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ROSA: An Andean Network of Social–Ecological Observatories

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We present the Andean Social–Ecological Observatory Network (ROSA, for Red de Observatorios Socioecológicos Andinos*), a continent-wide monitoring initiative established to address major challenges in the management of knowledge on social–ecological systems (SES) in the Andes. The Andes, the longest mountain chain in the world, provide key ecosystem services for human wellbeing across the continent. However, the region faces multiple impacts associated with climate change and land-use change related to demographic transitions, and thus long-term monitoring is key for developing adaptation strategies to this environmental change. ROSA constitutes a bottom-up initiative to systematize and integrate social and ecological monitoring efforts into observatories, and to do so under a coproduced framework that fosters science–policy dialogue and promotes sustainable land management. The main research questions addressed by these social–ecological observatories include understanding how distant and proximate drivers of change interact with local social, cultural, economic, and environmental contexts to influence the functioning of different SES in the Andes at multiple spatial and temporal scales. We describe the origins, structure, objectives, and strategies of ROSA and key challenges faced by different monitoring networks working in the region with regard to data generation and knowledge transfer. Currently, ROSA consists of 8 nodal observatories, comprising more than 50 monitoring initiatives focused on hydroclimate, ecological, and land-use dimensions. The bottom-up structure of ROSA is founded on proven expertise in long-term data gathering and analyses and on the strong commitment of nodal monitoring groups. Effective codesign and participatory monitoring are being developed so that ROSA can contribute to knowledge coproduction for sustainable land management.*

Keywords: *Andean social–ecological systems; decision-making processes; long-term monitoring; sustainable land management; transdisciplinary science.*

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Introduction

Background and relevance

The complex, dynamic, and multidimensional interactions of the components of social–ecological systems (SES) hinder the identification of causal relationships (Martínez-Fernández et al 2021). Addressing SES in biological and cultural diversity hotspots such as the Andes can help us to understand the interactions that emerge in a heterogeneous landscape and how these systems are affected by global changes. The Andes, the longest and second highest mountain range on Earth, extend from the tropics to southern Patagonia. The headwaters of South America's most important river systems originate here, providing essential ecosystem services for more than 65 million people in the Andean mountains and in the South American lowlands (Isbell et al 2017; Mathez-Stiefel et al 2017). Despite the importance of the Andes, initiatives that integrate social and ecological information at different spatial and temporal scales are scarce, limiting our understanding of the interactions of SES components and their responses to global changes (eg Collins et al 2011).

Long-term social–ecological monitoring (LTSEM) is a key mechanism by which to identify the essential factors that increase the resilience of SES to global change and reduce ecosystem degradation. Accordingly, the integration of data generated by existing LTSEM efforts and the dissemination of emerging information can facilitate participatory and sustainable management (Carilla, Aráoz, Osinaga, et al 2023). However, integrating LTSEM when considering broad spatial and temporal scales and the requirements and worldviews of diverse actors poses major challenges. The wide variety of networks in the Andes that address the generation of knowledge, its management, and its transfer to policymakers and the public creates various data-related, conceptual, and operational challenges (Carilla, Aráoz, Osinaga, et al 2023). These challenges are summarized as follows: (1) strike a balance between the thorough comprehension gained from local case studies and the global scope of integrated studies across disciplines and spatial scales; (2) attain a consistent and integrated monitoring approach in the Andes, including currently underrepresented social dimensions as well as experiences of participatory monitoring and codesign articulated with stakeholders; (3) handle the trade-off between locally specific studies and regional harmonization that emerges from bottom-up data gathering and synthesis; (4) effectively integrate diverse forms of knowledge, reconciling perspectives, beliefs, and traditional knowledge into unified conceptual models and systematic monitoring efforts; (5) achieve effective science–policy dialogues, addressing concrete questions and governance challenges; (6) implement participatory comanagement, considering social differences and minimizing conflicts; and (7) ensure the commitment of researchers to transdisciplinary and long-term monitoring efforts.

This article presents conceptual and methodological proposals for the creation, consolidation, and operationalization of an Andean Social–Ecological Observatory Network (ROSA, for *Red de Observatorios Socioecológicos Andinos*) (ROSA n.d.) in a governance framework. We describe the establishment of ROSA, which involved an analysis of gaps in existing SES monitoring efforts in the Andean region, as well as dialogues with scientists and stakeholders. We then discuss the consolidation process, which included the definition of ROSA's structure and agenda, the challenges addressed, and a first assessment of the progress of the nodal observatories that have joined the network.

