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Social Technology for the Protection of the *Páramo* in the Central Andes of Ecuador

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This study examined how the application of a concrete series of activities to protect the páramo *in the central Andes of Ecuador can be compared with social technology. This is understood as a way of developing, implementing, or managing technology in interaction with the population, with the aim of generating dynamics of social inclusion, improvement of living conditions, and sustainable development. A mixed methodology was used, including quantitative analysis based on satellite images available for 3 periods (1986–2000, 2000–2008, and 2013–2021) to determine* páramo *loss, and qualitative research to understand the relationship of communities to* páramo *changes. The patterns of land-use change, the situation of the* páramo*, and the main actions to protect the ecosystem were identified. The results showed that from the first to the second period, there was a loss of 17.2% of the* páramo*, while from the second to the third period, the loss decreased to 3.3%. This improvement can be attributed to the delimitation of conservation areas within communal areas, accompanied by restoration, a change in the dynamics of livestock ownership, and the creation of socioeconomic alternatives for farmers in the lowlands. This set of actions addresses 3 key issues: land use, livestock management, and community governance. We consider these actions to be social technologies because the conservation measures were adopted by an empowered community, open to cooperation and agreements, that understands the importance of protecting the* páramo *so that they and those living in the lower basins have access to water. This management vision is supported by several organizations working in the area and represents a line of action that the authorities should promote to prevent further loss of the* páramo *while simultaneously providing livelihood opportunities for the inhabitants of the area.*

Keywords: *social technology;* páramo *loss;* páramo *protection; socioeconomic alternatives; cooperation.*

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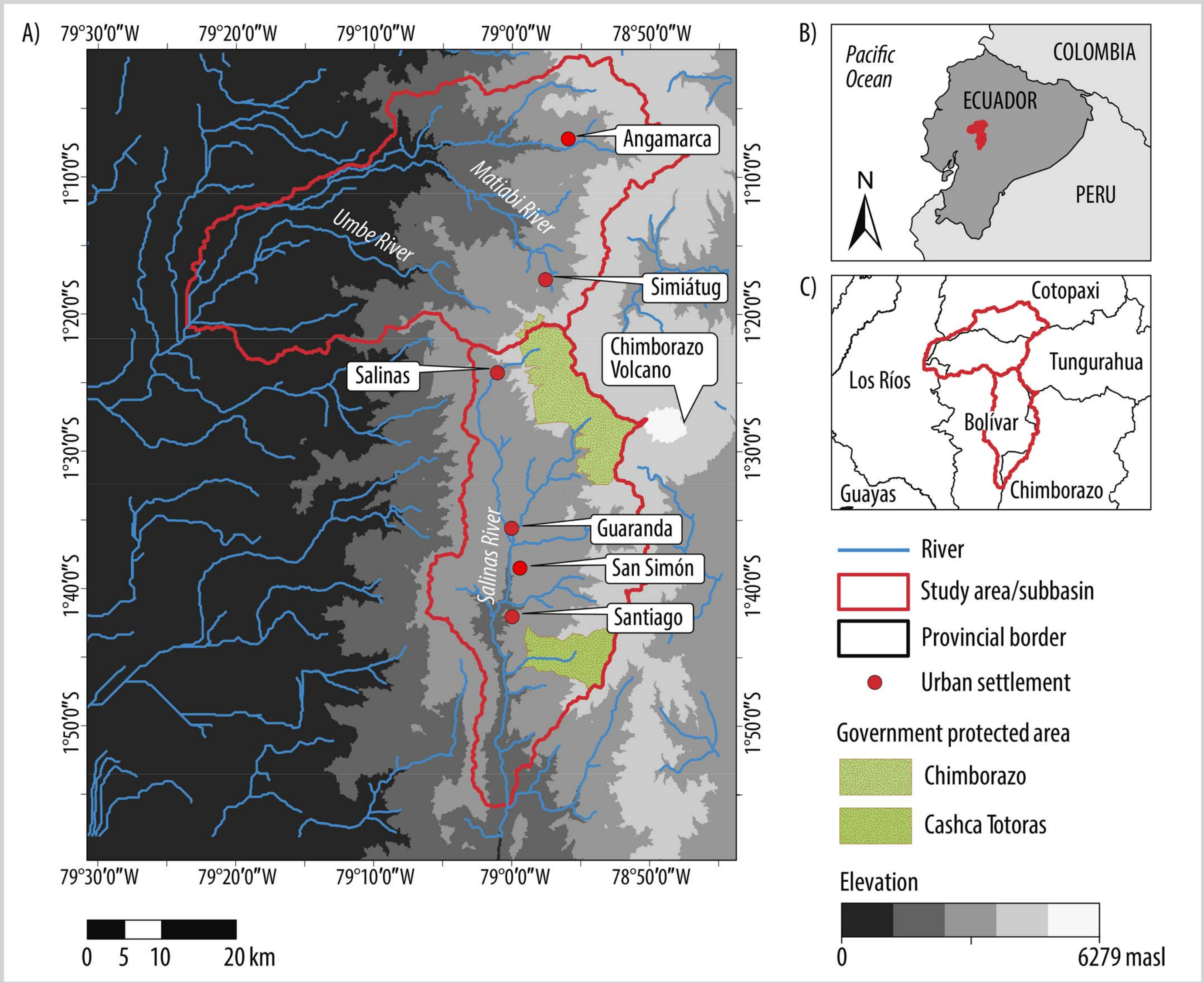
Introduction

