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Restoration of Andean Forests Using a Socioecological Approach: Case Study from the Aquia Mountain Community in Peru

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Polylepis *forests, growing up to 4800 m above sea level in the Peruvian Andes, have been severely decimated by human encroachment in the last centuries, causing declines in ecosystem services. In the last 2 decades, restoration projects in* Polylepis *forests have started to embrace local community needs. However, so far, these restoration projects are patchy, small scale, and poorly documented, hindering scaling and knowledge sharing across the mountain range. Here, we present the restoration procedures, outcomes, and success factors in a model restoration project in Aquia (Ancash, Peru). This project was part of a regional* Polylepis *corridor restoration project implemented by Instituto de Montaña between 2004–2009. We combined a document analysis of the archive of this nongovernmental organization (NGO) with 12 postproject semistructured interviews held in 2022 (with 10 community members and 2 NGO project managers) to give a long-term view of project outcomes and sustainability. The project restored 16 ha of* Polylepis *forest and improved 41.6 ha of mountain pastures. It reduced grazing pressure on forests by facilitating the creation of community conservation reserves in existing forests, offering farmers alternative farming livelihoods, and addressing needs highlighted by interviewees (improved livestock breeds, pasture seeds, and tools). A participatory design centered on improving livelihoods and formalizing restoration commitments in local conservation agreements, which allowed for long-term project persistence, ecological implementation, and social uptake. Prior socioecological diagnostic work, such as identifying community needs and designing viable restoration strategies appropriate to the challenging mountain context, made it possible to set up the project sustainably and codesign it in line with the community's needs and ways of living. Lessons learned highlight the need for: (1) formalization of conservation agreements, (2) incorporation of in-depth local knowledge, (3) purposeful participation and collaboration, (4) external agency support, (5) creation of local capacity, (6) monitoring of sustainability outcomes, and (7) development of medium- and long-term plans.*

Keywords: Polylepis*; conservation agreements; reforestation; livelihoods; socioecological systems; participation; cocreation; common-pool resources; Andes; mountain communities.*

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Background

Polylepis (Rosaceae) forests are an ecosystem within the Andean forests (*bosques Andinos*) that occurs at the limits of tree growth up to 4800 m above sea level (asl) across the Tropical Andes biodiversity hotspot (Simpson 1979; Espinoza and Kessler 2022). In the Andean forests of Peru, there are 24 species of *Polylepis*, with 16 classified as endangered, 2 classified as vulnerable, and 4 classified as near threatened (IUCN 2024). *Polylepis* forests provide local communities with vital ecosystem services, such as food sources for subsistence, water regulation and provision, and erosion prevention (Aucca and Ramsay 2005; Pinos 2020). They are substantial carbon storers (Montalvo et al 2018) and provide habitat for many threatened and endemic species (Fjeldså et al 1996). In Peru and Bolivia, *Polylepis* forests host 174 bird species (Quispe-Melgar et al 2020).

The challenges of restoring Andean forests

Using forest regeneration techniques, several actors (private, nongovernmental, public; see Cerrón Macha et al 2018) have sought to recover biodiversity, structure, and function of Andean forests, including rejoining forest habitats, recovering lost ecosystem services, and helping to mitigate and adapt to climate change (Durand and Sevillano 2017). Restoring the highly alpine *Polylepis* forests is challenging due to the slow seedling growth resulting from climatic, soil, and topographic constraints (Guariguata 2005). In addition, agricultural activities, such as grazing and fires, jeopardize forest regrowth, and it is hypothesized that Andean forest regeneration mainly occurs in ravines inaccessible to consumer-driven disturbances (Renison et al 2014). In practice, restoration of Andean forests is also hampered by a lack of knowledge of the sexual propagation of *Polylepis* and a focus on vegetative propagation from a small number of seed trees (Quispe-Melgar et al 2024).

Across restoration locations in Latin America, restoration success is limited by a high dependence on natural resources, land tenure conflicts, value divergences, and institutional fragility, requiring careful governance when implementing forest restoration (Aguiar et al 2021). Further barriers include having to account for local restoration priorities and livelihood realities and align with socioeconomic, cultural, and institutional considerations (Fischer et al 2020; Ota et al 2020; Elias et al 2021; Löfqvist et al 2022). Despite the recent emergence of restoration projects across Andean forests (see Cerrón Macha et al 2018), promoted by both government and nongovernmental institutions, sharing of effective best practices in *Polylepis* restoration is still scarce, as knowledge is often housed in project reports. Often, scientific studies focus on either ecological or social impacts, preventing the combined evaluation of restoration outcomes along the social, economic, and ecological axes.

The socioecological system of Andean forests in Peru

In the Peruvian Andes, local communities are intricately linked to the forests, benefiting from them, but also exploiting them. Drivers of loss of *Polylepis* forests include overexploitation due to grazing of sheep and cattle combined with burning to regenerate pastures (Fjeldså et al 1996), unsustainable wood and charcoal harvesting, and road expansions that hinder the forest regeneration process (Pinos 2020). Increases in fire frequency and intensity affect 15 of the 24 *Polylepis* species found in Peru (IUCN 2024). In recent times, it has been estimated that, in Peru, only 1.2–2.7% of the potential *Polylepis* forest cover remains, and this is in isolated patches (Fjeldså et al 1996), contrasting with the large Andean forest extent prior to Spanish colonization, when Inca forest management and reforestation allowed for well-preserved Andean forests (Cobo 1892; Chepstow-Lusty 2000). As a result, Andean forests do not have a significant place in present-day production systems of rural households and communities.

Andean forests form part of an intricate socioecological system found within the Puna elevation belt (4000–4800 masl), according to Pulgar Vidal's (1979) classification of the natural regions of Peru. This belt is dominated by grassy vegetation and a permanently cold climate with recurring frost, making it unsuitable for agriculture but a hotspot for animal husbandry. However, some *Polylepis* forests are also found in the lower agricultural zones, such as the "Suni" zone (3500–4000 masl), dominated by low-intensity production of tubers, and the more temperate "Quechua" zone (2300–3500 masl), characterized by the cultivation of diverse agricultural crops. The potential distribution of *Polylepis* forests overlaps and competes with areas of established traditional agricultural practices, such as subsistence farming and livestock herding (Aucca and Ramsay 2005).

The restoration project in Aquia

In 2004, the nongovernmental organization (NGO) The Mountain Institute (later renamed Instituto de Montaña) launched the "*Polylepis* Conservation Corridor in the South of Los Conchucos project" (*Proyecto Corredor de Conservación de Polylepis en el Sur de Los Conchucos*) to engage local communities in restoring *Polylepis* forests (Durand and Sevillano 2017) (see Box 1). From 2004–2009, 3 mountain communities restored 30.7 ha of forest: 16.23 ha in Aquia, 7.2 ha in Huasta, and 7.3 ha in Taparaco. Two communities, Santa Cruz and Chalhuayaco, withdrew after 2 years to work with a nearby mine, while another group in Taparaco planted *Polylepis* trees as farm plot boundaries but did not participate in forest restoration. Aquia stood out as a model site for socioecological restoration, as it restored the most land for the longest and continued the integration of forest restoration in household and community production systems and priorities. All 6 communities and 18 forestry groups had similar production systems and use of native forest resources. However, Aquia's more developed dairy system and larger territory gave it a distinct advantage.

