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Oswaldo Maillard

omaillard@fcbc.org.bo

Fundación para la Conservación del Bosque Chiquitano

David A. Keith

Centre for Ecosystem Science, University of NSW

José R. Ferrer-Paris

Centre for Ecosystem Science, University of NSW

Daniel M. Larrea-Alcázar

Asociación Boliviana para la Investigación y Conservación de Ecosistemas Andino-Amazónicos (Conservación Amazónica-ACEAA)

Maira T. Martinez-Ugarteche

Herbario del Oriente Boliviano (USZ), Museo de Historia Natural Noel Kempff Mercado, Universidad Autónoma Gabriel René Moreno

Alfredo Fuentes

Herbario Nacional de Bolivia, Instituto de Ecología, Universidad Mayor de San Andrés

Roberto Vides-Almonacid

Fundación para la Conservación del Bosque Chiquitano

Daniel Villaroel

Centro de Investigación de Biotecnología (BIOCEN), Universidad Católica Boliviana (UCB)

Irene Zager

Provita

Freddy S. Zenteno-Ruiz

Herbario Nacional de Bolivia, Instituto de Ecología, Universidad Mayor de San Andrés

Saúl Altamirano

Herbario Nacional Forestal Martín Cárdenas (BOLV)

Sergio M. Vicente-Serrano

Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (IPE–CSIC), Zaragoza, Spain

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Oswaldo Maillard[1,*], David A. Keith[2,3], José R. Ferrer-Paris[2,3], Daniel M. Larrea-Alcázar[4], Maira T. Martinez-Ugarteche[5,6], Alfredo Fuentes[7,8], Roberto Vides-Almonacid[1], Daniel Villarroel[9], Irene Zager[10], Freddy S. Zenteno-Ruiz[7], Saúl Altamirano[11] & Sergio M. Vicente-Serrano[12]

[1]Fundación para la Conservación del Bosque Chiquitano (FCBC), Santa Cruz, Bolivia.
[2]Centre for Ecosystem Science, University of NSW, Sydney, Australia.
[3]IUCN Commission on Ecosystem Management, Gland, Switzerland.
[4]Programa de Ciencia y Tecnología, Asociación Boliviana para la Investigación y Conservación de Ecosistemas Andino-Amazónicos (Conservación Amazónica-ACEAA), La Paz, Bolivia.
[5]Herbario del Oriente Boliviano (USZ), Museo de Historia Natural Noel Kempff Mercado, Universidad Autónoma Gabriel René Moreno, Santa Cruz, Bolivia.
[6]Department of Accelerated Taxonomy, Royal Botanic Gardens, Kew, Richmond, U.K.
[7]Herbario Nacional de Bolivia, Instituto de Ecología, Universidad Mayor de San Andrés, La Paz, Bolivia.
[8]Latin America Department, Missouri Botanical Garden, St. Louis, Missouri, USA
[9]Centro de Investigación de Biotecnología (BIOCEN), Universidad Católica Boliviana (UCB), Santa Cruz, Bolivia.
[10] Provita, Caracas, Venezuela
[11]Herbario Nacional Forestal Martín Cárdenas (BOLV), Cochabamba, Bolivia
[12]Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (IPE–CSIC), Zaragoza, Spain

*Corresponding author: omaillard@fcbc.org.bo

Abstract

Bolivia harbors a diversity of natural ecosystems that derive from its tropical location and major environmental gradients of the Andes. In recent decades, a wide variety of natural ecosystems in Bolivia have been depleted, degraded or altered at an alarming rate by human activities. To quantify the current status of Bolivia's ecosystems, we applied IUCN's Red List of Ecosystems methodology to 141 ecosystem types in terrestrial (98), freshwater-terrestrial (35) and freshwater (8) environments. Data were available to assess five subcriteria. Rates of change between 1973 and 2023 were estimated to assess subcriterion A1 (reduction in past distribution) and between ca. 1750 and 2023 to evaluate subcriterion A3 (reduction in historical distribution). The extent of occupancy (EOO) and area of occupancy (AOO) were estimated, respectively, to assess criteria B1 and B2 (restricted geographic distribution), in conjunction with qualitative information about declines and threats. Under subcriterion C1 (environmental degradation), long-term changes in precipitation, maximum temperature, minimum temperature, and relative humidity were analyzed. The analyses identified 15 ecosystem types as Critically Endangered (CR), 22 as Endangered (EN), and 39 as Vulnerable (VU). A further 22 ecosystem types were identified as Near Threatened (NT) and 43 as Least Concern (LC). Our results will inform prioritization of conservation investments and efforts (e.g., restoration of critically endangered ecosystems), identify areas where industrial or urban development would have an irreversible impact, and provide a baseline for collaborative monitoring progress toward global targets linked to the Kunming-Montreal Global Biodiversity Framework, specifically, the headline indicator A.1.

Keywords: Ecosystem collapse; ecosystem degradation; threat level; climate vulnerability; conservation.

Introduction

Bolivia faces unprecedented ecosystem loss; in recent decades, a wide variety of ecosystems have been degraded, altered, or are disappearing at an alarming rate due to various human activities, particularly in the lowlands [1]. As a result, Bolivia's deforestation rates were the second highest globally in 2024, surpassed only by those of Brazil [2]. Moreover, the reduction of these ecosystems is putting thousands of fauna and

flora species at risk, including endemic species and those of global conservation interest [3]. In this regard, there is an urgent need to identify the current state of each ecosystem type, to serve as an essential foundation for prioritizing ecosystem conservation actions, ongoing assessment and monitoring, and to ensure the sustainability of the functions and services they provide [4].

Ecosystems are complexes of organisms and the physical environment with which they are associated within a specific area [5], comprising four essential elements: a biotic complex, an abiotic environment, and the interactions between them, operating within a physical space [6]. However, concepts such as ecological resilience and ecosystem services recognize nature as a living, changing fabric, but with constraints that may limit their ability to function, provide services to people and sustain their characteristic biota [7]. Applying the ecosystem concept in megadiverse countries like Bolivia presents significant challenges related to non-equilibrium dynamics and high spatial heterogeneity, non-linear successional pathways, and disturbance driven regeneration [8]. Nevertheless, a spatially explicit approach to the ecosystem concept allows us to assign geographic locations to ecological functions and move from theory to land-use planning [9]. In Bolivia, ecosystem boundaries may be natural or arbitrary, but they can be characterized within a hierarchy of *a priori* selected spatial units (e.g., ecoregions, ecological systems) [10]. Additionally, there is also confusion regarding the application of the concept of biomes in the Bolivian context [11].

The International Union for Conservation of Nature (IUCN, https://iucn.org/) developed a unified standard to assess the status of all the world's ecosystems based on an evaluation of their risk of collapse, known as the Red List of Ecosystems (RLE) [7]. The RLE methodology can be applied at various scales and is based on a protocol of five criteria that assess evidence of the risk of ecosystem collapse. Risks to ecosystems are assessed through the reduction in, and restricted size of geographic distribution (criteria A and B) or environmental degradation of key processes and biotic components (criteria C and D) and quantitative risk analysis (criteria E) [7, 12]. Globally, the IUCN methodology has been applied across diverse scales, ranging from continental assessment (e.g., forests of the

Americas) [13], to country-level evaluations (e.g., Mozambique) [14], and to local areas studies (e.g., tropical glaciers) [15].

In Bolivia, the critical need to establish a national vegetation baseline to facilitate RLE assessments of terrestrial ecosystems was first emphasized in 2015 [16, 17], highlighting the importance of developing an integrated framework for biodiversity monitoring. Subsequently, in 2018, the first local-scale analysis assessment of ecosystems in the Chiquitano hills was conducted, evaluating 20 ecosystems and finding that 30% of them were Critically Endangered [18]. Later, a study identified that 17 of the 55 ecosystems in the lowlands of Bolivia are threatened [19], and in another study, 8 types of ecosystems were classified in threat categories for the Chiquitano Dry Forest ecoregion [20].

Despite these advances, to date there is no national-level assessment of ecosystems at risk of collapse using the IUCN RLE criteria. Such an assessment is urgently needed to develop national strategies for reducing risks to Bolivia's ecosystems and for reporting progress against internationally agreed targets in the Kunming-Montreal Global Biodiversity Framework (KMGBF), [21]. Notably, its monitoring framework adopts the IUCN Red List of Ecosystems as a Headline Indicator for reporting progress on ecosystem targets [22].

One of the strategies for ecosystem conservation is the establishment of protected areas, but this requires effective management. In Latin America in general, and as is the case in the Amazon, ecosystem protection depends on the effective management of these areas to reduce the loss of critical habitats resulting from deforestation and other threats [23]. In Bolivia, despite an extensive network of protected areas [24], ecosystems in a critical state of conservation may not be adequately protected. This calls for a more in-depth analysis of the current state of the country's ecosystems and their representation within the protected areas system.

The aim of this study is to conduct a comprehensive national-scale risk assessment of Bolivia's ecosystems, employing the IUCN Red List of Ecosystems (RLE) criteria to

inform strategic conservation actions and to demonstrate progress towards global biodiversity targets.

Study Area

Bolivia is a neotropical country with a total area of approximately 1,100,000 km², divided administratively and politically into nine departments. It is also a country of great contrasts, with elevations of 100 - 6,500 m a.s.l., climates varying from tropical to semi-arid to alpine, and vegetation ranging from wet and dry forests to montane herbfields and wetlands with different degrees of flood. Geomorphologically, there is a Highlands region in the western part of the country, traversed by the Western and Eastern Cordilleras, which frame a central plateau known as the Altiplano (between 3,400 and 4,000 m a.s.l.). In the central region lies a series of parallel mountain ranges known as the Andean slopes, and to the east are the extensive plains of the Lowlands region (<1,000 m a.s.l.), which occupy most of the territory and feature low- to medium-altitude mountain ranges derived primarily from the Precambrian shield system. This rough topography influences the country's complex climate. Average annual maximum temperatures vary across different regions, ranging from 32 °C in the lowlands to 16 °C in the Highlands [25]. The wet season occurs during the warm southern summer (i.e., December to February), while the dry season occurs during the winter (i.e., June to August) [25]. Precipitation ranges from <250 mm year^{-1} in the Lowlands in the southern region and Andean slopes to >2,000 mm year^{-1} in the Highlands [25]. Across the Highlands (plateau), mountain slopes, and in Lowlands there is a north-south humidity gradient, featuring predominantly seasonal to dry climates [26], possibly related to the tropical-subtropical position of the country, which has in the Chapare region (intersection of the Ichilo river basin and foothills) the place with the highest precipitation in the country (between 3,000 and 5,000 mm each year). Due to climatic variability and topographic complexity, Bolivia features rainforests, savannas, grasslands, dry forests, and high-mountain ecosystems, distributed across four biogeographic regions, Amazonian, Brazilian-Paranense, Chacoan, and Tropical South Andean [27].

Methods

Ecosystem Typology

The typology of natural ecosystems was based on the classification map (scale 1:250,000) of Complex of Ecological Systems (CES) of Bolivia [28], which is based on the standardized typology proposed by NatureServe [29]. This classification includes 141 different types of ecosystems, including water bodies and salt lakes. Because this mapping was developed using satellite imagery from the 1990s and 2000s, a visual reclassification was performed to reconstruct the potentially original vegetation (since 1750) within anthropogenic areas such as settlements and farmland, based on the proximity of extant ecosystem types and experts' field knowledge (Figure 1A). To identify areas modified by human use, data from the MapBiomas v.2 coverage (https://bolivia.mapbiomas.org) for the years 1985 and 2023 were downloaded, and values for human land-use classes (pasture, agriculture, urban areas, mining) were extracted. The reconstruction of anthropogenic or modified areas for 1973 was performed using the dataset of Landsat 1 satellite images from 1973–1975 downloaded from the EarthExplorer portal (https://earthexplorer.usgs.gov) and, as a reference, the land use change coverage for the lowlands generated by Killeen *et al.* [30] and the MapBiomas coverage for the entire country for 1985. The classifications of modified areas for 1973 and 2023 were vectorized and intersected with the reconstructed ecosystems (Figure 1B). Finally, Ecological Systems (ca. 1750, 1973, and 2023) were cross-referenced to the three upper levels (Realms, Biomes, and Ecosystem Functional Groups, EFG) of the Global Ecosystem Typology [31]. In total, three Realms were identified (Figure 1C; terrestrial, freshwater-terrestrial, and freshwater), distributed across seven biomes (Figure 1D) and 19 EFGs for Bolivia (Table S1). Data analysis was performed using default statistical functions in R [32]. Geostatistical analysis and map generation were conducted using ArcGIS Pro [33].

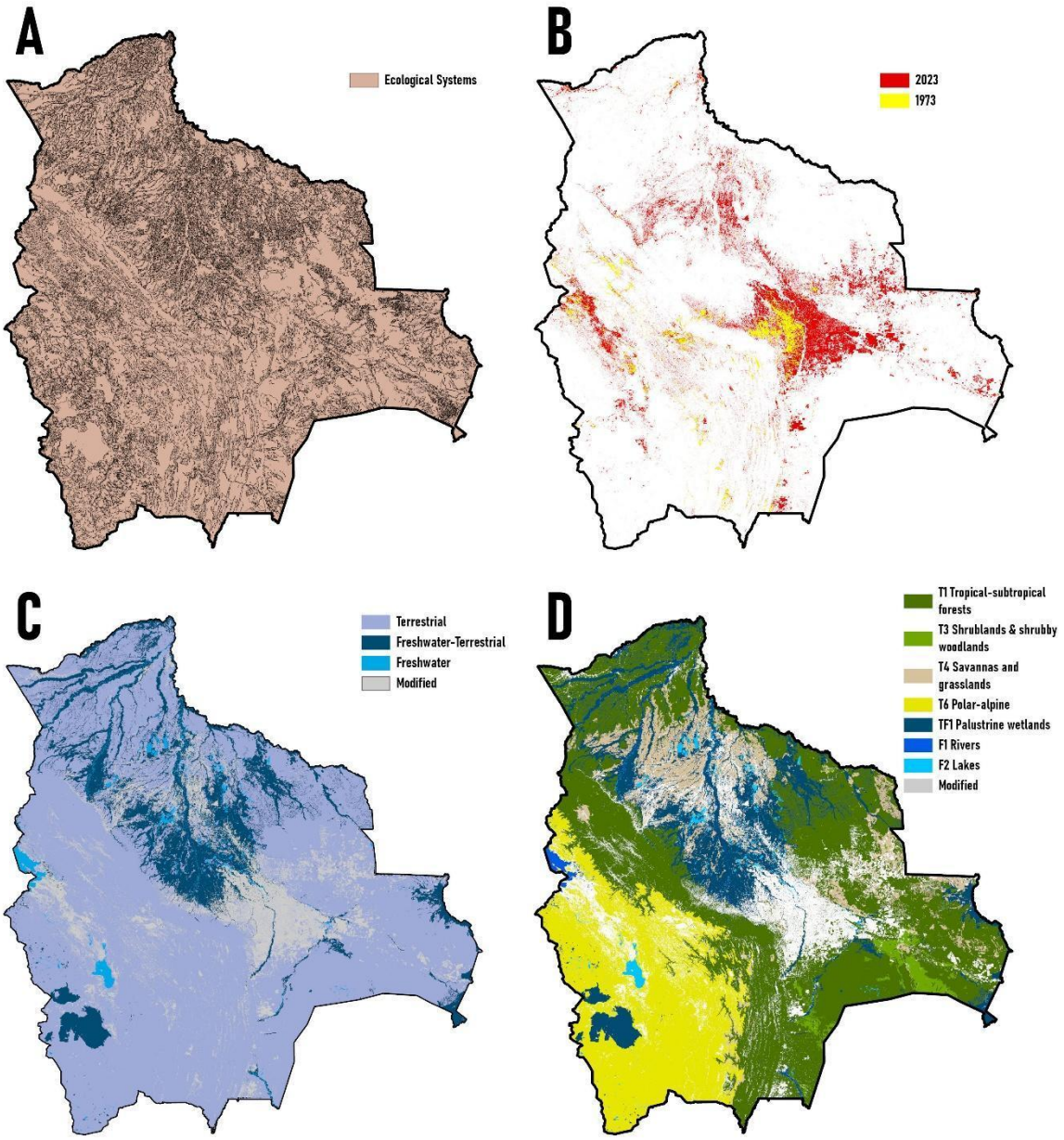


Figure 1. Spatial mapping and analysis used to classify the types of ecosystems in Bolivia. A) Ecological systems of Bolivia reconstructed to ca. 1750 (boundaries only); B) Distribution of modified ecosystems for 1973 and 2023; C) Distribution of IUCN Realms based on ecological systems of Bolivia; D) Distribution of IUCN Biomes based on ecological systems.

