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RESEARCH ARTICLE

'Sowing and harvesting water': Revisiting forest restoration in the Peruvian Andes through a multi-stakeholder analysis

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Abstract

1. Efforts to restore Peru's megadiverse Andean Forests are rapidly growing. While ecological determinants for restoration success are well known, knowledge on the socio-economic and governance conditions that allow for the success of ecological restoration using native species is scarce.
2. Using a multi-stakeholder approach, this paper analyses the motivations, preferences, success factors and governance models for effective ecological restoration of Andean Forests, through 75 semi-structured interviews with local community members, NGOs and government actors in 11 restoration sites in Peru.
3. We find that across sites and stakeholder groups, the primary motivations for Andean Forest restoration were tied to restoring and improving hydrological resources. Stakeholders valued Andean Forests mostly for their provisioning ecosystem services—with water provision valued by all stakeholders and firewood provision predominantly by communities—followed by regulating services (water retention and climate regulation).
4. Restoration success—the degree of perceived achievement of project objectives—was high at all sites and scored between 2.4 and 3 out of 3. Enabling factors for the restoration success were mostly social and institutional. There was no 'silver bullet' to successful restoration; rather, enabling factors included high resource dependence of communities, support from NGOs, participatory management and governance, and the creation of communal conservation agreements. Communities emphasized primarily social and institutional limiting factors, while government stakeholders emphasized technical challenges. We further identified three typologies of how projects engage and compensate communities: a 'payment model', a 'capacity model' and a 'mixed model' which differ in their rentability, longevity and socio-economic benefits provided.

For affiliations refer to page 649.

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5. All stakeholder groups favoured active forest restoration and community members identified desirable native plant species with local use and hydrological value. Interviewees also highlighted that restoration needs to go beyond forests, and combine native tree planting, agroforestry, restoration of mountain grasslands and peatlands to holistically improve water resources and long-term economic benefits at a landscape scale.
6. *Synthesis and applications*. Andean Forest restoration projects need to consider hydrological ecosystem services in all key restoration stages. Communities need to be involved through participatory processes and receive long-lasting benefits—both ecosystem services and livelihood incentives—to guarantee long-term project success.

KEYWORDS
Andean Forest, community participation, ecological restoration, ecosystem services, forest governance, local livelihoods, *Polylepis*, water provision

1 | INTRODUCTION

Globally, most restoration priority areas are located in areas with a low human development index (Löfqvist et al., 2022). As such, to achieve equitable and successful outcomes, it is critical that implementers understand and integrate social dimensions when planning, implementing and monitoring restoration. One such global restoration priority area with exceptional species richness and endemism is the Tropical Andes Biodiversity Hotspot, including Andean Forests (Strassburg et al., 2020).

Andean Forests have been extensively deforested and degraded for agriculture for thousands of years (Valencia et al., 2018), and this is particularly prevalent in Peru (Ministerio del Ambiente, 2015). Here, fire, overexploitation and deforestation continue to have negative impacts on ecosystem structure, biodiversity and local livelihoods in Andean Forests today (Armenteras et al., 2011; Aucca & Ramsay, 2005; Lippok et al., 2013; Oliver et al., 2017; Oliveras, Anderson, et al., 2014). Native Andean Forests in Peru currently occupy a fraction of their potential range (Ministerio del Ambiente, 2015). Because Andean Forests in Peru are extensively degraded, planting native tree species (hereafter 'Andean Forests restoration') is an important and widely used restoration technique.

At the same time, many rural Peruvian Andeans depend on subsistence and small-scale farming for their livelihoods, and communities are highly dependent on ecosystem services provided by remaining forests (Programa Bosques Andinos, 2021). The potential for restoration to improve livelihoods and provide key services is thus high—it can improve agricultural productivity by improving water regulation and preventing soil erosion (Báez et al., 2010), stimulate community economy by creating alternative livelihoods (Aucca & Ramsay, 2005), and can be an important component of sustainable forest management alongside education and conservation.

Many biophysical and technical conditions are known to enable or limit forest restoration in tropical mountain environments (Christmann & Oliveras Menor, 2021; Guariguata, 2005; Holl et al., 2000), but the social side of Andean Forest restoration is less well understood (Báez et al., 2010; Christmann & Oliveras Menor, 2021; Mathez-Stiefel et al., 2017). What motivates actors to restore Andean Forests, which socio-economic and institutional factors enable and limit restoration, and the types of restoration preferred by local communities in different contexts require more research (Pinos, 2020, but see Murcia et al., 2017). Globally, social factors have been identified as being more important than biophysical factors in driving forest restoration success; hence an understanding of the social circumstances is key (Elias et al., 2021; Löfqvist et al., 2022; Ota et al., 2020; Stanturf et al., 2014; Wilson & Coomes, 2019).

Investigating motivations and divergences between stakeholders to restore forests is key to designing effective landscape-scale restoration strategies, such as in Forest Landscape Restoration (Mansourian, 2024). Motivations can be intrinsic, relational or instrumental (IPBES, n.d.), and previous Andean cases suggest that motivation is often linked to forest ecosystem services. In a case from the Ecuadorian Andes, landholders were motivated to restore forests on farmland to recover scarce ecosystem services that forests previously provided, such as water supply, and saw restoration as symbolic of a commitment to farming culture (Wilson & Coomes, 2019). A case in Peru found that families' who were reliant on subsistence farming were less motivated to restore High Andean *Polylepis* forests because of perceived competition with agriculture, in contrast to people with more technological knowledge and a better understanding of ecosystem services (Joseph et al., 2021). Similarly, another Ecuadorian case showed that higher socioeconomic status increased interest in forest restoration, and people were motivated to restore to conserve water, protect soils and reduce wind (Báez et al., 2010).

The enabling factors that lead to restoration 'success' are also often socioeconomic. At a continental South American scale, Forest Landscape Restoration has been found to be limited by mostly social and institutional factors including (1) the high dependence of local

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communities and countries' economies on natural resources, (2) conflicts over land tenure and access, (3) divergence in perceptions and values between social actors, (4) the fragility of public institutions and policies (Aguiar et al., 2021) and (5) pervasive cross-scale bottlenecks in information flows and a chronic disregard for implementing monitoring approaches that connect the bottom up and top down (Evans et al., 2023). National-scale reports of Peruvian biomes (Cerrón Macha et al., 2018) have found that socio-economic factors, including land ownership, environmental education, political boundaries, conservation agreements and community organization, are key to restoration success.

Effective restoration can be achieved through a spectrum of governance models from creating direct economic incentives (Hartman & Cleveland, 2018), to communal participation approaches with indirect incentives (Wilson et al., 2019; Wilson & Coomes, 2019). In a study of Bolivian communal wetland restoration, financial incentives helped encourage people to participate initially, while aligning restoration goals related to perceived livelihood benefits and ecosystem services helped project continuity (Hartman & Cleveland, 2018). In the Ecuadorian Andes, forest restoration was motivated by perceived ecosystem scarcity and restoration success facilitated by communal land tenure of restoration sites which enabled a participatory, low-risk approach, and by engaging trusted leaders (Wilson et al., 2019; Wilson & Coomes, 2019).

So far, most socio-economic studies of Andean Forest restoration have focused on single landscapes and a few stakeholders (Báez et al., 2010; Durand & Sevillano, 2017; Joseph et al., 2021), rather than including multi-stakeholder perspective of perceptions, values, and preferences (but see Evans et al., 2023). This hinders upscaling of restoration from the local to the regional and national scale (Evans et al., 2023)—two research priorities stated for the conservation and governance of Andean Forests (Mathez-Stiefel et al., 2017). Another key priority for Andean Forest research is analysing the costs and benefits of restoration interventions and the most effective modes of forest governance (Pinos, 2020).

To successfully restore Andean Forests, we need to understand why, where and how to best implement restoration in a way that improves ecosystem services, biodiversity and local livelihoods. Peru contains the largest extent of the tropical Andean Forest zone (Programa Bosques Andinos, 2021) and recently pledged to restore 3.2 million hectares of degraded land under the Bonn Challenge. However, so far experiences and knowledge sharing of Andean Forest restoration in Peru are limited, and ecological restoration projects tend to be recent and small-scale (Murcia et al., 2017).

This study uses a meta-analysis of interviews in restoration project locations to elucidate stakeholder motivations for participating in Andean forest restoration, the enabling and limiting factors for successful restoration, and the impacts of and future directions for Andean forest restoration in the context of local actors in Peru. Using meta-analyses of local case studies provides an opportunity to gain a pluralistic understanding of how successful and equitable contextually effective restoration can be attained (Löfqvist et al., 2022). Specifically, our study aims to answer the following questions:

1. What are the motivations for forest restoration with native species in the Peruvian Andes across different stakeholder groups?
2. What restoration interventions are preferred by stakeholders (e.g. species, ecosystem types and restoration methods)?
3. Which social, economic, biophysical, institutional/legal and technical factors affect restoration success according to different stakeholder groups?
4. How do restoration projects impact community livelihoods?
5. Through what governance models do restoration projects achieve community benefits, project sustainability and restoration success?

2 | METHODS

2.1 | Study system: Peruvian Andean Forests

Peruvian Andean Forests cover only 3% of Peru's territory (Ministerio del Ambiente, 2015) and are classified into Andean montane forests (2000–3000 m a.s.l., extent of 3,072,387 ha = 2.39% of Peru's area) and High Andean Forests between (above 3000 m a.s.l., 831,825 ha = 0.65% of Peru's area). Pastures, plantations and agriculture occupy large areas of this region and rural communities depend heavily on the ecosystem services provided by remaining Andean Forests for their livelihoods (Baca, 2018). There is a pronounced dry season between May and September. Mean annual precipitation ranges from 1000 to 3000 mm and varies with location and topography (Arias et al., 2021; Malizia et al., 2020).

Within the Andean montane forests, there are seasonal montane forests and montane cloud forests which are permanently cloud-immersed. Canopy height ranges from 10 to 25 m, there is a high diversity of epiphytes, and forests contain both evergreen and deciduous tree species, including from the Podocarpaceae, Lauraceae, Rubiaceae, Juglandaceae, Meliaceae, Moraceae, Clusiaceae and Cunoniaceae families (Ministerio del Ambiente, 2015). Non-native timber species (*Eucalyptus* spp. and *Pinus patula*) are common due to large-scale reforestation campaigns promoted by the World Bank and the Forestry Law ('*Ley Forestal de 1963*') in the 1960s aimed at preventing erosion and providing fuel alternatives (Guariguata et al., 2017).