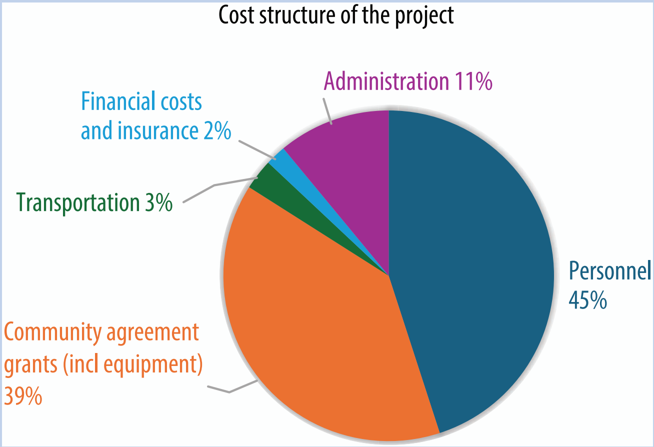
BOX 1: The "*Polylepis* Conservation Corridor in the South of Los Conchucos" project

The "*Polylepis* Conservation Corridor in the South of Los Conchucos" project operated over a 5 year period in 5 communities, Santa Cruz, Chalhuayaco, Taparaco, Aquia, and Huasta, situated in the buffer and transition zones of the southern section of the Huascarán Biosphere Reserve and National Park.

The project concept originated with the Huascarán Working Group (HWG), a dialogue platform established in 2000 by Huascarán National Park, The Mountain Institute (later renamed Instituto de Montaña), the company Antamina, and several other businesses in the energy, mining, and agriculture sectors that had projects or operations in areas surrounding the national park. It was managed and implemented by The Mountain Institute/Instituto de Montaña. Collaborating with local associations, families, and community assemblies, the project focused on forest restoration, grassland improvement, and livestock productivity. It involved approximately 2300 households.

Funded by Asociación Ancash, US$ 656,679 was invested in the project. A total of US$ 257,789 in conservation agreement grants was given to 18 forest committees. The cost structure of the overarching project is shown in the pie chart below. The budget for personnel (45% of project cost) was mainly dedicated to providing technical support and building the capacity of the 18 forestry committees. The budget for conservation agreements (39%) was dedicated to agricultural incentives and equipment costs. Prior to field restoration activities, the project received support from Conservation International's Global Conservation Fund for rapid ecological assessments of *Polylepis* forests (conducted by the NGO Asociación Ecosistémas Andinos [ECOAN]) and socioeconomic diagnostics and consultations with prospective communities (conducted by The Mountain Institute).

ECOAN conducted a rapid ecological assessment during the project's initial phase, identifying critical sites and establishing a biodiversity baseline. From September 2004 to December 2009, the project worked with 18 community groups ("forest committees") to restore *Polylepis* forests while enhancing grassland and livestock productivity to compensate for withdrawal of animals from restoration sites.



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This article presents a detailed case study of the restoration of Andean forests in Aquia. We analyzed the perceptions of local participants in the project through a semistructured survey on its process, outcomes, and impacts. These data are complemented by a document analysis of reports of The Mountain Institute/Instituto de Montaña and conservation agreements to:

- Describe key project characteristics and processes;
- Diagnose community needs and priorities;
- Assess the socioeconomic long-term outcomes of the project;
- Analyze factors that promoted or limited project success; and
- Synthesize lessons learned for transferability, scalability, and persistence of future projects.

Intervention approach and methodology

The restoration project

Location: Aquia (10°5′0″S; 77°8′0″W) is a district in the Bolognesi Province, Department of Ancash, Peru (Figure 1A). Sitting at the southern border of Huascarán National Park and Biosphere Reserve, it harbors the most extensive and diverse remnants of high-elevation *Polylepis* forests in the Andes (Figure 1B). The center of Aquia is located at an elevation of 3337 masl, but much of the community grazing land extends up to 4500 masl. The district of Aquia had 2062 inhabitants in 2017 (INEI 2018) and amounts to 5400 inhabitants if the wider area is included (Arévalo 2005). As a *Comunidad Campesina*, Aquia can implement culturally and linguistically relevant collective rights as a legally recognized Indigenous Quechua community. *Comunidades Campesinas* have strong cultural identities, native languages, ancestral land ties, and traditional social organization.

Aquia has an area of 50,000 ha. It sits within a socioecological landscape dominated by the glacial and alpine zone, with large areas of grassland and wetlands and abundant and well-distributed *Polylepis* forests. It has rocky outcrops and rock walls with extreme slopes, temperate valley agriculture for tubers and cereals, and alpine pasturing (Arévalo 2005). The main historical human factors explaining the current distribution of forests in Aquia and Huasta are the practices of keeping livestock and the expansion of the agricultural frontier (Dourojeanni 2010: 88). Forest restoration was implemented in 2 agricultural sectors, each managed by separate forestry committees: Yanatuna and Rimay Condor (Figure 1C, D).

Ecological implementation: The restoration project was implemented between 2005 and 2009 with the aim of conserving and restoring the *Polylepis* corridor linking the forests of Huascarán National Park. Two species of *Polylepis* with high conservation value were planted: *Polylepis weberbaueri*, a locally endangered species, and *Polylepis incana*, a species with wider distribution. Both species provide several ecosystem services, such as water regulation (intercepting mist with their leaves and slowly releasing it into the soil, as well as reducing peak flows), soil stabilization, the provision of habitat for various species of wildlife, and aesthetic and cultural value (Aucca and Ramsay 2005).

The restoration of *Polylepis* was done using vegetative propagation from aerial layering for *P. weberbaueri*, while *P. incana* was propagated with cuttings/stakes collected in native forests (Figure 2A) and propagated in communal nurseries (Mindreau and Zúñiga 2010). Aerial layering, whereby seedlings are propagated near the restoration site, was used to optimize logistics and transportation costs and to ensure the genetic material was locally viable. The sites were planted in the rainy seasons through communal workdays at 2 rocky sites at an elevation of 4000–4500 masl belonging to 2 agricultural associations: The Huamanhueque site was planted with members from the Yanatuna association, and the Isco site was planted with members from Rimay Condor. Overall, 16 ha were reforested with plants spaced at 3.5 × 3.5 m. Fences helped to exclude livestock and weeds in the first 2 years and to reduce crowding-out effects from adjacent fast-growing grasses. Irrigation was used to reduce seedling mortality during dry spells.