Collaborative LTSEM to promote informed decision-making and actions

A recent review of current monitoring in the Andes identified more than 200 LTSEM research initiatives, highlighting the need to consolidate the networks through ROSA. This monitoring database was compared with a conceptual model of knowledge management generated through participatory meetings (Carilla, Aráoz, Osinaga, et al 2023). In agreement with other studies (eg Peralvo et al 2024), Carilla, Aráoz, Osinaga, et al (2023) highlighted the need for an integrated long-term monitoring approach involving academia, governments, decision-makers, and civil society in coproduction processes to achieve sustainable land management. The authors also identified significant challenges to consolidating an integrated monitoring approach in the Andes, including the consideration of currently underrepresented social dimensions and the scarcity of participatory monitoring and collaborative research design (Carilla, Aráoz, Osinaga, et al 2023). Some pioneering national initiatives, such as the Strategy for Integrated Monitoring of High Mountain Ecosystems of Colombia (EMA; Llambí et al 2019), promote an integrated monitoring approach in high mountain environments, taking into account multiple scales and ecosystems and diverse SES. EMA also highlights the links between changes in socioeconomic, cultural, and political contexts with land-use and climate change, the provision of ecosystem services, and human wellbeing (Llambí et al 2019). This national, transdisciplinary approach has not been systematically replicated in other regions of the Andes; in contrast, existing thematic networks addressing biophysical aspects in the region are well consolidated.

Recognized international monitoring networks that assess vegetation responses to climate and land-use change include the Andean node of the Global Observation Research Initiative in Alpine Environments (GLORIA-Andes) (Red GLORIA-Andes n.d.) and the Andean Forest Network (RBA, for *Red de Bosques Andinos*) (RBA n.d.). Hydrological responses to land-use and land-cover change are covered by networks such as the *Iniciativa Regional de Monitoreo Hidrológico de Ecosistemas Andinos* (iMHEA) (iMHEA n.d.). These represent successful long-term collaborative initiatives that link Andean researchers who are using common monitoring protocols and addressing research questions at a continental scale (Cuesta et al 2017; Ochoa-Tocachi et al 2018; Malizia et al 2020). In addition, different studies have sought to combine biophysical metrics (eg land-cover dynamics or biological invasions) with socioeconomic processes (eg urbanization or migration) at regional scales within the Andes (Aide et al 2019; González et al 2024). These complementary approaches represent an essential foundation for ROSA to deal with the trade-off between local studies and regional standardization arising from its bottom-up approach. Globally, several platforms are dedicated to mountain monitoring (Adler et al 2018;

Shahgedanova et al 2021), such as the Global Mountain Biodiversity Assessment (GMBA, supported by Future Earth), the International Long-Term Ecological Research Network (ILTER), and the Global Network for Observations and Information on Mountain Environments (GNOME), linked with the Mountain Research Initiative (MRI). These platforms collect multiscale data from biophysical and social dimensions, with different approaches that aim to capture the complexity and heterogeneity of mountain SES. Yet, none of these effectively tackles social–ecological issues from an integrated perspective in the Andes. They do, however, provide specific and disciplinary integration strategies useful for the transdisciplinary approach of ROSA.

The ROSA Initiative

Approach and guiding questions

ROSA (ROSA n.d.) was created to gather information on social and ecological patterns and dynamics into observatories, integrating this information and making it available to decision-makers for the sustainable management of Andean SES. ROSA has adopted a bottom-up approach of consolidating and integrating existing ecological and socioeconomic monitoring initiatives in the Andes into regional mountain observatories. The aim of this integration is to refine a common conceptual framework, conduct regional analyses, and define protocols for collecting comparable social–ecological data (see Figure S1, *Supplemental material*, https://doi.org/10.1659/mrd.2023.00048.S1). The main research questions guiding ROSA focus on understanding (1) how SES and their dynamics are characterized in space and (2) which drivers influence Andean SES and how they interact with social, cultural, economic, and environmental contexts at multiple spatial and temporal scales. The integrated approach adopted by ROSA permits specific issues grounded in real-world problems linked to the United Nations Sustainable Development Goals (SDGs) to be addressed and indicators to monitor different SDGs to be identified.