IUCN Categories

The methodology used to assess the risk of ecosystem collapse in Bolivia follows the guidelines and principles for the Red List of Ecosystems (RLE) described in IUCN publications [7, 12, 34]. This methodology enables each ecosystem type to be classified into one of eight categories, representing different levels of risk. This is done by evaluating five criteria and thresholds that represent different symptoms of risk. The most extreme category is designated as Collapsed (CO), which marks the final outcome of ecosystem decline and transformation to a different ecosystem type. This is followed by the three categories representing threat in the strict sense: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU). Two other non-threat categories of conservation interest are Near Threatened (NT) and Least Concern (LC), while if there is insufficient information to assess the ecosystem, the category is Data Deficient (DD), and if no analysis was conducted, it is classified as Not Evaluated (NE).

IUCN Criteria and Thresholds

Ecosystems were classified into one of the eight IUCN categories based on analysis of the criteria and thresholds specified in the RLE protocol [7, 12, 34]. In this study, sufficient data were available to apply three of these criteria: A, reduction in distribution; B, restricted geographic distribution; and C, environmental degradation.

Criterion A: Decline in distribution

This criterion seeks to identify ecosystem types whose distribution is currently declining at a rapid rate or may decline in the near future [34]. The rate of change under subcriterion A1 was evaluated over the past 50 years (1973–2023), while subcriterion A3 was assessed based on the reduction in historical distribution from 1750 to 2023. It was assumed that conversion of natural ecosystems to anthropogenic types prior to 1750 was negligible, in line with historical records indicating minimal large-scale transformation during that period. The thresholds for subcriterion A1 define an ecosystem as Critically Endangered (CR) if its distribution declined by ≥ 80% over the past 50 years; as Endangered (EN) if its distribution declined by ≥ 50%; and as Vulnerable (VU) if its distribution declines by ≥ 30% (Table S2). The thresholds for subcriterion A3 are higher (CR 90%; EN 70%; VU 50%) because the time frame for assessing declines is longer (Table S2).

Criterion B: Restricted geographic distribution

Restricted distribution is defined as a condition that predisposes the system to spatially explicit threats, along with manifested decline, threat, or fragmentation [34]. In the assessment of criterion B, subcriteria B1 and B2 were generated. For subcriterion B1, Extent of Occurrence (EOO), the area of the minimum convex enveloping polygons encompassing the entire distribution of the ecosystem was calculated; for subcriterion B2, Area of Occupancy (AOO) was calculated based on the count of 10x10 km cells occupied, excluding cells that, in combination, account for less than 1% of the total mapped area of the ecosystem type. For subcriterion B1, an ecosystem type is categorized as CR, if EOO ≤ 2,000 km², EN if EOO ≤ 20,000 km², and VU if EOO ≤ 50,000 km² (Table S2). In subcriterion B2, an ecosystem type is categorized as CR if the number of occupied cells (AOO) is ≤ 2 cells, EN if AOO ≤ 20 cells, and VU if AOO ≤ 50 cells (Table S2). In addition to meeting these thresholds, there must be qualitative evidence that the ecosystem type is undergoing a continuing decline, is exposed to a threat that could cause a continuing decline in the near future or occupies a small number of locations (1 for CR status; 2 - 5 for EN; and 6 - 10 for VU).

Criterion C: Environmental Degradation

This criterion assesses indicators of abiotic environmental degradation, including reductions in habitat quality, loss of abiotic niche diversity for key biota, and declines in non-biological ecosystem processes [34]. In this study, we focused on subcriterion C1, utilizing data from meteorological stations to estimate recent changes in precipitation (mm, P), maximum temperature (°C, Tmax), minimum temperature (°C, Tmin), and relative humidity (%, RH). These indicators are particularly relevant for Bolivian ecosystems, which exhibit high sensitivity to climatic variability [35, 36, 37]. We analyzed data collected from 28 weather stations across Bolivia between 1973 and 2023. The time series included direct measurements of precipitation (P), air temperature (Tmin, Tmax), and relative humidity (RH), as provided by the National Meteorological and Hydrological Service of Bolivia (SENAMHI). Annual rates of change were calculated using linear regression models, with time as the independent variable and P, Tmax, Tmin, or RH as the

dependent variables. A rigorous quality control and homogenization protocol was implemented. First, rank data comparisons were conducted with adjacent stations [38]. Subsequently, the Standard Normalized Homogeneity Test (SNHT) [39] was applied to identify potential inhomogeneities within the series. All analyses were conducted using the CLIMATOL software package (https://www.climatol.eu/). For each ecosystem, decadal rates of change in P, Tmax, Tmin, and RH were estimated using the values from stations within or near the ecosystem's distribution. This ensures that, for example, estimates for lowland tropical forests are primarily based on data from lowland stations, rather than high-altitude stations where climatic trends may differ. For each ecosystem, the Relative Severity (RS) of change was calculated using an exponential function of decline:

$$RS = a\left(b^{OD/MD} - 1\right)$$

Where: *OD* is the Observed decline, *MD* is the Maximum decline and *a* and *b* are constants that determine the shape of the curve. For future projections the threshold of collapse is not known with certainty but we estimated it to be greater than 20% change for P, an increase of 4.5 °C for Tmax and Tmin, and 10 % change for HR. We adjusted parameters a and b to ensure this lower bound of the collapse threshold corresponds with a value of 80% RS.

RS values were calculated for each climatic variable, then aggregated using a maximum function, and risk categories were assigned to this aggregated value using predefined thresholds. The category thresholds for subcriterion C1 classify an ecosystem as Critically Endangered (CR) if environmental degradation averaged over the full distribution of the ecosystem type has reached ≥ 80% of the collapse threshold over the past 50 years; as Endangered (EN) if environmental degradation is ≥ 50%; and as Vulnerable (VU) if environmental degradation is ≥ 30% (Table S2).

Final risk categories

After the ecosystem type was assessed according to the five subcriteria, the highest category obtained for any of the criteria was designated the overall status of the ecosystem type [34] and reported in a summary table. We tallied the number of ecosystem types in each Red List category for each Ecosystem Functional Group, reflecting the headline

indicator A.1 agreed in the Global Biodiversity Framework Kunming-Montreal. We also calculated (the Red List Ecosystem Index (RLIE) [40] from data on the Red List risk categories assigned to the 141 ecosystems grouped by EFGs. The RLIE is expressed as a value ranging from 0 to 1, where decreases (toward 0) indicate more threatened ecosystems or a higher risk, and increases (toward 1) indicate improvements in risk status.

Complementarity of subcriteria

The complementarity of the five subcriteria (A1, A3, B1, B2, C1), measured on an ordinal scale (LC, NT, VU, EN, CR), was evaluated using the Partial Information Decomposition (PID) method [41]. The PID was calculated for each pair of criteria (X, Y) and each possible third criterion (Z), yielding four components: redundancy (shared information), the uniqueness of X and Y (exclusive information), synergy (information emerging from the interaction), and net synergy (synergy – redundancy). The values were averaged across all Zs to obtain an overall measure per pair. A permutation test was used to estimate the statistical significance ($p<0.05$, $p<0.01$, $p<0.001$) of each component by comparing the observed value against the distribution under independence of Z.

Applications for conservation

The final risk categories identified in this study were intersected with the cartography of protected areas at the national, departmental, indigenous, and municipal levels [42]. These analyses were conducted to assess Target 3 of the Kunming-Montreal Global Biodiversity Framework, commonly known as the "30x30" target, a global commitment to ensure that at least 30% of the planet's land, inland waters, and oceans are effectively conserved and managed by 2030 [21].

Results

Criterion A: Reduction in range

Over the past 50 years, the area of natural ecosystems transformed to anthropogenic ecosystems in Bolivia increased from 1.8 million to 13 million hectares, which corresponds to 1.6% and 12.0% of the entire country, respectively. These changes have resulted in shifts in status of ecosystem types that vary between different Ecosystem Functional Groups

(EFGs) based on recent past reductions in distribution (subcriterion A1) and historical reductions in distribution (subcriterion A3). Boreal and temperate fens (TF1.7) and Boreal, temperate and montane peat bogs (TF1.6) have undergone the largest reductions (Figure 2, Table S3). However, of the 141 ecosystems analyzed, 16 (11.3%) showed no decrease in area in the past 50 years (subcriterion A1), and 13 (9.2%) showed no decrease over the industrial era (subcriterion A3).

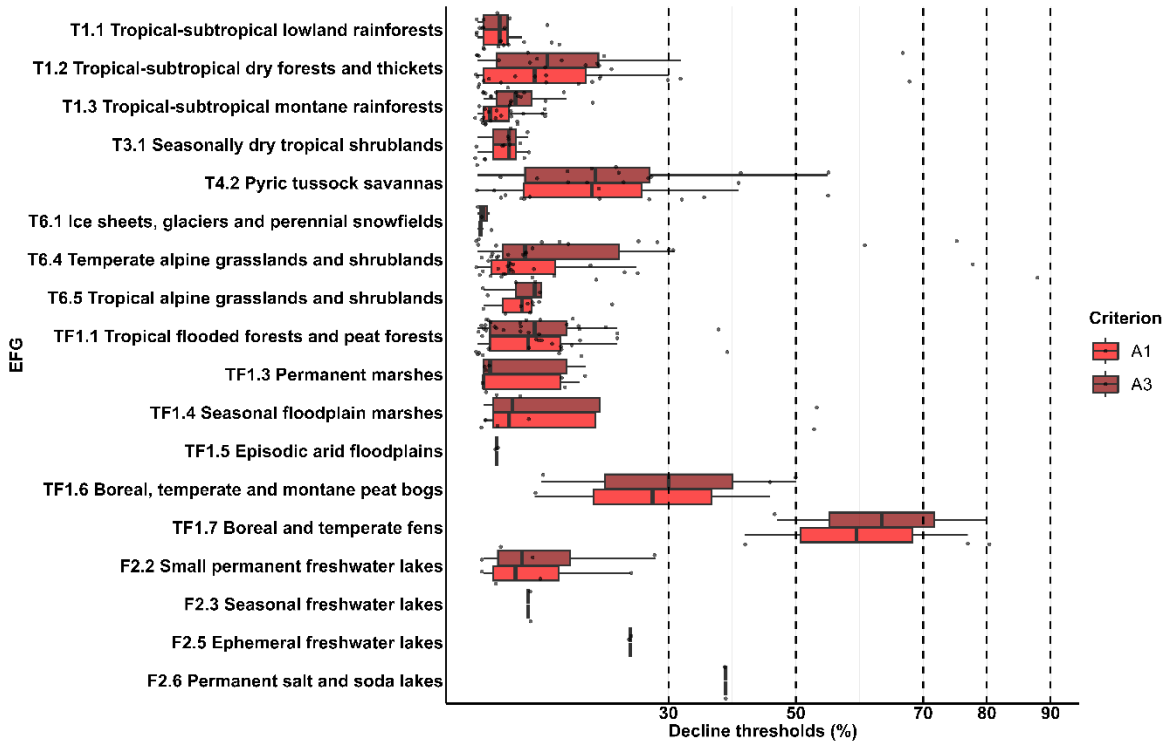


Figure 2. Estimates of decline in distribution of ecosystem types of Bolivia. Boxes and whiskers represent variation in decline among the ecosystem types within each Ecosystem Functional Group (EFG). Vertical dashed lines represent thresholds delimiting threat categories for subcriterion A1 (30%, 50%, 80%) and A3 (50%, 70%, 90%).

Under subcriterion A1, 6 (4.3%) ecosystem types were classified as EN, 7 (4.9%) as VU, 2 (1.4%) as NT and 126 (89.4%) as LC (Figure 3, Table S3). Analysis by EFG under A1 shows that the six ecosystems classified as EN were distributed among Temperate alpine grasslands and shrublands (T6.4; Altimontane grasslands and shrublands of the humid Puna, Xeric montane Bolivian-Tucuman shrublands), Tropical-subtropical dry forests and

thickets (T1.2; Transitional forests from northern Chaco to Chiquitania, on alluvial plain), Pyric tussock savannas (T4.2; Complex of alkaline savannas of Beni), Seasonal floodplain marshes (TF1.4; Palm groves and flooded savannas of the alkaline uplands of Beni) and Boreal and temperate fens (TF1.7; High Andean hygrophytic grasslands of the humid Puna).

Under subcriterion A3, 3 (2.1%) ecosystem types qualify in the EN category, 4 (2.8%) as VU, 8 (5.7%) as NT and 126 (89.4%) as LC (Figure 3, Table S3). The analysis by EFGs in A3 shows that the three categorized as EN were distributed among Temperate alpine grasslands and shrublands (T6.4; Xeric montane Bolivian-Tucuman shrublands, Altimontane grasslands and shrublands of the humid Puna) and Boreal and temperate fens (TF1.7; High Andean hygrophytic grasslands of the humid Puna).

