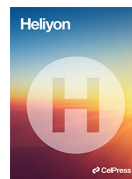


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## Review article

# Adaptive co-management of biodiversity in rural socio-ecological systems of Ecuador and Latin America

Francisco Neira<sup>a,\*</sup>, Santiago Ribadeneira<sup>b</sup>, Estefania Erazo-Mera<sup>c,d</sup>, Nicolas Younes<sup>d,e</sup><sup>a</sup> *Faculté des Sciences. Département de Biologie. Université de Sherbrooke, 2500 Bd de l'Université, Sherbrooke, QC J1K 2R1, Canada*<sup>b</sup> *Department of Physical & Environmental Sciences, University of Toronto, 1265 Military Trail, Scarborough, ON M1C 1A4, Canada*<sup>c</sup> *College of Public Health Medicine and Veterinary Sciences, James Cook University, Townsville, QLD 4878, Australia*<sup>d</sup> *Centre for Tropical Environmental and Sustainability Science, James Cook University, QLD, Australia*<sup>e</sup> *Fenner School of Environment and Society, Australian National University, Ngunnawal Country, Australia*

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## ABSTRACT

Biodiversity management in Ecuador, and across Latin America, focuses on using protected areas for conservation purposes. However, this management strategy does not adequately consider biodiversity interactions with humans by neglecting socio-ecological systems that provide many benefits especially to indigenous and other rural peoples. This paper reviews successful examples of local applications of adaptive co-management that incorporate socio-ecological interactions and the benefits they provide to rural communities in Latin America. These examples show the potential of applying adaptive co-management to manage biodiversity and to revitalize the development of rural communities across the region.

## 1. Introduction

Resiliency of socio-ecological interactions is critical for the subsistence and development of rural communities in Ecuador and Latin America through the use of biodiversity, ecosystem services (ES), or nature's contributions to people (NCP) (Muradian and Gómez-Baggethun, 2021). However, the region's highly abundant biodiversity has been overexploited by different large-scale economic actors, which has ultimately led to its degradation. As a case in point, Ecuador's economic model has been based on crude oil extraction, the conversion of natural forests to single-crop plantations of cacao or bananas, and, in recent years, the production of mineral resources, all of which has contributed to degrading its biodiversity (Southgate and Whitaker, 2004). To mitigate these pressures, protected areas (PAs) were established beginning in the 70s, not only in Ecuador, but also across Latin America. Generally, PAs have two purposes: to provide biodiversity conservation areas, and to promote sustainable uses of ecosystem services (MAE, 2016). Consequently, PA management across the region tends to focus on species conservation, which operates in a way that separates nature from culture (Latour, 1997), while ignoring socio-ecological interactions.

A proper understanding of these socio-ecological interactions is then essential to reinforce PA management (Bengtsson et al., 2021). Socio-ecological interactions are the result of people working towards various individual and collective goals as they transform biodiversity into something that benefits them (Hanna and Jentoft, 1996). Research on socio-ecological interactions considers the uncertainty and unpredictability arising from individual and collective behaviors while using biodiversity (Berkes and Folke, 2000). Such research should integrate the perception of traditional and rural peoples whereby culture and nature often form a continuum (Descola, 2005). The consideration of socio-ecological interactions to reinforce biodiversity and PA management makes it possible to identify the benefits they generate for human wellbeing, to understand their importance (i.e., intrinsic, economic, or relational values), and to integrate the representations of continuity between nature and culture into their management practices.

However, a framework to manage these socio-ecological interactions is not fully applied in Latin American PAs. To overcome this limitation, we propose applying adaptive management to reinforce PA governance. Adaptive management is based on the understanding of the changing interactions between humans and nature that occur in socio-ecological systems (SES) (Birgé et al., 2016), and allows flexible solutions to deal

\* Corresponding author.

E-mail address: [francisco.neira@usherbrooke.ca](mailto:francisco.neira@usherbrooke.ca) (F. Neira).<https://doi.org/10.1016/j.heliyon.2022.e11883>

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with uncertainty, unpredictability, and continuity (Maris and Bechet, 2010). Adaptive management of SES also considers ES, NCP, resilience, and relational values (relational values are not found in subjects or things; it is something integrated in historical processes, and in the changing and resilient socio-ecological interactions that humans maintain with nature (Muradian and Pascual, 2018) in its approach. Adaptive management is then relevant to many PAs and rural landscapes around the world (Liu and Li, 2017), but that has not been implemented in Ecuador (MAE, 2016) and has received limited attention in Latin America as a whole (Gelcich et al., 2009).

