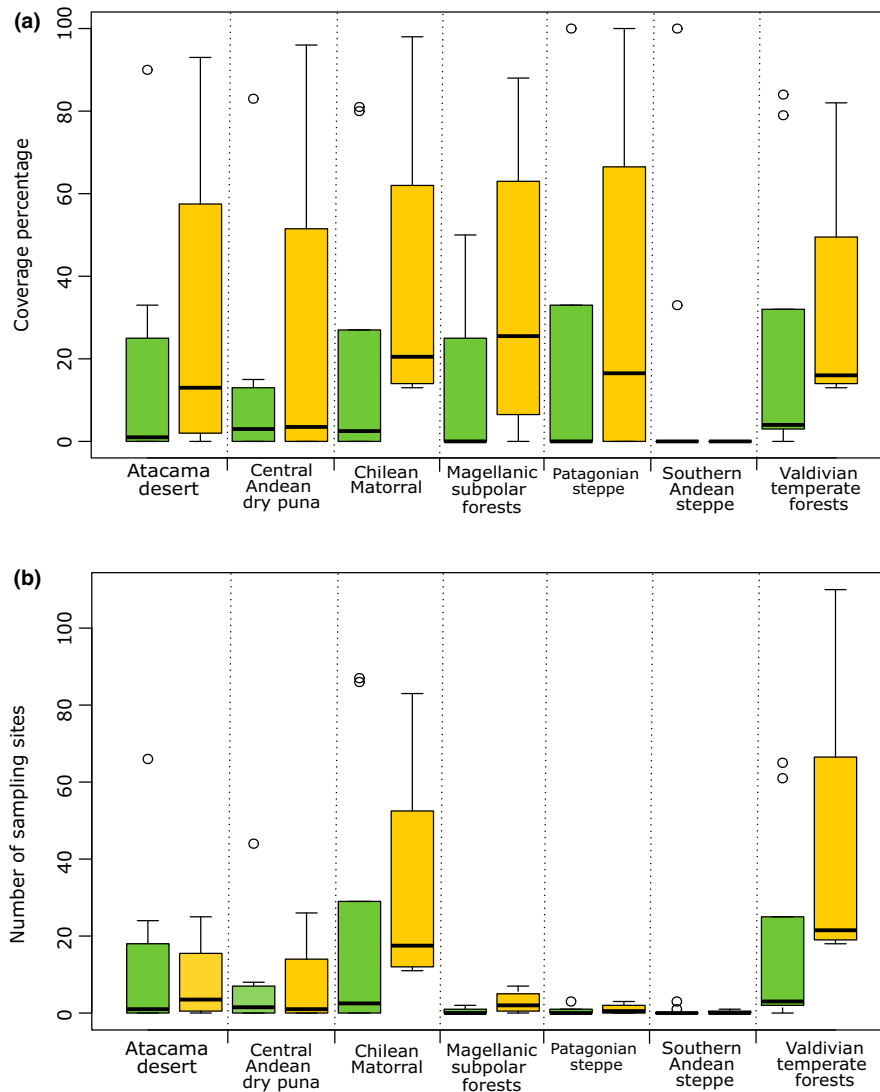


Fig. 3. Representativeness of percentage coverage (a) and number of sampling sites (b) for soil biodiversity (green bars) and ecosystem functions (yellow) in the seven continental Chilean ecoregions.

ecosystem functions and both) around the regions of La Araucanía (155 sampling sites), Los Ríos (54 sampling sites) and Los Lagos (70 sampling sites), especially in their Valdivian temperate forests. This reflects the historical interest of established research groups over the last four decades, as well as international collaborations, mainly originating from the Austral University of Chile and from La Frontera University (Godoy & Mayr 1989; Rubio *et al.* 1990; Godoy & Marín 2019).