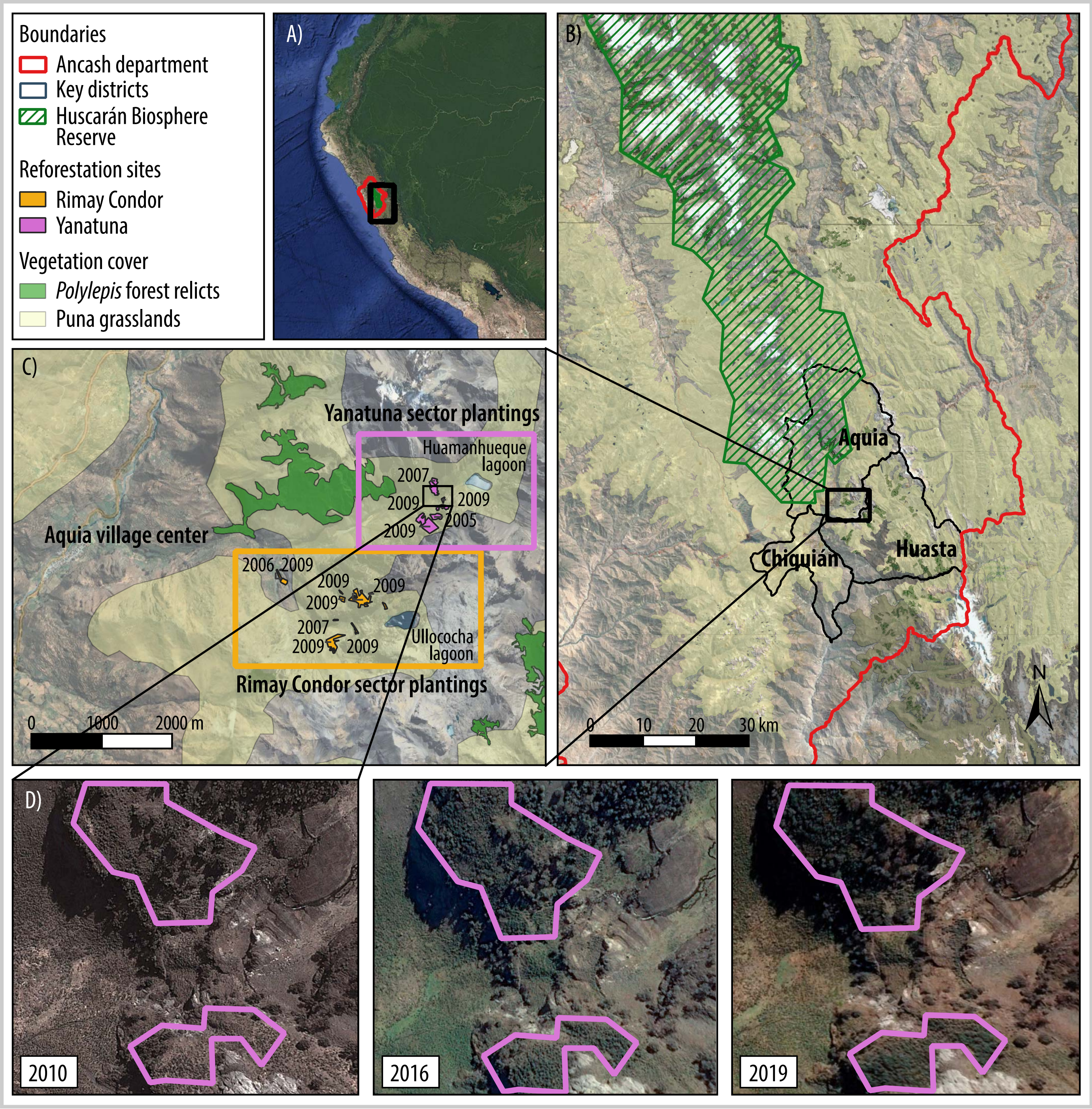
Socioeconomic implementation: Restoration in Aquia was conducted through participatory socioecological conservation agreements with the agricultural associations of Rimay Condor and Yanatuna. These agreements formalized support from the NGO, including funds for livestock improvement, tourism development, and better local schools, in return for the community's commitment to propagating new plants, reforesting, and conserving areas with *Polylepis* (Figure 2B). Developed in participatory workshops, the agreements honored Andean culture by using community-driven solutions and accessible language and being registered with local authorities for legitimacy. They set rules for protecting reforested areas, encroachment reporting, and compensation based on labor invested in reforestation. Participatory research helped to reduce pressure on the forests, while material support improved pastures, livestock productivity, and animal health. Improved pastures were used rotationally by association members, with NGO support for making rules governing the use of the new collective resources. Forest committees within each association managed the agreements, meeting monthly and revising agreements annually, enabling participatory adaptive monitoring.

The research

Postproject interviews: We conducted interviews in Aquia 13 years after the project ended (September and October 2022). The focus on Aquia stemmed from evidence of sustained local protection of the *Polylepis* plantation after the NGO intervention. Interviews explored local perceptions of outcomes to understand the driving factors behind this positive trend. While benefits, especially social ones, have endured beyond the project, long-term benefits have not been recently measured by the NGO. Hence, our study relied on perceived benefits, a nonquantifiable representation of realities.

Permission for the study was obtained from the community president and community. Key participants with historical experience were identified mostly via snowballing and community walks, resulting in 12 interviews, including 10 community interviews (8 community members,

FIGURE 1 Context map showing (A) the department of Ancash where the intervention was located; (B) a regional zoom into the *Polylepis* corridor around Huascarán National Park and the three districts of Aquia, Huasta, and Chiquian; and (C) the locations of the restoration plantings in the agricultural sectors of Rimay Conor and Yanatuna. The vegetation cover of Puna and *Polylepis* was extracted from the Mapa Cobertura Nacional (Ministerio del Ambiente 2015). (D) Google Earth imagery from the Yanatuna sites in 2010 (1 year after planting), 2016 (7 years after planting), and 2019 (10 years after planting).



2 community leaders) and 2 NGO interviews. A snowballing technique was deemed appropriate to identify key informants with the greatest involvement. However, we also supplemented interviews during walks in the community by approaching random community members and asking whether they had been involved.