This review article aims to (i) support PA stakeholders in the Ecuadorian and Latin American context in the active use of adaptive management and resilience building principles, by (ii) providing brief reviews of successful literature examples, in which adaptive management and resilience notions have been already implemented across Ecuador and Latin America. This is particularly relevant because Latin American PAs are mostly managed as silos or islands within a sea of rural landscapes and lack a framework that would allow them to integrally manage the surrounding socio-ecological dynamics (Palomo et al., 2014).

The methodology used for this review included three phases: (i) collection, (ii) selection, and (iii) analysis. First, the data collection process was conducted from 2016 to 2021 as part of the doctoral project carried out by the first author of this article. During this period, *the web of science* was used two times per year to search for papers titles, abstracts, and keywords that included the words “adaptive management” and “Latin America,” in conjunction with a set of 12 publications recommended by experts in the field of adaptive management in Latin America who were directly contacted between 2018 and 2020. This came to a total of 61 publications. Second, from that total, 17 publications containing specific examples of cases of adaptive management applications or explicitly mentioning traceable resilient socio-ecological interactions in Latin America were selected. Finally, from each of said 17 publications, we selected 17 examples (one example from each publication), which were coded using QDA Miner Lite v 2.0.9 into seven categories linked to the application of adaptive management or resilience in Latin America, namely (i) diversity, (ii) connectivity, (iii) control variables, (iv) adaptive thinking, (v) learning, (vi) participation, and (vii) governance, which are fully explained in section three of this paper.

In the following sections, we first justify the need to implement a SES approach in Latin America for biodiversity management that considers the continuities between cultures and natures. Then, we present seven principles to build resilience through adaptive management in Latin America and examples of local applications of these principles. Finally, we discuss the strengths and obstacles to implement adaptive management of biodiversity in Latin America.

## 2. From protected areas (Pas) to socio-ecological systems (SES)

PAs are the cornerstone of biodiversity conservation, covering over 12% of global land (Palomo et al., 2014). These areas, mostly located in rural settings and separated from human agency, are created to provide habitat for endangered wildlife and to conserve iconic species, landscapes, and seascapes (Watson et al., 2014). PAs are not always effective, with more than half of the PAs around the world showing significant management deficiencies (Leverington et al., 2010). These deficiencies are derived, in part, from the use of biodiversity management approaches that isolate nature from culture (Latour, 1997). When nature and culture are perceived as separated ontologies, two biodiversity management visions tend to arise: “nature for itself” and “nature despite people” (Mace, 2014). Both approaches use command-and-control biodiversity management philosophies (Holling and Meffe, 1996), which are broadly applied in the Ecuadorian SNAP (MAE, 2016) and in Latin America.

However, humans dominate over half of the global terrestrial environment (Watson et al., 2016), with Indigenous and rural Peoples' lands accounting for over 37% of all remaining natural lands, 20.7% of which lies within protected areas (Garnett et al., 2018). Many indigenous and