High Andean Forests are adapted to frost and drought, making them functionally and compositionally distinct from montane forests (Montalvo et al., 2018). They are characterized by the families Rosaceae, Myrsinaceae, Clusiaceae, Myrtaceae, Bignoniaceae and Scrophulariaceae. Above 4000 m a.s.l. High Andean Forests occur mostly as small forest relicts with few tree species of the genera *Polylepis* (Rosaceae, local name '*queñua*') growing up to 5000 m a.s.l., as well as *Buddleja* (Scrophulariaceae, '*kishuar*'), *Gynoxys* (Asteraceae, local name '*toqacho*', '*yuraq kishuar*') and *Escallonia* (Escalloniaceae, 't'asta') (Ministerio del Ambiente, 2015). Peruvian *Polylepis* forests only cover 2%–3% of their potential range due to a long history of exploitation for firewood and timber and degradation by escaped fires and livestock farming (Aucca & Ramsay, 2005; Fjeldså et al., 1996; Quispe-Melgar et al., 2020).

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2.2 | Description of stakeholders

In Peru, Andean Forest restoration is implemented by both the private and public sector on mainly community-owned land and involves multiple stakeholder groups (Cerrón Macha et al., 2018):

1. Government agencies: National-level agencies include the national forestry and wildlife service (SERFOR—*Servicio Nacional Forestal y de Fauna Silvestre*) whose main function is to promote the sustainable management of the country's wild flora and fauna.; the Protected Area Authority (SERNANP—*Servicio Nacional Áreas Protegídas por el Estado*); and decentralized public organizations (OPD—*organismos públicos decentralizados*). Regional and local governments also commission, fund and execute forest restoration.
2. Conservation and development-oriented non-governmental organizations (NGOs) at local (e.g. Conservación Amazonica), national (e.g. Instituto de Montaña) and inter-Andean (e.g. Acción Andina, Programa Bosques Andinos) levels.
3. Private enterprises (mining, water resource management or tourism) involved with restoration through company commitments, compensation schemes or payment for ecosystem services.
4. Local farming communities '*Comunidades campesinas*' who, since the Agrarian reform in 1968, have owned and farmed most of the High Andean land as individuals, agrarian cooperatives, farming groups or communities (Fonseca Martel & Mayer, 1978; MIDAGRI, n.d.). Communities partake in restoration activities through agricultural cooperatives, the communal governing bodies ('*junta directiva*'), or as individual farmers and herders. Farming communities range from 'modern' with access to contemporary amenities to more 'rural' communities pursuing traditional agriculture by farming native tubers, legumes, maize or squash, and/or herding sheep, horses, cows and camelids in the Puna (Fonseca Martel & Mayer, 1978). Traditional rural farming communities tend to have relatively poor health and low levels of education (Pinos, 2020).

2.3 | Interviews and fieldwork

We conducted semi-structured interviews in restoration project locations between August and October 2022 (the dry season) in the departments of Cusco, Apurímac and Ancash (Figure 1). Projects were chosen by filtering the Annex 2 project list from

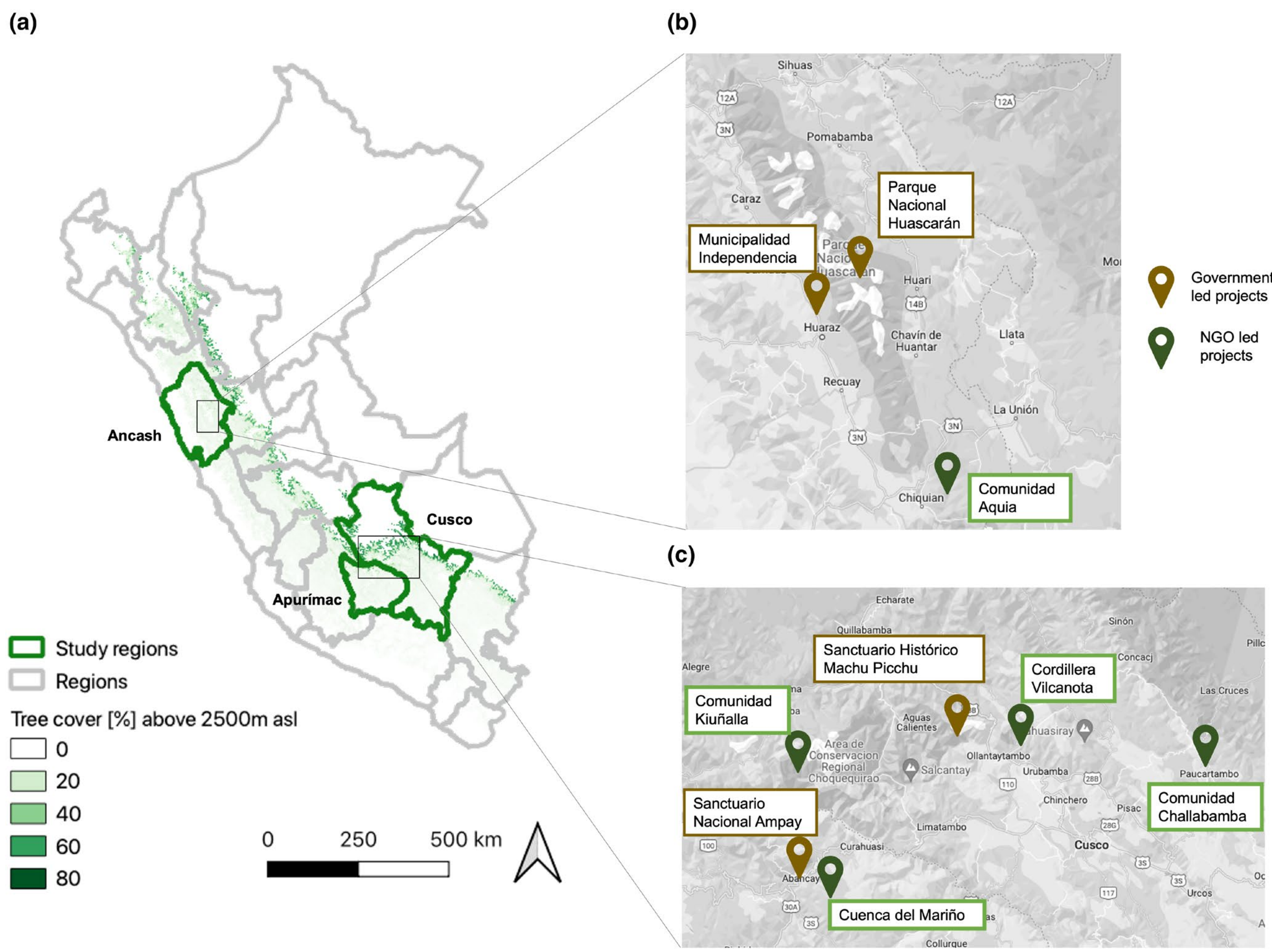

FIGURE 1 Location of study sites. (a) Map of Peru with the three case study regions overlaid over a map of forest cover percentages from GFCC above 2500 m a.s.l., (b) study sites in Ancash and (c) study sites in Apurimac and Cusco.

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TABLE 1 Specification of the 11 study sites.

	Elevation [m a.s.l.] and forest type	Stakeholder groups interviewed	Start of planning|start of restoration	Size of restoration intervention	Ecological restoration	Type of intervention	No. interviews	Success level (3 being maximum)
1. **Community of Kiuñalla**	3000–4414 (Andean montane forest)	NGOs: CEDES, Programa Bosques Andinos Community	2014|2018	1 community 100 ha total intervention area 30 ha restoration	Yes	Ecological restoration with mixed native species and conservation of native forests alongside livelihood improvements	11	2.6
2. **Watershed Cuenca del Mariño**[a]	2500–4200 (High Andean Forest)	NGO: CEDES Private: EMUSAP (water company) Community	2013|2016	3 communities 70 ha	Partly	Ecological restoration with *Polylepis* Grassland restoration, blue infrastructure (dams and reservoirs) Exotic Pine plantation	8	2.83
3. National sanctuary Ampay	2900 to 5235 (Andean montane forest)	Government: SERNANP	1990s|2002	120 ha	Yes	Tree planting with native Podocarpus Glomerata	4	NA
4. Department of Apurímac	2000–4000 (High Andean Forest)	Regional government (GORE)	266 communities	Planned: 30 Mio trees of which 20% native. 20 Mio ha	Partly	Some ecological restoration with *Polylepis* spp., *Escallonia* spp., *Salix* spp. and *Alnus* spp. Large-scale exotic Pine plantation	2	NA
5. **Community of Challabamba**[a]	2820–4000 (Andean montane forest)	NGO: ACCA Community	2021|2021	78,000 seedlings 40 ha	Yes	Ecological restoration with mixed native species & conservation of native forests	9	2.8
6. **Mountain range Vilcanota**	3000–4500 (High Andean Forest)	NGO: ECOAN Community	1998|2000	20 communities, 6 Mio seedlings	Yes	Ecological restoration with 7 species of *Polylepis* & conservation of native forests	13	2.4
7. Historic Sanctuary Machu Picchu[a]	2800–3000 (Andean montane forest)	Government: SERNANP	2002	20 ha/year 20,000 seedlings/year	Yes	Ecological restoration with mixed native species and with productive native species	2	NA
8. **National Park Huascarán**[a]	3400–6000 (High Andean Forest)	Government: SERNANP Community	Start in 1980	NA	Yes	Ecological restoration with *Polylepis*	7	NA
9. **Municipality Independencia**	3000–3900 (High Andean Forest)	Government: Municipality Community	2005	NA	Partly	Ecological restoration with *Polylepis*, but also large-scale plantation with exotic Pine	5	NA

(Continues)

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TABLE 1 (Continued)

	Elevation [m a.s.l.] and forest type	Stakeholder groups interviewed	Start of planning|start of restoration	Size of restoration intervention	Ecological restoration	Type of intervention	No. interviews	Success level (3 being maximum)
10. **Community of Aquia**[a]	3300–4500 (High Andean Forest)	NGOs: Instituto de Montana (IdM) ECOAN (since 2021) Community	IdM: 2004–2008 ECOAN: 2021	IdM: 20 ha during project and 20 ha goal post project ECOAN: 100,000 trees/year in 2022, 200,000 trees/year in 2023	Yes	Ecological restoration with 2 species of *Polylepis* & protection of native forests alongside agricultural and livelihood improvements	12	3
11. Department of Ancash	2000–4000 (High Andean Forest)	Government: Agrorural Regional government	Early 2000s	NA	Partly	Ecological restoration with *Polylepis*, but also large-scale plantation with exotic Pine	2	NA

Note: Bold indicates that the site was a focal site with more than five interviews conducted. Success level represents the average score of an interview question on perceived success and was only coded if answered by more than 5 respondents (with 1 = low success, 2-medium success, 3-high success).