When analysing who the first authors were, we found that of 149 first authors, only 36 (24.16%) were women. In addition, in 154 out of the 239 articles, the first author was affiliated to a Chilean institution (Appendix S3), mainly, La Frontera University (32), Chile University (30), Austral University of Chile (20),

Concepción University (18) and the Pontifical Catholic University of Chile (10). First authors affiliated to institutions from United States, Germany and Spain, also made a significant number of contributions (Appendix S3). The 239 articles were published in 108 scientific journals from a plethora of areas: from soil science and plant ecology to agronomy, geology, planetary science and others (Appendix S4). Just 7 of those 108 journals are Spanish-based, and the most common included Journal of Soil Science and Plant Nutrition (22), Soil Biology and Biochemistry (10), Revista Chilena de Historia Natural (8), Biology and Fertility of Soils (7) and Chilean Journal of Agricultural Research (7).

Some soil taxa such as Acari, Collembola, Nematoda, Formicoidea, Protista and Rotifera were barely

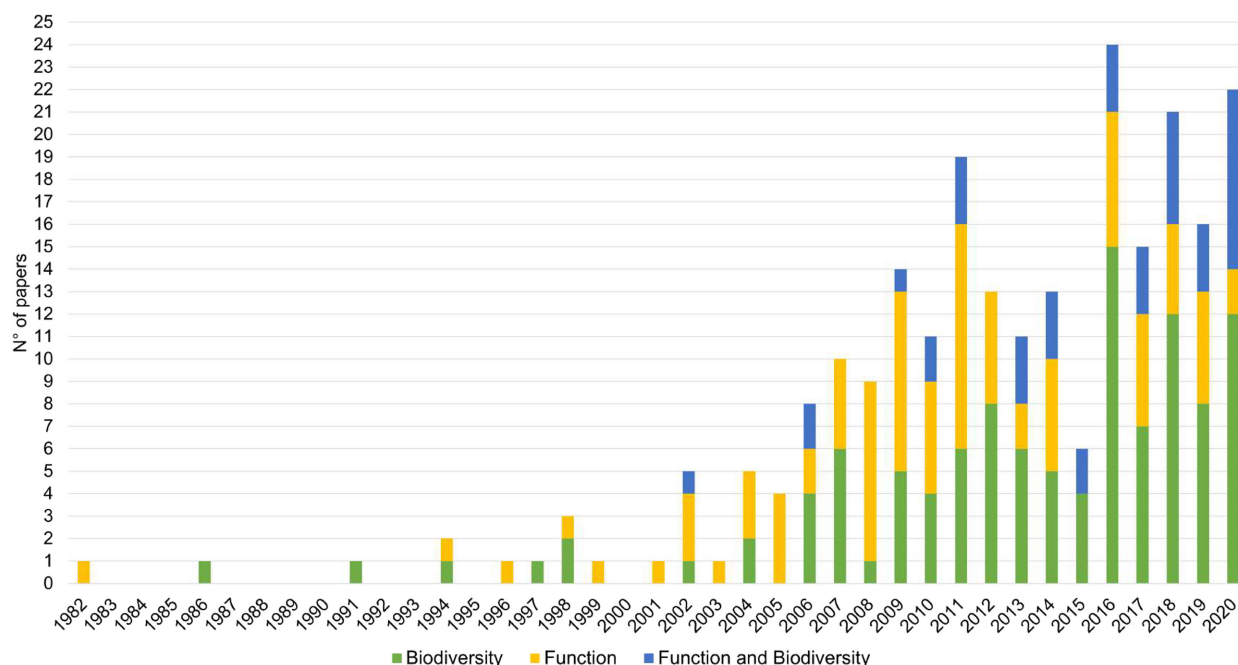


Fig. 4. Number of Web of Science articles (N° of papers) published for continental Chile and dealing with soil biodiversity (green), ecosystem functions (yellow) and both investigated together (blue). The Web of Science search was for the period 1945–2020, but the first study appears in 1982.