Ecuador has 13,371 km^2 of *páramo* (Andean Neotropical alpine tundra ecosystem), representing 5% of its territory (Beltrán et al 2009). The vegetation of this ecosystem combined with a spongy organic soil form a water-retention system from which several streams of great importance flow, especially in the dry season (Podwojewski and Poulenard 2011; Avellaneda et al 2014). The *páramo* has undergone rapid transformation and degradation due to agriculture, cattle ranching, and, in some cases, mining activities (Romo and Calero 2022). As a result of this degradation, water flows have decreased, and some communities report significant periods of drought (Calvo and Villaverde 2011). Most of the area is under communal tenure, as a result of colonization, marginalization, migration, and intermarriage, which affects the dynamics of land-use change according to community priorities (Hofstede et al 2014; Avellaneda-Torres et al 2015).

The *páramo* is important because of the ecosystem services that it provides, particularly that of water supply (Buytaert et al 2006; Mena and Hofstede 2006). Loss of the *páramo* means a reduction in water supply to adjacent fields and towns downstream in the catchment, leading to the search for water from increasingly distant sources (De la Cruz et al 2009). By the beginning of the 21st century, about 64% of the total area of *páramo* above 3000 masl had been altered by human activities (Hofstede, Coppus, et al 2002). Most studies for the conservation of *páramo* have analyzed conventional technology, understanding technology as those rules of instrumental action proposed with the aim of solving a given problem (Habermas 2008). In general, the actions planned for *páramo* management lack information on alternative or sustainable management strategies and do not take into account the opinions and knowledge of the communities that inhabit these areas; that is, they are neither participatory nor inclusive (Armijos 2014; Camacho 2014; Hofstede et al 2014; Castro et al 2020; Pomboza Tamaquiza and Parco-Asitimbay 2022). Taking these aspects into account could reduce social conflict and improve the effectiveness of long-term land management and the conservation of ecosystems; moreover, the proposed projects would respond to the reality of the community and contribute to its sustainability (Robineau et al 2010; López and Maldonado 2019; Vergara 2020; Leroy and Barrasa 2021; Suarez et al 2022).

FIGURE 1 (A) Study area consisting of the Umbe–Matiabi and Salinas subbasins with parish centers, state protected areas, and the cantonal capital town of Guaranda and its location in (B) Ecuador and (C) the provinces of central Ecuador. (Map by David Carchipulla-Morales)



Social technology conceived in the geopolitical South of Latin America is based on the search for community wellbeing, an aspect that differentiates it from the concept of social technology used in northern countries (Pozzebon and Fontenelle 2018). It is defined as a way of designing, developing, implementing, and managing technology, whether as a product, process, or organization, to solve social and environmental problems and, at the same time, generate social and economic dynamics of social inclusion, solidarity, and sustainable development (Thomas et al 2015). Social technology allows the entire community to participate in the design and decision-making processes for its implementation, as well as giving the community equal access to goods and services produced internally or externally (Fonseca 2010; Peyloubet et al 2010; Falcão Freitas and Scaramussa Da Silva 2019). Social technology recognizes experience and traditional knowledge in its associative form and local know-how as a result of endogenous development (Rezzoagli et al 2019), without neglecting external knowledge that can be assimilated as part of a technological construction adapted to a community's reality (Pozzebon and Fontenelle 2018; Arboleda et al 2019). Participation is the main concept included in social technology and is closely linked to social management, which primarily seeks collective interests (Cançado et al 2019; Rezzoagli et al 2019; Torres and Naranjo 2022).

This research aimed to determine whether there are significant changes in the patterns of *páramo* loss in the central highlands of Ecuador, and whether existing protection approaches in the area are consistent with the characteristics of social technology. This information is important because there are no up-to-date data on changes in the state of the *páramo* in this area, and existing conservation experiences have not been analyzed from this new technological perspective.

Study area and methods

The study area covers an area of 2750 km^2 and is located in the central inter-Andean region of Ecuador (Bolívar, Cotopaxi, and Chimborazo Provinces) (Figure 1). Due to its accessibility, it has been historically and nationally characterized by greater than average *páramo* loss (Mena

TABLE 1 Communities living in the study area.