Criterion B: Restricted geographic distribution

According to the results for EOO (subcriterion B1), 15 (10.6%) ecosystem types were classified as CR, 18 (12.8%) as EN, and 34 (24.1%) as VU. All of these showed evidence of continuing decline or exposure to a threat that could cause continuing decline, meeting the conditions required under subcriterion B1. In addition, 74 (52.5%) were identified as LC (Figure 3, Table S3). The analysis by EFGs in B1 shows that 15 ecosystem types classified as CR were distributed among Tropical-subtropical lowland rainforests (T1.1; Successional liana forests of Chiquitania, Bamboo forest of southwestern Amazonia), Tropical-subtropical dry forests and thickets (T1.2; e.g., *Podocarpus* forests on poorly drained soils of the Chiquitano hills), Tropical-subtropical montane rainforests (T1.3; e.g., High Andean pluvial *Polylepis* forest of Yungas), Seasonally dry tropical shrublands (T3.1; Sclerophyllous chaparrals on well-drained soils of the Heath-Lower Madidi), Temperate alpine grasslands and shrublands (T6.4; e.g., Altimontane grasslands and shrublands of the humid Puna), Tropical alpine grasslands and shrublands (T6.5; Montane saxicolous vegetation of Yungas), Tropical flooded forests and peat forests (TF1.1; Flooded Amazonian palm groves of northern Chiquitania), Seasonal floodplain marshes (TF1.4; Forests on poorly drained soils of eastern northern Chaco) and Boreal and temperate fens (TF1.7; Altimontane hygrophytic grasslands of the humid Puna).

Regarding the AOO results (B2), 3 (2.1%) ecosystem types were classified as CR, 14 (9.9%) as EN, and 15 (10.6%) as VU. In addition, 109 (77.3%) were identified as LC (Figure 3, Table S3). All of these showed evidence of continuing decline or exposure to a threat that could cause continuing decline, meeting the conditions required under subcriterion B2. The analysis by EFGs in B2 shows that the three ecosystems classified as CR were distributed among Tropical-subtropical montane rainforests (T1.3; Humid montane Bolivian-Tucuman forests of Alder), Tropical flooded forests and peat forests (TF1.1; Flooded Amazonian palm groves of northern Chiquitania) and Temperate alpine grasslands and shrublands (T6.4; Altimontane grasslands and shrublands of the humid Puna).

Criterion C. Environmental Degradation

Due to the sensitivity of ecosystems to reduced precipitation and increased minimum temperatures, 4 (2.8%) ecosystem types were classified as VU, 21 (14.9%) as NT and 116 (82.2%) as LC under subcriterion C1 (Figure 3, Table S3). The analysis disaggregated by EFGs shows that the four ecosystems classified as VU were distributed among Tropical-subtropical lowland rainforests (T1.1; Depressed terra firme forest of southern Amazonia) , , Tropical-subtropical dry forests and thickets (T1.2; Montane xeric inter-Andean forest and shrubland of Yungas), Tropical flooded forests and peat forests (TF1.1; Blackwater stagnant alluvial forest of southern Amazonia, Flooded forest and riparian vegetation of mixed waters of Amazonia) .

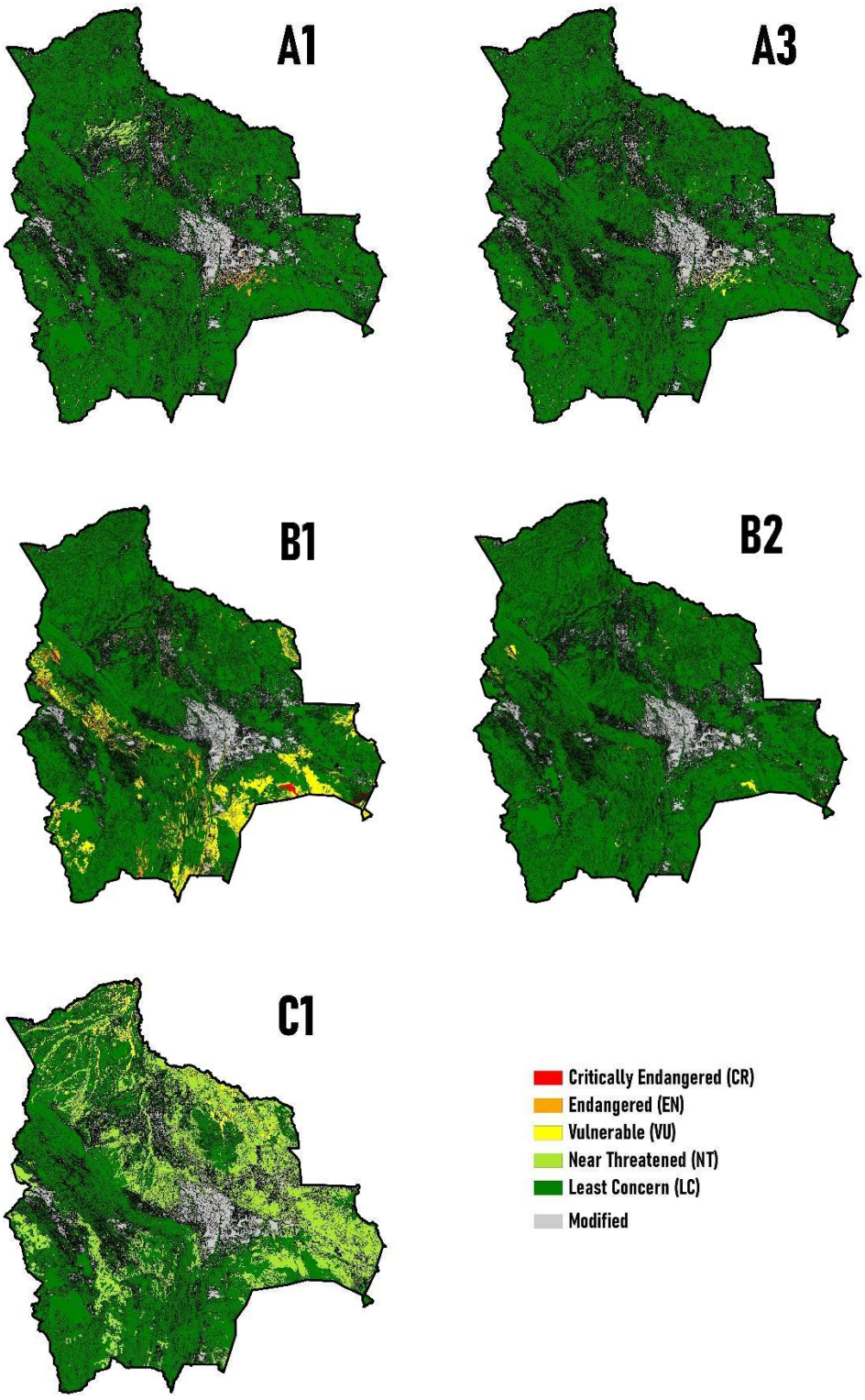


Figure 3. Spatial distribution of IUCN risk categories for ecosystem collapse in Bolivia, based on subcriteria A1, A3, B1, B2, and C1.

Overall risk categories

The analyses identified that 15 (10.6%) of ecosystems are classified as CR, 22 (15.6%) as EN, and 39 (27.7%) as VU. Additionally, 22 (15.6%) were categorized as NT and 43 (30.5%) as LC (Figure 4, Table S3). Disaggregation by EFG revealed pronounced heterogeneity in threat status across groups. For example, in Tropical-subtropical lowland rainforests (T1.1), 20.0% of ecosystem types are classified as CR, 10.0% as EN, 20.0% as VU, 10.0% as NT, and 40.0% as LC. In Tropical-subtropical dry forests and thickets (T1.2), 17.6% are CR, 11.8% EN, 29.4% VU, 23.5% NT, and 17.6% LC. Tropical-subtropical montane rainforests (T1.3) show 10.5% CR, 31.6% EN, 26.3% VU, 0.0% NT, and 31.6% LC. Temperate alpine grasslands and shrublands (T6.4) present 13.6% CR, 4.5% EN, 31.8% VU, 9.1% NT, and 40.9% LC. In Tropical alpine grasslands and shrublands (T6.5), the VU category predominates (42.9%), with 14.3% CR, 0.0% EN, 14.3% NT, and 28.6% LC. Several EFGs exhibit even more marked patterns. For instance, all ecosystem types in ephemeral freshwater lakes (F2.5) and seasonal freshwater lakes (F2.3) are classified as EN, while in permanent salt and soda lakes (F2.6), all types are VU. Certain groups, such as permanent lowland rivers/large freshwater lakes (F1.2/F2.1), are exclusively LC.

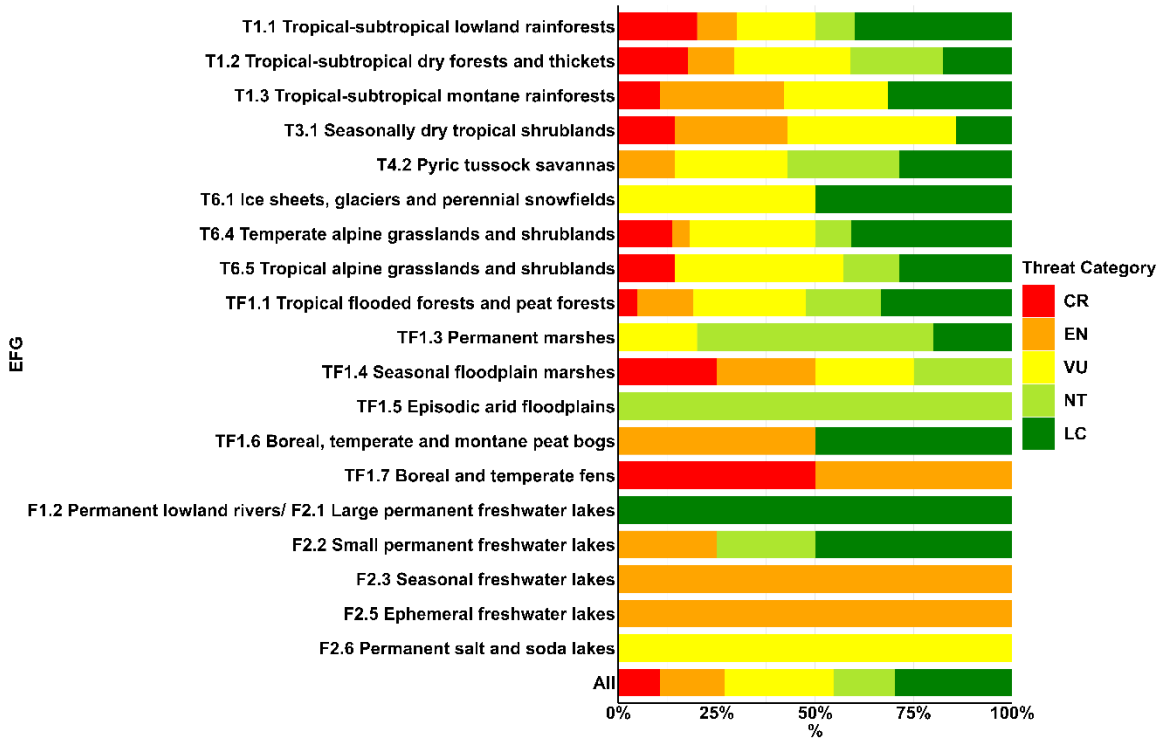


Figure 4. Proportion of IUCN Ecosystem Functional Group (EFG) types in Bolivia by threat category.

The spatial distribution of EFGs by threat category highlights clear contrasts (Figure 5). For CR, the largest surface proportions occur in Tropical-subtropical dry forests and thickets (T1.2) with 51.0%, followed by Seasonal floodplain marshes (TF1.4) with 24.6%, and Tropical-subtropical lowland rainforests (T1.1) with 11.6%. Temperate alpine grasslands and shrublands (T6.4) and Tropical-subtropical montane rainforests (T1.3) also have notable values, with 5.0% and 6.5% respectively. For EN, the highest area percentages are in T1.2 (32.9%), T1.3 (24.2%), and Pyric tussock savannas (T4.2) with 16.2%. Temperate alpine grasslands and shrublands (T6.4) and Tropical flooded forests and peat forests (TF1.1) also present relevant extents (7.8% and 6.4%, respectively). Regarding VU, the greatest spatial extension is found in T1.2 (21.9%), Tropical flooded forests and peat forests (TF1.1) (15.9%), T1.1 (11.6%), Seasonally dry tropical shrublands (T3.1) (11.2%), Temperate alpine grasslands and shrublands (T6.4) (10.2%), and T1.3 (9.5%).

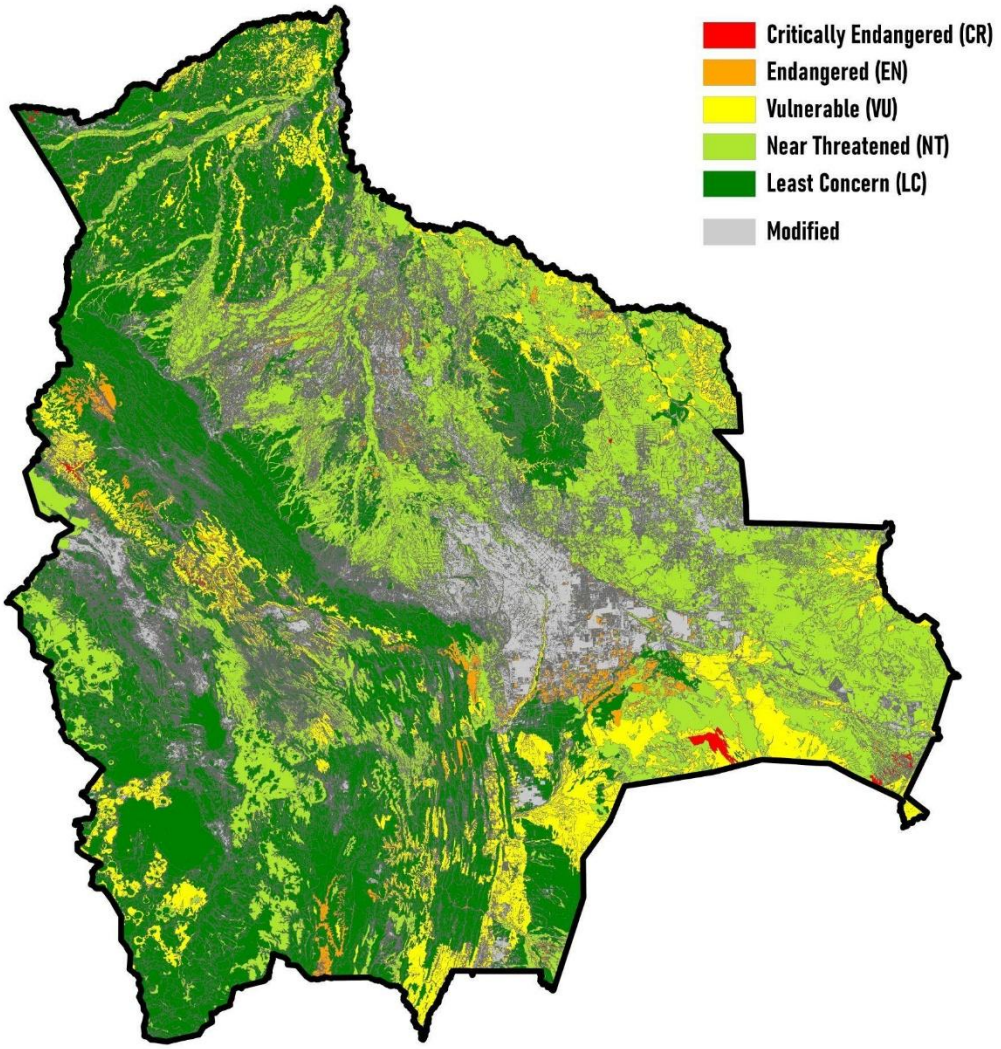


Figure 5. Spatial pattern of overall IUCN ecosystem collapse risk categories in Bolivia, based on subcriteria A1, A3, B1, B2, and C1.