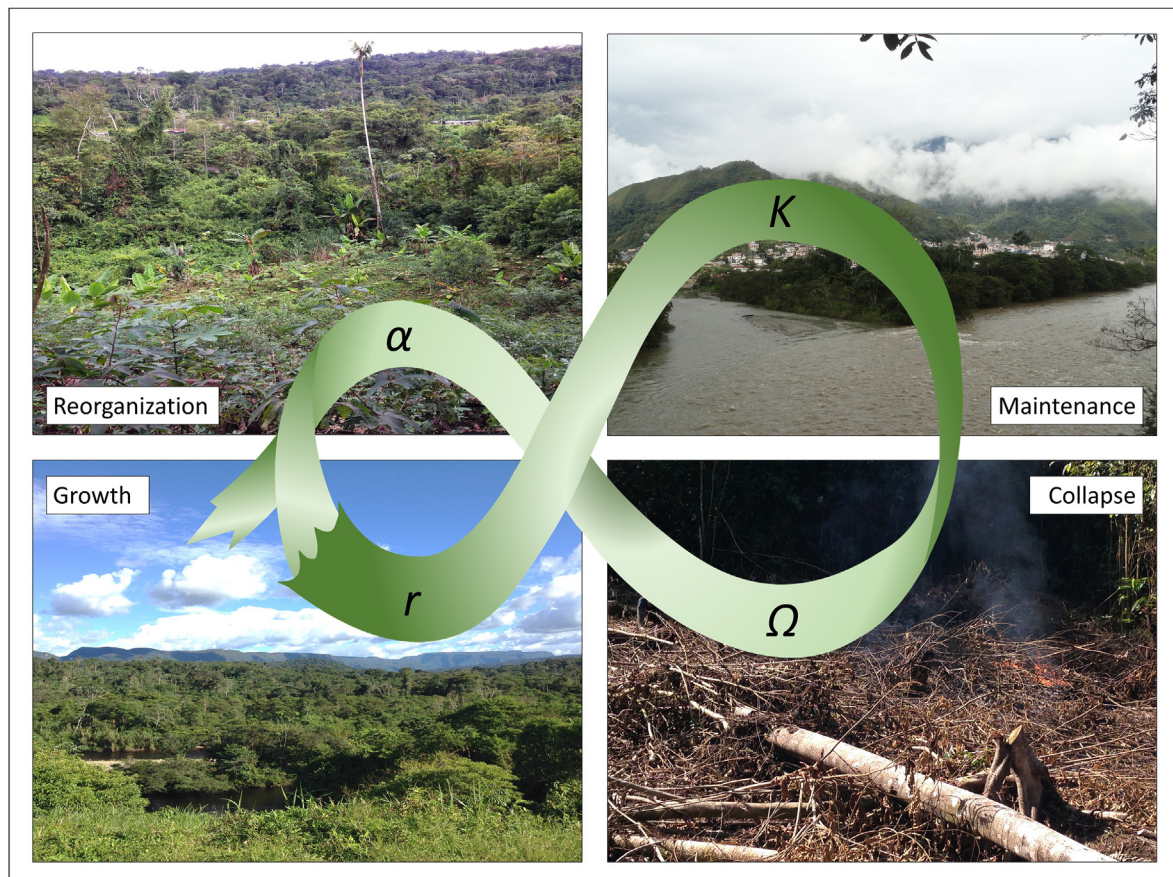
rural peoples hold legacy perceptions of continuity between nature and culture (e.g., Mayan, and Amazonian cultural forests), which must be considered when developing strategies for PA management (Balée, 2013). Evidence in Ecuador and other Latin American countries suggests that indigenous and rural peoples' territories act as buffers against deforestation, forest degradation, and natural disturbances (Walker et al., 2020). By considering natural ecosystems in PAs and rural landscapes together, highly important SES for biodiversity protection are formed. SES are defined as complex adaptive systems where ecosystems and human cultures interact and adapt to each other (Walker, 2020). As depicted in Figure 1, these interactions are resilient because they transform and adapt to changing conditions following a pattern of four phases: (i) growth, (ii) maintenance, (iii) collapse, and (iv) reorganization (Resilience Alliance, 2010), while continuing to provide benefits to humans (Huntsinger and Oviedo, 2014).

Examples of these adaptive and resilient interactions can be found in rural SES around Latin America. For instance, *Kayapó* communities in the Brazilian Amazon region use several species of plants and animals from different *apêtê* (forested areas that *Kayapó* use as productive spaces) for their subsistence. Their knowledge of regional microclimates is adaptive and resilient and allows them to exchange products obtained in different *apêtês* (Posey, 1985). In Panama, the *Kuna* people recognize *galaguna* sites as belonging to “the masters of the animals”. The “masters of the animals” are extraordinary beings than inhabit and coexist in the land. The *galaguna* are associated with the *Kuna*'s territorial reality and are dangerous places where excessive hunting is not allowed (Martínez Mauri, 2007). Similarly, the *Inca* model of cultural appropriation of the vertical space allows for production of a diverse range of agricultural products by cultural groups in different ecological zones of the Andes (Murra, 1985). These socio-ecological interactions have formed ancient, adaptive, and resilient SES in Latin America (Balée, 2013) which persist to the present day and now include several PAs. The adaptive management framework, which considers change, adaptation, legacies, and the perceptions of continuity between culture, nature, and resiliency of SES, will make it possible to address these new complexities (Brown, 2016).