Province	Canton	Parish	Communities
Bolívar	Guaranda	Simiátug	Boliche, Llullimunllo, Pímbalo, Laihua, Cruz de Ventanas, Gerrana
		Salinas	Salinas-Matiabí, Pambabuela, Verdepamba, Natahua, Yurauckha, Pachancho, Yacubiana
		San Simón	Soropotrero
	San Miguel	Santiago	Santa Rosa de Totoras
Cotopaxi	Pujilí	Angamarca	Chinipamba

2010). Hydrologically, the area corresponds to the Umbe–Matiabi and Salinas subbasins, both of which are adjacent to and tributaries of the Guayas River basin, which drains into the Pacific Ocean. Approximately 8.6% of the total area is included in the National System of Protected Areas. Areas of note are the Chimborazo Flora and Fauna Production Reserve with 151.2 km^2 (100% *páramo*) and the Cashca Totoras Protected Forest with 65.3 km^2 (50% *páramo*).

There are 16 rural communities in this area, living at 3000 masl (Table 1). The communities comprise 20% *mestizos* and 80% Indigenous descendants of the original peoples, the Tomabelas, Chimbos, and Warankas, who developed pottery, spinning, agriculture, and animal domestication (GAD Salinas 2015; Guzmán et al 2020). The living conditions in the area are precarious, with a poverty rate of 96.8% among the Indigenous population, 40.8% of children affected by chronic malnutrition, an illiteracy rate of 13.9%, 60% of households without sewerage, and 45% without potable water (Cabrera et al 2016). Currently, the goal is to improve this socioeconomic situation through a community development process promoted by local organizations that have been established in Salinas since 1970 (Polo 2021).

The methodology for this study consisted of a quantitative analysis of land-use change and *páramo* loss and a qualitative analysis of the sociotechnical approaches that have been taken to protect the *páramo*. The quantitative analysis determined the dynamics of land-use change and *páramo* loss using the spectral response mode in images from Google Earth Engine (Landsat missions) with a resolution of 30 m × 30 m (Mutanga and Kumar 2019). The mode was obtained from Google Earth Engine's ee.Reduce.mode algorithm, which generates a histogram for each pixel in the image (Gorelick et al 2017). Three analysis periods (1986–2000, 2000–2008, and 2013–2021) were defined based on the selected images (34 in Landsat 5, 39 in Landsat 7, and 35 in Landsat 8) that had less than 30% cloud cover (Mutanga and Kumar 2019). One land-use map was generated for each period. The spectral bands used in each mission were red, green, blue, near infrared, short-wave infrared, thermal, normalized difference vegetation index, enhanced vegetation index, and terrain elevation from the Shuttle Radar Topography Mission along with the terrain slope (Tamiminia et al 2020; Tariq and Shu 2020). The supervised classification process was performed on the Google Earth Engine platform using the Random Forest machine-learning algorithm, which allows iteration until the most frequent and accurate classification is obtained (Mahesh 2020). The model was trained using 100 decision trees on manually delineated polygons (Phiri et al 2020; Tassi and Vizzari 2020), based on land-use and land-cover information from the Ministry of Environment (MAE 2015). Finally, pixels identified as clouds were reclassified according to a visual analysis of the most common class in neighboring pixels to calculate the areas of each class (grassland, forest, *páramo*, crops, human settlements) for each of the study periods (Jiang et al 2010). Classification accuracy was assessed using confusion matrixes, which highlight the classification error from a comparison between the class initially assigned to the samples and the class obtained after applying the model (Tassi and Vizzari 2020). The first period was used as a baseline for *páramo* cover in the area of interest. The second and third periods were superimposed on this baseline to determine the variations in the *páramo*.

The qualitative analysis, which aimed to identify social technology forms related to protection of the *páramo*, was carried out through critical discourse analysis (Van-Dijk 2016). This looks for consistency and coherence, as well as transformation and legitimization of the discourse, until it reaches the points of view adopted and the ways in which individual and collective knowledge is organized (Pardo 2013). Semistructured interviews, guided field tours, and group interviews were applied (Hernández and Mendoza 2018). For its development, public and private organizations involved in the conservation and sustainable management of the *páramo* were identified and contacted (Smith and Osborn 2008). A stakeholder map was used to identify those organizations relevant to the conservation of the *páramo* (Alberich et al 2009). A list of potential interviewees was also defined, validated, and simplified (Hernández and Mendoza 2018). Each interviewee was asked to recommend other key actors who could be interviewed, using a snowball sampling technique (Tarrés 2014), so that only those who were essential to the analysis were included. The final sample of interviewees was based on the availability of interviewees and data saturation (Taylor et al 2016). Participants were selected according to the role they play in the *páramo* conservation dynamics (Table 2). In total, 6 women and 16 men were interviewed in 7 group sessions and 22 individual sessions, using a semistructured interview modality with open-ended questions (Duque and Aristizábal 2019). Some of the individual interviewees also participated in the group sessions (Flick 2007). The interviews were conducted between December 2021 and April 2022, and 29 transcripts were analyzed and coded.

The interview format included an introduction to the research (Appendix S1, *Supplemental material*, https://doi.org/10.1659/mrd.2022.00022.S1) and allowed

TABLE 2 Informant characterization.

