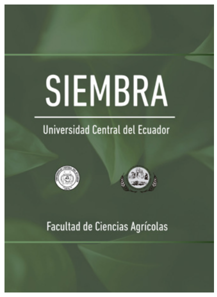
Analysis of natural resources and peasant practices in high altitude ecosystems. Case study: Cochapata community in Urcuquí-Ecuador



Análisis de los recursos naturales y prácticas campesinas en ecosistemas de altura. Caso de estudio: comunidad Cochapata en Urcuquí-Ecuador

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Abstract

The objective of this work was to analyze the relationship between perceptions and agricultural practices in the face of the effects of climate change from the agro-socio-economic context and the hydrological structure in the Cochapata high-altitude ecosystem in Urcuquí-Ecuador. The methodological strategy responds to the qualitative paradigm, case study method. Primary information was collected through landscape reading, interviews, and participant observation. It was found that the territory is occupied by timber industries, whose tree species are characterized by excessive water demand. The sub-paramo is inhabited by peasants in survival conditions who use the land to obtain goods for family sustenance using their labor force. Water distribution is of a hydro-social nature, as it excludes peasants from the right to irrigation and watering. Regarding the effects of the changing climate, the inhabitants perceive heat waves and variations in the rainy season in their daily lives; however, no agricultural practices were found to adapt to the climatic phenomenon. It is concluded that the vulnerability of the ecosystem is not directly related to climate change; it responds to historical failures in the distribution of ecosystem goods such as land and water, to the lack of knowledge of the peasant subject on the part of the state and society, and the excessive extractivism implemented during the last decades.

Keywords: high altitude ecosystems, agricultural practices, climate change, survival, natural resources

Resumen

El objetivo de este trabajo fue analizar la relación entre percepciones y prácticas agrícolas frente a los efectos del cambio climático desde el contexto agro-socio-económico y la estructura hidrológica en el ecosistema de altura Cochapata en Urcuquí-Ecuador. La estrategia metodológica responde al paradigma cualitativo, método de estudio de caso. Se levantó información primaria mediante lectura del paisaje, entrevistas y observación participante. Se encontró que el territorio está ocupado por industrias madereras cuyas especies arbóreas se caracterizan por excesiva demanda hídrica. El subpáramo está habitado por campesinos en condición de sobrevivencia que usan la tierra para obtener bienes de sustento familiar, valiéndose de su fuerza de trabajo. Se evidenció que la distribución

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del agua es de carácter hidrosocial, pues excluye al campesinado del derecho a riego y abrevadero. Respecto a los efectos del clima cambiante, los pobladores perciben en su cotidianidad olas de calor y variaciones en las temporadas de lluvias, sin embargo, no se encontraron prácticas agrícolas con intención adaptativa al fenómeno climático. Se concluye que la vulnerabilidad del ecosistema no guarda relación directa con el cambio climático, esta responde a las fallas históricas en la distribución de los bienes ecosistémicos tierra y agua, al desconocimiento del sujeto campesino por parte del Estado y de la sociedad, y al excesivo extractivismo implantado durante las últimas décadas.

Palabras clave: ecosistema de altura, prácticas agrícolas, cambio climático, sobrevivencia, recursos naturales

1. Introduction

Climate change is a global phenomenon that has gained momentum in recent years as a result of unbridled industrial models. Its adverse impacts on the population, ecosystems and the economy are currently one of the most pressing problems in nearly all countries. Latin America and the Caribbean are highly vulnerable to the effects of climate change due to their geography, topography and socioeconomic conditions.

According to the report of the Intergovernmental Panel on Climate Change (IPCC, 2014), uncontrolled uses of nature generate stressors on natural systems. The risks of climate change on freshwater and the ecosystems that supply water increase drastically, while greenhouse gas concentrations escalate (Ministerio del Ambiente, 2012).

Given that the impacts of climate change on human systems depend not only on climatic variables, but also on social and economic factors, they have a greater impact on people and communities in disadvantaged material conditions; this, occurs with greater incidence in Latin America (Sutton et al., 2011). The importance of strengthening training on issues related to climate change in both community and business environments is widely accepted, yet with an emphasis on academia and research. This is corroborated by a study carried out in Nicaragua, which sought to identify gaps related to climate change knowledge (Milán Pérez & Zúniga-González, 2021). The segment of the population suffering from water scarcity and river flooding has increased. One of the risks is associated with food insecurity, and failure/collapse of food systems susceptible to (affectation due to) climate variability and/or extreme weather events, such as droughts and heavy rains, particularly for poor populations in urban, peri-urban and rural settings (Ministerio del Ambiente del Ecuador, 2014).