The Red List Ecosystem Index (RLIE) for Bolivia was 0.68, indicating a moderate overall risk to the country's ecosystems (Table S4). The EFGs with the lowest RLIE values, and thus the highest levels of risk, include Boreal and temperate fens (TF1.7, 0.30), Seasonal freshwater lakes (F2.3, 0.40), Ephemeral freshwater lakes (F2.5, 0.40), Seasonal floodplain marshes (TF1.4, 0.50), and Seasonally dry tropical shrublands (T3.1, 0.54). These results highlight the pronounced vulnerability of wetland and seasonally dynamic ecosystems in Bolivia, underscoring the urgent need for targeted conservation actions.

Complementarity of subcriteria

The complementarity analysis revealed low levels of synergy among the five subcriteria (Figure 6). The observed values for net synergy were very low (mean: 0.0008, maximum: 0.0084), and, similar to overall synergy (mean: 0.0043, maximum: 0.0084), none of these values reached statistical significance. This indicates the absence of relevant non-additive interactions among the evaluated subcriteria. Conversely, redundancy reached statistical significance in only 20% of the pairs (mean: 0.0035, maximum: 0.0100), with very low absolute values, suggesting minimal information overlap between subcriteria. In contrast, uniqueness emerged as the most relevant component: it was significant in 60% of pairs (mean: 0.0815, maximum: 0.1077), and exhibited values notably higher than the others, indicating that each subcriterion mainly contributes unique and specific information. These results indicate that each subcriterion provides unique information, with low redundancy and minimal synergy among them, reinforcing the informational independence of the evaluated subcriteria.

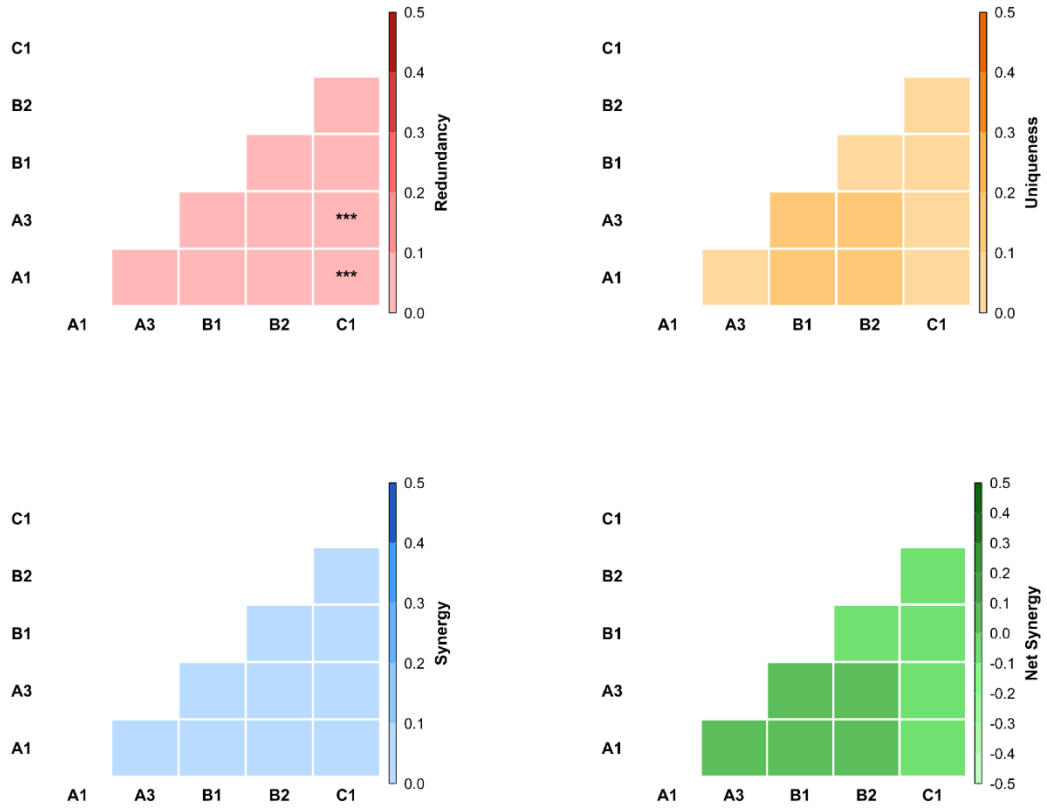


Figure 6. Complementarity of five subcriteria based on the components of redundancy, uniqueness, synergy, and net synergy. Statistical significance: *** $p < 0.001$.

Applications for conservation

The network of protected areas in Bolivia covers 35.7 million hectares (32.9% of the national territory), managed at national, departmental, indigenous, and municipal levels. Spatially, these protected areas cover 31.3% of the threatened ecosystems. Regarding the entirety of each threat category, the results show that 68.7% of ecosystems classified as CR, 35.8% of EN, and 44.0% of VU remain outside formal protection. (Table S5). For example, Tropical-subtropical dry forests and thickets (T1.2) represent the highest proportion of CR (9.4%), EN (22.3%), and VU (10.8%) outside protection, indicating significant exposure to degradation. Similarly, Tropical-subtropical montane rainforests (T1.3) and Pyric tussock savannas (T4.2) present notable proportions of EN (10.3% and 11.0%, respectively) and VU (5.1% and 3.6%) outside protection. Other EFGs with prominent gaps include

Temperate alpine grasslands and shrublands (T6.4, VU 9.4%) and Tropical alpine grasslands and shrublands (T6.5, VU 4.4%), as well as Tropical flooded forests and peat forests (TF1.1, VU 9.2%). Notably, in several of these ecosystems, the majority of threatened areas occur exclusively outside protected areas. These findings show that, despite the limited area of threatened EFGs in Bolivia, their ecological importance and vulnerability make their underrepresentation within the protected area network a significant conservation concern.

Regarding the 15 ecosystems classified as CR, 10 are completely outside the national protected areas system. In the Highlands, these include the High Andean pluvial *Polylepis* forest of Yungas, Secondary altimontane Bolivian-Tucuman shrublands, Altimontane hygrophytic grasslands of the humid Puna, and Altimontane grasslands and shrublands of the humid Puna. On the Andean slopes, the Montane xeric inter-Andean forest and shrubland of Yungas and the Humid montane Bolivian-Tucuman forests of Alder also lack any formal protection. In the Lowlands, the Bamboo forest of southwestern Amazonia, Successional liana forests of Chiquitania, and Flooded Amazonian palm groves of northern Chiquitania remain completely unprotected. This situation highlights the urgent need for targeted conservation measures to safeguard these highly vulnerable ecosystems.

Discussion

This study presents the first Red List of Ecosystems (RLE) assessment covering all terrestrial ecosystems of Bolivia. Previous studies have provided valuable contributions, either by focusing on specific regions (e.g., the Chiquitano Forest [18, 20] or by relying on global datasets with coarse spatial resolution that could not always be validated at the national scale [13]. In recent years, Bolivia has made notable efforts to develop national species-based red lists for plants [19, 43], insects [44] and vertebrates [45, 46, 47, 48, 49]. These assessments reflect the current state of knowledge for each taxonomic group, the availability of specialist expertise, and the key information needs and knowledge gaps identified for their conservation. While these assessments have been valuable scientific information sources, their impact on the development of public policy or research agendas promoting ecological or genetic studies of priority species has thus far been limited.

To enhance biodiversity conservation in Bolivia, it is essential to complement these efforts with a broader, ecosystem-scale perspective. Shifting from a population-community approach (focused on the risk of species extinction) to a process-functional approach (focused on the risk of ecosystem collapse) can revitalize debate and inform decision-making on conservation in the country. For example, it is estimated that Bolivia harbors approximately 16,000 vascular plant species, of which 2,661 are endemic, and 899 species are included on the IUCN Red List [50]. Given that it is not feasible in the short term to develop conservation actions or research plans for each individual species, addressing their collective impact through the lens of ecosystems offers a more effective path for biodiversity protection. In this context, integrating initiatives that range from area-based to species-based approaches, all sharing common parameters such as thresholds and predictions about species and their ecosystems, is key to optimizing conservation efforts. Similar to identifying extinction risk in species, having a national red list of ecosystems allows for more strategic prioritization and guidance, strengthening actions already underway in the country to halt biodiversity loss. The RLE thus provides a fundamental and complementary baseline for planning, monitoring, and decision-making in conservation across Bolivia.

The ecosystems of Bolivia are increasingly threatened by a complex array of anthropogenic factors, whose intensity and nature vary regionally due to the country's remarkable ecological diversity. In the lowlands, ecosystem loss and degradation result primarily from livestock farming (57%) and mechanized agriculture (33%), which together account for approximately 90% of deforestation, especially in the case of soy and other industrial crops [1]. These direct conversion pressures are amplified by public policies that promote the expansion of the agricultural frontier, legalize deforestation, and provide economic incentives for land conversion [51, 52]. Additionally, land speculation [53], recurrent wildfires [54], and increasing habitat fragmentation contribute to the vulnerability of these ecosystems [55] and further reduce ecosystems resilience. In contrast, threats in the Andean region operate through different mechanisms. Overgrazing and unsustainable agricultural practices intensify soil erosion and land degradation in high-altitude systems, thereby

accelerating the loss of ecosystem functionality and productivity [56]. These threat patterns are evident in our RLE results, which differentiate lowland tropical from Andean ecosystems.

One of the most significant challenges for the entire country, however, is climate change. Bolivia is highly sensitive to global warming, and its effects are already evident across diverse ecosystems. While precipitation shows marked temporal variability and not clear trends [36], recent analyses have demonstrated a sustained increase in air temperatures. Mean and minimum temperatures have risen by 0.17°C per decade, and maximum temperatures by approximately 0.25°C per decade [37]. This warming trend is driving the rapid retreat of tropical Andean glaciers, which has major implications for the regulation of water resources in downstream ecosystems and human populations [57, 58]. As a result of these cumulative pressures, Bolivian ecosystems exhibit differentiated risk levels, as reflected in their assignment to various threat categories.

Furthermore, our results underscore the heterogeneous expression of ecosystem collapse symptoms across different regions and functional groups. Complementarity analyses show that each of the three criteria assessed contribute distinct and unique information with low redundancy. For example, the Transitional forests from northern Chaco to Chiquitania is a relatively widespread ecosystems with high rates of decline in the last 50 years (criterion A), while the Humid sub-Andean Bolivian-Tucuman forests has lower rates of decline, but its restricted distribution (criterion B) puts it at a larger risk of collapse due to limited insurance against spatially explicit threats. On the other hand, the Flooded forest and riparian vegetation of mixed waters of Amazonia have low rates of decline and larger distributions, but are more exposed to the risks associated with climate change (criterion C).

Diagnosing the most prevalent symptoms across different regions and EFGs enables the development of conservation strategies tailored to specific ecological contexts. Our

analyses reveal marked differences in both the magnitude and type of threats by functional group and region. The proportion of ecosystems classified as threatened according to IUCN criteria varies depending on the criterion analyzed, with certain EFGs such as Tropical-Subtropical Dry Forests and Thickets, Temperate Alpine Grasslands and Shrublands, and Pyric Tussock Savannas exhibiting particularly high rates of area reduction, geographic restriction, or climate sensitivity. Importantly, these risk assessments are separate from the spatial analysis of protection status. Spatial analysis highlights that a substantial portion of threatened ecosystems remains outside protected areas. Notably, 31.3% of the total area classified as CR is unprotected, while for EN and VU, 64.2% and 56% respectively, lack protection. This pattern is especially pronounced in the aforementioned EFGs, where most threatened areas are found outside the protected area network.

Historically, national protected areas in Bolivia have been established or expanded primarily to conserve regions with the highest species richness and endemism, such as the Yungas and lowland forests. In recent decades, the creation of new national protected areas has slowed considerably, and this gap has been partially addressed through the designation of subnational protected areas [51]. Our results indicate that consolidating a conservation corridor encompassing the tropical rainforests, extending from the Amazon lowlands to the montane forests of eastern and western Bolivia, could form a strategic conservation arc. In contrast, savannas and grasslands, particularly in the Beni plains (including the Llanos de Moxos), require targeted conservation actions coordinated with the region's dominant livestock farming activities [52]. Similarly, the dry forests of the Chaco and Chiquitano demand special attention. Existing protected areas in these ecosystems are currently insufficient and represent barriers to curbing the accelerated expansion of deforestation [24], necessitating targeted management actions and additional investment. Furthermore, not only are threatened ecosystems outside protected areas underrepresented, but those within the national system of protected areas are also not managed effectively, thereby accelerating their degradation and increasing their vulnerability. In this context, ecological restoration efforts, both passive and active, could be effectively focused on these regions and their unique ecosystems. Regarding the south-central region, several ecosystems classified as EN and VU still face significant conservation gaps (e.g., High Andean

cardonales of western xerophytic zones, Altimontane and high Andean shrublands and grasslands of the eastern xerophytic Puna, High Andean shrublands and grasslands of the southwestern xerophytic Puna, Xeric inter-Andean montane Bolivian-Tucuman forests), and remain among the least represented in the national protected areas network. This underrepresentation is particularly evident across various xerophytic and high-altitude ecosystems, which have been consistently identified in previous studies as priorities for the legal establishment of new conservation areas [59, 60]. Our analysis found that more than 56% of Bolivia's terrestrial and palustrine ecosystems are threatened, although these ecosystems are concentrated in only 22.8% of the national territory. However, 31.3% of that area occupied by threatened ecosystems is already in protected areas. Moreover, 10 out of the 15 ecosystems classified as CR are not properly protected. This means that improvements to the protected area network in a relatively small area of the country could have major and very cost-effective benefits for ecosystem risk reduction and national ecologically sustainable development.