Informant no.	Characteristics
I1	Communicator/community resident
I2	Cantonal local government authority
I3	Parish local government authority
I4	NGO social projects technician
I5	Community leader
I6	NGO forestry expert
I7	NGO director
I8	NGO social projects/straw handicrafts expert
I9	Parish local government authority
I10	NGO agricultural expert
I11	NGO agricultural expert
I12	Parish local government authority
I13	NGO *páramo* expert
I14	Community leader
I15	Youth environmental activist/community resident
I16	NGO social projects expert
I17	Community leader
I18	Community leader/weaver
I19	Trader/community resident
I20	Community leader
I21	Trader/community resident
I22	Teacher/community resident

Note: NGO, nongovernmental organization.

the collection of information on (1) the current situation of the *páramo* and (2) actions to protect the *páramo* and how these could be perceived as social technology. The descriptive analysis of the interviews was carried out by identifying the occurrence of particular words, which allowed associations to be identified and classified. Subsequently, an analysis of discursive coherence and consistency was carried out by recognizing shared ideas, individual points of view, and their coexistence in the discourse (Pardo 2013).

Results

Changes in *páramo* coverage and land use

Figure 2 shows the variation in *páramo* cover in the study area for the 3 selected periods (1986–2000, 2000–2008, 2013–2021). In general, the north-central zone showed the greatest changes, with significant *páramo* loss, where land-use changes correspond to conversion from *páramo* to cropland. In the south, the conversion trend was from *páramo* to forest, which is consistent with the numerous pine plantations observed during field visits. The objective in this area is to produce timber, although these plantations are also used by communities to grow mushrooms and provide firewood for heating and cooking.

Analyzing this variation by periods, the map covering 1986–2000 represents the baseline. Comparing the second period to this, we see a loss of 17.2% of *páramo* (Figure 3), which means approximately 114.7 km^2 of *páramo* disappeared; this *páramo* was converted into pasture, forest, and crops, with the latter predominating (54.1%). This situation changed from the second to the third period, during which the rate of *páramo* loss slowed down to 3.3%; approximately 21.9 km^2 were lost and were converted mainly into pine forests (77.2%).

The slowdown in *páramo* loss in the third period occurred after the droughts between 2005 and 2008, when, according to one informant, "there were communities that had no water, [and] the rivers were dry, so they had to be supplied by tankers" (Informant 13). In 2008, this crisis led young community members with access to environmental training to propose that the sheep be removed from the highest parts of the *páramo* and that community protected areas be declared water reserves. These protected areas differ from government protected areas, where *páramo* loss continued (Figure 2), and the agricultural frontier and pine plantations progressed (Figure 4). This was the case in the Chimborazo Flora and Fauna Production Reserve, where the trend of *páramo* loss (1%) remained the same between the periods 2000–2008 and 2013–2021. The decisions of the new generations are based on the understanding that the water importance of the *páramo* is related to the unique characteristics of its soils and vegetation, which form an edaphic structure that acts like a sponge. Anthropogenic activities cause soil compaction and removal of vegetation cover, resulting in loss of water retention and regulation capacity (De la Cruz et al 2009). Table 3 presents the main causes of *páramo* loss that were observed during the field visits and the perceptions of the local population.

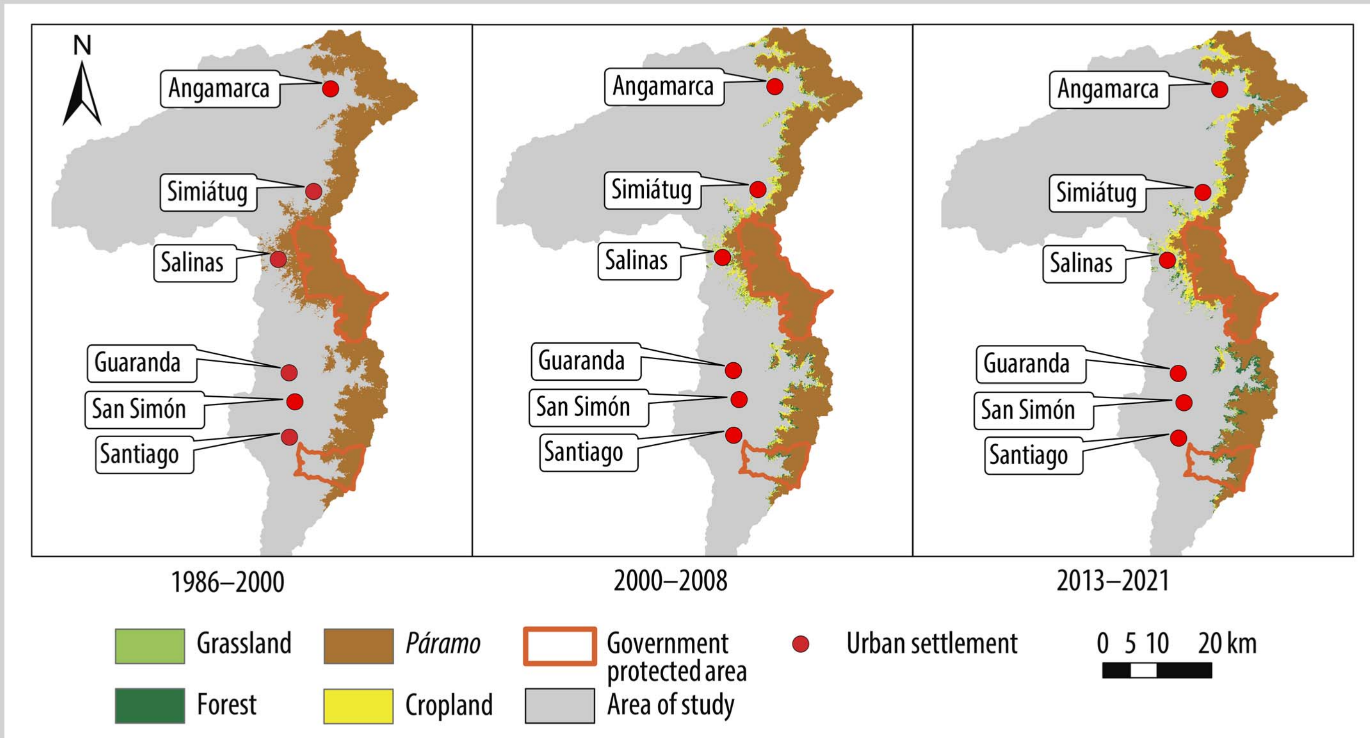
Social technology for *páramo* protection