[a]Featuring in a case study box in Supporting Information.

the policy brief from Cerrón Macha et al. (2018) to include only Andean Forests, and by asking interviewees for additional locally implemented projects during fieldwork (e.g. SERNANP projects were not listed in the annex). We focused on Cusco, Apurímac and Ancash as several projects were accessible in proximity. We visited a total of 11 restoration projects (Table 1): Seven ecological restoration projects where only native species were used (run by NGOs or the government protected area authority), and four projects (run by other government agencies) which incorporated native species ecological restoration with other types of planting (e.g. exotic plantations). Interviews focused exclusively on native restoration.

The nation-wide study by Cerrón Macha et al. (2018) identified a total of six restoration projects in 'Bosques Andinos' and Páramos (corresponding to our classification of High Andean Forests) and a total of 31 projects in Yungas (lower montane moist forests, some of which correspond to our classification of Andean montane Forests above 2000 m a.s.l.). Our selection of 11 projects hence provides a substantial coverage of existing projects in those ecosystem types. Projects were initiated between 2 and 30+ years prior; most had been running 5–10 years. Restoration sites were situated between 2800 and 4500 m a.s.l. encompassing both montane forests and high Andean Forests (Table 1). We complemented interviews with immersive field visits (Figure 2) of restoration sites (Figure 2a–c), greenhouse operations (Figure 2d,e) and capacity building workshops (Figure 2f).

We conducted 75 interviews with key people involved with key stages of restoration across five stakeholder groups (community members, community leaders, government officials, NGO managers and technicians, private and academic actors). Forty-four interviews (58%) were with community members who took part in restoration, 14 interviews (19%) with government workers, 12 interviews (16%) with NGO employees and a smaller number with Private and Academic Actors (4% and 3%, respectively).

Our proportion of interviews with NGO and government stakeholders is representative of the principal actors in Peruvian ecosystem restoration according to a nationwide study by Cerrón Macha et al. (2018). They showed that in mountain forests and Páramos NGOs lead 67% of projects and governments lead 17%, while in the Yunga Forests Andean Forests 55% are led by government actors and 29% by NGOs. We also carefully selected key local community members involved with the projects—particularly elders and Indigenous people—as these are the major beneficiaries and the local stewards of the restoration projects; 86.5% of interviewees were male and 13.5% female (Table 2). The proportion of female interviewees was low amongst community stakeholders due to a lack of females in leadership roles; however, we endeavoured to interview as many women as possible who had participated in restoration activities. Due to low sample sizes of private and academic actors, these were excluded in between-stakeholder comparisons. More than half of the interviewees were above the age of 50, likely because of the rural-to-urban migration of young people leaving farming communities (Aide & Grau, 2004).

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FIGURE 2 Field visits. (a) A 15-year-old mixed native forest restoration in Machu Picchu Sanctuary. Trees measure between 2 and 6 m. (b) An 18-year-old Reforestation with Polylepis racemosa on a mountain slope at 4500 m a.s.l. in the community of Aquia. (c) A fenced site with reforestation using Polylepis near a lagoon in Huascarán National Park. (d) A greenhouse with 80,000 bare roots planted Polylepis seedlings in the Cordillera de Vilcanota. (e) Women from the community sorting Polylepis stakes at the greenhouse near Challabamba and (f) a practical fire prevention workshop run by ECOAN In the Cordillera de Vilcanota. Consent was given by all people recognizable in the photos.

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Two to 15 interviews were conducted per site, and we selected seven 'focus' sites where we conducted more than five interviews (Kiuñalla, Challabamba, Cuenca del Mariño, Vilcanota, Huascarán, Independencia and Aquia). Two interviews were conducted via video conference. We identified interviewees through key informant sampling with community leaders or project managers, snowballing and during walks in the communities.

TABLE 2 Demographic characteristics of interviewees.

Demographic characteristic	Categories	Number of interviewees [%]
Age	≤30	9 [12.1%]
	30–50	25 [33.3%]
	≥50	41 [54.6%]
Gender	Male	64 [85.3%]
	Female	11 [14.7%]
Involvement in agriculture	Yes	46 [61.3%]
	No	29 [38.7%]
Education	School	43 [57.3%]
	University	32 [42.7%]
Stakeholder group	Community	44 [58.6%]
	Government	14 [18.6%]
	NGO	12 [16%]
	Private	3 [4%]
	Academia	2 [2.7%]
Residence of interviewee	Rural	49 [65.3%]
	Urban	26 [34.6%]

Interviews were voluntary, uncompensated and conducted after receiving written informed consent. The consent procedure involved the researchers either reading out the consent form, or the participant reading it themselves, depending on literacy. After this, the participant signed a consent form which is stored with the lead author. Interviews used a semi-structured template (Text S1) using nine themes (1) restoration motivations, (2) values of forests for their livelihoods, (3) the restoration objectives of the project, (4) perception of degree of success in reaching the objectives scored on a scale of 1–3, (5) perceived enabling and limiting factors, (6) perceived impacts and benefits, (7) restoration preferences, (8) recommendations for other communities and (9) visions for the future and other comments. We further conducted in-depth technical interviews (Text S2) with the project managers at four of the focal restoration sites (Aquia, Kiuñalla, Vilcanota and Challabamba). Fifteen interviews were carried out in Quechua and translated into Spanish during the transcription. Original versions of the translated quotes are provided in Table S3. The study was approved by the ethics board of the University of Oxford (CUREC: SOGE1A2021-215); supplementary references are given below the main references.

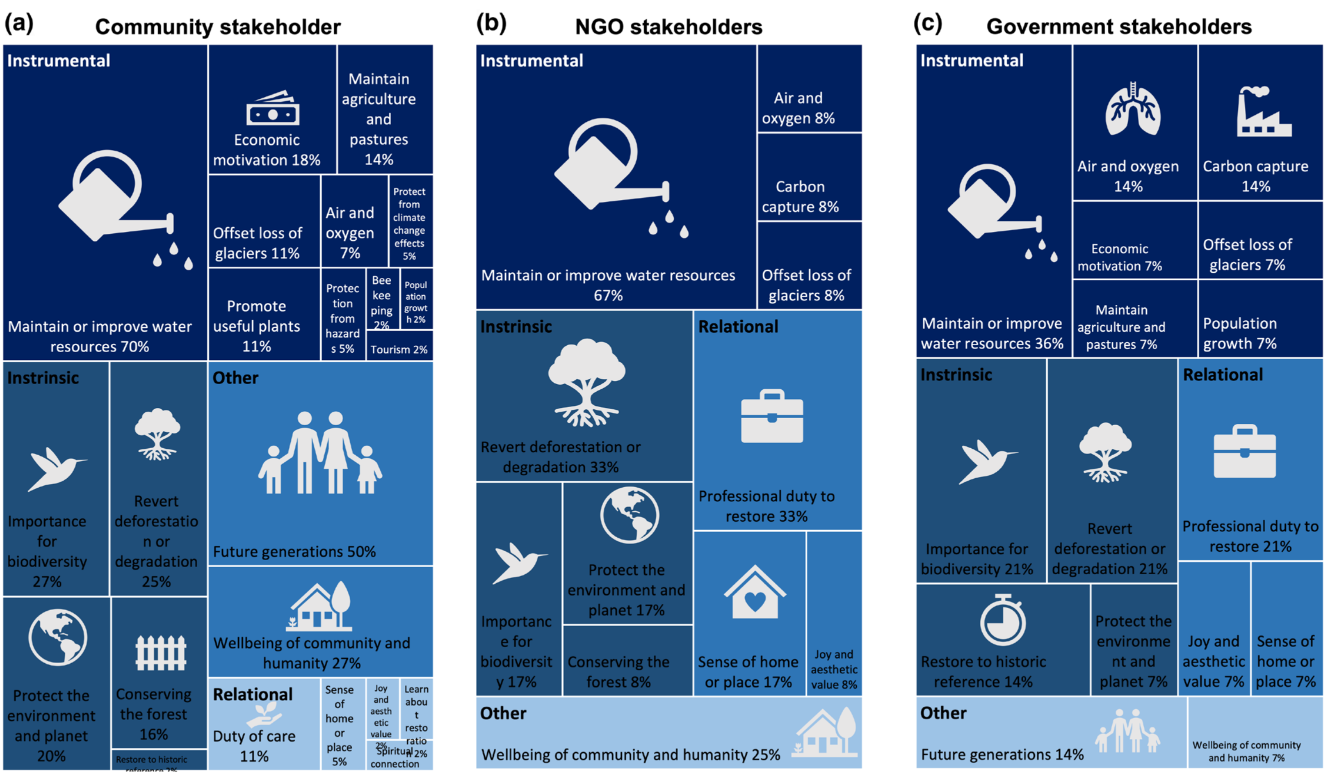

FIGURE 3 Motivations for Andean Forest restoration for each stakeholder group shown as percentage of interviewees within the stakeholder group (a) community stakeholder (44 respondents), (b) NGO stakeholder (14 respondents) and (c) government stakeholder (12 respondents). The different shades of blue represent the four motivation categories.

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2.4 | Analysis

Data was analysed thematically using inductive and deductive coding in NVivo. We categorized restoration motivations as intrinsic, relational, or instrumental (IPBES, n.d.). We used the MEA ecosystem services framework to categorize forest values and uses into supporting, regulating, provisioning and cultural services (Millennium Ecosystem Assessment, 2005). We used five categories (social, institutional, governance, biophysical and technical) for enabling and limiting factors, following other categorizations for restoration (Cerrón Macha et al., 2018; Le et al., 2014). Interview codes were analysed by number of interviewees who mentioned a certain code, and by frequency of occurrence of coding references. We provide quantitative numbers as relative numbers (%) of overall interviewees (i.e. of 75) and of % within a stakeholder group (e.g. % of community members = number of community members mentioning a code divided by 44 total community interviewees, Table 2) to provide relative multi-stakeholder comparisons.