studied and were represented by just a few sites concentrated in some specific administrative regions. Several reasons could explain this: (i) An historical lack of interest in such groups, as for example the established research groups mentioned above have focused mainly on bacteria (for the Atacama Desert) and fungi (for Valdivian temperate forests); (ii) The difficulties that the sampling for some of those groups carry out; and (iii) The relatively simple methods for bacteria, fungi and archaea sampling from the soil, especially over the last decade with next-generation sequencing techniques. This trend, where soil bacteria and fungi are the most studied taxa is not unique to this study (Guerra *et al.* 2020) and besides reflecting the ubiquity of such taxa (Teder-soo *et al.* 2014; Delgado-Baquerizo *et al.* 2018; Egidi *et al.* 2019; Cano-Díaz *et al.* 2020; Větrovský *et al.* 2020), it also shows their central role in ecosystem functioning, as usually taught in soil ecology. Perhaps the other soil taxa should be more studied to disentangle unknown relationships with soil ecosystem functions. Also, as ‘nutrient cycling’ encompass a great number of processes, it is understandable that this was the soil ecosystem function with most sampling sites.

Ecoregions like the Magellanic subpolar forests, the Patagonian steppe and the Southern Andean steppe are of extremely hard access, with few (if any) populated areas and universities or research centres nearby. These regions presented very few sampling

points for soil biodiversity and ecosystem functions in our study. Nonetheless, they are quite interesting from an above-ground biodiversity perspective, showing high plant richness (for the Magellanic subpolar forests; Rozzi *et al.* 2008) and complex biodiversity patterns across geographic zones and vegetation types (for the Patagonian steppe and the Southern Andean steppe; Peri *et al.* 2016). Ideally, all ecoregions of Chile in all their extension should have at least a medium density of sampling sites for soil biodiversity and ecosystem functions at the same time, which is far from being the case.

In the 2019 United Nations Climate Change Conference (COP 25), Chile (co-organiser) presented an unprecedented upgrade on the state of its biodiversity, particularly with the encouragement of improving, strengthening and implementing soil biodiversity monitoring programmes, being soil one of the most vulnerable ecosystem components (Rojas *et al.* 2019). It was emphasised that intensified soil use, inadequate agricultural practices, grazing, agroforestry and urbanisation lead to well-known soil threats such as erosion, pollution, acidification, nutrient leaching, salinisation and loss of soil biodiversity and organic matter (Rojas *et al.* 2019). Also during COP 25, the main causes of native biodiversity loss were identified (for the period 1995–2016; Marquet *et al.* 2019): For the regions of Valparaíso, Metropolitan, O’Higgins, Los Lagos and Magallanes, it was the replacement of natural ecosystems for meadows and shrubs, previous

to livestock and urbanisation processes. For regions such as Maule, Biobío, La Araucanía and Los Ríos, the main cause of biodiversity loss was the replacement of native forests for commercial, fast-growing plantations (Marquet *et al.* 2019), like *Pinus radiata*, which retains high amounts of nitrogen, negatively affecting soil biodiversity (Oyarzún *et al.* 2007).

CONCLUSIONS AND FUTURE DIRECTIONS

Now with a clearer picture of which are the geographic (all regions of Chile except for the central zone, and parts of the Atacama Desert and the Valdivian temperate forests), taxonomic (all soil taxa except for bacteria and fungi, in the above-mentioned regions) and functional (all soil ecosystem functions except for nutrient cycling, on the above-mentioned regions) gaps of soil ecology in Chile, we can call for action. First, we need to feed the database constructed on this review, as some soil biodiversity and/or ecosystem functions studies in continental Chile might not have been included. Second, we need to extract, analyse and model the raw data contained in these and future articles, in order to make predictions (i.e. where soil biodiversity of certain taxa should be higher) and test those predictions with competitive funding. Third, as a Chilean soil ecology community, there is a need for open data and open collaborations, which is currently ongoing with global initiatives like Soil BON (Guerra *et al.* 2021; Potapov *et al.* 2022), which offers standardised sampling protocols and chemical and molecular methods, for soil microbial and macro-organism communities. This initiative has already participants from Chilean institutions, but given its global scale, we think within the country we need to develop our own national effort, associating different universities and researchers and applying for funding through special funding opportunities that the national agency in Chile (ANID) offers, like the Millennium Institutes. Fourth, we need even more integration between the researchers studying soil biodiversity and those studying soil ecosystem functions. And fifth, we need specific legislation for soil biodiversity *per sé*, besides its importance for ecosystem functioning, soil restoration and food production, for conserving such biodiversity (Guerra *et al.* 2021). Ideally, hotspots of belowground biodiversity could serve as a criterion for defining conservation areas.