Eight communities in this area defined and implemented a series of activities to protect and restore the affected *páramo* areas. This was the result of a community development process in which local knowledge was combined with recommendations from foreign experts, resulting in the formation of social technology. Table 4 divides these activities into 4 categories, which are related to 3 relevant issues: land use, livestock, and community governance.

Conservation: This measure involved the release of large areas of *páramo* with the aim of making them exclusively water recharge areas, without anthropogenic activities. To consolidate these areas, the communities had to agree to cede their territories, as one of the informants explained:

> *The areas were defined by the community assembly; there is no agriculture, hunting, or grazing. The park ranger checks that there are no animals in the* páramo*; if any are found, they are taken to the community, and the owners are fined, and if they are from another community, they are informed.*
>
> (*Informant 5*)

FIGURE 2 Loss of *páramo* in the study area between the periods 1986–2000, 2000–2008, and 2013–2021. (Map by David Carchipulla-Morales)



Young community leaders, supported by local experts, led this self-management process. With more knowledge of the importance of the *páramo* and the effects of agricultural and cattle-raising activities, they could inform the entire community about the advantages and disadvantages of this measure. In the beginning, there were opponents: Farmers did not understand the ecosystem services that the *páramo* provides, and it was not easy for them to give up their land to a protected area.

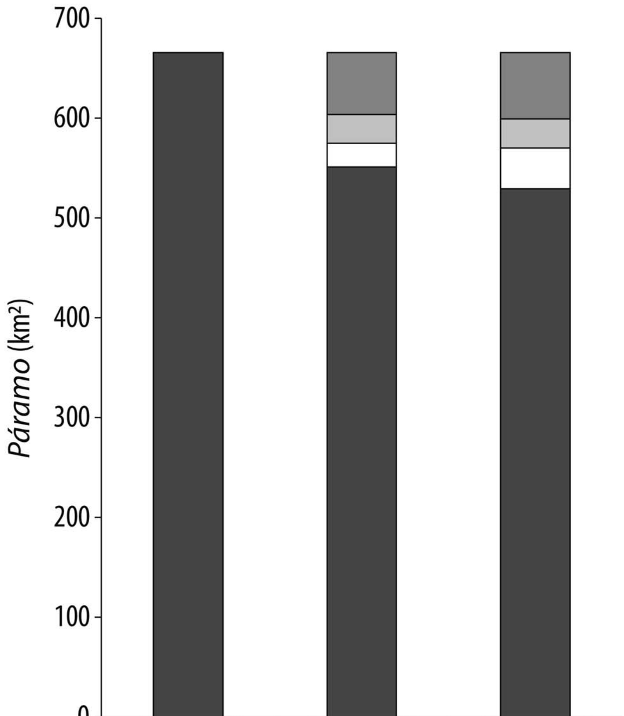
Conservation took place under the modality of direct economic incentives to the community (US$ 30/ha/y), supported by the central government through the *Socio Páramo* Program (De Koning et al 2011). The communities decided whether or not to participate in this program through means of an assembly discussion. If they opted in, the money they received was invested by the community in genetically improved livestock, park rangers, socioeconomic alternatives, and community improvements; in other words, the goal was to protect the *páramo* while generating inclusive social and economic dynamics.

Other communities, through agreements and cooperation, decided to maintain water reserves without being part of a direct monetary incentive program; this was because they understood the importance of having water resources during the dry season, which is why, according to them, "its care has no price" (Informant 5). With this logic, the parish of Simiátug liberated 39.8 km^2 of *páramo* and declared it a Water Protection Area, recognized as a protected area by the Environmental Agency, with the objective of ensuring water supply to 42 downstream communities (10,000 people) (EFE and Redacción Primicias 2022). Since 2021, a broader project has been sponsored by the European Union in partnership with local governments and several nongovernmental organizations (NGOs). This project aims to promote a decree for the creation of a *Páramo* Biological Corridor, with initial participation from Salinas and Simiátug, but open to the future integration of neighboring communities.