Interviews were semistructured, lasting 10–60 minutes. They covered project objectives, success factors, barriers, community benefits, and preferences (Appendix S1, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00017.S1). Interviews were recorded following a consent process (ethical approval CUREC: SOGE1A2021-215). One in-depth interview (Appendix S2, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00017.S1) was also conducted with the project manager to discuss project details and processes. Interviews were transcribed manually and analyzed thematically using NVivo, categorizing responses by social and economic outcome categories. Barriers and challenges

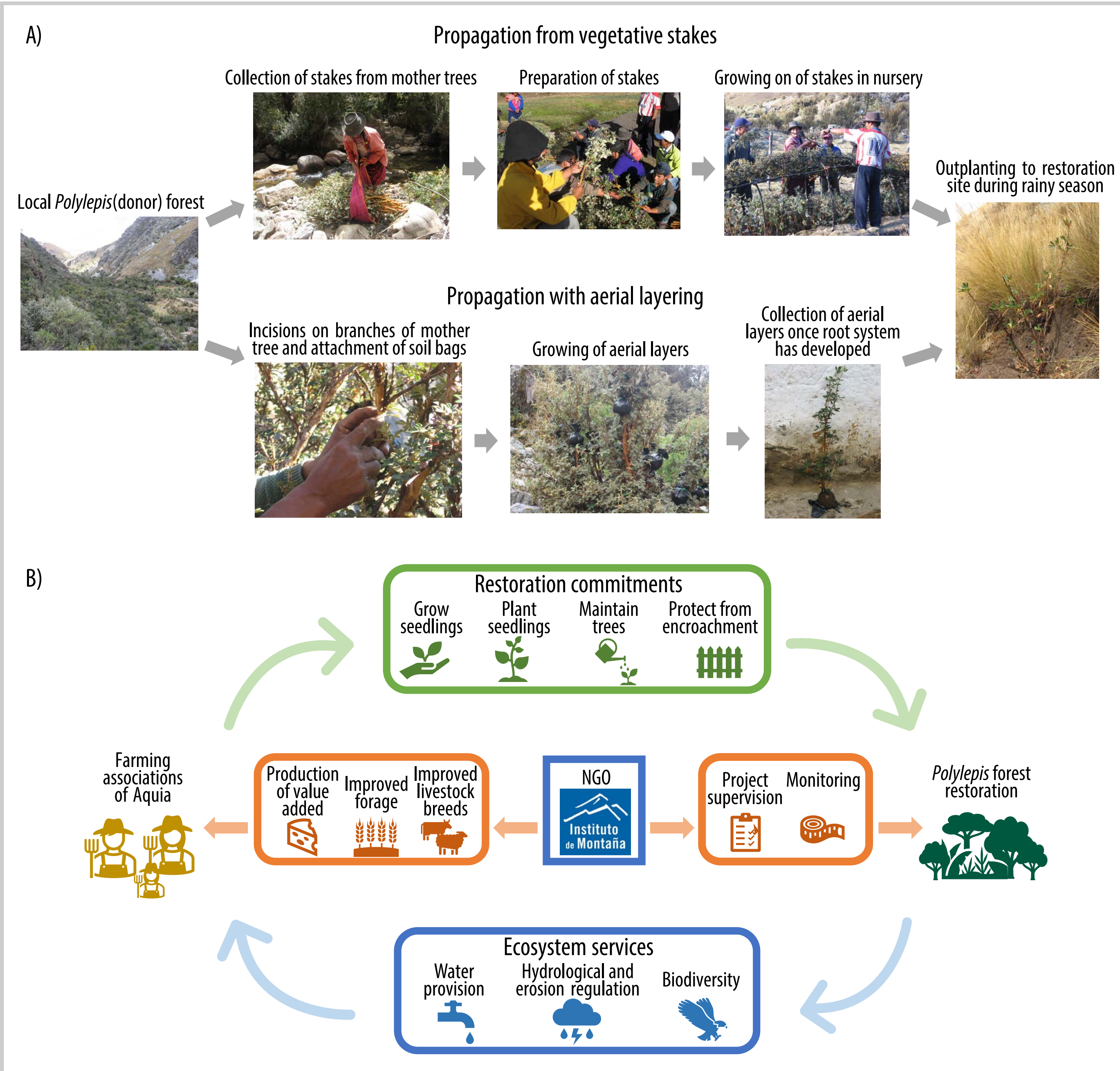


FIGURE 2 Ecological and governance processes of the project: (A) the 2 main propagation procedures for *Polylepis*; (B) actors and transactions regulated in the conservation agreements.

were coded into social, biophysical, technical, economic, and institutional/governance categories according to the categories outlined by Cerrón Macha et al (2018). All quantitative data are shown as a percentage of all interviewees or as a percentage of stakeholder groups.

Document analysis: We analyzed NGO documents written between 2005 and 2010 (Table 1) to extract information on socioeconomic diagnostic and quantitative project outcomes, success factors, and lessons learned. These reports summarized the diagnostic activities, processes, and outcomes of the project, drawing on the experience of Instituto de Montaña staff, participatory workshops with forestry committees, and household and key informant interviews. Unfortunately, we were not able to include sufficient ecological data on the forest growth performance, as the relevant ecological monitoring reports were not available.

Transformative results

Preexisting socioeconomic needs

The socioeconomic needs of the community were identified in 2005 through a diagnostic study (Arévalo 2005) that

TABLE 1 Sources used during document analysis.

Data source	Annual reports	Conservation agreements	Final project outputs
Description	Produced by The Mountain Institute/Instituto de Montaña for the project *Proyecto Corredor de Conservación de* Polylepis *en el Sur de Los Conchucos*	Legal document between NGO and forestry committees	Produced by NGO staff: - project outcome study; - handbooks; - publications
Documents reviewed during document analysis	Arévalo (2005) Arévalo (2007) Arévalo (2008) Mindreau (2008) Mindreau (2009)	Comité Forestal de Yanatuna-Humanhueque (2009) Comité Forestal de Rimay Condor (2009)	Schaub (2009) Mindreau and Zúñiga (2010) Dourojeanni (2010)

included participatory workshops, interviews, and surveys. The study focused on (1) community organization, (2) current land cover and use, (3) socioeconomic characteristics and needs, and (4) forest resources and use. Based on this, The Mountain Institute elaborated the key problems and solutions to be provided through the project (Table 1).

Diagnostic findings (Table 2A) included the prevalence of a primary subsistence production system, where 42% of households relied on cattle and 27% relied on sheep. Agriculture was centered on potato production for 37% of households, while 30% produced fodder. Land use surrounding the community was communal but quasi-private, whereby the community assigned exclusive use rights to families across generations, but landholders could not sell land to outsiders. The high alpine grasslands were open access, and the *Polylepis* forests were entirely open for household consumption, such as for firewood and medicinal use. The diagnostic investigation identified socioeconomic challenges, largely related to the need to improve community livelihoods, clarify land tenure, and better organize communal governance and processes (Table 2B). For each problem, community members in the workshops suggested solutions and actions. These ranged from provision of key materials (seeds, irrigation infrastructure, dams, livestock medicine) to capacity building and training for improved governance and improvements of livelihoods (Table 2C).

Perceived socioeconomic outcomes postproject

In our interviews in 2022, many tangible social and economic benefits were mentioned by both community and NGO stakeholders (Figure 3), aligning with findings from the diagnostic study (Table 2B, C) and the NGO reports.