ACKNOWLEDGEMENTS

The authors thank Carlos A. Guerra for helpful suggestions. To the Fondecyt regular project No. 1190642 (ANID—Chile), the long-term research

development programme RVO 67985939 by Czech Academy of Sciences and the funding of ANID + Convocatoria Nacional Subvención a Instalación Academia convocatoria año 2021 + Folio SA77210019.

AUTHOR CONTRIBUTIONS

César Marín: Conceptualization (lead); data curation (equal); funding acquisition (supporting); investigation (lead); methodology (lead); project administration (equal); supervision (equal); validation (lead); writing – original draft (lead); writing – review and editing (lead). **Javiera Rubio:** Data curation (lead); formal analysis (lead); investigation (equal); methodology (equal); software (lead); validation (equal); visualization (lead); writing – original draft (supporting). **Roberto Godoy:** Conceptualization (supporting); funding acquisition (lead); investigation (equal); methodology (supporting); project administration (lead); resources (lead); supervision (lead); writing – original draft (supporting); writing – review and editing (supporting).

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

The data sets generated during and analysed during the current study are available in the *figshare* repository, <https://figshare.com/s/c7b6dce6b12edfbc5e7d>

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SUPPORTING INFORMATION

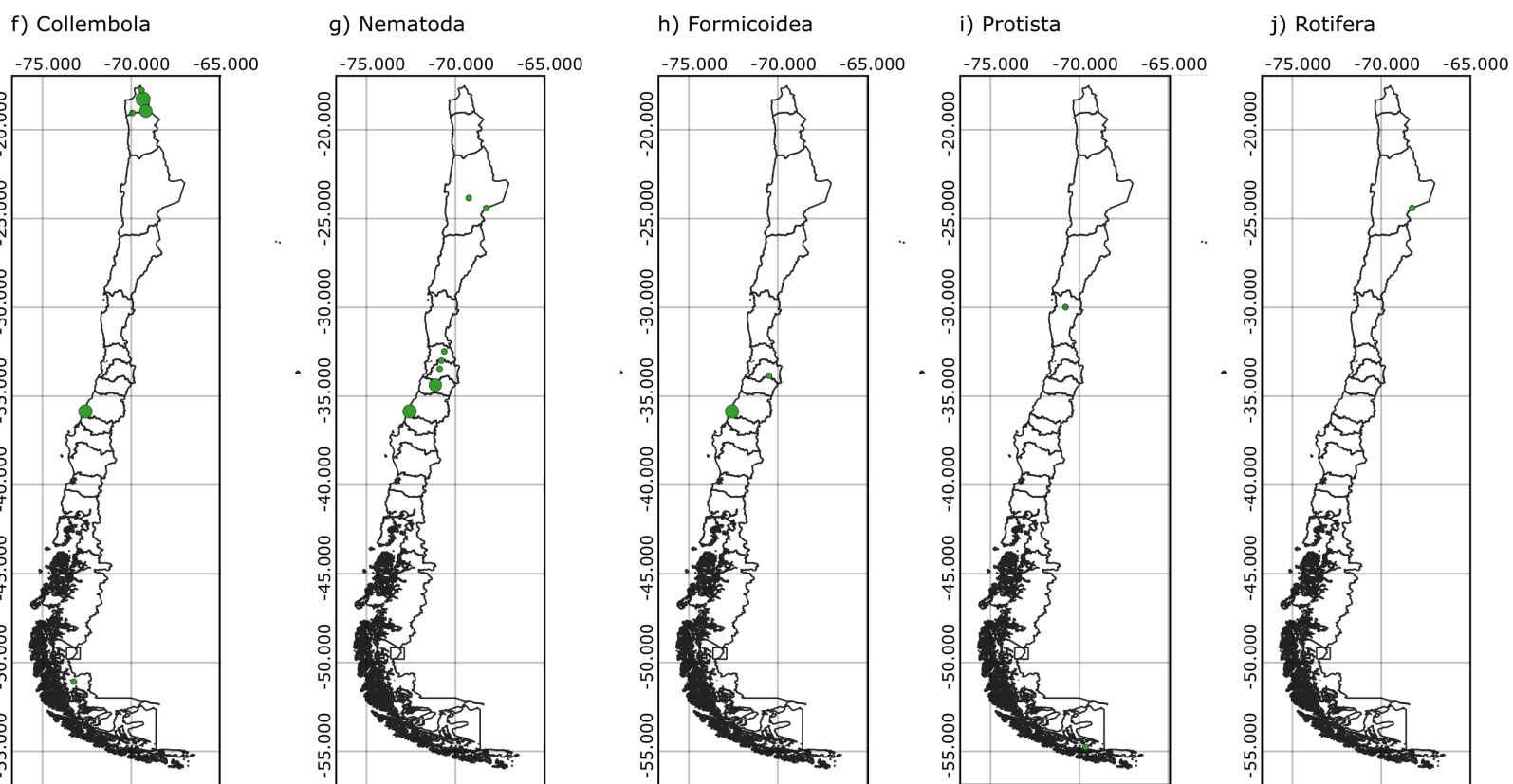
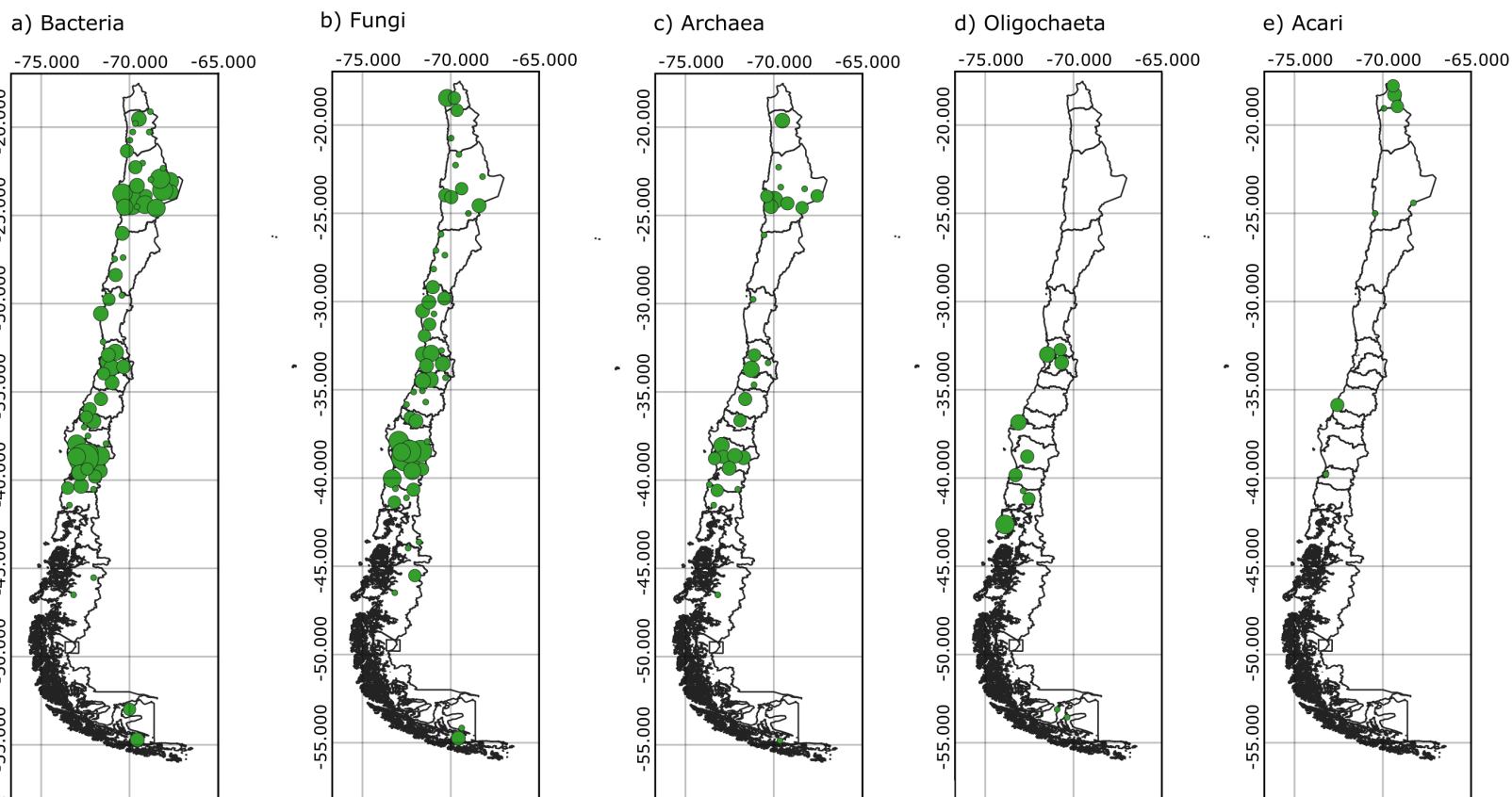
Additional supporting information may/can be found online in the supporting information tab for this article.