SES and social–ecological land system mapping

A first step to characterizing SES is to consider the physical and biotic environment, human populations, and their institutions, and the processes and feedbacks among these components (Verburg et al 2009; Martín-López et al 2017). The complexity and diversity of SES can be classified using social–ecological land systems (SELS), which are typologies that consider the main social and ecological processes occurring within land systems (Boillat et al 2017). SELS have been classified and mapped in South America using geographic and social–ecological features that are quantifiable at a continental scale (Zarbá et al 2022). ROSA seeks to downscale this continental classification to the Andes and include some specific features (eg snow cover). Andean SELS constitute a geographic framework for analyzing the representativeness of the observatories and to identify underrepresented regions.

The consolidation of ROSA

The consolidation phase of ROSA included 3 workshops and a webinar in 2023 with the goal to exchange information and ideas with 25 experts working in Andean SES. In 2 virtual workshops, we presented a draft map of Andean SELS and discussed the variables to be included in their definition, identified existing monitoring networks in the Andes and other mountains, and outlined the creation of ROSA. In the third, face-to-face workshop, held in Tucumán, Argentina, ROSA members, the provincial government, and local nongovernmental organizations (NGOs) presented their experiences with SES monitoring sites throughout the Andes. The participants discussed the operational structure and functioning of ROSA and identified priority lines of research to address social–ecological challenges, generating an explicit space for science–policy dialogue and commitment by the participants to the sustainability of the network. The final products of the workshops were presented at a webinar organized by the Global Land Program (GLP) (GLP 2023M).

During the workshops, we elaborated an agenda for strengthening and increasing the visibility of ROSA. The proposed actions comprised relevant tasks at different stages of development related to data management, collaborations, capacity building, communication, finances, and research (Table 1). One key ongoing activity is the production of a book that includes information about each ROSA observatory, and monitoring efforts comprising both biophysical and social research that can contribute to a comparative continental analysis of the dynamics and drivers in diverse Andean SES from Venezuela to Argentina.

The objectives of ROSA

The main objectives of ROSA are to:

1. Gather, systematize, and combine monitoring efforts across the Andes into a network of nodal observatories focused on the main Andean SES, identify geographic and thematic knowledge gaps, and publish the information (addressing challenges 1 and 2).
2. Connect the knowledge derived from integrated and codesigned monitoring to decision-making processes and the sustainable management of Andean SES (addressing challenges 4 and 6).
3. Enhance South–South cooperation among researchers and institutions from Andean countries involved in ROSA, facilitating collaboration, capacity building, knowledge coproduction, and communication on a continental scale. This aims to foster science–policy dialogue, promote the integration and sustainability of the monitoring processes developed in each observatory, and articulate them with governance processes (addressing challenges 3, 5, and 7).

Strategies for the functioning of ROSA

ROSA defines "monitoring" as the repeated recording of a variable of interest following a standard protocol and defines monitoring sites as "observatories," where series of social and environmental variables are collected regularly, where multiple actors participate, and where monitoring is integrated into a broader framework of governance and sustainable land management (eg the Chocó Andino approach in Ecuador; Peralvo et al 2024). ROSA adopts a bottom-up approach, building on existing ecological and

TABLE 1 Summary of the strategies and activities planned for ROSA based on the purposes of the network and the challenges that each strategy addresses. (Table continued on next page.)

Purpose	Strategies	Status	Challenges
1. Data management	1.1. Compile and publish initial metadata for monitoring initiatives within each observatory	Done	(2) Attain consistent and integrated approach
	1.2. Establish formal commitment and protocol to share data internally among ROSA researchers to address common research goals	Ongoing	(1) Balance local and global perspectives (7) Ensure commitment of researchers to the goals
	1.3. Advance the integration of social, political, economic, biological, and environmental data in common databases	Future direction	(2) Attain consistent and integrated approach
	1.4. Generate standardized protocols to gather comparable social–ecological data at all the Andean observatories	Future direction	(3) Handle local/regional trade-off emerging from bottom-up data processing
2. Collaborations	2.1. Join with other mountain networks (eg GLP, MRI) to work on common tasks (eg workshop organization, publications, data integration)	Ongoing	(6) Implement participatory comanagement
	2.2. Promote science–policy–stakeholder dialogue and coproduction of knowledge among academics, communities (urban and local), organizations, and decision-makers from landowners to government institutions (and within each group) through workshops	Partly done, partly ongoing	(5) Achieve effective science–policy dialogues (6) Implement participatory comanagement
3. Experience exchange and capacity building	3.1. Generate regional spaces for experience exchange and capacity building to address integrated social–ecological monitoring approaches, participatory research, science–policy dialogue, and codesign/comanagement (eg workshops, webinars, newsletters)	Partly done, partly ongoing	(3) Handle local/regional trade-off emerging from bottom-up data processing (5) Achieve effective science–policy dialogues (6) Implement participatory comanagement
4. Communication	4.1. Increase ROSA's visibility and outreach through publications, policy briefs, and participation in conferences and meetings to reach the scientific community	Ongoing	(5) Achieve effective science–policy dialogues
	4.2. Reach broader audiences with a website for ROSA that includes general information on the network and the observatories (https://condesan.org/rosa/)	Done	(5) Achieve effective science–policy dialogues
5. Financial strategies	5.1. Identify financial sources and funding mechanisms and submit proposals for workshops, organizational activities, publications, and expert hiring (eg data manager, web designer)	Ongoing	(7) Ensure commitment of researchers to the goals
6. Research priorities	6.1. Publish scientific articles detailing the objectives, structure, and selected observatories of ROSA across the Andes	Done	(1) Balance local and global perspectives (3) Handle local/regional trade-off emerging from bottom-up data processing (7) Ensure commitment of researchers to the goals