Social outcomes: Most postproject interviewees focused on social outcomes (Figure 3), mentioning educational activities promoting environmental awareness and capacity (mentioned by 100% of interviewees):

> *Instituto de Montaña was already giving us talks, raising awareness, and we were also landing in our reality, and that's why we were dedicated to do that.*
>
> (*Community member*)

In particular, 25% of all interviewees (30% of community members) mentioned the capacity and experience created through field trips:

> *We've always had workshops here, we've gone to field trips, we've gone out to other towns.*
>
> (*Community member*)

Further, the involvement of school children in educational activities on *Polylepis* forests was mentioned by all NGO interviewees and 20% of community members:

> *When I went to school, they [the NGO] invited us [to participate]. There were some incentives, I was the winner of a painting competition on* Polylepis. *I was inspired [. . .] I would have been 16 or 17 years old, I won the contest, and I was invited to join the reforestation in the Isco sector.*
>
> (*Community leader*)

According to the NGO reports, educational and communication efforts with children and the community were emphasized in the later project years to ensure project sustainability after project completion (Schaub 2009).

Both NGO postproject interviewees and the NGO closure reports also highlighted social outcomes of improved organization and governance, as new forestry committees were formed, which united to improve their socioeconomic livelihoods and served as role models for the community in addressing environmental problems (Schaub 2009).

Economic outcomes: Interviewees mostly highlighted perceived economic outcomes (Figure 3) related to agricultural improvements specified in the conservation agreements. The improvement of pastures was mentioned by 90% of community members and both NGO interviewees:

> *We have improved pastures. We have experience with types of pastures according to the elevation.*
>
> (*Community member*)

This was also aided by tool provision (50%) for planting and land management:

> *We got support with various tools, barbed wire to fence off seedlings. We have even put up posts for the wires.*
>
> (*Community member*)

TABLE 2 Community diagnostic study run in 2005 by The Mountain Institute in the community of Aquia and its results (Arévalo 2005).

Diagnostic information	A) Key findings	B) Problems identified	C) Solutions and actions of the project
General: Organization of the community	The community has 9 sectors. It has about 5400 inhabitants across 500 community families.	Lack of organization	Organizational talks and training; dialogue with and participation of community members from all sectors and agricultural associations
		History of corruption of the authorities and community members	Talks on values and ethics
Space and land: Community map, land tenure map	The main land use is grazing, followed by agriculture and forestry. The valley areas are very narrow and have been transformed for 60% pasture and 40% agriculture. Natural forests (>4000 masl) are an important source of firewood. Access is free. They are in serious decline. Land in the valley is privately owned and used for grazing improved cattle and for agriculture. The upper areas are communal and used for grazing hardier local breeds.	Litigation with neighboring community members for infringing boundaries	Work with public registries to place boundary markers for the community of Aquia
Socioeconomic: Community institutions, sources of income and expenses, migration schedule, services, most frequent health problems	The rearing of dairy cows is the most important economic activity supporting a long value chain extending to Lima. It has been commercialized via family members. Sheep are important for wool, which is sold beyond the community of Aquia, as well as locally for breeding. The main source of employment is related to the livestock production chain through day labor. The average monthly income is PEN 216 (US$ 56) in the dry season and PEN 225 (US$ 60) in the rainy season. Cheese producers' income is around PEN 500 (US$ 132).	Low productivity of agriculture and livestock	Provide technical support in livestock and agriculture
		Lack of water for irrigation	Dam lagoons, improve canals, and afforest; manage technology-driven irrigation (combined application of water and fertilizer)
		Pasture shortages from August to December	Construct irrigation canals and dams, and plant improved pastures
		Sheep and cattle breeding problems	Provide training, purchase breeding stock, plant improved pasture
		Shortage of work	Generate micro-enterprises in livestock and fish farming, etc
		Lack of a permanent doctor in the health center	Employ a permanent and professionally trained doctor
Forest resources and use: Interest in conserving forests, use of fuels for energy purposes, use of forests	Uses of the *Polylepis* forests, in order of importance, are firewood, tool handles, wood for traditional household implements, bark for tannery, and ornamentation. Community has access to gas. However, 100% of the population continues the traditional use of firewood.	Indiscriminate felling of native forests	Training on the importance of forest conservation, incentivize reforestation
		Hunting of wild animals	Training on the importance of forest conservation, incentivize reforestation
		Lack of payments by Antamina (mining company) for impacts on community land by mining	Enforce according to the compensation agreements made in the past by means of a dialogue table

FIGURE 3 Social and economic outcomes mentioned in the interviews by community members (10 interviewees) and NGO members (2 interviewees). Only outcomes mentioned by more than 25% of all interviewees are listed.

		Community ($n = 10$)	NGO ($n = 2$)	Total ($n = 12$)
Social outcomes	Capacity building and education	100%	100%	100%
	Field visits and trips	30%	0%	25%
	Education and participation of kids	20%	100%	33%
Economic outcomes	Provision of seeds and grasses	90%	100%	92%
	Tools and materials	40%	100%	50%
	Improved livestock	20%	100%	33%

and for irrigation of their farms:

> *[The NGOs] have given us hoses for technified [sic] irrigation.*
>
> (*Community member*)

Improvements in livestock rearing, such as better breeds and medical care, were mentioned by 33% ($n = 4$):

> *[We got] support with the acquisition of dairy cattle: for each community (association) member they gave us three cows.*
>
> (*Community member*)

Improvements of current agricultural practices in Aquia were designed purposefully into the conservation agreements to reduce extensive grazing pressure in the collaboratively identified restoration areas. This reduced forest encroachment and damage by instead providing alternatives through improving pasturing conditions in the valleys and ultimately achieving a higher yield per animal. The technological transition to improve livelihoods facilitated the implementation of later activities, reinforcing educational and cultural activities around the reforestation initiatives.

Throughout the project duration, the NGO documented the improvements in agriculture in the annual reports. Immediate measurable benefits were an increase in milk productivity of cows because of better breeds and pastures. For example, Rimay Condor and Yanatuna households increased milk production from 4 L/d to 10 L/d and from 7.5 L/d to 11.5 L/d per cow, respectively, during the project. Improved sheep breeds resulted in a small increase in wool (2.4 to 2.5 kg/sheep) and a large increase in meat (from 13 to 20 kg/sheep) (Schaub 2009). However, families were aware that increasing economic productivity would require improved access to markets, stable milk prices, added value products, and financing to facilitate lasting economic growth (Schaub 2009). One community interviewee stated that:

> *The [NGOs] have taught us other tasks as well, for example, they have taught us to make this blancmange, yogurt.*
>
> (*Community member*)

However, our document analysis showed that members mostly chose not to focus on creating dairy-derived products due to lack of time, processing facilities, marketplaces, and the need for more milk. Our postproject interviews showed a small potential for increased tourism (10% of community interviewees):