In addition to identifying ecosystems that should be prioritized for conservation due to their risk of collapse and high endemism, it is also essential to recognize those requiring research and restoration initiatives. For example, the Sclerophyllous chaparrals of transitional Chiquitania to the Chaco on sandy soils (VU) remain poorly studied in terms of biodiversity and are under significant pressure from human activities. These ecosystems would greatly benefit from targeted research and restoration interventions. aimed at improving our understanding of their ecological dynamics and informing evidence-based management strategies Such efforts are crucial to prevent ecosystem collapse and maintain ecological functions.

The availability of a comprehensive and systematic assessment of Bolivia's terrestrial ecosystems represents a major advancement for conservation planning and evidence-based policy development. This foundational dataset enables the identification of priority areas for halting ecosystem decline and collapse risk, guiding effective restoration, while also facilitating the integration of ecological criteria into public policy design. It supports the strategic allocation of resources, optimization of the protected area network, and targeted

implementation of restoration initiatives in key landscapes to enhance ecological connectivity and resilience. Importantly, robust baseline information positions Bolivia to align its national strategies with international commitments under the Kunming-Montreal Global Biodiversity Framework. Specifically, the assessment informs the achievement of Target 1 (ensuring effective conservation and management of at least 30% of terrestrial and marine areas), Target 2 (restoring at least 30% of degraded ecosystems), and Target 3 (halting human-induced extinction of threatened species and reducing extinction risk). By doing so, Bolivia can strengthen its reporting mechanisms, foster international cooperation, and improve access to global funding for conservation. The documented high levels of vulnerability, remarkable biodiversity, and significant endemism found in many of these ecosystems underscore their urgency and suitability as priorities for inclusion in the expansion of protected areas and other conservation areas such OECM (Other Effective Area-based Conservation Measures) and indigenous territories. In addition, these same characteristics make them prime candidates for large-scale ecological restoration efforts and for fulfilling the 30x30 conservation target. Protecting and restoring such ecosystems not only addresses national conservation needs but also contributes to global biodiversity goals. In this context, the use of the Red List of Ecosystems as both a technical and policy tool is essential for guiding effective and sustainable interventions. Its adoption will help consolidate biodiversity conservation as a core element of Bolivia's national development agenda, ensuring that ecological integrity and resilience are maintained for future generations. It is crucial to design and implement a system for monitoring the risk of ecosystem collapse. This study is a first step.

Conclusions

This comprehensive Red List assessment delivers the first nationwide, multi-criteria evaluation of the risk status of Bolivia's terrestrial ecosystems, generating an essential scientific baseline to inform conservation policy and management. The major findings of this study can be summarized as follows:

i. Over the past 50 years, the area of natural ecosystems converted to anthropogenic use in Bolivia increased from 1.8 million hectares (1.6% of the country) to 13 million hectares (12%). The most severe contractions occurred in boreal and temperate fens and peat bogs.

ii. Of the 141 ecosystem types assessed, 10.6% are classified as Critically Endangered (CR), 15.6% as Endangered (EN), and 27.7% as Vulnerable (VU). The highest concentrations of threatened ecosystems are found among tropical-subtropical lowland rainforests, dry forests, montane rainforests, and alpine grasslands.

iii. Restricted geographic range and environmental degradation are primary drivers of risk. Notably, 15 ecosystem types are CR and 22 are EN for extent of occurrence, with wetlands and seasonally dynamic systems showing the lowest Red List Ecosystem Index (RLIE) values (as low as 0.30).

iv. Complementarity analysis reveals that each IUCN criterion contributes unique, non-redundant information, supporting the need for a multi-dimensional assessment framework to fully capture ecosystem risk.

v. Although Bolivia's protected area network covers 32.9% of the national territory, only 68.7% of CR, 35.8% of EN, and 44.0% of VU ecosystems are represented within these areas. Significant conservation gaps persist for the most threatened and ecologically important functional groups.

This assessment reveals clear patterns of risk of collapse that can inform conservation priorities and strategies for halting ecosystem degradation and advancing effective conservation in Bolivia. The Red List of Ecosystems (RLE) and the Red List Ecosystem Index (RLIE) data and indices developed here enable robust national monitoring and scenario planning, but also directly support Bolivia's capacity to meet international commitments, such as those set by the Kunming-Montreal Global Biodiversity Framework. Bolivia's National System of Protected Areas, which includes both national and subnational areas, should be reviewed and adjusted based on the results of this study.

Planning connectivity corridors and involving the indigenous and private sectors in conservation efforts for critical ecosystems, especially in buffer zones, should be a priority for the country's decision-makers. Strengthening science-based management, closing protection gaps for threatened ecosystems, and fostering collaboration among stakeholders will be crucial for preserving the country's unique biodiversity and ensuring resilient landscapes for future generations.

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Author contributions

OM: Conceptualization, methodology, data curation, formal analysis, investigation, visualization, writing – original draft, writing – review & editing. DAK: Conceptualization, methodology, formal analysis, investigation, visualization, writing – original draft, writing – review & editing. JRF-P: Conceptualization, methodology, formal analysis, investigation, visualization, writing – original draft, writing – review & editing. DML-A: Conceptualization, writing – original draft, writing – review & editing. MTM-U: Writing – review & editing. AF: Writing – original draft, writing – review & editing. RV-A: Conceptualization, supervision, writing – original draft, writing – review & editing. DV: Writing – review & editing. IZ: Conceptualization, methodology, supervision. FSZ-R:

writing – review & editing. SA: writing – review & editing. SMV-S: writing – review & editing.

Disclosure

The authors declare no conflict of interest, financial or otherwise.

Consent for publication

Not applicable.

Clinical trial number

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Competing interests

The authors declare no competing interests.

Data availability

All data supporting the findings of this study are available within the paper and its Supplementary Information.

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Supplementary Information

Table S1. The Global Ecosystem Typology (biomes) and the Functional Ecosystem Group (EFG) proposed by Keith et al. (2022)[1] and cross-referenced with the classification of Ecological Systems of Bolivia proposed by Navarro and Ferreira (2011)[2].

IUCN Global Ecosystem Typology (Biomes)[1]	**IUCN Ecosystem Functional Group (EFG)[1]**	**Ecosystem code[2]**	**Ecosystem name (English)[2]**	**Ecosystem name (Spanish)[2]**
T1 Tropical-subtropical forests	T1.1Tropical-subtropical lowland rainforests	CES408.549	Bamboo forest of southwestern Amazonia	Bosque con Bambu del suroeste de la Amazonia
		CES406.231	Chiquitano transitional forests to the Amazon on well-drained soils	Bosques chiquitanos de transición a la Amazonía sobre suelos bien drenados
		CES408.576	Depressed terra firme forest of southern Amazonia	Bosque de tierra firme depresionada del sur de la Amazonia
		CES406.235	Evergreen seasonal Amazonian forest of the Chiquitano Precambrian Shield	Bosque siempreverde estacional amazónico del Escudo Precámbrico Chiquitano
		CES408.566	Forest of isolated ranges of south-central Amazonia	Bosque de serranías aisladas del centro-sur de la Amazonia
		CES408.570	Forest of the pre-Andean glacis of Southwestern Amazonia	Bosques del glacis preandino del Suroeste de la Amazonia
		CES408.518	Palm forest of south-central Amazonia	Bosque de palmas del centro-sur de la Amazonia

		CES408.544	Seasonal evergreen forest of the peneplain of southwestern Amazonia	Bosque siempreverde estacional de la penillanura del suroeste de la Amazonia
		CES408.545	Sub-Andean seasonal evergreen forest of southwestern Amazonia	Bosque siempreverde estacional subandino del suroeste de la Amazonia
		CES406.239	Successional liana forests of Chiquitania	Bosques sucesionales de lianas de la Chiquitania
	T1.2 Tropical-subtropical dry forests and thickets	CES406.237	Chiquitano transitional forests to the Chaco on moderately to poorly drained soils	Bosques chiquitanos de transición al Chaco sobre suelos medianamente a mal drenados
		CES502.256	Forests of the sand dunes of northwestern Chaco	Bosques de los arenales del Chaco noroccidental
		CES502.262	Forests on poorly drained soils of northwestern Chaco	Bosques sobre suelos mal drenados del Chaco noroccidental
		CES502.258	Hygrophytic forests of northern Chaco	Bosques higrofíticos del Chaco septentrional
		CES409.075	Montane xeric inter-Andean forest and shrubland of Yungas	Bosque y arbustal montano xerico interandino de Yungas
		CES406.230	Podocarpus forests on poorly drained soils of the Chiquitano hills	Bosques de *Podocarpus* sobre suelos mal drenados de las serranías chiquitanas
		CES502.265	Pre-Andean transitional forests of northwestern Chaco	Bosques transicionales preandinos del Chaco noroccidental

		CES406.233	Semi-deciduous hydrophytic and phreatophytic forests of Chiquitania	Bosques semidecíduos hidrofíticos y freatofíticos de la Chiquitania
		CES409.196	Sub-Andean-inter-Andean phreatophytic Bolivian-Tucuman forests	Bosques freatófilos subandino-interandinos Boliviano-Tucumanos
		CES409.209	Subhumid riparian montane Bolivian-Tucuman forests	Bosques subhúmedos ribereños montanos Boliviano-Tucumanos
		CES406.238	Subhumid semi-deciduous forest of Chiquitania and Beni	Bosque subhúmedo semideciduo de la Chiquitania y el Beni
		CES502.280	Transitional forests from northern Chaco to Chiquitania, on alluvial plain	Bosques transicionales del norte del Chaco a la Chiquitania, sobre llanura aluvial
		CES502.279	Transitional forests from northern Chaco to Chiquitania, on rocky substrates	Bosques transicionales del norte del Chaco a la Chiquitania, sobre sustratos rocosos
		CES502.264	Transitional forests from northern Chaco to Chiquitania, on sand dunes	Bosques transicionales del norte del Chaco a la Chiquitania, sobre arenales
		CES409.056	Xeric basimontane forest of southern Yungas	Bosque basimontano Xérico de Yungas del Sur
		CES502.267	Xeric forests of ancient alluvial plains of northwestern Chaco	Bosques xéricos de las llanuras aluviales antiguas del Chaco noroccidental

		CES409.211	Xerophytic inter-Andean-sub-Andean Bolivian-Tucuman forests	Bosques xerofíticos interandino-subandinos Boliviano-Tucumanos
	T1.3 Tropical-subtropical montane rainforests	CES409.043	Altimontane pluvial forest of Yungas	Bosque altimontano pluvial de Yungas
		CES409.044	Altimontane pluvio-seasonal forest of Yungas	Bosque altimontano pluviestacional de Yungas
		CES409.048	Basimontane pluvial forest and palm grove of Yungas	Bosque y palmar basimontano pluvial de Yungas
		CES409.054	Basimontane pluvio-seasonal humid forest of Yungas	Bosque basimontano pluviestacional húmedo de Yungas
		CES409.053	Basimontane pluvio-seasonal subhumid forest of southern Yungas	Bosque basimontano pluviestacional subhumedo de Yungas del sur
		CES409.920	High Andean pluvial Polylepis forest of Yungas	Bosque de Polylepis altoandino pluvial de Yungas
		CES409.198	Humid montane Bolivian-Tucuman forests of Alder	Bosques húmedos montanos Boliviano-Tucumanos de Aliso
		CES409.201	Humid sub-Andean Bolivian-Tucuman forests	Bosques húmedos subandinos Boliviano-Tucumanos
		CES409.195	Low altimontane edapho-xerophytic montane and basimontane Bolivian-Tucuman forests	Bosques bajos edafoxerófilos montanos y basimontanos Boliviano-Tucumanos

		CES409.197	Montane Bolivian-Tucuman forests of Pine of the Mountain	Bosques montanos Boliviano-Tucumanos de Pino de Monte
		CES409.050	Montane pluvial forest of Yungas	Bosque montano pluvial de Yungas
		CES409.051	Montane pluvio-seasonal humid forest of Yungas	Bosque montano pluviestacional húmedo de Yungas
		CES409.921	Montane pluvio-seasonal subhumid forest of Yungas	Bosque montano pluviestacional subhumedo de Yungas
		CES409.205	Sub-Andean Bolivian-Tucuman forests transitional with Yungas	Bosques subandinos Boliviano-Tucumanos de transición con los Yungas
		CES408.543	Sub-Andean evergreen forest of southwestern Amazonia	Bosque siempreverde subandino del suroeste de la Amazonia
		CES409.203	Sub-Andean-inter-Andean riparian Bolivian-Tucuman forests	Bosques ribereños subandino-interandinos Boliviano-Tucumanos
		CES409.206	Subhumid Bolivian-Tucuman forests of the lower sub-Andean	Bosques subhúmedos Boliviano-Tucumanos del subandino inferior
		CES409.207	Subhumid Bolivian-Tucuman forests of the upper sub-Andean	Bosques subhúmedos Boliviano-Tucumanos del subandino superior
		CES409.208	Subhumid montane Bolivian-Tucuman forests	Bosques subhúmedos montanos Boliviano-Tucumanos

T3 Shrublands & shrubby woodlands	T3.1 Seasonally dry tropical shrublands	CES406.252	Edapho-xerophytic savannas of Chiquitania (Rocky Cerrado, Rocky Field)	Sabanas edafoxerofíticas de la Chiquitania (Cerrado rupestre, Campo rupestre)
		CES408.554	Saxicolous shrubland of hills and ranges of south-central Amazonia	Matorral saxícola de colinas y serranías del centro-sur de la Amazonia
		CES406.223	Saxicolous shrublands and thickets of Chiquitania (Lajas)	Arbustales y matorrales saxícolas de la Chiquitania (Lajas)
		CES406.242	Sclerophyllous chaparrals of transitional Chiquitania to the Chaco on sandy soils (Abayoy)	Chaparrales esclerófilos de la Chiquitania de transición al Chaco sobre arenales (Abayoy)
		CES408.575	Sclerophyllous chaparrals on well-drained soils of the Heath-Lower Madidi	Chaparrales esclerófilos sobre suelos bien drenados del Heath-Bajo Madidi
		CES502.270	Shrublands and thickets on recently poorly drained paleochannels of northern Chaco	Arbustales y matorrales sobre paleocauces recientes mal drenados del Chaco septentrional
		CES502.275	Wooded savannas of the sand dunes of northwestern Chaco	Sabanas arboladas de los arenales del Chaco noroccidental
T4 Savannas and grasslands	T4.2 Pyric tussock savannas	CES406.240	Cerradão of Chiquitania and Beni	Cerradao de la Chiquitania y el Beni
		Co06Beni	Cerrado complex of northern Beni	Complejo del cerrado del Beni Norte
		Co02Beni	Complex of alkaline savannas of Beni	Complejo de sabanas alcalinas del beni