TABLE 1 Continued. (First part of Table 1 on previous page.)

Purpose	Strategies	Status	Challenges
6. Research priorities (cont'd)	6.2. Publish a classification of SELS for the Andes using biophysical and socioeconomic variables	Ongoing	(1) Balance local and global perspectives (2) Attain consistent and integrated approach
	6.3. Publish a book that describes the history, current state, and dynamics of the nodal Andean observatories based on their monitoring systems and other available information	Ongoing	(1) Balance local and global perspectives (2) Attain consistent and integrated approach
	6.4. Continue to answer relevant questions and develop working hypotheses around interactions and feedback in environmental, land-use, socioeconomic, and political changes in biodiversity, ecosystem services, and human wellbeing in representative areas of the Andes at different spatial scales (including the views of local stakeholders)	Future direction	(4) Integrate diverse forms of knowledge (6) Implement participatory comanagement
	6.5. Analyze the functioning of Andean SES and possible interaction of variables characterizing SES	Future direction	(2) Attain consistent and integrated approach (4) Integrate diverse forms of knowledge
	6.6. Describe temporal, elevational, and latitudinal patterns of the territorial dynamics in the Andes	Future direction	(3) Handle local/regional trade-off emerging from bottom-up data processing
	6.7. Identify the political and economic exogenous (global demands, international policies, telecouplings) and endogenous drivers (eg tourism) that affect biodiversity and human wellbeing in the Andes	Future direction	(1) Balance local and global perspectives
	6.8. Develop an integrated conceptual model to analyze SES dynamics at multiple temporal and spatial scales	Future direction	(5) Achieve effective science–policy dialogues

social monitoring sites in the Andes and integrating them into a network of nodal observatories. These nodal observatories are intended to serve as learning sites, and a key ongoing task has been to organize, systematize, and publish local/regional information generated by long-term research and monitoring at each observatory. In a second phase, ROSA will expand the network to fill geographic and thematic gaps in SELS by establishing additional observatories and filling spatial gaps with sensitive proxies (eg remote sensing to track human-associated activities such as urbanization) and by incorporating new sources of information (eg social data elicited from big data). A unified conceptual framework and protocol for the observatories will be developed over the medium to long term to enable the collection of comparable social–ecological data and to promote the integration of monitoring into decision-making processes at multiple scales.

ROSA researchers aim to make observations and analyze data at different temporal and spatial scales. These efforts include (1) analysis of environmental history; (2) monitoring at the plot site scale to represent the variability of environmental conditions and ecosystems within a nodal observatory; (3) monitoring at the landscape scale (Turner and Gardner 2015), defined in terms of functional units (eg watershed, municipalities), where monitoring points (eg plots, hydroclimate stations) are distributed along main gradients of interest (eg topography, land use); and (4) monitoring at the regional or continental scale, where observatories are distributed through the Andes and represent different biomes, political contexts, and SELS. The scaling up of data from the plot level to broader scales will allow the estimation of ecosystem processes or services (eg carbon stocks [see Cuesta, Calderón-Loor, et al 2023]; or hydrological regulation [see, eg, Rodríguez-Morales et al 2019; Jimenez and Aráoz 2024]). ROSA emphasizes the importance of comparative analyses that consider the representativeness of nodal sites under diverse criteria to tackle the challenge of integration at regional scales (eg different socioeconomic/political and environmental systems).