> *Thanks to this reforestation, the hill or mountains can now be more attractive, more striking. You can dabble into tourism, with horseback riding, in guided tours.*
>
> (*Community leader*)

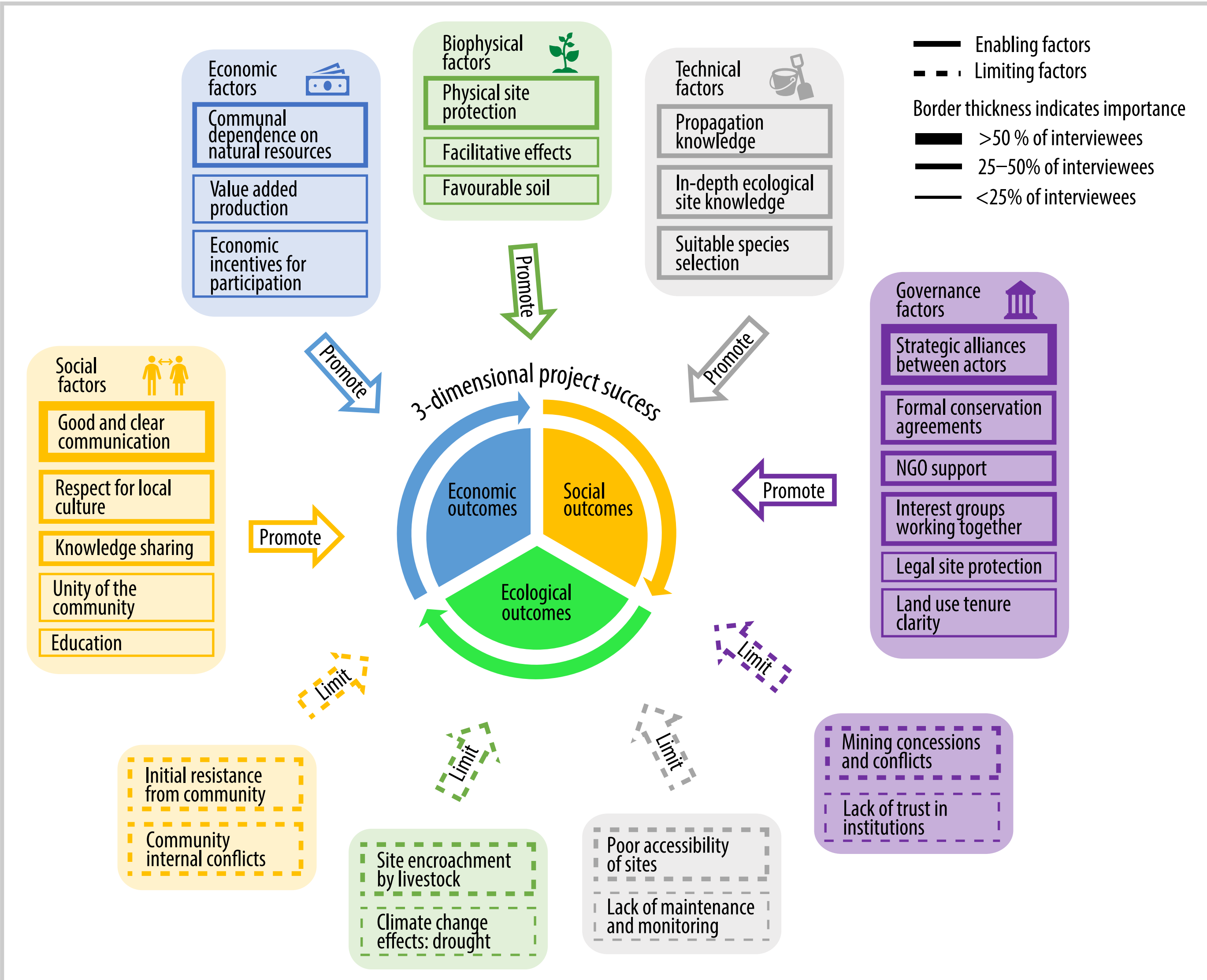
Looking at additional NGO reports (Mindreau 2008, 2009), forestry associations engaged in restoration agreements because of the prospect of exchanging direct use of low-productivity pastures in the *Polylepis* forest zone for higher-productivity pastures and animals. This was indeed achieved as, by 2009, the Rimay Condor association had successfully established rainfed plots of enriched native pastures in the upper Puna. These were used by the group on a rotational basis, 3 months per year, to herd 103 cows in total. Additionally, irrigated forage plots for private household use were established in the lower Quechua zone. The area of newly improved pastures (41.6 ha) greatly exceeded the area of *Polylepis* reforestation (5.1 ha) plantings (Mindreau 2009; Schaub 2009).

Perceived enabling and limiting factors for project success

In our postproject interviews, project success was perceived as a multidimensional concept leading to social, ecological, and economic outcomes. Success was impacted by several promoting and enabling factors, which we categorized into governance, social, economic, technical, and biophysical factors (Figure 4). Interviewees mostly focused on enabling factors of social and governance nature.

Social enabling factors: These included the high quality of communication between the project managers and the community (mentioned by 50% of interviewees) and a project design respectful of local culture. However, there

FIGURE 4 Enabling and limiting factors for three-dimensional restoration success in Aquia identified during the postintervention interviews. Dashed boxes indicate limiting factors; continuous ones indicate promoting factors. Border thickness indicates percentage of interviewees.



was initial resistance from the community assembly (mentioned by 33% of interviewees), and NGO reports also state that there was initial mistrust toward the NGO and fear they would not keep their promises. However, this changed substantially during the project duration (Schaub 2009). Knowledge sharing and creation (50% of interviewees) through capacity building was mentioned as a key success factor:

> *If [the NGOs] have left us something it's the knowledge, the Yanatuna community tells the [members] "To such and such place, such and such date, we will have a talk/workshop" and [the members] will go there. We are going to unite, to learn [. . .].*
>
> (*Community member*)

Governance enabling factors: From a governance perspective, the conservation agreements, which define alliances and NGO support, were mentioned as a primary enabling factor by over 50% of interviewees (Figure 4). The agreements were also a key institutional tool in overcoming governance challenges, such as minimizing community distrust due to prior mining activities (noted by 33%). An early obstacle was land-use conflicts, as community lands near *Polylepis* forests were traditionally used for grazing, complicating conservation efforts, as explained by a community member:

> *The [sites] are all community lands, that would be the barrier, requesting spaces from the general assembly, because the space is not completely free, because there are commoners who come there to graze their animals and from that they live.*
>
> (*Community member*)

The agreements clarified land tenure rights and site protection—enabling factors highlighted by 41% of interviewees, as exemplified by a community member:

> *[The agreement] also delimits the areas used as pasture lands because reforesting hectare after hectare is useless if animals enter to graze there. It would be foolish work; an agreement is needed to use the land.*
>
> (*Community member*)