This measure is in line with the provisions of social technology, since each community appropriated a method according to its reality and conditions while fulfilling the objective of clearing the high *páramo* areas. As a result, 12 years after their nearby *páramo* had first been placed under protection, several interviewees claimed that the soils, which were previously hard as rock and without natural vegetation, were now true sponges, where native plants grew again, where native fauna of the area that was thought to be lost (deer, wolves, and rabbits) was once again attracted, and where water flows were constant throughout the year. The recovery of the water retention contrasts with other studies that indicate that the *páramo* has only one life (Buytaert et al 2002; De la Cruz et al 2009). Therefore, hydro-meteorological stations are needed in this area to record these changes.

Restoration: Many *páramo* areas outside the reserves were subject to erosive processes as a result of slash-and-burn agriculture, cattle ranching, and intensive farming. The communities noticed this and, in collaboration with government institutions and NGOs, began community campaigns to replant native vegetation. This activity is taking root in the area according to one of the informants: "People are becoming aware of the importance of restoration" (Informant 14). Therefore, when necessary, the community intervenes in the areas of neighboring communities, strengthening solidarity and promoting the recovery of the *páramo*. In Salinas, the local youth group called *Sembrando Vida* (Sowing Life) meets with the entire

FIGURE 3 Transformation of the *páramo* by period, 1986–2000, 2000–2008, and 2013–2021, based on the analysis of Landsat images.



	1986–2000	2000–2008	2013–2021
Cropland	0	62.2	66.3
Pasture	0	28.6	29.5
Forest	0	23.9	40.8
Páramo	665.8	551.1	529.2

community (children, teenagers, adults, women, and the elderly) every year to plant native plants to restore the *páramo* and its lagoons.

To date, 15,000 plants have been planted in the parish of Salinas alone. These were donated by local governments and NGOs. According to the testimonies received, the results of this community activity will be seen in about 12 years. At present, there is a project in the area that includes the restoration of the entire *páramo* reserve strip in the parishes of Salinas and Simiátug, with the goal of planting 350,000 plants by 2025.

Change in the dynamics of livestock ownership: Another important component of this social technology relates to livestock ownership outside the protected areas, in lower-lying areas that are still *páramo*. The communities, aware of the need to avoid overgrazing in these areas, have reconsidered the custom of families maintaining large flocks of sheep and limiting grazing areas. One of the informants stated:

> *Ten years ago, the páramo was full of sheep; each family (about 200) had between 300 and 400 small sheep, plus llamas that grazed freely. Today, the emphasis is on reducing the number of sheep, with a maximum of 20 per family. [The sheep are] genetically improved for triple use (meat, milk, and wool).*
>
> (*Informant 9*)

This is a technique that is gaining acceptance, supported by funding for livestock change from *Socio Páramo* payments and NGOs.

Creation of socioeconomic alternatives (pluriactivity): The decrease in the area of highlands used for sheep grazing and agriculture has affected people's already precarious livelihoods. However, motivated by the need to protect the *páramo*, several organizations have helped to develop the communities' capacity to carry out alternative economic activities. The Institute of Ecology and Development of Andean Communities (IEDECA), German Technical Cooperation (GIZ), Salesian Family Foundation (FFS), Populorum Progressio Ecuadorian Fund (FEEP), and the Foundation Union of Peasant Organizations of Salinas (FUNORSAL), among others, have focused their efforts on generating economic alternatives and consolidating solidarity in community enterprises (Polo 2021). Within this range of possibilities, one informant stated:

> *Farmers who settle in the lowlands receive support from the government and NGOs (loans and training) to improve the productivity of their land and livestock, so they do not have the need to expand the agricultural frontier to the higher areas.*
>
> (*Informant 5*)

The markets for the alternative products listed in Table 4 remain limited, but they are expected to expand over time, on the premise that their sale and consumption help to protect the *páramo*. This stimulation of the economy, achieved through social management, has brought about important social and environmental changes, as the quality of life of many of the inhabitants of these communities has improved. In some cases, however, the profits generated by these activities do not equal the profits generated by raising livestock in the *páramo*, but they do contribute to the family budget and curb intentions to expand agricultural activities to higher elevations.