ROSA researchers will build conceptual models that consider the guiding questions on the different scales of analysis, and, wherever possible, these models will be coconstructed with the different actors involved in land management (particularly at the observatory scale). The models will allow the main drivers of change (eg climate change, land-use change) to be explicitly identified, response variables (eg social and environmental conditions) to be monitored, and functioning hypotheses to be compared with data (Etienne et al 2011; Llambí et al 2019; Carilla, Aráoz, Osinaga, et al 2023). In addition, these coproduced conceptual models constitute a common language for integrating knowledge, beliefs, and cultures. Although their construction is challenging, they must be evaluated in terms of their utility for specific purposes (eg to identify LTSEM gaps; see Carilla, Aráoz, Osinaga, et al 2023). These conceptual models will help to address the challenges of integrating monitoring efforts from local studies to a regional network in the bottom-up approach.

Organizational structure

The ROSA team is composed of researchers from an initial set of nodal observatories, with the expectation of including additional researchers and observatories. These researchers are committed to sustaining LTSEM at each site, promoting an integrative analysis of the information and data available on different social–ecological processes, identifying knowledge gaps and opportunities that can be progressively addressed, and including local decision-makers and organizations in the monitoring cycle. ROSA has defined an initial governance structure constituted by a steering committee with one representative each from the northern (Venezuela, Colombia, Ecuador), central (Peru, Bolivia), and southern (Chile, Argentina) Andes. Additionally, ROSA has an advisory board of 6 researchers, several technicians, and a capacity-building specialist that offers support for knowledge management and communication, science–policy dialogue, database management, and fundraising. The board is working toward the maintenance of long-term monitoring observatories in the Andes. ROSA's organizational structure seeks to tackle challenges by creating dialogue spaces, coparticipatory management, and commitment to ensure ROSA's sustainability (see Figure S1, *Supplemental material*, https://doi.org/10.1659/mrd.2023.00048.S1).

Selection of nodal observatories

Four criteria were considered when selecting the initial set of ROSA nodal observatories.

(1) A meaningful geographic unit with clear administrative borders: A second-order administrative unit (typically a municipality, or a set of adjacent municipalities) was proposed as a reference frame for ROSA observatories because social and demographic data are usually aggregated at this administrative level. This also offers a clear opportunity to link monitoring to decision-making, including social and economic dimensions. In addition, observatories can be linked to physiographic units such as catchments/watersheds and their ecosystems or land-cover/land-use types. This allows changes that occur along physiographic and land-use gradients to be quantified. Incorporation of information from larger administrative units (eg state/province/region, protected areas, or particular economic land-use areas), in which the observatory is located, and which are relevant for the functioning of its SES, is also desirable. In addition, contextual information from outside the borders could be relevant for specific analyses, for example, data from nearby urban centers, wider hydrological watersheds, or specific mountain ranges.

(2) Representativeness of SES widely distributed in the Andes: Ideally, observatories across the Andes should be representative of the physiographic and sociocultural diversity of Andean SES to grasp the heterogeneity of the Andean system. Representativeness can be assessed through different criteria. The first criterion is to include at least one observatory from each country to represent socioeconomic, political, and cultural diversity. Biological representativeness can be based on ecoregions or biomes. In addition, representativeness can be based on SELS (or Andean SELS) classification as a key input (Boillat et al 2017; Zarbá et al 2022; Table 2).

(3) Availability of high-quality long-term data at different scales: The characterization, comparison, and detection of changes in SES must be based on reliable quantitative data. Data sharing is a key factor in the successful functioning of the ROSA network, so a critical assessment of the quality, potential uses, and limitations of available data is being undertaken. To adequately characterize an SES, replicable datasets reflecting cultural heritage, human development, environmental context, and history are required; for a list of indicators, see Appendix S1 (*Supplemental material*, https://doi.org/10.1659/mrd.2023.00048.S1).

Detailed field surveys (eg vegetation composition and cover in permanent plots), following established protocols (eg GLORIA or RBA), accurately depict a local system, ensuring that it can be compared with other systems. This can be complemented with remotely sensed and global data models (eg the normalized difference vegetation index, or the snow cover extent and duration; Carilla, Aráoz, Foguet, et al 2023), which usually present large spatial coverage and regular revisitation, allowing regional/global comparisons. The combination of locally measured processes and large-scale patterns permits the calibration and validation of social–ecological indicators. With the advent of big data, collaborative networks are becoming increasingly capable of addressing questions that depend on large volumes of data (Gorelick et al 2017). For example, biodiversity assessments through the Global Biodiversity Information Facility (GBIF) and similar collaborative networks could be considered to characterize regional processes, or to integrate and enrich local data from permanent plots (Cuesta, Carilla, et al 2023; Gonzalez et al 2023). The lack of high-quality local data, in addition to limited data access, which is essential to calibrating large-scale datasets, usually constitutes a limiting condition.