3 | RESULTS AND DISCUSSION

3.1 | Demand for ecosystem services drives restoration motivations

All stakeholders—especially community members—stated they engaged in forest restoration primarily for instrumental reasons, that is, to achieve something particular for people (Figure 3a–c). Seventy per cent of community members and 67% of NGO stakeholders cited maintaining and improving water resources for agriculture. As one community leader explained: 'You have to reforest [...] to sow and harvest water you have to work well with the planting, [you have to choose] which plants attract [the water] well, like Queñua [*Polylepis* spp.] and the paja [Stipa Icchu] which also traps the mist' (Community leader). Community members were also motivated by direct economic reasons (18% of community members), a desire to improve agriculture and livestock farming (14%) and to promote useful plants (11%). Fifty per cent of community members were motivated to improve livelihoods for future generations, and 27% mentioned the wellbeing of their community. Restoring Andean Forest using native species for local and regional water benefits was often linked to the concept of 'Sowing and harvesting water' ('Siembra y cosecha de agua'), a term originating two decades ago in Ayacucho (ABA—Ayacucho, n.d.). 'Sowing and harvesting water' combines a variety of activities that intercept and retain water in a landscape, including activities that are thought to improve water recharge in the subsoil and aquifers and increase humidity through fog collection by trees and in situ water recharge (e.g. wetland and grassland conservation and restoration and reforestation with native water-conserving species) (ABA—Ayacucho, n.d.). Our findings on the motivations linked to water services align with the 'Ecosystem service scarcity path' theory reported in other Andean countries (Wilson et al., 2019): in the Ecuadorian Andes the main motivation for communal tree planting was to restore water resources, and 4–7 years post-restoration community members reported improved water quality and quantity. Farmers in our study frequently mentioned the direct importance of forest restoration in improving water availability for their agricultural livelihoods: 'The forest in this zone is giving us water and it is capturing water and, given the dry season, this is quite a lot of support. Because if we didn't have water, how would we do what we need to do?' (Community member). In Peru, communities are willing to restore and steward the land to counteract the loss of water due to rapid deglaciation, landscape degradation and changing rainfall patterns (Zimmer et al., 2022). This 'water motivation path' is particularly timely given the recent prolongation of dry seasons, deglaciation and water scarcity amplified by unsustainable land use practices in the Peruvian Andes (Giráldez et al., 2020; Motschmann et al., 2020).

All stakeholder groups mentioned intrinsic motivations to restore forests including reverting deforestation or degradation, restoring biodiversity or environmental protection. Relational motivations, which reflect a symbolic relationship with nature through identity, were mentioned particularly by NGO and government stakeholders, with comments mostly related to professional duty of 'caring for nature' (Figure 3b,c). Government and NGOs hence shared a range of more conservation-driven motivations such as reversing deforestation, and a sense of moral or professional duties to restore. That different stakeholders are motivated by different reasons to restore forest has been reported from many different contexts throughout the tropics (Ota et al., 2020).

Provisioning ecosystem services were most mentioned by all stakeholder groups (84% of all interviewees) when asked how forests contribute to the wellbeing and livelihoods of communities (Figure 4a). Water provision was mentioned by 61% of community members, 50% of NGOs and 36% of government stakeholders, followed by provision of wood for fuel and construction (41% of community members, 25% of NGOs and 29% of government stakeholders). Regulating services (Figure 4c) was mentioned by 41% of all interviewees: water retention was the most frequently cited (23% of community members, 33% of NGOs and 14% of government stakeholders), followed by climate regulation (14%, 8% and 7% respectively). Despite the frequent perception of water-related ecosystem services, to date the effects of forest restoration with native species on the water balance of tropical montane forest systems remains understudied (but see Bonnesoeur et al., 2019; Bruijnzeel, Mulligan, & Scatena, 2011; Bruijnzeel, Scatena, & Hamilton, 2011). Interviewees mentioned anecdotal pathways through which forests and reforestation contributed to improved water quality and quantity. Andean Forests were related to aquifer recharge and water retention: '[Andean Forests] contribute to regulation of water flow and act like great sponges. The soil is full of mosses and leaves, they capture the humidity and infiltrate it slowly into the soil' (NGO technician) and 'The forests retain water during the wet periods, and this allows us to be able to count on our water reservoirs during the dry season. We witnessed that Queñua [Polylepis] is a tree that traps water' (Private actor). Community

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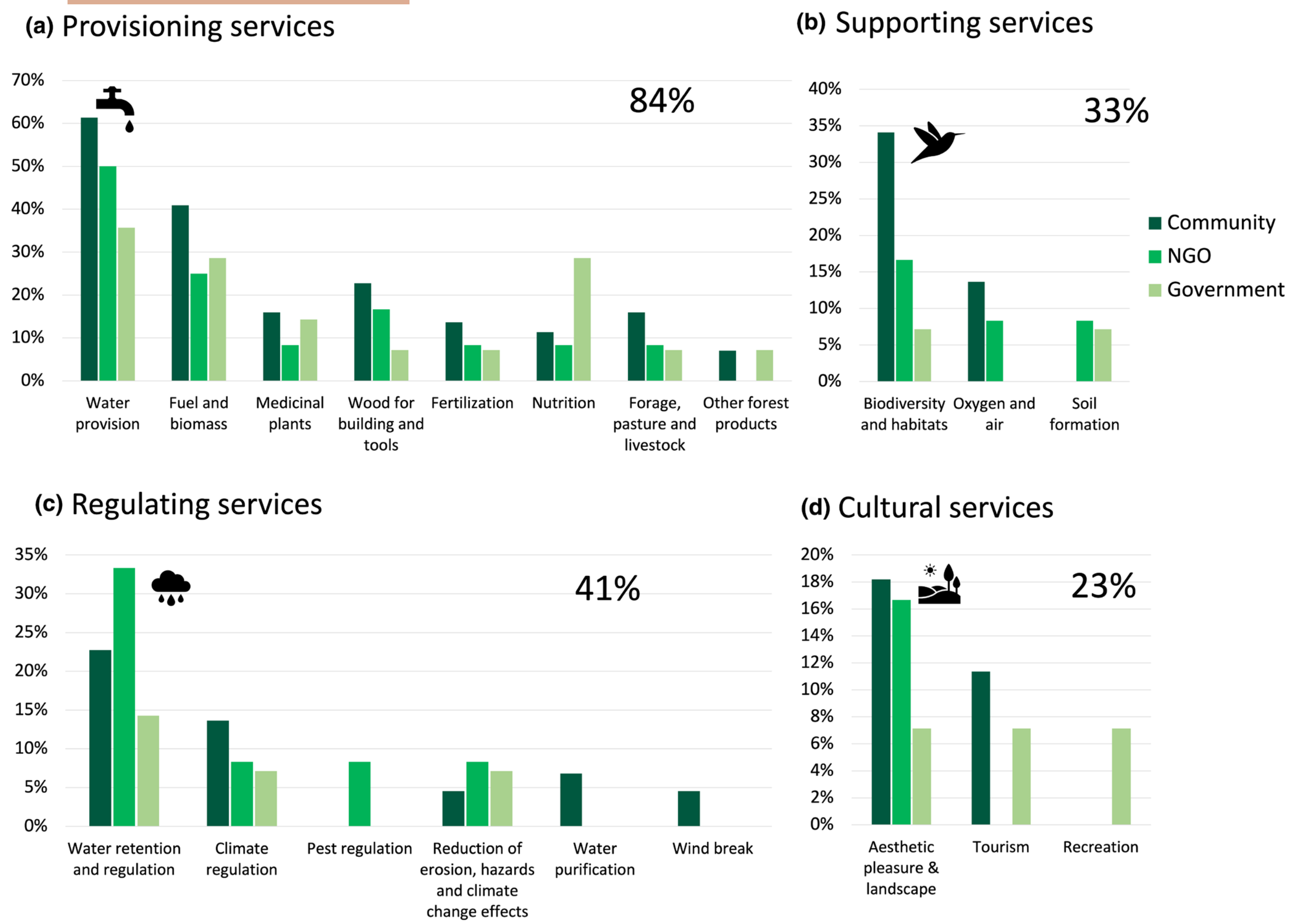

FIGURE 4 Ecosystem services of Andean Forests for each stakeholder group. % represents the percentage of interviewees within each stakeholder group. For grouped across all stakeholders please see Figure S1. Ecosystem services are categorized according to the Millennium Ecosystem Assessment (2005).

members believed native species to 'retain water through their roots', 'catch cloud water' and increase local humidity ('the forest creates humidity'). This in line with emerging knowledge on the 'forest sponge-effect' whereby tropical forest intercept cloud water droplets from fog, retain moisture in the soil and extend water availability into the dry season (Ogden et al., 2013). Hydrological studies in tropical forests in Panama have shown that mature and secondary native forests show high vertical water flow during storm events and recharge the ground water (Birch et al., 2021). Apart from regulating water quantity, our study respondents highlighted that Andean Forests also control water quality ('the [forested] basin is like a filter, like a big sponge'—community member). To date, hydrological effects of forest restoration with native species in the Andes are largely unknown, although studies on afforestation with exotic trees have found a detrimental effect on downstream water supply (Bonnesoeur et al., 2019). Many references on hydrological effects were anecdotally derived from local field observations, as highlighted by an NGO official: 'the local people have understood that the Queñua [Polylepis] contributes to water recharge. Still, we can't tell this [water flow effect] quantitatively, but qualitatively yes [it contributes to recharge]'.

All stakeholders referred to supporting ecosystem services (Figure 4b), such as a biodiversity and habitat value, especially community stakeholders (34%) compared to NGO (16%) and government stakeholders (6%). As an academic researcher put it: 'There is obviously biodiversity—the forest is a refuge for the Andean bear and there are quetzals in Huanipaca'. Cultural services (Figure 4d), such as aesthetic values and tourism and recreation, were mentioned by 23% of all interviewees.

At the global level, restoration initiatives often aim to restore forests to improve ecosystem services such as biodiversity and carbon sequestration. However, in our study based on 11 projects in Central and Southern Peru, people restore Andean Forests for the local benefits they provide; improving water resources is the primary motivation for all stakeholders and seen as the lifeline of communities for agriculture. The desire to restore forests for the direct, local benefits was found across the Andes (Báez et al., 2010; Durand & Sevillano, 2017; Joseph et al., 2021; Ota et al., 2020; Wilson et al., 2019; Wilson & Coomes, 2019). This presents an opportunity to capitalize on global support for restoration that also provides local benefits. Restoring Andean Forests might eventually yield opportunities for carbon markets, but there is a scalar difference between

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well-funded global restoration goals (carbon, biodiversity), and the landscape-level goals identified in this study that directly benefit local people (improved water services). National and regional hydrological payment schemes are funding mechanisms that incorporate local water-related restoration (Box S1).

3.2 | Restoration preferences: Interventions, species choice and ecosystem type

Restoration interventions (Figure 5a) mentioned included native species restoration, conserving existing forests, conserving and restoring grasslands, agroforestry, silvopastoral systems and exotic plantations (Figure S2). This aligns with many of the principles of Forest Landscape restoration, whereby different restoration interventions are designed at a landscape scale to restore multiple functions, conserve and enhance natural ecosystems and tailor approaches to local contexts (Besseau et al., 2018). Accordingly, strategic zonation of interventions was emphasized in many interviews to tailor interventions to three types of zones: forest systems (Andean montane forests, High Andean Forests), non-forest systems (Puna grasslands, wetlands) and human-centred systems (fields and pastures, immediate proximity to settlements/villages).