Lessons learned

Although government institutions have been involved in this area, this has not been enough, and *páramo* loss within government protected areas has continued. Currently, there are no systematic government-led *páramo* management plans, nor is there a water fund to provide resources or establish guidelines for the care and protection of the ecosystem, as is the case elsewhere in the country (UNDP 2020; Wiegant et al 2022). However, despite the lack of resources, community actions are not significantly different from those in place in similar areas that do have a water fund (Tapia et al 2011; Terán et al 2019). The difference lies in the fact that the communities themselves, who are autonomous, empowered, organized, and aware of their reality, have agreed and configured a series of concrete actions to protect and conserve the *páramo*. This way of establishing tools (rules of instrumental action) for the management of the *páramo* in a collective way is social technology, based on inclusive participation, cultural values (solidarity and cooperation), the possibility of choice, a combination of techniques, and the search for the common good (Giraldo 2012; Dagnino 2014; Gómez 2014; Pozzebon et al 2021). This is the contribution of social technology to

FIGURE 4 Parceling of the *páramo* and advancement of pine plantations. (Photo by María Cristina Torres, 2021)

areas that have unique characteristics, dynamics, and realities (such as mountain areas), where it is possible to improve the living conditions of the people while maintaining the balance of the ecosystems.

Community participation and decisions by consensus

The delineation of *páramo* areas for reserves, the selection of areas and plants for restoration, the restriction of grazing areas, and the reduction of livestock numbers are actions that have been achieved as part of a process widely debated by the community. All families and their members are invited to participate in this process, nothing is imposed, and decisions are made by consensus. One of the interviewees stated:

> *This decision-making practice is a cultural tradition—there are no individual decisions; they are collective. First agreements are reached in the family, and then the community moves forward.*
>
> (*Informant 10*)

TABLE 3 Most important causes of *páramo* loss.

Identified factor	Perceptions
Introduction of pine trees	"More research is needed to propose alternatives to pine plantations" (Informant 6). Pine is a source of firewood and timber for communities, but it is not technically managed, and, since it is an exotic species unsuited to *páramo* soils, it is a threat in many places because it consumes a lot of water, reduces water yields, and eventually dries out the soil (Hofstede, Groenendijk, et al 2002).
Population growth	"The families continue to grow, with up to 10 or 12 children, the land is divided up, the *páramo* is parceled out for private use, which has an increasing impact" (Informant 11). This reality invites us to reflect on the type of inheritance that will be left to new generations, given the fragility of the ecosystem and the strong pressure on new families that do not have land in the middle and lower zones, and so try to move to the higher zones and establish cattle ranches (De la Cruz et al 2009; Lasso 2009).
Expansion of agriculture	"Without being aware of the damage, the tractor is used" (Informant 18). Tillage is more intensive, and tractor use is more frequent, which damages the soil and slows down its ability to regenerate (Lasso 2009).
	"Although the practice of slash-and-burn has been stopped, in some way, it is still present in one way or another as a habit of some farmers to expand pasture areas, and it is also common to use of herbicides indiscriminately to eliminate nonproductive [plants] more quickly" (Informant 13). These types of practices are not regulated by the competent authorities, nor are their consequences analyzed in terms of their impact on water quality (Cuesta et al 2014).
	"The increase in livestock in the highlands also affects the quality of the water that reaches the villages (fecal coliforms) and is a latent problem for the water" (Informant 3).
Reduction of communal lands	"There is a loss of the sense of community; even though it is written on paper, everything tends to be individual, and this contributes to the deterioration of the *páramo*" (Informant 2). This sense is important because it promotes collective needs being met under a cooperative commitment between all members of the community (Artigas et al 2014).

TABLE 4 Social technology developed by communities to protect the *páramo*.

Action	Description
Conservation	Demarcation of *páramo* areas located in the highest parts and declaration of them as water reserve zones.
	Livestock of any kind, hunting, and human settlements are prohibited.
	Only tourists are allowed to enter.
	These areas are guarded by a park ranger hired by the community.
Restoration	Restoration of areas degraded by burning or erosion.
	Only native *páramo* species are planted.
Change in the dynamics of livestock ownership	Consists of 3 measures: • Reduction in the number of sheep and cattle; • Limitation of grazing areas; • Acquisition of genetically improved sheep (triple purpose), which consume less water and less pasture. Five sheep can produce the same amount of milk as a single cow.
Creation of socioeconomic alternatives	These activities are complementary to agriculture and livestock raising, which reduce the pressure on the use of the *páramo* and can be grouped as follows: • Community tourism; • Straw handicrafts and weaving; • Food (dried mushrooms, llama sausages, nougat, farmed trout, sheep's cheese, organic vegetables, medicinal plants, etc).

The process has been supported with technical advice from several NGOs working in the area. This has allowed the communities to make the best decisions based on their reality and recognize their own knowledge (Pozzebon 2015).

This form of organization is characteristic of a deliberative democracy, the foundations of which are participation, transparency, dialogue, and accountability, and wherein the political and social forces allow citizens to participate and influence decisions that affect their lives (Cançado et al 2019). It promotes community governance based on networks, partnerships, and multistakeholder dialogue. This strengthens environmental agreements (Villarroel 2014). Such governance is not hierarchical; there is a tendency toward collaboration, flexibility, positive incentives, negotiation, and nonmanipulative persuasion (Cohen 2013).