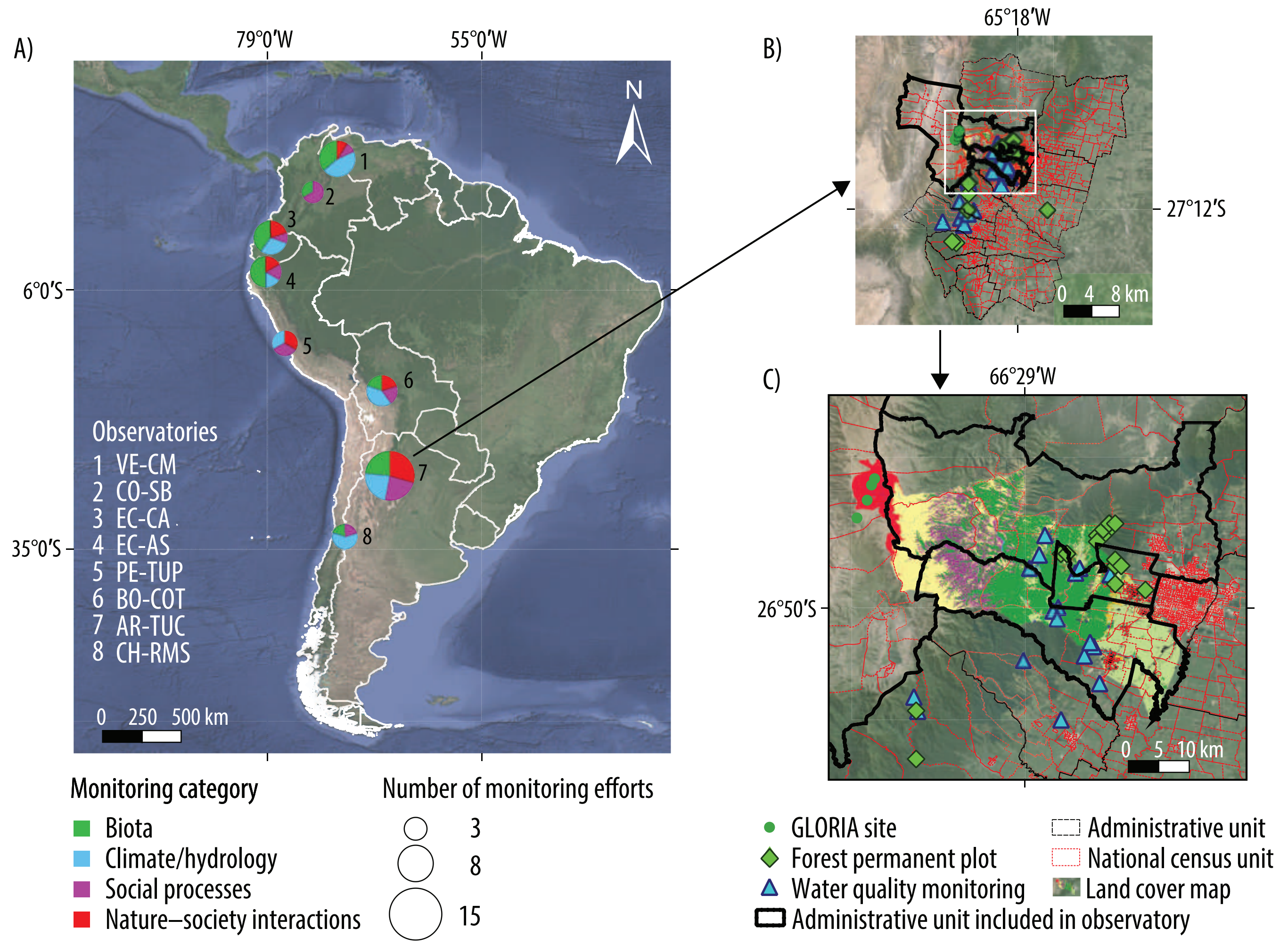
(4) Local research teams engaged in LTSEM: The core information for ROSA is derived from local surveys conducted by researchers, municipalities, national governments, or other actors (eg citizen science), following established protocols. ROSA is also able to include additional data sources (eg opportunistic records, collaborative databases, or remotely sensed information). These data, which are crucial for rigorous comparative analyses at a continental scale, must be verified by local teams with a strong long-term commitment to the importance of LTSEM and experience in collaborative regional analysis. While understanding the advantages of sharing information (profiting from the experience of established

TABLE 2 The 8 current nodal observatories of ROSA. Their identifiers (IDs) are ordered from north to south. Their names correspond to their geographical location, which encompasses one or several second-order administrative units (usually one or several municipalities). The area is that of the second-order administrative unit (s) that constitute the observatory. We also indicate the institution and researcher(s) responsible for the creation of and follow-up on each observatory, and their contact information.