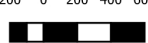
Appendix S1 Distribution of the 10 soil taxonomic groups in continental Chile.

Appendix S2 Distribution of the four soil ecosystem functions in continental Chile.

Appendix S3 Affiliations of the first author of the generated database.

Appendix S4 Main journals of the generated database, only including journals with at least two or more articles.



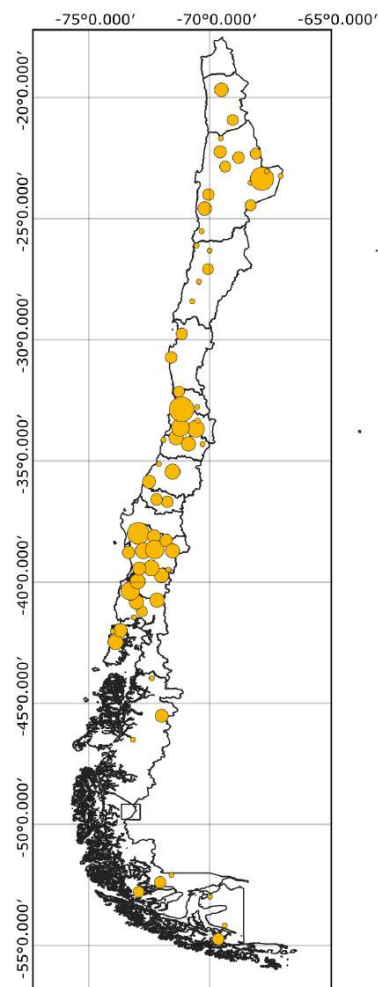



Projection:
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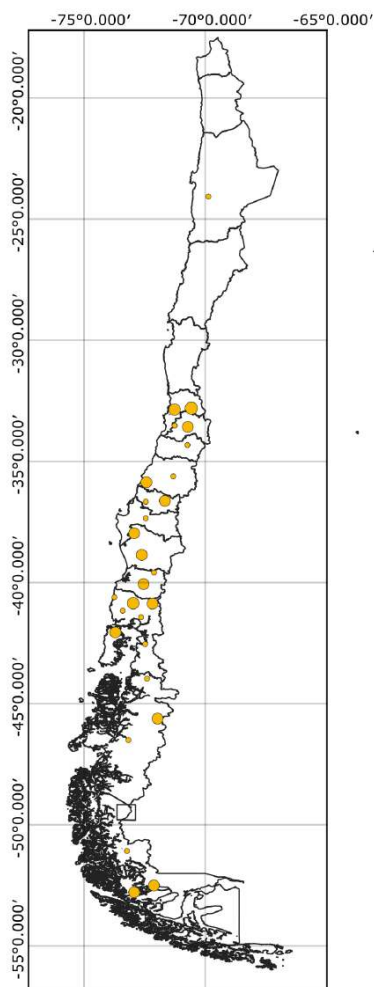
Number of sampling sites