Document analysis of the NGO reports supports the effectiveness of the agreements and advocating for iterative improvements in management and enforcement of protection of conservation areas:

> *[The conservation agreements] should establish management rules, give value to the resource, reducing problems due to fire, uncontrolled logging, uncontrolled grazing and bark extraction. Strengthening capacities to objectively manage conservation areas will include [. . .] the ability to apply sanctions when recovery areas are negatively affected and improve awareness among areas destined for grazing, restoration and conservation or other activity that demands order in the territory.*
>
> (Arévalo 2008: 22)

Economic enabling factors: Economically, the community's dependence on natural resources (mentioned by 42% of all interviewees), particularly on water and fertile grazing land, promoted interest and continued participation in the project:

> *The pastures are needed for the cattle and [. . .] water is essential for their milk and for the population and cattle. For [the people] water is key, and can be generated by having forests above. That's what they say very clearly, this is how they capture the rain to have water.*
>
> (*NGO worker*)

Indirect economic incentives (25%), such as the provision of improved livestock breeds and pasture grasses by the NGO, also promoted project success. The NGO reports, however, also emphasize that direct payments to community members to participate in conservation should be avoided, as these change their objectives and interests (Schaub 2009). A minor economic limiting factor was related to loss of labor time of project participants:

> *We had to dedicate ourselves, sacrifice our time to dedicate ourselves to [the reforestation]. We individually have daily tasks here for our subsistence, planting our potatoes, irrigating our pastures, etc. We had to stop doing those tasks to do the reforestation; that was a bit of a difficulty.*
>
> (*Community member*)

Technical enabling factors: During the planting and restoration implementation, technical factors included good knowledge of the sites (25% of interviewees), resulting from several diagnostic site visits, a larger-scale site prioritization exercise, and the involvement of trained restoration practitioners and ecologists. The NGO ECOAN, which is specialized in conservation of *Polylepis* forests and biodidversity, was also involved throughout the ecological planning and implementation. Particularly, ecological and technical knowledge of the species ecology (25%) and of adequate propagation process (33%) promoted plant survival and establishment success. Much of this existing and newly acquired knowledge on the propagation and planting of *P. weberbaueri* and *P. incana* used in Aquia was later documented in a dedicated manual titled *Manual de forestería comunitaria de Alta Montaña* (Mindreau and Zúñiga 2010).

Biophysical enabling factors: These were mentioned by interviewees to a lesser extent. Some mentioned that physical site protection through fencing promoted ecological outcomes (33%), resonating with others who mentioned that encroachment by livestock was a limiting factor (25%):

> *To protect [the sites], since there is also a grazing area, you have to delimit them, because if there is not that delimiting fence, the animals get in, they eat it.*
>
> (*Community leader*)

Favorable soil conditions and facilitative effects promoted ecological success; however, prolonged droughts were mentioned as a biophysical challenge compounded by recent amplifications in climate changes. This also resonates with findings in the NGO reports, which state that community members worried about *Polylepis* seedlings dying from droughts, increased temperatures, and wind, or being more susceptible to pathogens, as well as difficulties in irrigating due to lack of water (Schaub 2009).

Lessons learned

The long-term success lies in the multidimensional social and economic opportunities generated for the community, many of which were still perceived 13 years after the project. Based on our interviews and document analysis, we discuss the main lessons learned that allowed project sustainability and persistence, and we highlight challenges for scaling up forest restoration across similar mountain landscapes.

Conservation agreements centered around livelihood needs

The restoration project was mostly perceived positively by community interviewees and the NGO reports. Driven by diverse social and economic outcomes, the project showed that a livelihood-focused, pluralistic approach to restoration (Di Sacco et al 2021; Elias et al 2021) can be effective, even in complex settings. In Aquia, reforestation was part of a broader livelihood vision that went beyond tree planting, to improve environmental education and technical skills for ongoing agricultural activities. While the project approach was pluralistic, it was also implemented in a sequence that respected the priorities of the community at the starting point.

As shown in our interviews, workshops, field trips, and training improved skills and capacities, enhancing community participation and interest in the project. Organizational skills gained during the project, such as managing pasture rotation, likely contributed to long-term commitment. A community member explained:

> *We have been trained on all the values of the [*Polylepis*] plant . . . we have learned a little about doing something . . . Now with this experience, we know how to improve our pastures, and . . . blancmange preparation.*
>
> (*Community member*)

The NGO's report also suggested potential new livelihood options to be explored in the future: "Incentives could be native crops . . . such as native potato, Quiñua, Maca, or Ulluco, with a conservation aspect" (Schaub 2009).

Use of conservation agreements was not a one-way transactional mechanism used by the NGO to deliver tangible benefits and demand effective reforestation, but primarily served to build trust and social capital, which were essential for project implementation and monitoring. The

2 agricultural associations (Yanatuna and Rimay Condor) received compensation for their reforestation work, but they also gained pride and social value by visibly contributing to the community and reducing conflicts between households over communal pastures.

Diagnostic studies and monitoring

Pre-implementation studies were conducted in communities with *Polylepis* forest remnants suitable for reforestation (Arévalo 2005; Dourojeanni 2010). Thereafter, unsuitable sites, such as those near major mining operations, were excluded. Site selection involved community participation and a patient approach. Both interviews and NGO report analysis emphasized species selection and propagation methods as crucial factors for success, given the growth and establishment limitations faced by local *Polylepis* species (Wesche et al 2008). Aerial layering and stake propagation were strategic decisions made in the diagnostic project phase to enhance seedling survival (Mindreau and Zúñiga 2010).

From a monitoring perspective, our interviews complemented sociodiagnostic data collected by Instituto de Montaña in the 2010s. Indirect economic incentives from conservation agreements improved long-term livelihoods for agriculture and livestock farming. While ecological outcomes are only anecdotal, and could not fully be determined, recent site visits revealed a closing forest, suggesting locally appropriate restoration methods. However, there was no ecological field monitoring beyond the project termination in 2009, a weakness experienced in many projects after funding ceases, and this remains a focal activity that should be addressed in this United Nations Decade on Restoration (Monitoring Task Force 2024). Future projects could address this ecological monitoring gap through participatory community monitoring, leveraging local data collectors (Evans et al 2018). Informal monitoring, such as regular monthly check-ins between forestry associations and the NGO in Aquia, could examine the socioecological system's complexity to understand the linkages among community, forests, and agriculture, and assess whether project adaptations are needed. Additionally, social monitoring through formal interviews conducted by external parties—such as those done by the first author of this study—provides an independent perspective and complements outcome assessments (Evans et al 2018).