## 3. Principles to implement adaptive management and adaptive co-management in Latin America

Adaptive management prioritizes resilience building in SES and is considered a learning-based framework for biodiversity management that treats policies as hypotheses and actions as ways for testing those hypotheses (Resilience Alliance, 2010). Adaptive co-management derives from adaptive management and is defined as a process tailored to specific places and situations by which institutional arrangements and ecological knowledge are revised during a dynamic process of learning-by-doing (Olsson et al., 2004). Adaptive co-management has been indirectly trialed at small scales in Ecuador and Latin America. For example, the rural farming community of Loma Alta in western Ecuador modified land allocation patterns, established new rules for the use of forest goods and services, and created the first community-owned forest reserve in the country (Becker and Ghimire, 2003). In Mexico, the indigenous multiple-use strategy of tropical forest resources achieved successful management in terms of biodiversity conservation, resilience, and sustainability (Toledo et al., 2003). However, adaptive co-management implementation in Latin America continues to be rare.

There are several approaches to assess and build resilience of SES through adaptive management that could be introduced and implemented in Latin America. Ostrom (2009) proposed a framework that identifies ten variables to assess and achieve a sustainable SES (size, productivity, predictability, mobility, number of users, leadership, norms, knowledge, importance of users and collective rules). However, this approach does not consider sufficiently ecological or ecosystemic variables equally important to achieve SES resilience. In 2010, the Resilience Alliance proposed a five-stage assessment framework (system description, system dynamics, system interactions, governance, and



**Figure 1.** The four phases of the adaptive cycle that characterize many rural SES in Latin America are: (i) growth ( $r$ ), (ii) maintenance ( $K$ ), (iii) collapse ( $\Omega$ ), and (iv) reorganization ( $\alpha$ ).

assessment feedbacks). This approach was equally criticized for failing to provide meaningful metrics to the proposed variables (Angeler and Allen, 2016). The Resilience, Adaptation and Transformation Assessment framework (O’Connell et al., 2015) builds on the Resilience Alliance (2010) assessment retaining a focus on dynamic systems while also guiding the identification of relevant indicators to measure, monitor, and implement resilience over time (Quinlan et al., 2016). In addition to the high level of subjectivity in its application, the gap between ecology and social sciences, as well as that existing between qualitative and quantitative approaches to assess resilience, remains (Angeler and Allen, 2016).

To fill these gaps, Biggs et al. (2015a,b) proposed a framework to build resilience and sustain ecosystem services based on the Resilience Alliance (2010) approach, in which key actors, ecological structures, and their interactions are considered. The authors argue that a focus on measurement means simplification, which makes it necessary to justify one simplification over another. As a result, resilience assessments will always be partial and incomplete (Quinlan et al., 2016). This framework proposes seven principles to assess socio-ecological interactions and the benefits generated by biodiversity to people, particularly indigenous and rural peoples. We think this approach is useful for Ecuador and Latin America, where these interactions and benefits are omnipresent, especially in biosphere reserves that include Pas and rural settings. In the remainder of this manuscript, these seven principles will be summarized, alongside examples to guide their application through adaptive management in the region.

The first principle refers to “maintaining diversity and redundancy,” where response diversity and functional redundancy are key parameters (Kotschy et al., 2015). Response diversity is the range of reactions that different cultural (i.e., subsistence practices, knowledge, and institutions) and ecological (i.e., species and traits) elements of a SES are

displayed in response to a given disturbance (Elmqvist et al., 2003). Functional redundancy refers to cultural and ecological traits performing similar, often complementary, functions in a SES (Gardner et al., 2009). Several Latin American countries are megadiverse, something that increases ecological resilience since biodiversity enhances the stability of biomass production and thus ecosystem functioning (Isbell et al., 2017). Similarly, multifunctionality, as a subsistence strategy, is a relational value of rural households, particularly in developing countries (Wilson, 2010), which increases social resilience by constructing a diverse portfolio of activities and social support capabilities in order to improve their wellbeing (Brown, 2016).