Solidarity and cooperation

Most of the communities in this area, being Indigenous, maintain the principles of the Andean worldview, which privileges the interests of the community over those of the individual. Relationships are based on reciprocity, cooperation, and solidarity; they follow the idea that all members of the community belong to the same family, which makes them equal and confers the same welfare rights (López 2010; Montalván et al 2020). Water scarcity has provided an opportunity to demonstrate these principles, as in the case of parish of San Simón, where, 10 years ago, the community, the cantonal government, the parish government, the mayor, and other entities jointly raised the money needed to purchase the land that now forms the Quinllunga de San Simón Water Protection Area; therefore, according to one of the interviewees: "The consolidation of the reserve was a cooperative achievement" (Informant 9).

In other communities, cooperation means working together. As one interviewee commented: "In 2020, at least 300 to 400 people got together to help restore [the *páramo*]" (Informant 1). In this mission, if necessary, they also restore *páramo* areas of neighboring communities, thus showing solidarity and commitment to the recovery of the *páramo*. Another form of cooperativism, understood as interest in the community, can be observed in the town of Salinas, where community organization for endogenous development has contributed to strengthening the productive framework and improving the quality of life of the population (Franco 2023). Similarly, solidarity is demonstrated by using the profits of different community enterprises in programs aimed at improving the living conditions of the communities and generating new socioeconomic alternatives (Naranjo 2009). Self-management and social participation are key aspects of this process, which seeks to reduce pressure caused by direct use of the *páramo*.

Discussion and the way forward

The understanding and disposition presented by some communities in Simiátug and Salinas, mainly around the protection of the *páramo*, represent an example of how a good community organization can be seen as social technology that generates dynamics of social and economic inclusion and sustainable development. The main advantage of social technology is that it is the result of collective decisions, which guarantee that the technologies adopted will be supported by the community. This innovative systemic vision has made it possible to design sociotechnical solutions that have slowed the rate of the *páramo* loss and adapted to the reality of the people living in the area (Thomas 2011).

TABLE 5 Key government support issues to consider.

Measurement type	Action
Legal	Create a legal framework for the conservation, use, and sustainable exploitation of the *páramo*.
	Designate existing *páramo* community reserves as water protection areas to allow them to have recognized management plans and community governments that are responsible for their implementation and management.
	Create a water fund to promote solidarity among all water users in the basin and to support the protection of the *páramo*.
Economic	Find resources for conservation incentives and ease of access to attract more participants.
	Invest in tourism infrastructure to reach competitive levels and adequately exploit the scenic beauty of this ecosystem.
	Facilitate the opening of markets for alternative products generated by the community.
Social	Strengthen community organizations to achieve greater participation of the communities settled in the area to reach agreements on the protection of the *páramo*.
	Conduct a feasibility study for the relocation of communities to the lower zone in order to provide them with better livelihood opportunities.
	Provide leadership training and ongoing environmental education programs for the entire population living in the watershed.
	Conduct studies on the productive capacity of the communities, which will expand the possibility of economic alternatives, based on the potential of the area and the skills of the people.

Unfortunately, this vision is not shared by all communities in the study area, which leads to the existence of very fragmented zones adjacent to reserve areas and also within government protected areas. In Ecuador, there is talk of a loss of 4 ha of *páramo* per day (Romo and Calero 2022), which shows how thin the line is that separates bad management from good management, despite the proximity, where some understand the importance of the *páramo*, and others do not. This may be due to factors related to the lack of leaders trained in environmental issues and community management, low or nonexistent communication with the environmental authority, low credibility of the commune authorities, isolation of community members, or a lack of alternatives for economic subsistence (Avellaneda et al 2014); these aspects may not allow the articulation of a social technology for the protection of the *páramo*. Table 5 presents the main actions necessary, on the part of the environmental authority, to strengthen and guarantee, over time, the progress made by the social technology developed by the communities for the protection of the *páramo*.

Conclusion

Study of the situation of the *páramo* in the central zone of Ecuador shows a slowing of the rate of its loss, which is encouraging. This positive change is due to the decisions of some communities that, through a wide consultation and consensual endogenous processes, as well as the opportune use of political and economic conjunctures with external agents, have defined a set of actions to preserve and recover the *páramo*. This community management of the *páramo* in the area corresponds to the characteristics of social technology, since, based on the interests of the communities, it has been possible to reconcile their new position as protectors of the *páramo* with their economic needs.

This type of process is important because it shows that it is possible to generate proposals based on local knowledge, dynamics, and capacities, rather than waiting for or passively accepting projects that do not fit their reality and thus ultimately fail. The participatory planning of these communities has contributed to the conservation of the *páramo* because it is supported by all members, who have shared objectives and know and accept their role in achieving those objectives. There is a reflection on the space in which these communities live, which promotes cultural aspects such as the Andean world view and their relationship with nature.

These advances in the community management of the *páramo* should be analyzed by the central government in its development of regulations that allow for the integral protection of the *páramo*, regardless of the jurisdiction to which it belongs. This implies harmonizing the conservation of the *páramo* with respecting the rights of the population that inhabits this ecosystem (economic subsistence) through the implementation of inclusive policies based on social technology.

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Supplemental material

APPENDIX S1 Applied interview.

Found at: https://doi.org/10.1659/mrd.2022.00022.S1.