NGO stakeholders (50%) mentioned protecting native ecosystems as a complementary strategy, and government actors (79%) frequently mentioned restoring non-forest ecosystems such as Puna grasslands, wetlands and shrublands (Figure S2). Agroforestry—despite not being specifically asked about in the interviews—was identified as preferable particularly by NGOs (42%), with a minority of community and government referring to it (both 15%). Community members preferred tree species with direct use value or agricultural benefits: 'what we must plant around these fields is basul [*Erythrina falcata*] and pisonay [*Erythrina edulis*] because the leaves are going to feed the plants. [...] Pisonay can also serve as fodder for guinea pigs and cows' (*Community member*). Agroforestry has been shown to be a particularly useful technique in poorer rural areas due to its cost-effectiveness, its ability to offer income while facilitating natural regeneration (Moreno-Casasola, 2022), but in an Andean context might only be suitable alongside the milder montane forests adjacent to communities, not High Andean Forests.

Most interviewees (59% of overall interviewees, 57% of community, 58% of NGOs and 50% of government stakeholders) preferred planting exclusively native trees, mentioning over 40 desirable species (Figure 5c). In the NGO-led project sites (Kiuñalla, Marino, Challabamba, Aquia and Vilcanota) the preference for exclusively native species was higher than in the municipality-led restoration site Independencia where 80% of interviewees preferred a mix of native and exotic species. In the National Park Huascarán all interviewees preferred native species only. Restoring water resources was integrated into the design of most restoration projects, particularly for those led by NGOs (Box S1). Communities and NGOs prioritized reforestation with native species adjacent to headwaters, springs, and streams, and preferred native tree species considered as water 'savers': 'You must plant enough Queñua [Polylepis] to retain water' (NGO actor) and 'We must work with the plants that attract water well, like the Queñua [Polylepis] and Icchu grass [Stipa Icchu]' (Community member). These differences in preferences between different stakeholders, point to the need to support a variety of different restoration approaches with diverse goals within a landscape is restoration is to be adopted and sustained over large spatial and temporal scales (Wilson & Cagalanan, 2016).

Nearly half (48%) of all interviewees (45% of community, 25% of NGOs and 71% of government stakeholders) had negative opinions on exotic species (Figure 5b) because of the observed undesirable effects they have on water resources: 'If there is eucalyptus near the water springs, this sucks out all the water.' (Community leader). Contrasting with a study in the Ecuadorian Andes, where farmers associated exotic trees with soil improving and food producing benefits (Wilson & Coomes, 2019), in our study exotics were seen to drive deterioration of farmland: 'The leaves and the roots of the Eucalyptus ruin the ground for us. [...]. It doesn't even serve us as fertilizer' (Community member). Further, exotic species were often seen as 'water suckers', and many interviewees underlined that exotic species need to be far away from water resources: 'We know that pine and eucalyptus are the ones that dry up the water, therefore, they cannot be planted at the headwaters' (NGO actor). However, some interviewees—particularly NGO and government actors—highlighted the importance of Eucalyptus wood as an alternative fuel source: 'Eucalyptus is key here in the sanctuary because it avoids the cutting of native forest. It can be used by the communities [for firewood]. But for new plantations we must [...] identify where the water springs are, how to avoid impacts of the eucalyptus on water' (Government actor).

Our interviews focused on forest restoration, but despite this all stakeholder groups (13% of overall interviewees, 5% of community, 17% of NGOs and 14% of government stakeholders) mentioned restoring non-forest ecosystems (Figure S2) such as the high Andean grasslands ('*Puna*' or '*Pajonal*') and wetlands ('*bofedales*') to improve water resources: 'I wish that all institutions support the planting of Icchu in the highlands, wetlands, in the hills. So that [these ecosystems] can help with our water resources, because every day the planet is drying up more.' (Community member). Andean grasslands provide many essential ecosystem services including regulating water, soil fertility, providing food, wool, and fibre, and regulating microclimates (Rolando et al., 2017). Puna grasslands also show high belowground productivity storing similar amounts of carbon as Andean cloud forests (Oliveras, Girardin, et al., 2014).

3.3 | The social, economic, biophysical, institutional and technical factors driving perceived restoration success

Interviewees scored the overall success of the restoration projects they participated in on a scale of 1–3. All focus sites with enough

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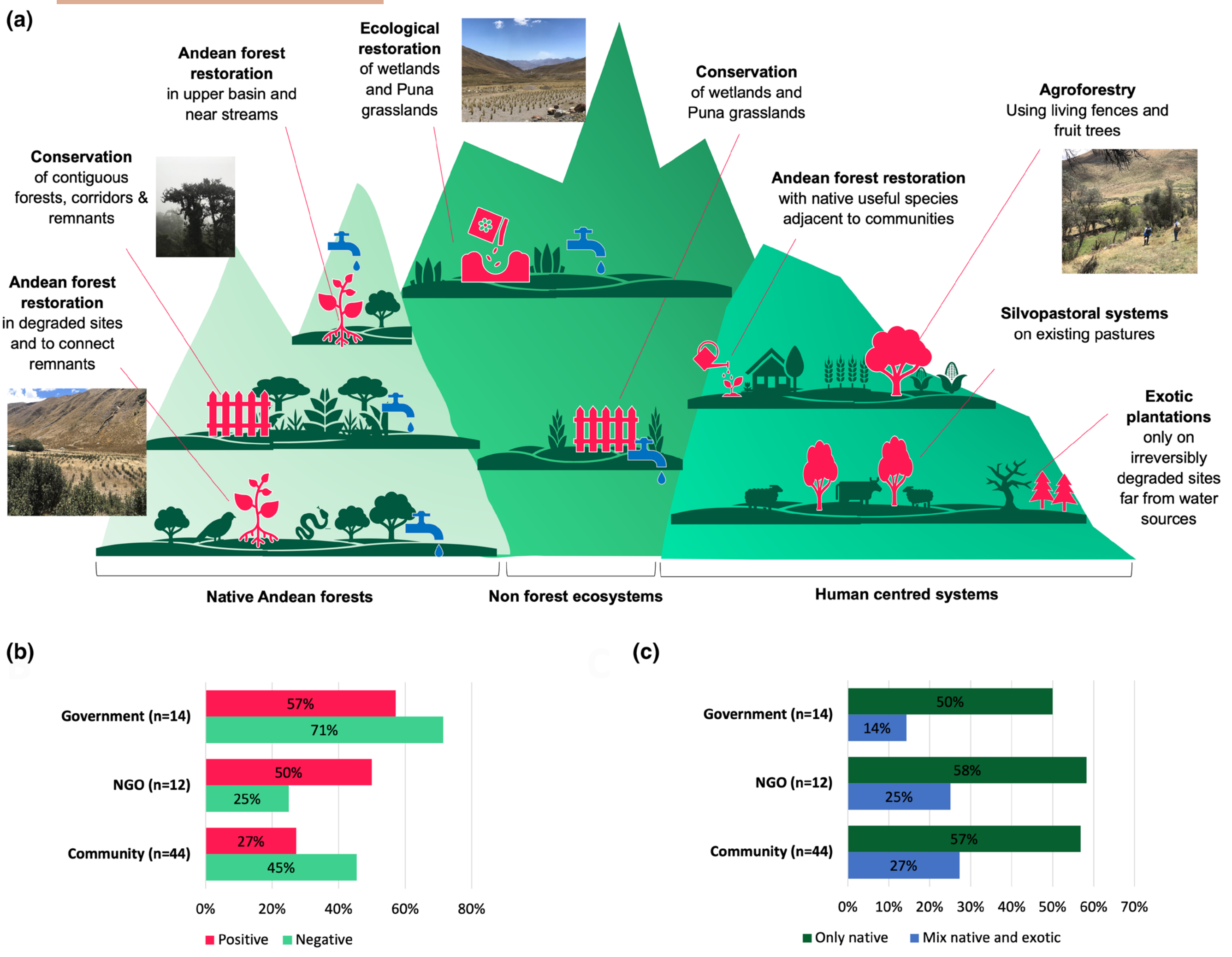

FIGURE 5 (a) Conceptual figure for a range of restoration preferences mentioned by Interviewees. These cover three 'zones': Native Andean Forests, non-forested ecosystems and human centres systems. The major methods mentioned are Native Andean forest restoration, ecological restoration of grasslands and wetlands, conservation of forest and non-forest systems, agroforestry, silvopastoral and to a minor extent exotic plantations for firewood. (b) Opinions on exotic species (Eucalyptus, Pine) across the main three stakeholder groups, (c) types of species preferred for planting.

respondents (Aquia, Kiuñalla, Challabamba, Vilcanota, Huascarán, Cuenca del Mariño, Independencia) had average success scores between 2.44 and 3 (Table 2) and were considered successful by participants. Participants attributed success to a variety of reasons, such seedling survival, achievement of biodiversity benefits or improved water resources, as highlighted by a community leader describing project success: 'the planted seedlings are young […], beautiful and [the forest] already harbours plenty of birds, there is humidity, and it looks nice' (Community leader).

3.3.1 | Limiting factors

NGO and community stakeholders cited that social factor—such as a lack of education about the importance of forests, unsustainable land use and community resistance factors limited restoration first and foremost, while government stakeholders focused more evenly on biophysical, institutional, and economic factors (Figure 6a).