The second principle is “manage connectivity”. Connectivity governs flows of species, energy, and resources. Habitat fragmentation disrupts it, which leads to the degradation of ecosystem functions (Isbell et al., 2017). As an example, besides mimicking the trophic stratification of forests, *chakras* and *ajas* (the productive spaces of *kichwa* and *shuar* indigenous peoples in the Ecuadorian Amazon) serve as connecting spaces between these productive areas and the surrounding forests or PAs. From a social perspective, individuals are influenced by the people with whom they have frequent interactions and are likely to develop a reasonable level of mutual understanding about resource status (Crona and Bodin, 2006), which ultimately contributes to building SES resilience. Reciprocity, a relational value, is the cement that holds social networks together (Wagner, 1981). These connectivity characteristics are repeated across Latin America. For example, the Maya continued to manage mosaics of agricultural areas and forests that provide ES that are complementary to their livelihoods (Gómez-Pompa and Kaus, 1999).

The third principle implies “managing slow variables and feedbacks” (Biggs et al., 2015a). Biodiversity in Amazonian ecosystems is a slow variable that has barely changed since 13,000 BP. This could be partly

because the interactions between cultivated areas (cultural fast variables) and natural vegetation enlarge or reduce niches for species (Balée, 2013). Ecologically, these interactions between slow and fast variables have contributed to maintaining the region as a tropical rain forest (Roosevelt, 2014). Socially, different cultural groups can have discrepancies in the level of importance placed on individualism or collectivism as relational values, and these perspectives might affect resilience through the adherence, values, or beliefs (slow variables) that guide practices (fast variables) related to biodiversity (Brown, 2016). Feedbacks are loops in the dynamics of the slow and fast variables (Scheffer et al., 2009). For example, increased forest burning (positive feedback) reinforces the loss of native species, while reducing this practice (negative feedback) has the opposite effect.

The fourth principle, “fostering complex adaptive systems thinking,” refers to the integration of local stakeholders’ worldviews to SES adaptive co-management given by adaptations to change (Brown, 2016). Worldviews are cultural frameworks, “mental customs,” that function as guides to understand and transform reality (Bohensky et al., 2015). These mental customs are legacies (Ellis et al., 2021) or anachronisms that entail patterns of behavior and belief. Thus, worldviews are relational values, representations of continuity between culture and nature relevant to some indigenous and rural peoples of Latin America. For example, Mesoamerican people derived their worldview from being rooted in the soil of a particular place. The layer of soil that sustains all life on earth was seen by them as a living entity (Marcos, 1995). In the four adaptive cycle phases of SES resilience and transformation (growth, maintenance, collapse, and reorganization), the legacies carried by worldviews can facilitate SES reorganization from these memories (Ellis et al., 2021).

The fifth principle, “encourage learning,” builds wisdom from individual and collective knowledge about community relationships and interactions with biodiversity (Cundill et al., 2015). As learning implies knowing the relationship of living beings (including humans) with one another and with their environment, it can be considered a relational value of biodiversity (Chan et al., 2016). The links between learning and knowledge are developed, encoded, and transmitted through language (Maffi, 2005). Practically every Amazonian language dedicates a large percentage of vocabulary to naming and describing plants and animals (traditional taxonomies), thus reflecting the empirical knowledge of such biodiversity (Balée, 2013). Local knowledge is then fundamental to carry cultural legacies, anachronisms, and memories that make the continuity of the adaptive co-management cycle possible (Berkes and Turner, 2006). Learning from past experiences is a crucial step to SES reorganization and, thus, to improve SES resilience.

The sixth principle, “broaden participation,” calls for the inclusion of diverse stakeholders as well as local actors in SES to build resilience (Leitch et al., 2015). Participation makes it possible to distribute or redistribute ES that are loaded with asymmetries, complex power dynamics, and political struggles between groups of people (Robards et al., 2011). Participation results from the interaction between actors and institutions, as well as the relationships between them (Bodin and Crona, 2009). Cooperation between local actors, local institutions, and other rural stakeholders in ecosystems co-management is an indicator of SES resilience and a biodiversity relational value (Chan et al., 2016). In Ecuador, for example, a *Cofán* indigenous community participated in a one-year program that monitored the abundance of freshwater turtles (*Podocnemis expansa* and *Podocnemis unifilis*) in their territory. As a result, the community obtained quantitative results that changed their perception regarding the abundance of turtles, and hence, became protective of their eggs (Townsend et al., 2005).