		Co01Beni	Complex of non-alkaline savannas of Beni transitional to Cerrado	Complejo de sabanas no alcalinas del beni transicionales al cerrado
		CES406.251	Flooded savanna of the lowlands of Beni	Sabana inundable de los bajíos del Beni
		CES406.246	Hygrophytic savanna with mounds of the Cerrado	Sabana higrofítica con montículos del Cerrado
		CES406.249	Mesotrophic seasonally flooded herbaceous savanna of Beni	Sabana herbácea mesotrofica estacionalmente inundada del Beni
		CES409.062	Montane and basimontane wooded savanna of Yungas	Sabana arbolada montana y basimontana de Yungas
		CES406.250	Oligotrophic seasonally flooded herbaceous savanna of Chiquitania and Beni	Sabana herbácea oligotrófica estacionalmente inundada de la Chiquitania y el Beni
		CES406.248	Open hygrophytic savanna of the uplands of Beni and Chiquitania	Sabana abierta higrofítica de las semialturas del Beni y la Chiquitania
		CES409.219	Pluvio-seasonal montane Bolivian-Tucuman grasslands	Pajonales pluviestacionales montanos Boliviano-Tucumanos
		CES406.241	Poorly drained cerradão of the non-alkaline uplands of Cerrado and Beni	Cerradao mal drenado de las semialturas no alcalinas del Cerrado y Beni
		CES408.557	Savanna of south-central Amazonia transitional to Cerrado	Sabana del centro-sur de la Amazonia transicional al Cerrado

		CES408.560	Wooded and shrubby savannas of the Upper Amazonia on waterlogged soils	Sabanas arboladas y arbustivas de la alta Amazonia sobre suelos anegables
T6 Polar-alpine	T6.1 Ice sheets, glaciers and perennial snowfields	CES505.033	Open high Andean geliturbated vegetation of southwestern xerophytic Puna	Vegetación abierta geliturbada altoandina de la Puna xerofítica suroccidental
		CES409.090	Subnival geliturbated vegetation of the humid Puna	Vegetación geliturbada subnival de la Puna húmeda
	T6.4 Temperate alpine grasslands and shrublands	CES505.023	Altimontane and high Andean shrublands and grasslands of eastern xerophytic Puna	Matorrales y herbazales altimontanos y altoandinos de la Puna xerofítica oriental
		CES409.087	Altimontane grasslands and shrublands of the humid Puna	Pajonales y Matorrales Altimontanos de la Puna Húmeda
		CES409.194	Altimontane pluvio-seasonal Bolivian-Tucuman forest	Bosque altimontano pluviestacional BolivianoTucumano
		CES505.014	High Andean cardonales of western xerophytic Puna	Cardonales altoandinos de la Puna xerofítica occidental
		CES505.008	High Andean low forests of eastern xerophytic Puna	Bosques bajos altoandinos de la Puna xerofítica oriental
		CES505.007	High Andean low forests of western xerophytic Puna	Bosques bajos altoandinos de la Puna xerofítica occidental
		CES505.028	High Andean shrublands and grasslands of northern xerophytic Puna	Pajonales y matorrales altoandinos de la Puna xerofítica norte

		CES505.029	High Andean shrublands and grasslands of southwestern xerophytic Puna	Pajonales y matorrales altoandinos de la Puna xerofítica suroccidental
		CES505.027	Hygrophilous high Andean grasslands of xerophytic Puna	Pajonales higrofílos altoandinos de la Puna xerofítica
		CES505.022	Hygrophilous high Andean shrublands of xerophytic Puna, tholares	Matorrales higrófilos altoandinos de la Puna xerofítica, tholares
		CES505.003	Inter-Andean xerophytic shrublands of the lower eastern Prepuna	Arbustales xerofíticos interandinos de la Prepuna inferior oriental
		CES505.005	Low altimontane forests of central xerophytic Puna	Bosques bajos altimontanos de la Puna xerofítica central
		CES409.074	Low and shrub altimontane forests of the humid Puna	Bosques bajos y arbustales altimontanos de la Puna húmeda
		CES505.009	Low inter-Andean xerophytic forests of the upper eastern Prepuna	Bosques bajos xerofíticos interandinos de la Prepuna superior oriental
		CES505.032	Open high Andean geliturbated vegetation of northern and eastern xerophytic Puna	Vegetación abierta geliturbada altoandina de la Puna xerofítica septentrional y oriental
		CES505.010	Phreatophytic forests of the xerophytic montane belt	Bosques freatófilos del piso montano xerofítico
		CES505.019	Psammophilous altimontane and high Andean shrublands of xerophytic Puna	Matorrales altimontanos y altoandinos psammófilos de la Puna xerofítica

		CES505.036	Riparian vegetation of the xerophytic montane belt	Vegetación ribereña del piso montano xerofítico
		CES409.212	Secondary altimontane Bolivian-Tucuman shrublands	Matorrales altimontanos secundarios Boliviano-Tucumanos
		CES505.035	Vegetation of the high Andean salt flats of xerophytic Puna	Vegetación de los salares altoandinos de la Puna xerofítica
		CES409.210	Xeric inter-Andean montane Bolivian-Tucuman forests	Bosques xéricos interandinos montanos Boliviano-Tucumanos
		CES409.217	Xeric montane Bolivian-Tucuman shrublands	Matorrales xéricos Montanos Boliviano-Tucumanos
	T6.5 Tropical alpine grasslands and shrublands	CES409.218	Altimontane Bolivian-Tucuman grasslands	Pajonales altimontanos Boliviano-Tucumanos
		CES409.058	High Andean and altimontane shrub grassland pluvial of Yungas	Pajonal arbustivo altoandino y altimontano pluvial de Yungas
		CES409.059	High Andean and altimontane shrub grassland pluvio-seasonal of Yungas	Pajonal arbustivo altoandino y altimontano pluviestacional de Yungas
		CES409.084	High Andean grasslands of the humid Puna	Pajonales altoandinos de la Puna húmeda
		CES409.213	Montane pluvio-seasonal Bolivian-Tucuman shrublands	Matorrales pluviestacionales montanos Boliviano-Tucumanos
		CES409.067	Montane saxicolous vegetation of Yungas	Vegetación saxícola montana de Yungas

		CES409.046	Pluvio-seasonal altimontane Polylepis forest of Yungas	Bosque de Polylepis altimontano pluviestacional de Yungas
TF1 Palustrine wetlands	TF1.1 Tropical flooded forests and peat forests	CES408.526	Blackwater stagnant alluvial forest of southern Amazonia	Bosque aluvial de aguas negras estancadas del sur de la Amazonia
		CES408.567	Clearwater stream forest of south-central Amazonia	Bosque de arroyos de aguas claras del centro-sur de la Amazonia
		CES408.528	Clearwater stream forest of southwestern Amazonia	Bosque de arroyos de aguas claras del suroeste de la Amazonia
		Co08Beni	Complex of clearwater and blackwater forest and riparian vegetation of Beni	Complejo de bosques y vegetación riparia de aguas claras y negras del Beni
		Co07Beni	Complex of mixed-water forest and riparian vegetation of Beni	Complejo de bosques y vegetación riparia de aguas mixtas del Beni
		CES408.550	Complex of successional riparian whitewater vegetation of Amazonia	Complejo de vegetación sucesional riparia de aguas blancas de la Amazonia
		Co05Beni	Complex of whitewater forest and riparian vegetation of Beni	Complejo de bosques y vegetacion riparia de aguas blancas del Beni
		CES406.243	Flooded Amazonian palm groves of northern Chiquitania	Palmares amazónicos inundables de la Chiquitania norte
		CES408.535	Flooded forest and riparian vegetation of blackwater of southwestern Amazonia	Bosque inundable y vegetación riparia de aguas

				negras del suroeste de la Amazonia
		CES408.571	Flooded forest and riparian vegetation of mixed waters of Amazonia	Bosque inundable y vegetación riparia de aguas mixtas de la Amazonia
		CES408.574	Flooded forest of the alluvial plain of blackwater rivers of south-central Amazonia	Bosque inundable de la llanura aluvial de ríos de aguas negras del centro-sur de la Amazonia
		CES408.531	Flooded forest of the whitewater alluvial plain rivers of southwestern Amazonia	Bosque inundable de la llanura aluvial de ríos de aguas blancas del suroeste de la Amazonia
		CES406.225	Flooded low thorny forest of the alkaline uplands of western Beni	Bosque bajo espinoso inundable de las semialturas alcalinas del Beni occidental
		CES502.259	Flooded riparian and recent alluvial plain forests of the Chaco	Bosques inundables ribereños y de llanuras aluviales recientes del Chaco
		CES406.499	Flooded riparian forests of the Western Pantanal	Bosques ribereños inundables del Pantanal Occidental
		CES408.578	Forest flooded by stagnant whitewaters of southwestern Amazonia	Bosque inundado por aguas blancas estancadas del suroeste de la Amazonia
		CES406.226	Gallery forest of the lowlands of Beni	Bosque de galería de los bajíos del Beni

		CES408.538	Palm swamp forests of the alluvial plain of the Upper Amazonia	Bosques pantanosos de palmas, de la llanura aluvial de la Alta Amazonia
		CES502.257	Phreatophytic forests of the Chaco (Algarrobo woodlands)	Bosques freatofíticos del Chaco (Algarrobales)
		CES406.232	Riparian forests of the Chiquitano Precambrian Shield	Bosques ribereños del Escudo Precámbrico Chiquitano
		CES502.254	Successional riparian shrublands and forests of the Chaco	Arbustales y bosques riparios sucesionales del Chaco
	TF1.3 Permanent marshes	Co04Beni	Complex of swamps of Beni	Complejo de pantanos del beni
		Co03Beni	Complex of whitewater-flooded savannas of Beni	Complejo de sabanas inundables por aguas blancas del beni
		CES406.514	Neotropical aquatic and marsh vegetation of the Pantanal	Vegetación acuática y palustre neotropical del Pantanal
		CES408.573	Palm swamp forest of the alluvial plain of southern Amazonia	Bosque pantanoso de palmas de la llanura aluvial del sur de la Amazonia
		CES408.552	Swampy grassland of the alluvial plain of the Upper Amazonia	Herbazal pantanoso de la llanura aluvial de la alta Amazonia
	TF1.4 Seasonal floodplain marshes	CES502.271	Flooded palm groves of northern Chaco	Palmares inundables del Chaco septentrional
		CES502.263	Forests on poorly drained soils of eastern northern Chaco	Bosques sobre suelos mal drenados del Chaco septentrional oriental

		CES406.494	Open forests and hygrophytic wooded savannas of the Southwestern Pantanal	Bosques abiertos y sabanas arboladas higrofíticas del Pantanal Suroccidental
		CES406.245	Palm groves and flooded savannas of the alkaline uplands of Beni	Palmar y sabana inundables de las semialturas alcalinas del Beni
	TF1.5 Episodic arid floodplains	Lago Salado	Salt Lake	Lago Salado
	TF1.6 Boreal, temperate and montane peat bogs	CES409.072	High Andean peat bogs of the humid Puna (peatlands)	Bofedales altoandinos de la Puna húmeda (turberas)
		CES505.004	High Andean peat bogs of the xerophytic Puna	Bofedales altoandinos de la Puna xerofítica
	TF1.7 Boreal and temperate fens	CES409.085	Altimontane hygrophytic grasslands of the humid Puna	Pajonales higrofíticos altimontanos de la Puna húmeda
		CES409.086	High Andean hygrophytic grasslands of the humid Puna	Pajonales higrofíticos altoandinos de la Puna húmeda
F1 Rivers and streams/F2 Lakes	F 1.2 Permanent lowland rivers/ F2.1 Large permanent freshwater lakes	Cuerpo de agua	Water body	Cuerpo de agua
F2 Lakes	F2.2 Small permanent freshwater lakes	CES409.089	High Andean aquatic and marsh vegetation of the humid Puna	Vegetación acuática y palustre altoandina de la Puna Húmeda
		CES505.034	High Andean aquatic and marsh vegetation of xerophytic Puna	Vegetación acuática y palustre altoandina de la Puna xerofítica

		CES406.253	Neotropical aquatic and marsh vegetation of Chiquitania and Beni	Vegetación acuática y palustre neotropical de la Chiquitania y el Beni
	F2.3 Seasonal freshwater lakes	CES502.276	Neotropical aquatic and marsh vegetation of the Chaco	Vegetación acuática y palustre neotropical del Chaco
	F2.5 Ephemeral freshwater lakes	CES502.272	Open flooded savannas of northern Chaco	Sabanas abiertas inundables del Chaco septentrional
	F2.6 Permanent salt and soda lakes	CES502.277	Vegetation of the flooded salt flats of northern Chaco	Vegetación de los salares inundables del Chaco septentrional
	F2.2 Small permanent freshwater lakes	CES408.568	Aquatic and marsh vegetation of Amazonia	Vegetación acuática y palustre de la Amazonia

Table S2. Decline thresholds used for the estimation of each subcriterion. A1: Rate of change (%) for the past 50 years (1973–2023). A3: Rate of change (%) in historical distribution (1750-2023). B1: Area of the minimum convex polygons in km² (2023), B2: Occupied 10 x 10 km cells (2023). C1: Relative severity (%) based on observed values for precipitation, maximum temperature, minimum temperature, and relative humidity.