Observatory ID	Observatory name	Second-order administrative unit	Area (km^2)	Institution	Responsible/PI	Contact
1 VE-CM	Cordillera de Mérida, Venezuela	Santos Marquina and Rangel municipalities	1291	Instituto de Ciencias Ambientales y Ecológicas, Universidad de Los Andes	Luis Daniel Llambí	ldllambi@gmail.com
2 CO-SB	Cordillera Oriental, Sabana de Bogotá, Colombia	Municipalities from Cundinamarca department	5325	Instituto de Investigación de Recursos Biológicos Alexander von Humboldt Fundación Cedrela	Natalia Norden; Ana Belén Hurtado; Omar Ruiz Nieto	nnorden@humboldt.org.co ahurtado@humboldt.org.co oruiz@humboldt.org.co
3 EC-CA	Reserva de Biósfera del Chocó Andino, Ecuador	Pichincha provincial government; Quito Metropolitan District, San Miguel de los Bancos, and Pedro Vicente Maldonado municipalities	2869	Universidad San Francisco de Quito and Facultad Latinoamericana de Ciencias Sociales (FLACSO) Ecuador	Francisco Cuesta; Blanca Ríos; Nicolás Cuvi	fcuesta@usfq.edu.ec; briostouma@gmail.com; ncuvi@flacso.edu.ec
4 EC-AS	Andes sur del Ecuador	Loja canton and San Lucas, Santiago, and Jimbilla parishes	660	Universidad Nacional de Loja, Centro de Investigaciones Tropicales del Ambiente y Biodiversidad (CITIAB)	Tatiana Ojeda Luna; Nikolay Aguirre	tatiana.oluna@unl.edu.ec; nikolay.aguirre@unl.edu.ec
5 PE-TUP	Tupicocha, Perú	Huarochirí and Lima	120	CONDESAN	Vivien Bonnesoeur	bonnesoeur.vivien@protonmail.com
6 BO-COT	Cordillera Central, Cordillera Oriental de Bolivia, Cordillera del Tunari, Bolivia	Cochabamba department, Tunari National Park, Quillacollo province, Tiquipaya municipality	572	Universidad Católica Boliviana "San Pablo," Sede Cochabamba	Wanderley J. Ferreira	wferreira@ucb.edu.bo
7 AR-TUC	Tucumán, Argentina	Lules, Yerba Buena, Tafi Viejo, and Tafí del Valle departments, Tucumán province	4651	Instituto de Ecología Regional (IER), Universidad Nacional de Tucumán (UNT)–Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)	Ricardo Grau; Julieta Carilla	chilograu@gmail.com; julietacarilla@gmail.com
8 CH-RMS	Cordillera Central, Región Metropolitana de Santiago, Chile	San José de Maipo and Lo Barnechea municipalities	7773	Centro de Investigación en Tecnologías para la Sociedad (C+), Universidad del Desarrollo	Patricia Breuer; Petra Wallem	p.breuer@udd.cl; petra.wallem@gmail.com

Note: PI, principal investigator.

FIGURE 1 (A) Distribution of the selected nodal observatories, and their thematic monitoring categories. For an explanation of the observatory codes, see Table 2. (B) Spatial scales are illustrated using the example of Observatory 7, showing Tucumán province, with its second-order administrative units (municipalities) and national census units, the administrative units included in the observatory (thicker boundary lines), and the locations of monitoring efforts focused on vegetation and hydrology. (C) Detail additionally showing a land-cover map of the Rio Lules basin. (Map by Yohana Jimenez).



Source of base map: Google Satellite, accessed via the QuickMapServices plugin in QGIS. Source of National Census units: National Institute of Statistics and Census, revised by Rodriguez and De Grande (2022). Source of land cover map: Jimenez et al (2021)

monitoring networks in the region), research groups must be able to address the trade-off between locally specific questions and the use of standardized protocols.