The last principle is to “promote polycentric governance of SESs.” Governance is polycentric when actors from different institutions interact at different levels of the public policy-making processes (Schoon et al., 2015). Formal and informal institutions (especially in rural settings) are social systems that, over time, provide decision rules for adjusting and accommodating conflicting demands from different stakeholders (Ciriacy-Wantrup and Bishop, 1975). The interaction between formal and

informal institutions is important as it could reinforce the resilience of SES by including adaptive community management techniques (Anderies et al., 2004) and relational values (Arias Arévalo et al., 2017). As an example, the Mexican recognition of community-based tenure institutions has enabled some locally adapted agroecosystems to be resilient in the face of change, specially where cultural indigenous values and traditional institutions support agricultural management (Alcorn and Toledo, 2000). Unfortunately, polycentric governance is not actively applied in Latin America.

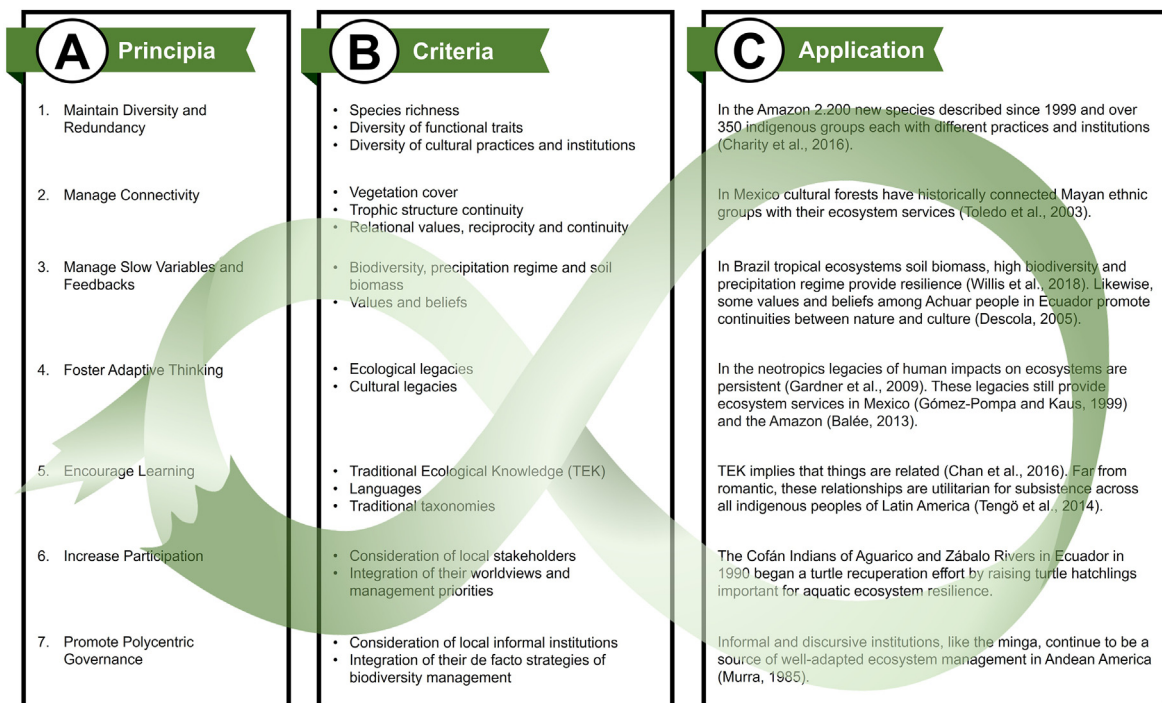
The application of these seven principles for building the resilience of SES through adaptive and co-adaptive management in Ecuador and Latin America could contribute to revitalizing the development of rural areas (Liu and Li, 2017) and the protection of biodiversity through the region. The seven principles to building resilience, the application criteria, and more examples of their application in Latin America are summarized in Figure 2.

#### 4. Discussion: strengths and obstacles to adaptive management implementation in Latin America

This article has presented examples of local biodiversity management and resilience building in various rural and indigenous Latin American SES. All these examples are based on the worldviews and sociocultural legacies that these communities maintain, so they constitute historical and *de facto* local applications of adaptive management in these SES. Therefore, the seven resilience building principles of Biggs et al. (2015a, b) presented in this article are already partially applied across the region through diverse subsistence activities, traditional ecological knowledges (TEK), and different forms of local institutional management of SES. Diversity, connectivity, and the control of slow variables and feedbacks are the three principles of resilience building that are more common applied at local and community levels in the region. As a result, the integration of such applications of local management could contribute to strengthening the adaptive management of PAs and SES, the biodiversity they harbor, and the benefits they generate for local human communities in the region.