• 1 • 2 - 5 • 6 - 15 • 16 - 20 • >20

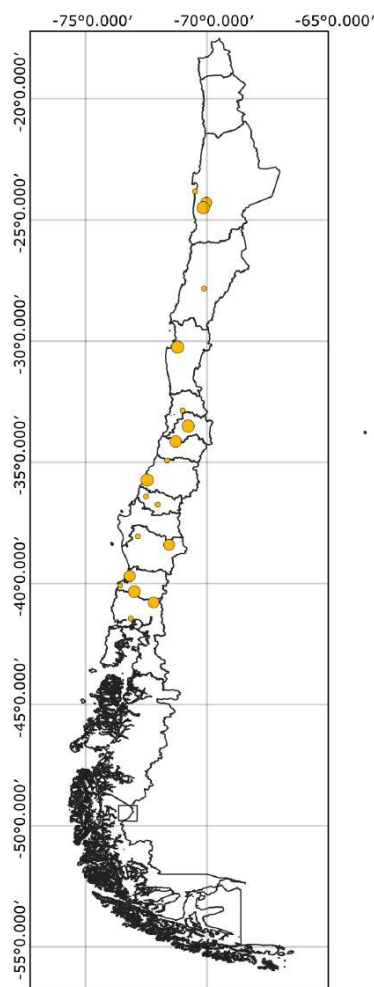
a) Nutrient cycling



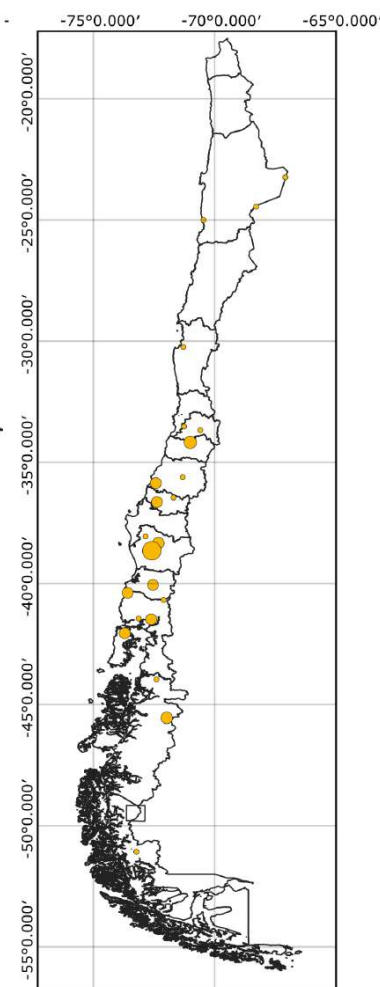
b) Decomposition





c) Water infiltration



d) Soil respiration