Social factors (Figure 6a.1) at the community level included uncontrolled fires for agriculture (45% of all interviewees, 23% of community, 58% of NGOs and 79% of government stakeholders), a lack of environmental awareness (24% of overall interviewees, 32% of community, 33% of NGOs and 36% of government stakeholders), and fear of land grabbing (21% of overall interviewees, 12/44 27% of community, 17% of NGOs and 0% of government stakeholders). A community leader said: 'I have always focused on telling [the community] they should not light fires, some burning garbage, some near the forests. Sometimes […] I have seen that more than 200 ha have caught fire near the ravine' (Community leader). Uncontrolled human-induced fires were a challenge mentioned by all stakeholders. Despite fires being used for centuries in the Puna grasslands to manage grazing resources, recent changes in climate and land use are increasing the incidence and area of fire (Manta et al., 2018) which

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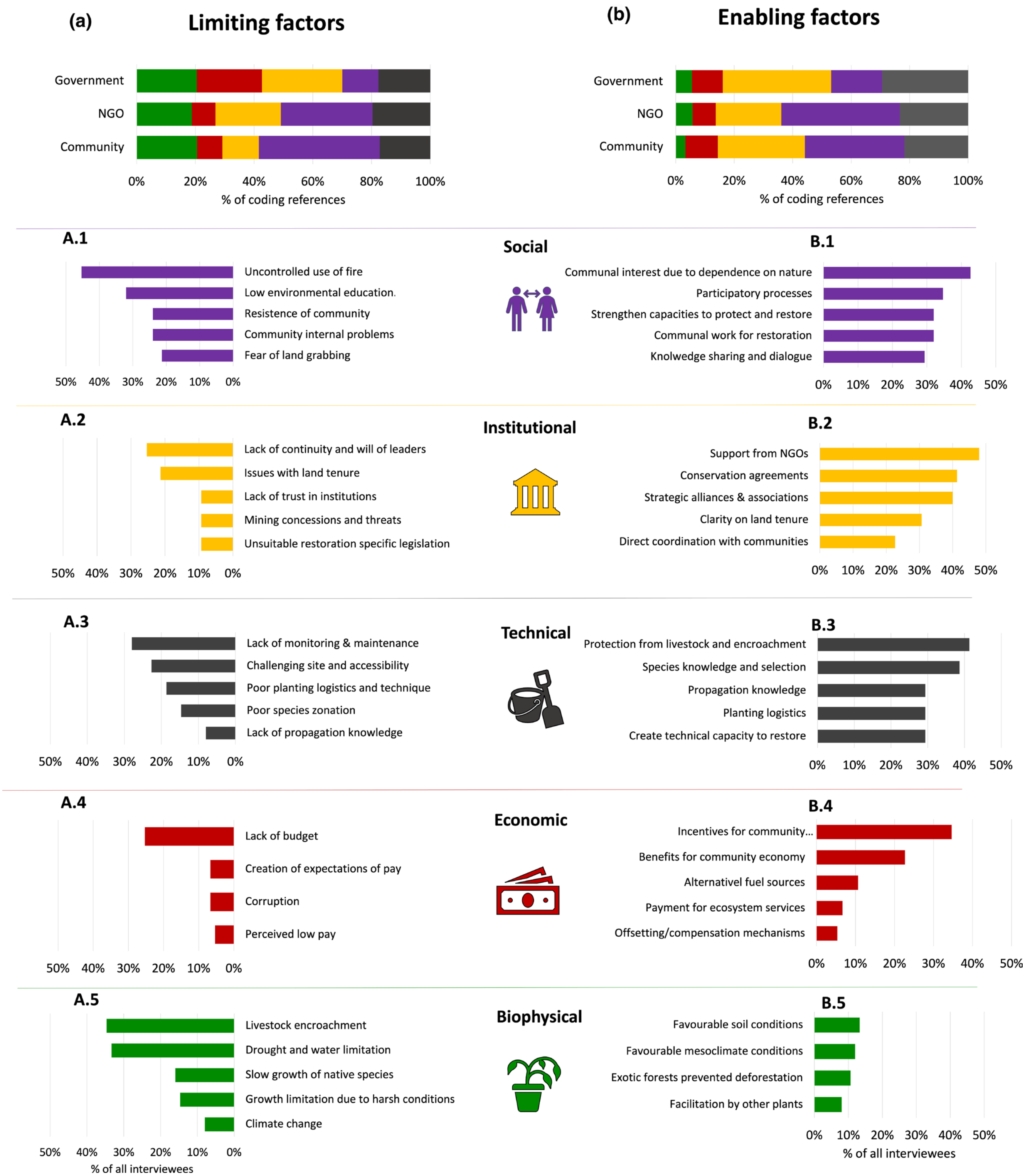

FIGURE 6 Liming (a) and Enabling (b) factors for successful Andean Forest restoration. Top diagrams show breakdown by stakeholder group, bottom diagrams (a.1–a.5 and b.1–b.5) show breakdown by each factor category.

spread into less fire adapted Andean Forests including cloud forests, including into our study departments of Cusco and Apurímac (Manta et al., 2018; Román-Cuesta et al., 2011). Appropriate training for fire management and adaptation strategies is important for successful restoration. The NGO ECOAN, for example, held fire prevention workshops with community leaders who then serve as leaders of community fire brigades (Figure 3f). A lack of awareness of forest benefits hindered restoration work: 'We are still not well educated [on environmental conservation]. Some of my colleagues are cutting the Intimpas [*Podocarpus glomerata*], while others are protecting the

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mature Intimpas which are more than 500 years old.' (community leader). Promoting education and strengthening capacities to protect and restore Andean Forests is especially important for creating self-sufficient and community-run projects beyond the project timeline. Capacity building must go beyond technical restoration skills to include sustainable land management more holistically, including protecting existing forests.

Institutional barriers, mostly cited by government officials (Figure 6a.2), included a lack of commitment and continuity of leaders at local and regional levels (27% of all interviewees, 16% of community, 33% of NGOs and 43% of government stakeholders), and land tenure conflicts at restoration sites (25% of all interviewees, 11% of community, 8% of NGOs and 57% of government stakeholders). Communities are governed by short-term committees ('juntas directivas'): 'the president [of the community] only lasts 2 years, and suddenly another president is elected and is not interested [in the restoration]. So, I would say that the institutions need to come and train the community, the president that leaves and [the one who] enters to ensure continuity' (Community member). Recovering Andean Forests is a multi-decade endeavour (Aragón et al., 2021; Oliveras, Malhi, et al., 2014). We found that short leadership terms—at the communal and government level—often resulted in fluctuating support, funding and community interest for restoration, leading to a lack of continuity and sustained support. On the other hand, dedicated community leaders and community forestry groups, such as reforestation committees, helped achieve restoration outcomes, as previously found in Forest Landscape Restoration initiatives across the tropics (Ota et al., 2020).

All actors—particularly government stakeholders—mentioned a lack of monitoring and maintenance of sites (28% of interviewees, 16% of community, 17% of NGOs and 64% of government stakeholders) (Figure 6a.3). An academic actor noted: 'There is no maintenance in the first months, years. [...] It is not enough to simply plant, you must accompany this process. [...] But there is still a long way to go to have evidence of interventions' (Academic actor). Difficulties in conducting monitoring are prevalent in restoration practice and are currently compounded by a lack of training on forest landscape monitoring across Latin America (Evans et al., 2023). Drone monitoring of remote restoration sites is a promising future avenue in remote Andean Mountain locations (Robinson et al., 2022).

Main biophysical limitations (Figure 6a.5) were livestock encroachment (35% of all interviewees, 23% of community, 50% of NGOs and 57% of government stakeholders) and water limitations (33% of overall interviewees, 34% of community, 25% of NGOs and 43% of government stakeholders). Slow growth of native species (16% of overall interviewees, 7% of community, 8% of NGOs and 36% of government stakeholders) was particularly emphasized by government actors: 'but how long will a Queñua [*Polylepis* spp.] forest take us, sometimes 200 years. It is a very slow growth [...] you would have to have a lot of heart [patience] that they grow for my children. [The community] already want to see something sooner [...]' (government actor). Interviewees mentioned the difficulty of growing Andean tree species, concurring with previous research identifying slow vegetative growth, harsh bioclimatic conditions, livestock herbivory and high fragmentation as factors limiting tree growth (Pinos, 2020; Vásquez et al., 2014; Wesche et al., 2008). Two techniques were used to improve the scale of planting and planting success of *Polylepis* spp. which can regenerate from cuttings: (1) collecting branches from mother trees to propagate in the greenhouse ('propagación con esqueje') or (2) aerial layering ('acodo aéreo') whereby little ring incisions are made around living tree branches and a bag of soil is attached at the incision point to promote root growth (Mindreau & Zúñiga, 2010). Collection sites and mother trees need to be strategically selected to not overstrain healthy *Polylepis* populations, as mentioned by an NGO actor 'Every time we are producing more [stakes], there are more mutilated branches from the forests because I have to make cuttings'. Stake orchards' can be created to source genetic material (Box S3). Using other Andean high-altitude species such as *Buddleja* spp. ('kishuar' [*Buddleja incana*] & 'colle' [*Buddleja coriaceae*], see Table S2) should also be considered to ensure higher species diversity and resilience of restoration sites.

Restoration sites were often located in remote, upstream areas, causing access challenges for both planting and monitoring. This lack of accessibility was mentioned by 23% of interviewees (23% community, 42% NGO, 14 government): 'to Huamanhuece we go on horseback. Walking we would get tired—this is far away' (Community member). Propagating and transporting seedlings with bare root can solve weight-related transport challenges, a technique used by the NGO ECOAN to plant up to 200,000 seedlings per day. Decentralizing greenhouse infrastructure and placing greenhouses close to restoration sites also helps reduce logistic challenges (Box S3). Aerial layering of *Polylepis* eliminates the need for a greenhouse as seedlings are grown in forest relicts close to restoration sites (Mindreau & Zúñiga, 2010).

3.3.2 | Enabling factors

NGO stakeholders and community interviewees cited social enabling factors most frequently (41% and 34% of coding references of said stakeholder group) whilst government stakeholders cited social factors less (17% of coding references) (Figure 6b).

Across all interviewees, but particularly amongst NGO actors, participatory processes (35% of all interviewees, 16% of community, 83% of NGOs and 36% of government stakeholders) were key for the long-term success of forest restoration (Figure 6b.1). These are key in all project stages: selecting sites, choosing species to plant and determining locally appropriate ways of implementation and compensation. Working closely with local communities to develop social and economic benefits is key for achieving restoration outcomes (Aucca & Ramsay, 2005; Hartman & Cleveland, 2018). Without this, many restoration projects fail (Rosa et al., 2020). Hence, restoration should be planned in partnership with community committees, through participative workshops and planning days. Community tasks 'faenas' were described by NGO-stakeholders as 'very powerful' to implement restoration, using community established structures that

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provide a social space for dialogue and sharing: 'Every year when we do the planting the community gets together, we dress ourselves [in traditional dresses], prepare food, and pay tribute to Pachamama, then we dance [...] These are the reasons why the community willingly takes part.' (Community member).

Local dependence on natural resources leading to communal interest in restoration were key success factors (43% of all interviewees, 36% of community, 75% of NGOs and 43% of government stakeholders) 'Success begins with the decision of the community. The community identified that the water flow was decreasing due to their crops, so they made the decision to restore their forests because they realized that the degradation of the forests caused reductions in water flow' (NGO actor). We found that a higher degree of dependence on natural resources—typical for subsistence farming in Latin America (Aguiar et al., 2021)—led to a high level of communal interest and restoration engagement: 'We are delighted to work with the reforestation, especially when it is about water' (community member). Restoration was not seen to compete with subsistence agriculture or livestock farming, but to benefit it through 'sowing and harvesting water', contrary to previous findings (Joseph et al., 2021). Our findings concur with work in the Ecuadorian Andes, where communities with higher natural resource reliance were more engaged in forest restoration (Wilson & Coomes, 2019).