Characteristics of the nodal observatories

Currently, the ROSA network comprises 8 nodal observatories along the Andes, across 7 Andean countries, overseen by researchers from academic institutions and an NGO (Figure 1; Table 2; see also Figure S1, *Supplemental material*, https://doi.org/10.1659/mrd.2023.00048.S1). Nodal observatories have documented 53 specific monitoring efforts, mainly focused on climate, hydrology, and biota dynamics. Regarding biota, most observatories belong to continent-wide vegetation monitoring networks (ie GLORIA-Andes, RBA, and the Rastrojo program). All observatories monitor social processes, mainly through the national population and agricultural censuses (associated with the administrative unit of analysis), and 6 observatories monitor nature–society interactions (eg land-use and land-cover change). So far, geomorphological processes have not been systematically monitored in most of the observatories, except for soil monitoring. Two observatories have public data available, while to obtain data from the others, contact with the institutions or researchers is required. Explicit participation and continuous dialogue with policymakers and other local stakeholders in the context of monitoring processes (local community organizations, etc) are still major challenges, with 3 pioneering observatories showing different levels of consolidation of these interactions—only one observatory has produced a publication (Cuesta, Calderón-Loor, et al 2023) (Table 3; see also Appendices S2 and S3, *Supplemental material*, https://doi.org/10.1659/mrd.2023.00048.S1). Regarding data management, as this is a collaborative process, the criteria established by each contributor must be respected. We expect to make data available in the medium term with a restriction policy similar to that of the GLORIA-Andes network (Red GLORIA-Andes n.d.).

TABLE 3 The number of ongoing monitoring initiatives in each of the current nodal observatories of ROSA by key monitoring category and by status of interaction with policymakers.

Observatory ID	Monitoring category				Interaction with policymakers		
	Biota	Climate/ hydrology	Social processes	Nature–society interactions	Initial stages	Advanced stages	Concrete product
1 VE-CM	4	5	1	1	1	0	0
2 CO-SB	1	0	2	0	0	0	0
3 EC-CA	4	3	1	2	0	0	1
4 EC-AS	3	1	1	1	0	0	0
5 PE-TUP	0	2	2	2	1	0	0
6 BO-COT	1	2	1	1	1	2	0
7 AR-TUC	4	4*	4	5	2	1	0
8 CH-RMS	1	3*	1	0	0	0	0

Note: The observatory codes are explained in Table 2. Monitoring with public access to data is indicated with an asterisk (*).

Highlights and conclusions

ROSA is an Andean regional collaborative initiative that aims to synthesize, systematize, and integrate different sources of information to understand the dynamics of social and ecological systems across the region, filling the existing knowledge gaps. The Andes provide common ground and opportunities relevant to global mountain science, despite, and because of, the complex and heterogeneous nature of this long and diverse mountain chain at different scales. There are institutions and stakeholders interested in consolidating the ROSA initiative, including a motivated group of researchers, local communities, and governments associated with observatories with shared interests and principles (transparency, objectivity, commitment), working in a transdisciplinary approach, with institutional support. They offer reliable monitoring sites as prospective nodal observatories; these efforts combine the value of past monitoring systems and knowledge of environmental history with the progressive inclusion of modern methods and approaches.

ROSA is supported by the background and experience of several preexisting networks that have collaborated across the Andes, using standard protocols and sharing information and approaches for more than a decade (eg GLORIA, RBA). It also has the support of regional/international organizations and scientific societies (CONDESAN, GLP). During the process of establishing and consolidating ROSA, different challenges faced by regional networks were considered. Throughout this article, we have discussed ways of addressing these challenges, but, in some cases, we acknowledge that we still have a long way to go. The main challenges include effectively integrating social and ecological research efforts; circumventing biases associated with different scales and variable types and sources of information; generating mechanisms to answer questions that society (particularly local stakeholders) considers relevant to effectively manage SES; and understanding how these questions change based on emerging needs.

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OPEN PEER REVIEW

This article was reviewed by Sébastien Boillat and Fabian Drenkhan. The peer review process for MountainAgenda articles is open. In shaping target knowledge, values are explicitly at stake. The open review process offers authors and reviewers the opportunity to engage in a discussion about these values.

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Supplemental material

FIGURE S1 Organization chart showing the governance structure of ROSA.
APPENDIX S1 Biophysical and socioeconomic indicators and variables.
APPENDIX S2 Metadata on monitoring efforts of the selected observatories.
APPENDIX S3 Linking efforts among academia, communities, and government.

Found at: https://doi.org/10.1659/mrd.2023.00048.S1