Ecosystems	**A1 (%)**	**A3 (%)**	**B1 (km2)**	**B2 (AOO units)**	**C1 (%)**
Saxicolous shrublands and thickets of Chiquitania (Lajas)	5	5	75352	115	22
Flooded low thorny forest of the alkaline uplands of western Beni	38	39	15598	14	16
Gallery forest of the lowlands of Beni	13	13	96845	318	23
Podocarpus forests on poorly drained soils of the Chiquitano hills	0	0	251	6	13
Chiquitano transitional forests to the Amazon on well-drained soils	3	3	65177	387	23
Riparian forests of the Chiquitano Precambrian Shield	15	16	63431	53	22
Semi-deciduous hydrophytic and phreatophytic forests of Chiquitania	30	32	243244	620	29

Evergreen seasonal Amazonian forest of the Chiquitano Precambrian Shield	1	1	79441	619	29
Chiquitano transitional forests to the Chaco on moderately to poorly drained soils	8	8	210957	761	28
Subhumid semi-deciduous forest of Chiquitania and Beni	16	19	435622	1646	29
Successional liana forests of Chiquitania	0	0	202	3	14
Cerradão of Chiquitania and Beni	17	18	434867	840	30
Poorly drained cerradão of the non-alkaline uplands of Cerrado and Beni	32	36	111420	277	20
Sclerophyllous chaparrals of transitional Chiquitania to the Chaco on sandy soils (Abayoy)	5	5	38510	260	18
Flooded Amazonian palm groves of northern Chiquitania	0	0	35	1	20
Palm groves and flooded savannas of the alkaline uplands of Beni	53	53	26806	176	19
Hygrophytic savanna with mounds of the Cerrado	22	27	273648	301	30
Open hygrophytic savanna of the uplands of Beni and Chiquitania	41	41	140660	211	22
Mesotrophic seasonally flooded herbaceous savanna of Beni	22	23	113747	268	22
Oligotrophic seasonally flooded herbaceous savanna of Chiquitania and Beni	19	19	369474	507	30
Flooded savanna of the lowlands of Beni	14	14	169312	449	26
Edapho-xerophytic savannas of Chiquitania (Rocky Cerrado, Rocky Field)	4	4	61642	40	19
Neotropical aquatic and marsh vegetation of Chiquitania and Beni	9	10	414620	1201	29
Open forests and hygrophytic wooded savannas of the Southwestern Pantanal	3	3	33517	112	18
Flooded riparian forests of the Western Pantanal	2	2	43582	82	18
Neotropical aquatic and marsh vegetation of the Pantanal	1	1	46136	113	18
Palm forest of south-central Amazonia	5	5	75148	173	22
Blackwater stagnant alluvial forest of southern Amazonia	1	1	331178	642	31
Clearwater stream forest of southwestern Amazonia	3	4	129117	715	20
Flooded forest of the whitewater alluvial plain rivers of southwestern Amazonia	10	12	366446	1184	29
Flooded forest and riparian vegetation of blackwater of southwestern Amazonia	1	1	88795	165	21
Palm swamp forests of the alluvial plain of the Upper Amazonia	7	7	41180	37	20
Sub-Andean evergreen forest of southwestern Amazonia	5	7	78696	512	25

Seasonal evergreen forest of the peneplain of southwestern Amazonia	4	4	135147	1083	24
Sub-Andean seasonal evergreen forest of southwestern Amazonia	7	13	85014	368	25
Bamboo forest of southwestern Amazonia	4	4	1379	20	17
Complex of successional riparian whitewater vegetation of Amazonia	16	20	262195	155	29
Swampy grassland of the alluvial plain of the Upper Amazonia	1	2	392156	745	30
Saxicolous shrubland of hills and ranges of south-central Amazonia	7	7	7283	15	17
Savanna of south-central Amazonia transitional to Cerrado	0	0	26762	95	19
Wooded and shrubby savannas of the Upper Amazonia on waterlogged soils	4	4	261554	377	24
Forest of isolated ranges of south-central Amazonia	0	0	28708	109	19
Clearwater stream forest of south-central Amazonia	0	0	101107	495	26
Aquatic and marsh vegetation of Amazonia	1	1	15611	38	18
Forest of the pre-Andean glacis of Southwestern Amazonia	11	12	81251	463	24
Flooded forest and riparian vegetation of mixed waters of Amazonia	2	3	406455	563	30
Palm swamp forest of the alluvial plain of southern Amazonia	1	1	231507	498	27
Flooded forest of the alluvial plain of blackwater rivers of south-central Amazonia	1	1	330307	222	23
Sclerophyllous chaparrals on well-drained soils of the Heath-Lower Madidi	0	0	99	4	20
Depressed terra firme forest of southern Amazonia	1	1	325287	829	31
Forest flooded by stagnant whitewaters of southwestern Amazonia	22	22	295905	1006	29
Altimontane pluvial forest of Yungas	1	3	43818	92	22
Altimontane pluvio-seasonal forest of Yungas	2	7	7971	82	20
Pluvio-seasonal altimontane Polylepis forest of Yungas	9	10	22490	45	21
Basimontane pluvial forest and palm grove of Yungas	1	1	66691	379	24
Montane pluvial forest of Yungas	1	6	69384	325	22
Montane pluvio-seasonal humid forest of Yungas	5	6	34141	98	23
Basimontane pluvio-seasonal subhumid forest of southern Yungas	4	14	60563	293	23
Basimontane pluvio-seasonal humid forest of Yungas	0	1	14319	73	22
Xeric basimontane forest of southern Yungas	0	13	30409	97	21

High Andean and altimontane shrub grassland pluvial of Yungas	2	4	42627	132	23
High Andean and altimontane shrub grassland pluvio-seasonal of Yungas	6	9	38410	194	23
Montane and basimontane wooded savanna of Yungas	8	9	8905	31	18
Montane saxicolous vegetation of Yungas	1	1	160	5	15
High Andean peat bogs of the humid Puna (peatlands)	46	50	11757	76	22
Low and shrub altimontane forests of the humid Puna	18	25	24444	114	19
Montane xeric inter-Andean forest and shrubland of Yungas	2	3	860	14	30
High Andean grasslands of the humid Puna	19	21	130082	485	26
Altimontane hygrophytic grasslands of the humid Puna	42	47	172	4	14
High Andean hygrophytic grasslands of the humid Puna	77	80	15341	87	23
Altimontane grasslands and shrublands of the humid Puna	61	78	28	2	14
High Andean aquatic and marsh vegetation of the humid Puna	24	28	52444	85	23
Subnival geliturbated vegetation of the humid Puna	1	2	38340	114	21
Altimontane pluvio-seasonal Bolivian-Tucuman forest	3	4	6060	66	10
Low altimontane edapho-xerophytic montane and basimontane Bolivian-Tucuman forests	1	7	20018	29	19
Sub-Andean-inter-Andean phreatophytic Bolivian-Tucuman forests	11	21	105113	175	25
Montane Bolivian-Tucuman forests of Pine of the Mountain	2	3	65414	196	22
Humid montane Bolivian-Tucuman forests of Alder	11	18	23	2	14
Humid sub-Andean Bolivian-Tucuman forests	2	2	24522	153	19
Sub-Andean-inter-Andean riparian Bolivian-Tucuman forests	6	11	19918	56	21
Sub-Andean Bolivian-Tucuman forests transitional with Yungas	1	1	9707	59	16
Subhumid Bolivian-Tucuman forests of the lower sub-Andean	6	11	39332	167	22
Subhumid Bolivian-Tucuman forests of the upper sub-Andean	3	5	52487	366	21
Subhumid montane Bolivian-Tucuman forests	1	10	11432	33	17
Subhumid riparian montane Bolivian-Tucuman forests	11	11	3784	32	16
Xeric inter-Andean montane Bolivian-Tucuman forests	10	12	31836	63	18

Xerophytic inter-Andean-sub-Andean Bolivian-Tucuman forests	4	6	99052	658	27
Secondary altimontane Bolivian-Tucuman shrublands	7	9	108	3	25
Montane pluvio-seasonal Bolivian-Tucuman shrublands	8	10	77347	468	27
Xeric montane Bolivian-Tucuman shrublands	75	88	1741	26	15
Altimontane Bolivian-Tucuman grasslands	7	8	88532	286	27
Pluvio-seasonal montane Bolivian-Tucuman grasslands	3	4	37661	185	20
High Andean pluvial Polylepis forest of Yungas	5	5	722	12	21
Montane pluvio-seasonal subhumid forest of Yungas	0	5	3521	16	17
Successional riparian shrublands and forests of the Chaco	8	9	37278	60	21
Forests of the sand dunes of northwestern Chaco	1	1	31122	217	18
Phreatophytic forests of the Chaco (Algarrobo woodlands)	15	16	46218	114	20
Hygrophytic forests of northern Chaco	19	20	222638	633	29
Flooded riparian and recent alluvial plain forests of the Chaco	10	10	80768	149	24
Forests on poorly drained soils of northwestern Chaco	19	19	204514	698	28
Forests on poorly drained soils of eastern northern Chaco	1	1	1983	28	19
Transitional forests from northern Chaco to Chiquitania, on sand dunes	0	0	1981	26	16
Pre-Andean transitional forests of northwestern Chaco	17	18	23998	225	19
Xeric forests of ancient alluvial plains of northwestern Chaco	9	9	59041	433	21
Shrublands and thickets on recently poorly drained paleochannels of northern Chaco	8	8	12516	22	18
Flooded palm groves of northern Chaco	7	8	225159	266	29
Open flooded savannas of northern Chaco	24	24	38198	20	23
Wooded savannas of the sand dunes of northwestern Chaco	1	1	32197	125	17
Neotropical aquatic and marsh vegetation of the Chaco	8	8	16552	12	20
Vegetation of the flooded salt flats of northern Chaco	39	39	93555	68	19
Transitional forests from northern Chaco to Chiquitania, on rocky substrates	0	0	26453	193	18
Transitional forests from northern Chaco to Chiquitania, on alluvial plain	67	68	90869	449	24
Inter-Andean xerophytic shrublands of the lower eastern Prepuna	3	6	131290	412	25

High Andean peat bogs of the xerophytic Puna	9	10	125005	192	18
Low altimontane forests of central xerophytic Puna	3	5	60883	313	20
High Andean low forests of western xerophytic Puna	0	0	106066	60	15
High Andean low forests of eastern xerophytic Puna	1	1	49171	85	20
Low inter-Andean xerophytic forests of the upper eastern Prepuna	2	6	121496	289	23
Phreatophytic forests of the xerophytic montane belt	5	31	21125	30	15
High Andean cardonales of western xerophytic Puna	2	3	33721	207	19
Psammophilous altimontane and high Andean shrublands of xerophytic Puna	5	5	55462	144	18
Hygrophilous high Andean shrublands of xerophytic Puna, tholares	13	14	190998	1181	24
Altimontane and high Andean shrublands and grasslands of eastern xerophytic Puna	8	9	175629	854	26
Hygrophilous high Andean grasslands of xerophytic Puna	25	30	149555	592	22
High Andean shrublands and grasslands of northern xerophytic Puna	4	4	231006	878	28
High Andean shrublands and grasslands of southwestern xerophytic Puna	0	0	33044	156	16
Open high Andean geliturbated vegetation of northern and eastern xerophytic Puna	2	2	146825	372	20
Open high Andean geliturbated vegetation of southwestern xerophytic Puna	0	0	101085	301	18
High Andean aquatic and marsh vegetation of xerophytic Puna	3	4	146605	275	20
Vegetation of the high Andean salt flats of xerophytic Puna	8	9	178733	789	20
Riparian vegetation of the xerophytic montane belt	23	28	30611	23	15
Complex of non-alkaline savannas of Beni transitional to Cerrado	27	27	109770	570	21
Complex of alkaline savannas of Beni	55	55	42578	219	19
Complex of whitewater-flooded savannas of Beni	16	17	139845	437	26
Complex of swamps of Beni	13	14	187134	1034	29
Complex of whitewater forest and riparian vegetation of Beni	13	14	224975	1264	29
Cerrado complex of northern Beni	7	7	58196	434	21
Complex of mixed-water forest and riparian vegetation of Beni	8	8	18426	129	19
Complex of clearwater and blackwater forest and riparian vegetation of Beni	7	10	4059	43	18
Water body	3	3	622943	467	29

Salt Lake	0	0	53273	210	16

Table S3. Threat categories for Bolivia's ecosystems based on subcriteria A1, A3, B1, B2, and C1.

Ecosystems	**A1**	**A3**	**B1**	**B2**	**C1**	**Final**
Saxicolous shrublands and thickets of Chiquitania (Lajas)	LC	LC	LC	LC	LC	LC
Flooded low thorny forest of the alkaline uplands of western Beni	VU	NT	EN	EN	LC	EN
Gallery forest of the lowlands of Beni	LC	LC	LC	LC	LC	LC
Podocarpus forests on poorly drained soils of the Chiquitano hills	LC	LC	CR	EN	LC	CR
Chiquitano transitional forests to the Amazon on well-drained soils	LC	LC	LC	LC	LC	LC
Riparian forests of the Chiquitano Precambrian Shield	LC	LC	LC	LC	LC	LC
Semi-deciduous hydrophytic and phreatophytic forests of Chiquitania	VU	NT	LC	LC	NT	VU
Evergreen seasonal Amazonian forest of the Chiquitano Precambrian Shield	LC	LC	LC	LC	NT	NT
Chiquitano transitional forests to the Chaco on moderately to poorly drained soils	LC	LC	LC	LC	NT	NT
Subhumid semi-deciduous forest of Chiquitania and Beni	LC	LC	LC	LC	NT	NT
Successional liana forests of Chiquitania	LC	LC	CR	EN	LC	CR
Cerradão of Chiquitania and Beni	LC	LC	LC	LC	NT	NT
Poorly drained cerradão of the non-alkaline uplands of Cerrado and Beni	VU	NT	LC	LC	LC	VU
Sclerophyllous chaparrals of transitional Chiquitania to the Chaco on sandy soils (Abayoy)	LC	LC	VU	LC	LC	VU
Flooded Amazonian palm groves of northern Chiquitania	LC	LC	CR	CR	LC	CR
Palm groves and flooded savannas of the alkaline uplands of Beni	EN	VU	VU	LC	LC	EN
Hygrophytic savanna with mounds of the Cerrado	LC	LC	LC	LC	NT	NT

Open hygrophytic savanna of the uplands of Beni and Chiquitania	VU	NT	LC	LC	LC	VU
Mesotrophic seasonally flooded herbaceous savanna of Beni	LC	LC	LC	LC	LC	LC
Oligotrophic seasonally flooded herbaceous savanna of Chiquitania and Beni	LC	LC	LC	LC	NT	NT
Flooded savanna of the lowlands of Beni	LC	LC	LC	LC	LC	LC
Edapho-xerophytic savannas of Chiquitania (Rocky Cerrado, Rocky Field)	LC	LC	LC	VU	LC	VU
Neotropical aquatic and marsh vegetation of Chiquitania and Beni	LC	LC	LC	LC	NT	NT
Open forests and hygrophytic wooded savannas of the Southwestern Pantanal	LC	LC	VU	LC	LC	VU
Flooded riparian forests of the Western Pantanal	LC	LC	VU	LC	LC	VU
Neotropical aquatic and marsh vegetation of the Pantanal	LC	LC	VU	LC	LC	VU
Palm forest of south-central Amazonia	LC	LC	LC	LC	LC	LC
Blackwater stagnant alluvial forest of southern Amazonia	LC	LC	LC	LC	VU	VU
Clearwater stream forest of southwestern Amazonia	LC	LC	LC	LC	LC	LC
Flooded forest of the whitewater alluvial plain rivers of southwestern Amazonia	LC	LC	LC	LC	NT	NT
Flooded forest and riparian vegetation of blackwater of southwestern Amazonia	LC	LC	LC	LC	LC	LC
Palm swamp forests of the alluvial plain of the Upper Amazonia	LC	LC	VU	VU	LC	VU
Sub-Andean evergreen forest of southwestern Amazonia	LC	LC	LC	LC	LC	LC
Seasonal evergreen forest of the peneplain of southwestern Amazonia	LC	LC	LC	LC	LC	EN
Sub-Andean seasonal evergreen forest of southwestern Amazonia	LC	LC	LC	LC	LC	LC
Bamboo forest of southwestern Amazonia	LC	LC	CR	EN	LC	CR
Complex of successional riparian whitewater vegetation of Amazonia	LC	LC	LC	LC	NT	NT
Swampy grassland of the alluvial plain of the Upper Amazonia	LC	LC	LC	LC	NT	NT
Saxicolous shrubland of hills and ranges of south-central Amazonia	LC	LC	EN	EN	LC	EN
Savanna of south-central Amazonia transitional to Cerrado	LC	LC	VU	LC	LC	VU