Institutional/legal enabling factors (Figure 6b) included support from NGOs (48% of interviewees, 66% of community, 8% of NGOs and 29% of government stakeholders), formal conservation agreements with communities (41% of overall interviewees, 39% of community, 67% of NGO and 21% of government stakeholders), strategic alliances (40%, 18% of community, 83% of NGOs and 71% of government stakeholders) and clearly defined land tenure (31% of overall interviewees, 20% of community, 58% of NGOs and 21% of government stakeholders) (Figure 5b.2). NGO stakeholders highlighting the importance of land tenure security. As one community leader stated: 'it is social work to explain to the community that they will keep owning the land, no one will grab it—they can still use it'. Formalizing forest conservation agreements is also crucial to avoid informal appropriation of territories by subgroups because of their investment of restoration labour. Fencing was also necessary to physically protect restoration sites from illegal grazing as previously found (Aguirre et al., 2011).

We found that strategic, multi-layered and polycentric arrangements and alliances were key to achieving restoration goals—including alliances between local organizations such as farming cooperatives and community groups, and between actors involved in landscape management of different hierarchical levels, like local NGOs, regional governments, government agriculture initiatives (AGRORURAL), national protected area authorities and private actors (e.g. water companies and tourism companies). Multi-level and polycentric structures are thought to work well due to their ability to flexibly respond to local scale problems and to make level-dependent decisions in a way a centralized single-actor system cannot (Lebel et al., 2006). A key example of such a strategic multilayer alliance is the cases of the Mariño River basin and Nor Yauyos Cochas (Box S1). Crucially, to scale up restoration and translate large-scale commitments into realities, scale-sensitive governance arrangements are needed, whereby different governance levels are connected and aligned across scales to harness different skill sets, effectively use existing knowledge and create relevant capacity (Wiegant & Guariguata, 2023).

Government actors cited technical factors more (29% of coding references within the government stakeholder group) than NGOs and communities (23% and 22% of coding references within the respective stakeholder groups) (Figure 6b). These included physically protecting restoration sites (31% of all interviewees, 39% of community, 75% of NGOs and 29% of government stakeholders) from livestock and encroachment (Figure 6b.3), as emphasized by a government official 'If you want a short-term guarantee, you have to fence it'. Species knowledge and selection (39% of interviewees, 20% of community, 75% of NGO and 71% of government stakeholders) were a prominent enabling factor and can be leveraged by using Traditional ecological knowledge, which is a foundation for successful and equitable forest restoration (Reyes-García et al., 2019; Robinson et al., 2021). Many of the communities we visited had intricate knowledge of Andean Forests with a female elder referring to 80 medicinal species occurring in the local forest. Involving such knowledgeable community members in restoration planning is crucial to (1) create a baseline of species in the native forest, (2) identify which plants are most valued by local communities and (3) and learn how to propagate and position these plants. In the restoration sites Kiuñalla biodiversity baselines were established through interactive approaches with the community: 'we did workshops to recover knowledge [on forest tree diversity], and competitions where women took part to see who could retrieve the most diversity from the forest' (Academic actor).

The importance of building the technical capacity to restore was mentioned by all stakeholder groups (29% of all interviewees, 32% of community, 33% of NGOs and 29% of government stakeholders). 'In areas recovering from fires, degraded areas, and eroded soils we basically have produced more Polylepis racemosa, because it has its advantages, it is stronger, it spreads faster than the others and it adapted better in the area' (government actor). To a smaller extent, interviewees referred to favourable soil and microclimate conditions as key biophysical enabling factors (13% and 12%) in promoting plant establishment and growth (Figure 6b.5).

A key factor for success was creating economic incentives for community participation (Figure 6b.4), mentioned by 35% of all interviewees (41% of community, 50% of NGOs and 21% of government stakeholders). As a community leader said: 'Economically [the project is successful] because there is work. People worked earning their minimum salary, as an incentive' (Community leader). Incentives and socio-economic benefits are known to be important for successful restoration (Ota et al., 2020). In the Andes, developing health infrastructure, improving nutrition and education have been suggested as foundations for a community's engagement in restoration (Pinos, 2020). In our study, almost all projects provided benefits, like community development, improved agriculture, alternative

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livelihoods, or direct monetary payments, to community economy as highlighted by a community leader 'The NGO did not only help with reforestation but also with artisanal work, solar panels and greenhouses' (Community leader).

3.4 | Restoration project's impacts on community livelihoods

Forest restoration projects had numerous perceived positive and negative impacts for communities (Table S1). Positive impacts were mentioned by 100% of interviewees.

3.4.1 | Positive impacts

Across the projects a multitude of direct and indirect positive impacts were delivered for the communities, largely corresponding Pathway 2 (livelihood, well-being and resilience impacts) and (Pathway 3 indirect livelihood impacts and improved ecosystem functions) of the framework of Forest Landscape Restoration outcomes by Erbaugh and Oldekop (2018).

Direct economic benefits (mentioned by 60% of all interviewees, 68% of community, 92% of NGOs and 57% of government stakeholders) included paying workers for their labour and contributions to a community fund for activities like seedling provision (Table S1), which provides an incentive-based implementation mechanism (Erbaugh & Oldekop, 2018). Such payments were prominent in the ECOAN project in Vilcanota where 12 of the 13 interviewees mentioned the livelihood impact of direct payments provided by the NGO in return for communities raising seedlings: 'Not only that, ECOAN gives us a pay for helping with the planting, also when we make plants ourselves in the communal nursery ECOAN buys them from us, the income and the plants are for us' (Community leader). Government-led projects emphasized creating jobs: '[A benefit was to] […] provide labour [opportunities] to the communities, because many don't have a job […]. It was a substantial contribution to the social and economic part of the project, beyond the environmental part.' (Government actor). Payments varied from token payments (9.25$/day in Challabamba) to locally adjusted daily wages (18.5$/day in Machu Picchu).

Indirect economic benefits, which accrue over long time scaler, were mentioned by 77% of interviewees and frequently across all stakeholder groups (70% of community, 100% of NGOs and 79% of government stakeholders). These included creating alternative livelihood options such as tourism, artisanry or pisciculture, which are examples of key mechanisms to create community resilience in forest landscape restoration projects (Erbaugh & Oldekop, 2018). The implementing organization also provided indirect support by offering tools and materials for agriculture and infrastructure, seeds for pastures and agriculture and cooking fuel (gas or wood from Eucalyptus plantations) (Table S2). In protected areas where farming families held ancient land rights, livestock farmers participated in restoration in return for using state-owned grazing land within the protected areas. As discussed above, restored water resources were also a major indirect ecosystem benefit cited, with a perceived impact on agricultural production and sustainability, as shown in community forest restoration initiatives Ecuadorian Andes (Wilson et al., 2019).

The most notable non-economic benefit was community capacity building and education (91% of community members, 67% of NGO members and 50% of government members) (Table S2). An NGO actor describes this: 'We have just started training on forest fire prevention. This Sunday […] we will [do a training on] managing sprinkler irrigation and then […] a training in tourism […] and nutrition with their own products to improve food security' (NGO actor). To a smaller extent, projects also engaged school kids and increased community environmental awareness. NGO actors particularly highlighted improved communal governance and elevated communal identity and pride (25% of NGO members).

3.4.2 | Negative impacts

Whilst 17% of all interviewees did not report any negative impacts, some chief negative impacts mentioned included opportunity costs for agriculture and livestock (29% of all interviewees, 36% of community, 50% of NGOs and 29% of government stakeholders): 'The people surrounding the reforestation were uncomfortable saying that they are fencing the path of my animals, but later awareness improved and now they no longer say anything.' (Community leader). Issues with opportunity costs are common in restoration projects in the tropics, and benefits and incentives derived from restoration projects need compensate for foregone income, especially in areas where reforestation displaces intense agricultural land uses (Ota et al., 2020). In our case, there were opportunity costs associated with the use of the now conserved forests for timber and wood: 'Before [the farmers] cut down [forest] indiscriminately everywhere. [Now we] get firewood {eucalyptus} for each family 100 cuttings. If the NGO had not intervened right now, the hill would already be bare.' (Community leader).

3.5 | Restoration governance models to achieve community benefits and project sustainability

We identified three models of project governance based on how communities participated and were compensated: the 'payment model', the 'mixed model' and the 'capacity-building model' (Figure 7). Differentiation of these governance modes was done qualitatively using the restoration motivations, the classification of success and limiting factors and the types of livelihood impacts. Our typology partially overlaps with the three-class typology created for restoration projects in Latin America and the Carribbean (Coppus et al., 2019).

The 'payment model'—used often by governmental institutions—pays participants directly (Figure 7a—see Independencia and Ancash) for contractual labour or provides other direct economic benefits. In 'payment model' sites community members

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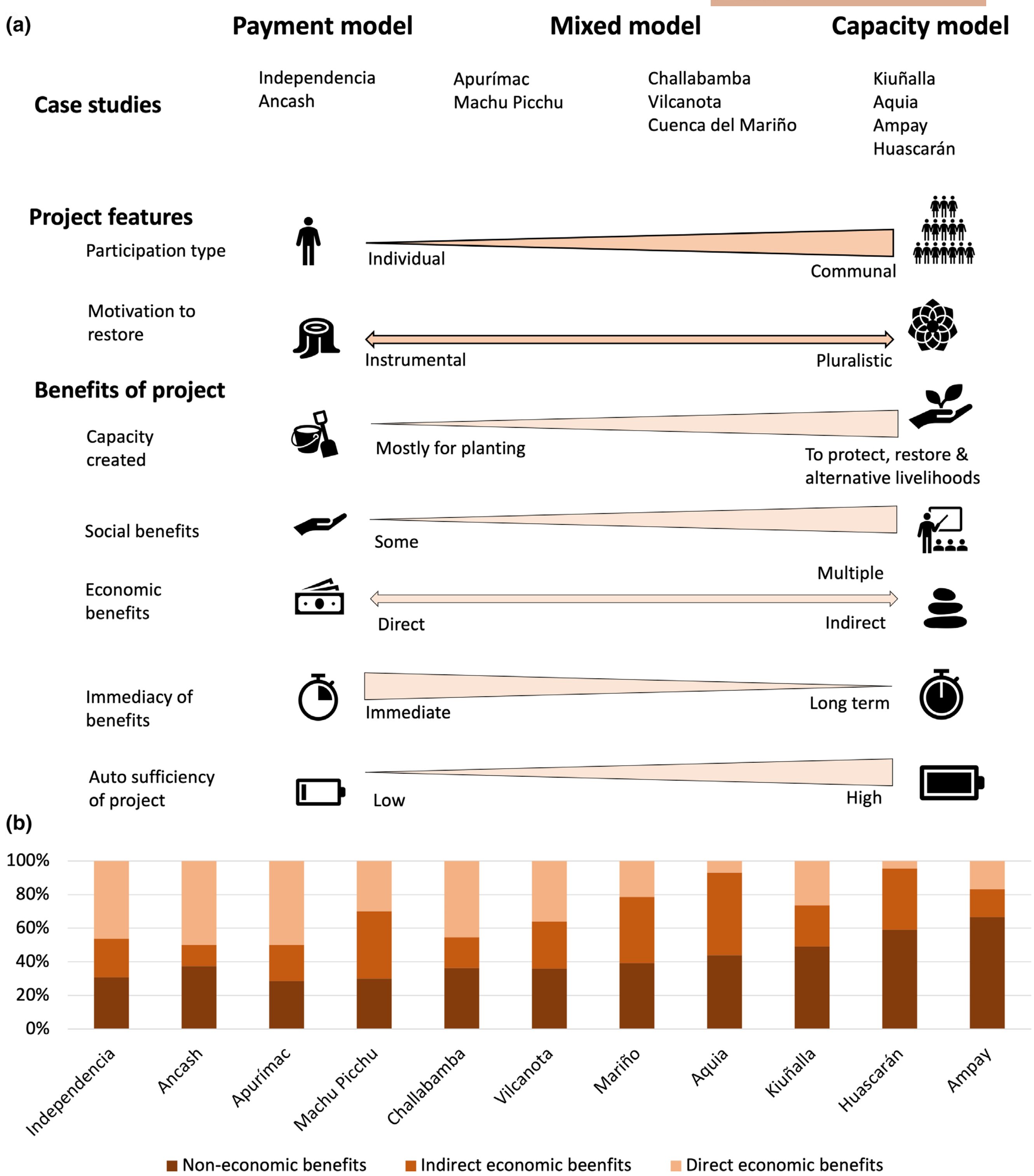