To trigger effective adaptive biodiversity management processes at landscape scales in Latin America, we recommend that PAs be managed as parts of SES (Palomo et al., 2014). The concept of “biosphere reserve” aims to manage the landscape around PAs, along with their corresponding SES. This includes a variety of transition zones with different uses that are part of socio-ecological interactions (Reed, 2019). To this effect, biodiversity reserves integrate PAs into SES, as well as a diversity of land uses and ecosystem benefits (ES or NCP) that increase landscape resilience (Palomo et al., 2014). Implementing and expanding the current network of biosphere reserves in the region is then consistent with adaptive and co-adaptive strategies because both share one key objective: to test approaches that enable better understanding and management of changes and interactions between social and ecological systems (UNESCO, 2021).

There are 130 biosphere reserves in Latin America, seven of which (including Galápagos and Yasuní biosphere reserves) are located in Ecuador (UNESCO, 2021). The Galapagos biosphere reserve is considered a rural SES that generates a varied flux of ES and NCP (Dirección del Parque Nacional Galápagos, 2014). However, the long-standing problem of not integrating completely human agency (i.e. tourism), TEK, and local formal and informal institutions undermines the management of the reserve (Grenier, 2007). Similarly, in Yasuní biosphere reserve, extractive activities (crude oil and timber) continue to generate serious environmental and social impacts and conflicts (Fontaine and Narváez, 2007). These two examples highlight how current management of biosphere reserves in Latin America fails to consider the social principles of resilience building (i.e. adaptive thinking, learning, participation and governance) and the social drivers of rural change (i.e. migration to cities, poverty, lack of education and demographic growth), exacerbating conservation conflicts (Lecuyer et al., 2018).



**Figure 2.** The seven principles of resilience building, their application criteria, and several examples of application in various rural landscapes in Latin America.

However, we believe the two most significant obstacles to the implementation of adaptive management throughout the region are low participation (and even the exclusion) of many local populations, together with their worldviews and knowledge systems, from the management of SES, PAs, or biosphere reserves (Gerique et al., 2017); and the maintenance of the everlasting and sole interest in species and ecosystems protection that continues to dominate over local interests of local populations for development (Chapin, 2004). Together, these aforementioned failures and obstacles generate conflicts that can hinder both the management of PAs and the development of the human communities that interact with them (Bengtsson et al., 2021). Therefore, we believe that SES, PAs, and biosphere reserves in the region need to implement adaptive management following the resilience building principles we have presented in this review. This would make it possible to better consider the benefits of socioecological interactions on both humans and biodiversity, landscape scales of SES, and relational values expressed through these social–ecological interactions.

In conclusion, this review article contributes to reinforcing the conceptual basis required to implement adaptive management or adaptive co-management in rural settings in Ecuador and Latin America and to maintain resilient flows of benefits (ES or NCP) provided by SES. Relational values are important when evaluating the benefits provided by biodiversity and assessing SES resilience, as seen in the examples of resilient and relational interactions in the Ecuadorian and the Latin American context that we presented in this article. The framework we propose is justified due to the current biodiversity management practices in the region, which are based on command-and-control approaches that tend to separate nature from culture. Further, these approaches are insufficient when it comes to protecting biodiversity, which does not improve human wellbeing and development in the long run. On the other hand, adaptive co-management considers the interactions between people and nature, uncertainties linked to these socio-ecological interactions, anachronisms or legacies underlying SES reorganizations, and the sociocultural benefits that biodiversity brings in terms of revitalizing rural societies. Subsistence practices, traditional ecological knowledge, and formal and informal institutions are factors that enable adaptive co-management and should be integrated into biodiversity management

strategies in Latin America. Finally, approaches to biodiversity co-management are limited, and so is the willingness of certain national institutions to include a plurality of values, knowledge, and the institutions needed to implement adaptive co-management. Despite this, we believe that a gradual integration of the adaptive approach into biodiversity management practices will be a valuable way to revitalize rural settings and Ecuadorian and Latin American PAs.

### Declarations

#### Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

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#### Data availability statement

No data was used for the research described in the article.

#### Declaration of interest's statement

The authors declare no conflict of interest.

#### Additional information

No additional information is available for this paper.

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