Challenges and opportunities in scaling up *Polylepis* restoration

Large-scale reforestation faces key obstacles: (1) Most high-elevation land is used for extensive livestock production, (2) household labor is limited, (3) diverting time to planting trees has a high opportunity cost, and (4) experimenting with new strategies carries risk. Though conservation agreements were positive incentives, each agricultural association in Aquia managed to plant only 6000 trees annually. Further, forest establishment and persistence require irrigation: "You not only have to think about planting *Polylepis*, but also its maintenance and the issue of irrigation. Without adequate irrigation . . . seedlings will not survive" (Schaub 2009). Communities also adopted intensive grazing, planting, and management of 20 ha of improved pastures. This shift in grazing posed risks, even with NGO technical support. Smallholders need time to incorporate native reforestation into their systems, and once positive outcomes are clear, reforestation may progress slowly over longer periods. The NGO closure report notes that "the impact of the project is basically limited to the forestry committee members. . .it has not been possible to improve the situation of the community or region," which would be crucial for socioeconomic sustainability (Schaub 2009).

The Aquia experience offers strategies for scaling small interventions over time. Successful pilot sites like Aquia can serve as models for nearby areas, promoting local knowledge sharing and cost-effective extension systems using local expertise. The project closure report noted as a limitation that "[Instituto de Montaña] project staff had to be continuously present for technical advice" (Schaub 2009). To tackle this staff requirement, peer-to-peer dialogue and communal restoration on low-risk land could be considered to scale up restoration efforts, as they have proven effective for sharing practices across the Andes (Wilson and Coomes 2019). A key lesson for scaling up mentioned by the NGO is to "fight for good relations with authorities and communities fostering involvement and increasing project sustainability" (Schaub 2009).

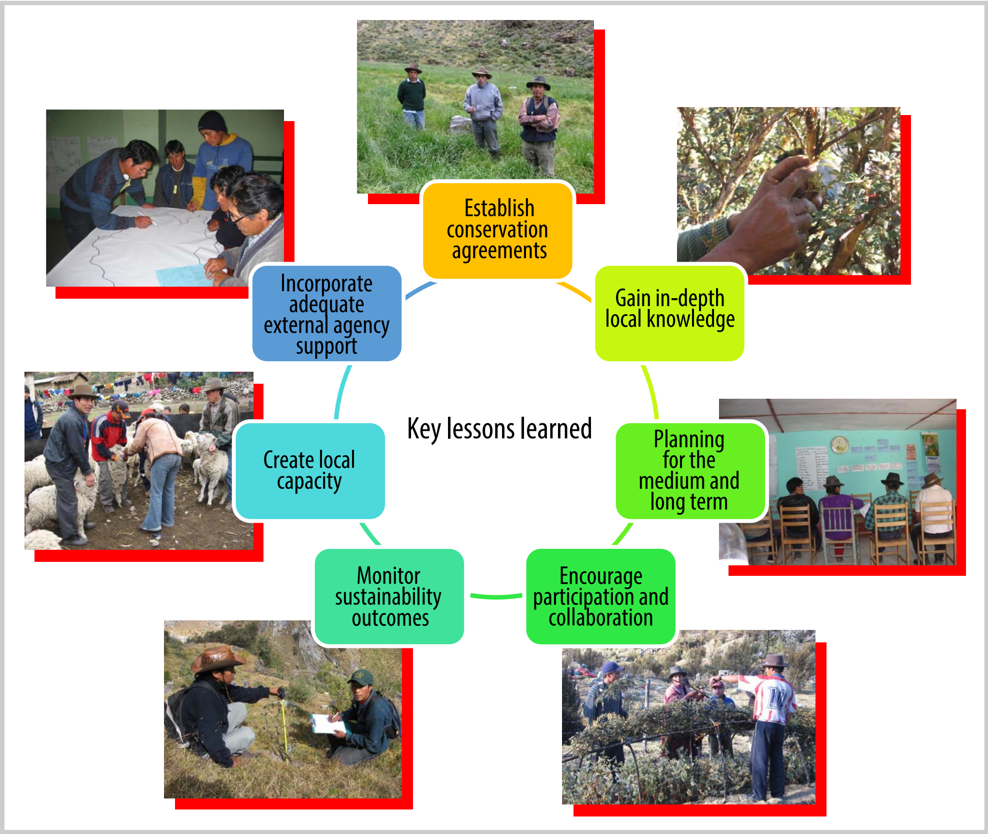
In Aquia, 16 ha were restored over 4 years. Despite the small project size, clusters of small interventions contribute significantly to land restoration, which is vital for the 30 × 30 initiative (CBD n.d.) in Latin America. Strategically placed patches can catalyze natural regeneration and connect forest relicts. If ecosystem services of communal pilot sites become visible, this can inspire reforestation on private lands (Wilson et al 2019). However, scaling up faces land tenure challenges, as rights in the Andes are tied to labor investment and continued use (Robert 2006). Yanatuna and Rimay Condor wish to expand reforestation but need access to communal land, risking future land rights disputes (Schaub 2009).

Conclusion and way forward

Socioecological reforestation of Andean forests requires forward-looking strategies and a patient approach if long-lasting benefits are to be achieved. The Aquia case provides 7 key lessons to support the expansion of native forests that have limited economic value in the short term (Figure 5).

- Establish conservation agreements: Clear bilateral conservation agreements are essential for project success, offering tangible benefits and fostering community livelihoods. Such agreements could serve as a model for rural restoration worldwide.
- Gain in-depth local knowledge: Understanding and valuing local biodiversity, site characteristics, and propagation methods help to ensure ecological success. Such diagnostic studies need to precede implementation, and their time and labor must be accounted for in restoration planning.
- Encourage participation and collaboration: Working with communal institutions from the project outset, respecting traditions, and resolving and addressing existing conflicts are vital for social acceptance and trust. Procedures and activities need to be inclusive and aligned with cultural norms to ensure enduring community support.
- Incorporate external agency support: NGOs can help to develop training-of-trainers programs in partnership with experienced agents in successful pilot cases (eg reforestation techniques, new production technologies, organizational

FIGURE 5 Key lessons learned to achieve a socioeconomically viable reforestation project.



skills, monitoring, value chains linked to forest services). This can reduce implementation costs and help embed reforestation in larger rural development programs.

- Create local capacity: Instead of providing purely monetary incentives, providing local people with proper training equips them with technical skills, education, and awareness about the significant impact they have on the environment and community. This increases their commitment and job satisfaction, and it strengthens the effectiveness and long-term success of restoration projects.
- Monitor sustainability outcomes: Participatory design to monitor progress of reforestation programs coupled to wellbeing, environment, and livelihood targets as defined by the community could be the foundation for self-sustaining monitoring programs.
- Plan for the medium and long term: A weak point of the reforestation project in Aquia was the lack of a long-term road map in the conservation agreements. The development hypothesis of reforestation projects could anticipate results to be expected after the project cycle ends, identifying, together with the community, a strategy to scale up restoration to secure ecosystem services clearly linked to economic growth or other end goals established by the community.

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Supplemental material

APPENDIX S1 Questions for interviews with community members.
APPENDIX S2 Questions for technical interview with project manager.