FIGURE 7 Three governance models identified and assigned to each case study area. (a) Classification of the three models according to project features and benefits of project. Motivations to restore are classified according to the IPBES framework, Pluralistic motivations include a combination of intrinsic, instrumental and relational motivations. (b) Types of benefits between the 11 project sites, classified as in Table S1 and sorted by quantity of respondents who mentioned non-economic benefits.

were more motivated by instrumental economic reasons with less intrinsic desire to restore: 'We are now 310 community members [...] And we helped [with the restoration] because the money helped us' (Community member). Although communities often sought short-term benefits, projects with a pure 'Payment approach' may not generate long-term social and capacity benefits beyond technical planting and may not instil an intrinsic desire in the communities to restore, as previously found in Ecuador (Wilson & Coomes, 2019).

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Previous research on market-based approaches has found that direct payments only provide incentivization for the duration of the payment, risking destructive action once payments cease (Wilson & Cagalanan, 2016) In one community, members did not clearly understand how restoration could benefit water or biodiversity, and instead commented that they did restoration because they were top-down told so: 'The government told us that we had to reforest with Queñua' (Community member).

The 'capacity model' (Figure 7a) actively involves whole community groups as agents of change, generates multiple social benefits, and creates indirect economic benefits intended to outlast project time scales (Figure 7b—Aquia & Kiuñalla, Ampay and Huascarán). The 'capacity model' promotes improved agricultural practices and alternative livelihood activities (e.g. by sowing higher productivity grasses, better livestock breeds and value-added production), aligning with many of the 10 golden rules for people-centred restoration (Rule 2—actively engaging communities as agents of change, Rule 6—generating multiple benefits including social benefits) (Elias et al., 2021). Implementers provide material resources to improve land management (tools, fences and irrigation infrastructure) and households (gas cookers and Eucalyptus firewood). This model integrates environmental education and long-term capacity building to promote project longevity by creating an appreciation of the ecosystem services provided by the Andean Forests (Durand & Sevillano, 2017). The case study of Aquia exemplifies this model as community members received a suite of livelihood benefits and had a high degree of environmental awareness and project appreciation even 13 years after the end of the project (Box S2). In some government protected areas people engaged in restoration in retribution for grazing rights and were described as well-organized and environmentally conscious 'The pasture users are organized, and because they live in the conservation area, they assume this responsibility and contribute' (Government actor).

The 'mixed model' (Figure 7a) uses aspects of both the payment and the capacity model—thereby providing both economic and non-economic livelihood benefits on shorter and longer timescales—such as in Vilcanota, Challabamba and Cuenca del Mariño, Machu Picchu and Apurímac (Figure 7b). In Vilcanota, permanent financial incentives meant community members wanted to permanently work with the NGO: 'With that [money] we already have at least some cents for the family fund, for these reasons we do not want ECOAN to withdraw [support]' (Community leader). Such long-term funding is one of the key determinants of restoration longevity in the tropics (Nerfa et al., 2021). In Challabamba, community members, particularly women, are individually paid to work in the greenhouse, but trees are planted during communal workdays 'faenas' without compensation. The NGO also provided workshops based on community needs and helped improve irrigation infrastructure (Box S2). In Cuenca del Mariño, capacity benefits were blended with Payments for ecosystem services provided by the local water company. Such blended benefit model, when implemented in a way to benefit marginalized groups, can help provide an equitable distribution of costs, risks and benefits of the restoration (Elias et al., 2021).

We found that purely direct economic incentives and a top-down governance approach (such as provided in some of the 'payment model' sites) were not always the most effective at motivating restoration. Rather, projects offering tangible social and non-economic benefits (i.e. 'Capacity model' and 'Mixed Model' sites) fostered an intrinsic desire for local communities to restore forests and produced more local support for restoration, holistic restoration success, longevity and higher community engagement, adding to a growing body of literature on typologies of restoration projects (Coppus et al., 2019).

Our study provides a multistakeholder view based on 11 restoration projects and a detailed comparison of 3 major stakeholder groups. It is not exhaustive, and there are additional restoration projects across Peru not included due to logistics and research constraints. Some location bias might remain due to a focus on sites in the central part of the Andes. However, our study provides an overview of stakeholder motivations in a diverse set of restoration projects of various scales and models with a large emphasis on community preferences and opinions. Future studies could include a more focused view of emerging private stakeholders—which as part of growing carbon markets are becoming increasingly more prominent and open new opportunities for financing restoration.

4 | CONCLUSION

Our investigation reveals that motivations driving Andean Forest restoration revolve around instrumental goals, particularly centred on water provision and direct benefits, echoing the 'ecosystem-scarcity path' theory (Wilson & Coomes, 2019). A community oriented and water-centred approach to restoration is needed for Andean Forests, which strategically allocates restoration interventions in the mountain landscape, optimizes for ecosystem service provision, promotes native biodiversity and directly benefits local communities. It should be designed with a multi-decadal vision to guarantee longevity and ongoing provision of ecosystem services.

Our analysis underscores the importance of considering socio-economic, institutional, biophysical and technical conditions to enhance restoration outcomes, acknowledging their variability amongst their perceived importance amongst stakeholders. We identified several promising socio-economic and governance mechanisms for restoration, including formalized community conservation agreements, payment for ecosystem service schemes and the creation of alternative livelihoods. Meaningful stakeholder engagement and active participation of communities and land users are indispensable and can be fostered by strategic alliances and a polycentric and horizontal governance centred around a capacity-building approach.

Given the vast socio-economic and ecological diversity in the Andes, and the reliance of people on forested and non-forested ecosystems, we advocate for a diverse array of restoration approaches using native species. A spectrum of restorative actions which align with the key motivations and benefits identified in this study would include native forest conservation, restoration with native species,

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agroforestry, silvopastoral systems, conservation and restoration of Puna grasslands and some instances of productive restoration to provide alternative sources of firewood. Crucially, the identification of optimal restoration sites and methods must incorporate a landscape approach which integrates priorities of water provision, biodiversity conservation and livelihood enhancement, and involve mountain communities right from the start.

AUTHOR CONTRIBUTIONS

Tina Christmann—Conceptualization, methodology, investigation, transcription, data curation, formal analysis, visualization, writing—original draft, writing—review & editing, funding. Imma Oliveras Menor—Conceptualization, methodology, planning and logistical support, writing—review & editing, supervision—lead. Sarah Jane Wilson—Conceptualization, methodology, writing—review & editing, supervision. Aida Cuni-Sanchez—Conceptualization, methodology, writing—review & editing. Yadvinder Malhi—Conceptualization, writing—review & editing, supervision. Mayté López-Aranda—Investigation, transcription, data curation, writing—review & editing. Isaías Cjuno Turpo—Investigation, transcription, data curation, writing—review & editing. Augusto Ramirez—Planning and logistical support, writing—review & editing. Marlene Mamani—Planning and logistical support, writing—review & editing. Vidal Rondán—Planning and logistical support, writing—review & editing. Marco Arenas—Planning and logistical support, writing—review & editing. Jorge Recharte—Writing—review & editing. Francisco Medina Castro—Planning and logistical support, writing—review & editing. Omar Amador Carrión Moreno—Planning and logistical support, writing—review & editing. Frida Blanca Gonzalez Cabello—Planning and logistical support—writing—review & editing. Constantino Aucca Chutas—Planning and logistical support—writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The first author (Tina Christmann), the advisors (Imma Oliveras Menor, Yadvinder Malhi, Aida Cuni-Sanchez, Sarah Jane Wilson) and Isaías Cjuno Turpo have no conflict of interest. The other authors (Mayté López-Aranda, Augusto Ramirez, Marlene Mamani, Vidal Rondán, Marco Arenas, Jorge Recharte, Frida Blanca Gonzalez Cabello, Constantino Aucca Chutas, Omar Amador Carrión Moreno, Francisco Medina Castro) were or are involved in institutions that implement forest restoration in the Andes.

DATA AVAILABILITY STATEMENT

Data has been uploaded to Dryad on the following link: https://doi.org/10.5061/dryad.tqjq2bw8m.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Text S1: Interview guide.

Text S2: Technical interview guide.

Figure S1: Ecosystem services of Andean Forests aggregated for all stakeholder groups.

Figure S2: Restoration preferences of the three key stakeholder groups for the future.

Table S1: Benefits of restoration projects mentioned by stakeholder groups.

Table S2: Species mentioned by communities for future restoration interventions including their taxonomy, elevation range and local uses * indicates the local use/value was taken from an ecotourism guide by Baiker and Collatupa (2011).

Table S3: Translation of quotes used in the manuscript, and their original unedited Spanish version.

Box S1: Case study: Cuenca del Mariño.

Box S2: Case study Challabamba vs Aquia.

Box S3: Case study experiences of overcoming technical and biophysical challenges from government led restoration.

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