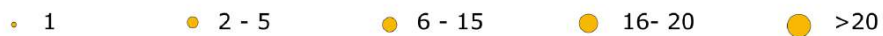


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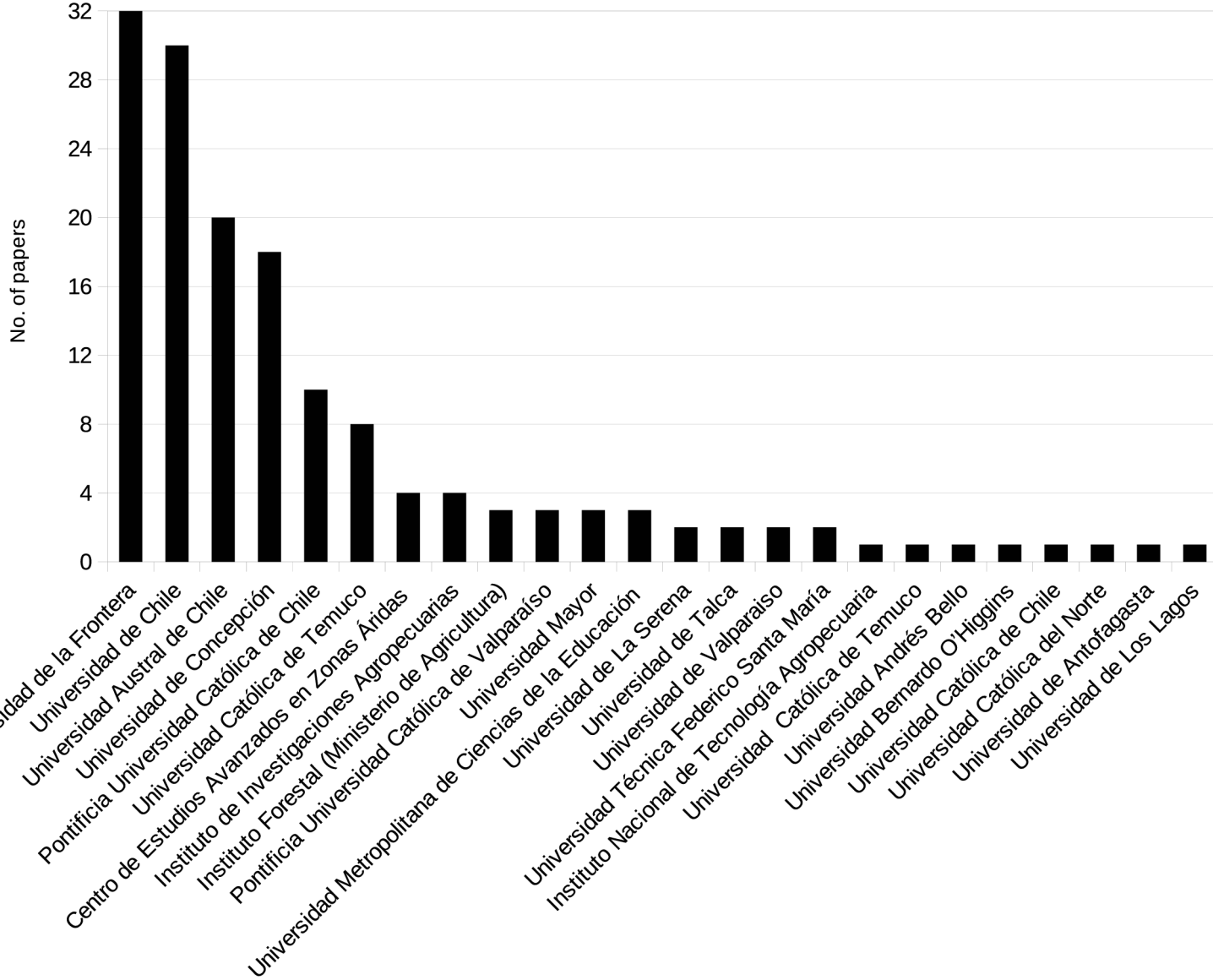
 Projection:

 WGS 84 /EPSG: 4326

Number of sampling sites



a.



b.