Wooded and shrubby savannas of the Upper Amazonia on waterlogged soils	LC	LC	LC	LC	LC	LC
Forest of isolated ranges of south-central Amazonia	LC	LC	VU	LC	LC	VU
Clearwater stream forest of south-central Amazonia	LC	LC	LC	LC	LC	LC
Aquatic and marsh vegetation of Amazonia	LC	LC	EN	VU	LC	EN
Forest of the pre-Andean glacis of Southwestern Amazonia	LC	LC	LC	LC	LC	LC
Flooded forest and riparian vegetation of mixed waters of Amazonia	LC	LC	LC	LC	VU	VU
Palm swamp forest of the alluvial plain of southern Amazonia	LC	LC	LC	LC	NT	NT
Flooded forest of the alluvial plain of blackwater rivers of south-central Amazonia	LC	LC	LC	LC	LC	LC
Sclerophyllous chaparrals on well-drained soils of the Heath-Lower Madidi	LC	LC	CR	EN	LC	CR
Depressed terra firme forest of southern Amazonia	LC	LC	LC	LC	VU	VU
Forest flooded by stagnant whitewaters of southwestern Amazonia	LC	LC	LC	LC	NT	NT
Altimontane pluvial forest of Yungas	LC	LC	VU	LC	LC	VU
Altimontane pluvio-seasonal forest of Yungas	LC	LC	EN	LC	LC	EN
Pluvio-seasonal altimontane Polylepis forest of Yungas	LC	LC	VU	VU	LC	VU
Basimontane pluvial forest and palm grove of Yungas	LC	LC	LC	LC	LC	LC
Montane pluvial forest of Yungas	LC	LC	LC	LC	LC	LC
Montane pluvio-seasonal humid forest of Yungas	LC	LC	VU	LC	LC	VU
Basimontane pluvio-seasonal subhumid forest of southern Yungas	LC	LC	LC	LC	LC	LC
Basimontane pluvio-seasonal humid forest of Yungas	LC	LC	EN	LC	LC	EN
Xeric basimontane forest of southern Yungas	LC	LC	VU	LC	LC	VU
High Andean and altimontane shrub grassland pluvial of Yungas	LC	LC	VU	LC	LC	VU
High Andean and altimontane shrub grassland pluvio-seasonal of Yungas	LC	LC	VU	LC	LC	VU
Montane and basimontane wooded savanna of Yungas	LC	LC	EN	VU	LC	EN

Montane saxicolous vegetation of Yungas	LC	LC	CR	EN	LC	CR
High Andean peat bogs of the humid Puna (peatlands)	VU	VU	EN	LC	LC	EN
Low and shrub altimontane forests of the humid Puna	LC	LC	VU	LC	LC	VU
Montane xeric inter-Andean forest and shrubland of Yungas	LC	LC	CR	EN	VU	CR
High Andean grasslands of the humid Puna	LC	LC	LC	LC	LC	LC
Altimontane hygrophytic grasslands of the humid Puna	VU	NT	CR	EN	LC	CR
High Andean hygrophytic grasslands of the humid Puna	EN	EN	EN	LC	LC	EN
Altimontane grasslands and shrublands of the humid Puna	EN	EN	CR	CR	LC	CR
High Andean aquatic and marsh vegetation of the humid Puna	LC	LC	LC	LC	LC	LC
Subnival geliturbated vegetation of the humid Puna	LC	LC	VU	LC	LC	VU
Altimontane pluvio-seasonal Bolivian-Tucuman forest	LC	LC	EN	LC	LC	EN
Low altimontane edapho-xerophytic montane and basimontane Bolivian-Tucuman forests	LC	LC	VU	VU	LC	VU
Sub-Andean-inter-Andean phreatophytic Bolivian-Tucuman forests	LC	LC	LC	LC	LC	LC
Montane Bolivian-Tucuman forests of Pine of the Mountain	LC	LC	LC	LC	LC	LC
Humid montane Bolivian-Tucuman forests of Alder	LC	LC	CR	CR	LC	CR
Humid sub-Andean Bolivian-Tucuman forests	LC	LC	VU	LC	LC	VU
Sub-Andean-inter-Andean riparian Bolivian-Tucuman forests	LC	LC	EN	LC	LC	EN
Sub-Andean Bolivian-Tucuman forests transitional with Yungas	LC	LC	EN	LC	LC	EN
Subhumid Bolivian-Tucuman forests of the lower sub-Andean	LC	LC	VU	LC	LC	VU
Subhumid Bolivian-Tucuman forests of the upper sub-Andean	LC	LC	LC	LC	LC	LC
Subhumid montane Bolivian-Tucuman forests	LC	LC	EN	VU	LC	EN
Subhumid riparian montane Bolivian-Tucuman forests	LC	LC	EN	VU	LC	EN
Xeric inter-Andean montane Bolivian-Tucuman forests	LC	LC	VU	LC	LC	VU
Xerophytic inter-Andean-sub-Andean Bolivian-Tucuman forests	LC	LC	LC	LC	LC	LC
Secondary altimontane Bolivian-Tucuman shrublands	LC	LC	CR	EN	LC	CR

Montane pluvio-seasonal Bolivian-Tucuman shrublands	LC	LC	LC	LC	NT	NT
Xeric montane Bolivian-Tucuman shrublands	EN	EN	CR	VU	LC	CR
Altimontane Bolivian-Tucuman grasslands	LC	LC	LC	LC	LC	LC
Pluvio-seasonal montane Bolivian-Tucuman grasslands	LC	LC	VU	LC	LC	VU
High Andean pluvial Polylepis forest of Yungas	LC	LC	CR	EN	LC	CR
Montane pluvio-seasonal subhumid forest of Yungas	LC	LC	EN	EN	LC	EN
Successional riparian shrublands and forests of the Chaco	LC	LC	VU	LC	LC	VU
Forests of the sand dunes of northwestern Chaco	LC	LC	VU	LC	LC	VU
Phreatophytic forests of the Chaco (Algarrobo woodlands)	LC	LC	VU	LC	LC	VU
Hygrophytic forests of northern Chaco	LC	LC	LC	LC	NT	NT
Flooded riparian and recent alluvial plain forests of the Chaco	LC	LC	LC	LC	LC	LC
Forests on poorly drained soils of northwestern Chaco	LC	LC	LC	LC	NT	NT
Forests on poorly drained soils of eastern northern Chaco	LC	LC	CR	VU	LC	CR
Transitional forests from northern Chaco to Chiquitania, on sand dunes	LC	LC	CR	VU	LC	CR
Pre-Andean transitional forests of northwestern Chaco	LC	LC	VU	LC	LC	VU
Xeric forests of ancient alluvial plains of northwestern Chaco	LC	LC	LC	LC	LC	LC
Shrublands and thickets on recently poorly drained paleochannels of northern Chaco	LC	LC	EN	VU	LC	EN
Flooded palm groves of northern Chaco	LC	LC	LC	LC	NT	NT
Open flooded savannas of northern Chaco	LC	LC	VU	EN	LC	EN
Wooded savannas of the sand dunes of northwestern Chaco	LC	LC	VU	LC	LC	VU
Neotropical aquatic and marsh vegetation of the Chaco	LC	LC	EN	EN	LC	EN
Vegetation of the flooded salt flats of northern Chaco	VU	NT	LC	LC	LC	VU
Transitional forests from northern Chaco to Chiquitania, on rocky substrates	LC	LC	VU	LC	LC	VU
Transitional forests from northern Chaco to Chiquitania, on alluvial plain	EN	VU	LC	LC	LC	EN

Inter-Andean xerophytic shrublands of the lower eastern Prepuna	LC	LC	LC	LC	LC	LC
High Andean peat bogs of the xerophytic Puna	LC	LC	LC	LC	LC	LC
Low altimontane forests of central xerophytic Puna	LC	LC	LC	LC	LC	LC
High Andean low forests of western xerophytic Puna	LC	LC	LC	LC	LC	LC
High Andean low forests of eastern xerophytic Puna	LC	LC	VU	LC	LC	VU
Low inter-Andean xerophytic forests of the upper eastern Prepuna	LC	LC	LC	LC	LC	LC
Phreatophytic forests of the xerophytic montane belt	LC	NT	VU	VU	LC	VU
High Andean cardonales of western xerophytic Puna	LC	LC	VU	LC	LC	VU
Psammophilous altimontane and high Andean shrublands of xerophytic Puna	LC	LC	LC	LC	LC	LC
Hygrophilous high Andean shrublands of xerophytic Puna, tholares	LC	LC	LC	LC	LC	LC
Altimontane and high Andean shrublands and grasslands of eastern xerophytic Puna	LC	LC	LC	LC	LC	LC
Hygrophilous high Andean grasslands of xerophytic Puna	NT	NT	LC	LC	LC	NT
High Andean shrublands and grasslands of northern xerophytic Puna	LC	LC	LC	LC	NT	NT
High Andean shrublands and grasslands of southwestern xerophytic Puna	LC	LC	VU	LC	LC	VU
Open high Andean geliturbated vegetation of northern and eastern xerophytic Puna	LC	LC	LC	LC	LC	LC
Open high Andean geliturbated vegetation of southwestern xerophytic Puna	LC	LC	LC	LC	LC	LC
High Andean aquatic and marsh vegetation of xerophytic Puna	LC	LC	LC	LC	LC	LC
Vegetation of the high Andean salt flats of xerophytic Puna	LC	LC	LC	LC	LC	LC
Riparian vegetation of the xerophytic montane belt	LC	LC	VU	VU	LC	VU
Complex of non-alkaline savannas of Beni transitional to Cerrado	NT	LC	LC	LC	LC	NT
Complex of alkaline savannas of Beni	EN	VU	VU	LC	LC	EN
Complex of whitewater-flooded savannas of Beni	LC	LC	LC	LC	LC	LC
Complex of swamps of Beni	LC	LC	LC	LC	NT	NT
Complex of whitewater forest and riparian vegetation of Beni	LC	LC	LC	LC	NT	NT

Cerrado complex of northern Beni	LC	LC	LC	LC	LC	LC
Complex of mixed-water forest and riparian vegetation of Beni	LC	LC	EN	LC	LC	EN
Complex of clearwater and blackwater forest and riparian vegetation of Beni	LC	LC	EN	VU	LC	EN
Water body	LC	LC	LC	LC	NT	NT
Salt Lake	LC	LC	LC	LC	LC	LC

Table S4. Risk indicator for EFGs in Bolivia based on the Red List Ecosystem Index (RLIE).

EFGs for Bolivia	**RLIE**
T1.1 Tropical-subtropical lowland rainforests	0.68
T1.2 Tropical-subtropical dry forests and thickets	0.62
T1.3 Tropical-subtropical montane rainforests	0.62
T3.1 Seasonally dry tropical shrublands	0.54
T4.2 Pyric tussock savannas	0.74
T6.1 Ice sheets, glaciers and perennial snowfields	0.80
T6.4 Temperate alpine grasslands and shrublands	0.72
T6.5 Tropical alpine grasslands and shrublands	0.69
TF1.1 Tropical flooded forests and peat forests	0.77
TF1.3 Permanent marshes	0.80
TF1.4 Seasonal floodplain marshes	0.50
TF1.5 Episodic arid floodplains	0.80
TF1.6 Boreal, temperate and montane peat bogs	0.70
TF1.7 Boreal and temperate fens	0.30
F1.2 Permanent lowland rivers/ F2.1 Large permanent freshwater lakes	1
F2.2 Small permanent freshwater lakes	0.8
F2.3 Seasonal freshwater lakes	0.40
F2.5 Ephemeral freshwater lakes	0.40

F2.6 Permanent salt and soda lakes	0.60
All	0.68

Table S5. Spatial distribution (%) of IUCN Ecosystem Functional Group (EFG) types in Bolivia by threat category within protected and unprotected areas.

IUCN Ecosystem Functional Group (EFG)	**CR**		**EN**		**VU**	
	Protected	**Unprotected**	**Protected**	**Unprotected**	**Protected**	**Unprotected**
T1.1 Tropical-subtropical lowland rainforests	-	11.61	-	-	4.98	6.65
T1.2 Tropical-subtropical dry forests and thickets	41.67	9.37	10.56	22.32	11.09	10.84
T1.3 Tropical-subtropical montane rainforests	0.43	6.04	13.93	10.26	4.40	5.05
T3.1 Seasonally dry tropical shrublands	0.26	-	0.54	1.85	6.93	4.32
T4.2 Pyric tussock savannas	-	-	5.21	10.97	3.03	3.56
T6.1 Ice sheets, glaciers and perennial snowfields	-	-	-	-	0.85	1.32
T6.4 Temperate alpine grasslands and shrublands	1.51	3.44	0.97	6.82	0.73	9.44

T6.5 Tropical alpine grasslands and shrublands	0.30	-	-	-	2.07	4.39
TF1.1 Tropical flooded forests and peat forests	-	0.18	1.33	5.07	6.68	9.24
TF1.3 Permanent marshes	-	-	-	-	1.64	0.18
TF1.4 Seasonal floodplain marshes	24.48	0.13	1.00	3.58	1.44	0.92
TF1.5 Episodic arid floodplains	-	-	-	-	-	-
TF1.6 Boreal, temperate and montane peat bogs	-	-	0.62	0.94	-	-
TF1.7 Boreal and temperate fens	0.04	0.54	0.17	1.31	-	-
F 1.2 Permanent lowland rivers/ F2.1 Large permanent freshwater lakes	-	-	-	-	-	-
F2.2 Small permanent freshwater lakes	-	-	1.08	0.87	-	-
F2.3 Seasonal freshwater lakes	-	-	0.25	0.07	-	-
F2.5 Ephemeral freshwater lakes	-	-	0.17	0.12	-	-
F2.6 Permanent salt and soda lakes	-	-	-	-	0.14	0.13
All	68.69	31.31	35.83	64.17	43.97	56.03