Within the global context, the Global Water Partnership [GWP] has been promoting regionally integrated water resources management [IWRM] programs since 1996. The application of IWRM is being studied, and requires a change in the way the international community deals with the water issues. There is no one-size-fits-all plan, but challenges that seek to secure water for people, food production, protection of vital ecosystems, risk management, capacity building, building political will, promoting collaboration across borders. All this in a delicate balance between the use of water to sustain a growing world population, and the protection of water functions and characteristics (GWP, &Comité de Consejo Técnico [TAC], 2000).

For its part, the Inter-American Commission on Human Rights [CIDH, in spanish], in its preliminary report on poverty, extreme poverty and human rights in the Americas, reported that it is the countries that produce the least amount of emissions that will have their natural and human systems most affected, due to their less safe livelihoods, dependence on natural assets, marginalization and greater vulnerability to hunger and poverty (CIDH, 2016).

In this context, for rural development programs to be feasible, they must integrate the knowledge of social actors on agricultural practices in the face of the effects of climate change. According to Freire (2005), "many projects of a political or educational nature have failed because they took only their own view of reality". In other words, applying a global model based on climate change scenarios where the actors are developing countries generates actions that are not at all effective, as they do not respond to the climatic, biophysical, socioeconomic and demographic aspects of each locality, as the designs do not integrate the capacities of the communities (Beltrán et al., 2015).

It should be noted that one of the ecosystem aspects seriously affected by climate change is water, which is currently already degraded due to the contamination of its sources; inhabitants of the canton dump agricultural supplies, wastewater, plastic containers in irrigation ditches and main rivers: Cariyacu, Palacara, Salado, San José, San Vicente and Tupiza. The largest number of water authorizations are for hydroelectric, irrigation and domestic use; however, there exists no control, planning, or technical studies concerning the irrigation systems. However, what stands out is the weakness of institutional institutions to implement integrated water management, coupled with a weak technical capacity, and poor social organization (GADM de Urcuquí, 2014).

However, the populations without access to irrigation in the highlands of Urcuquí canton are the most vulnerable due to water grabbing, concentration and exclusion on the part of the haciendas, and the disruption of the ecosystem caused by extractive industries. Gaybor Secaira (2010) points out that most of the rural population has little access to irrigation, due to the enormous concentration in intensive production of the predominant hacienda system.

Within this framework, investigating territorial perceptions in marginalized high altitude populations in the face of climate change is justified, inasmuch as the appreciations and agricultural practices of rural dwellers help in the construction of soil and water management models in the conditions in which they develop (Soares et al., 2018). For this, in this local scale research (exercise), it was convenient to use a qualitative approach, which made it allows to point out that each human society has its own perception of the climate, being its actions and reactions therefore differentiated (Retamal et al., 2011).

This exploratory study investigates the general context of agricultural practices, interprets and relates the perceptions and reactions of local actors in the high altitude communities of Cochapata and Azaya, with respect to the effects of climate change. It was possible to contrast the new land uses, and correlate these with other internal and external problems of the system. An attempt was made to capture the pattern of the investigated reality in order to communicate it to the interested parties: the scientific community, policy makers, agencies and institutions related to the problem.

Within this context, it is necessary to analyze the relationship between perceptions and agricultural practices from the agro-socio-economic context in the ecosystem of the Cochapata community in Urcuquí. In conclusion, we ask ourselves, is there a relationship between perceptions about the effects of climate change and agricultural practices in the Cochapata high altitude ecosystem?

2. Materials and Methods

2.1. Description of the method

This work was carried out with a descriptive approach. Residents of the study area were interviewed about changes in the landscape, transformations of the territory, family life, irrigation ditches, land use and significant socio-environmental events that occurred during the last five decades. The landscape reading and interviews were conducted over a period of eight consecutive weeks. Data on agricultural practices, peasant economy and conflicts over access to water were approached with participant observation technique through occasional visits to events such as harvests, *mingas*, and assemblies. For example, the area was visited during the watering pond construction stages. During the process, perceptions were collected; in addition, we periodically assited to meetings at the state water agency for the defense of the Nambal irrigation ditch and the right to water.

2.2. Ecosystem definition and approach

Eighty years ago, the concept of ecosystem, widely used in academic and scientific circles and by environmental decision-makers, was proposed as a basic unit of nature. It is a reference to understand how living beings -including human beings- and their relationships with the environment, function. In the academic-scientific sphere, the term ecosystem is proposed as the framework concept and central theory in ecology to refer to spatial units where the exercise of zoning, diagnosis and management of the territory is possible. Thus, the representation of the concept of ecosystem is part of a language referring to specific natural sites important to society (Armenteras et al., 2016).

Indeed, the criteria for studying ecosystems derive from the identification of serious problems of landscape degradation derived from inadequate land and water uses, and a high risk of occurrence of natural disasters. In this scheme (Figure 1). The dimension of human societies is represented within their ecosystem context, in a methodological framework that includes structure, function, disturbance and affected ecosystem services with a valuation perspective (Andrade Perez & Navarrete Le Blas, 2004).

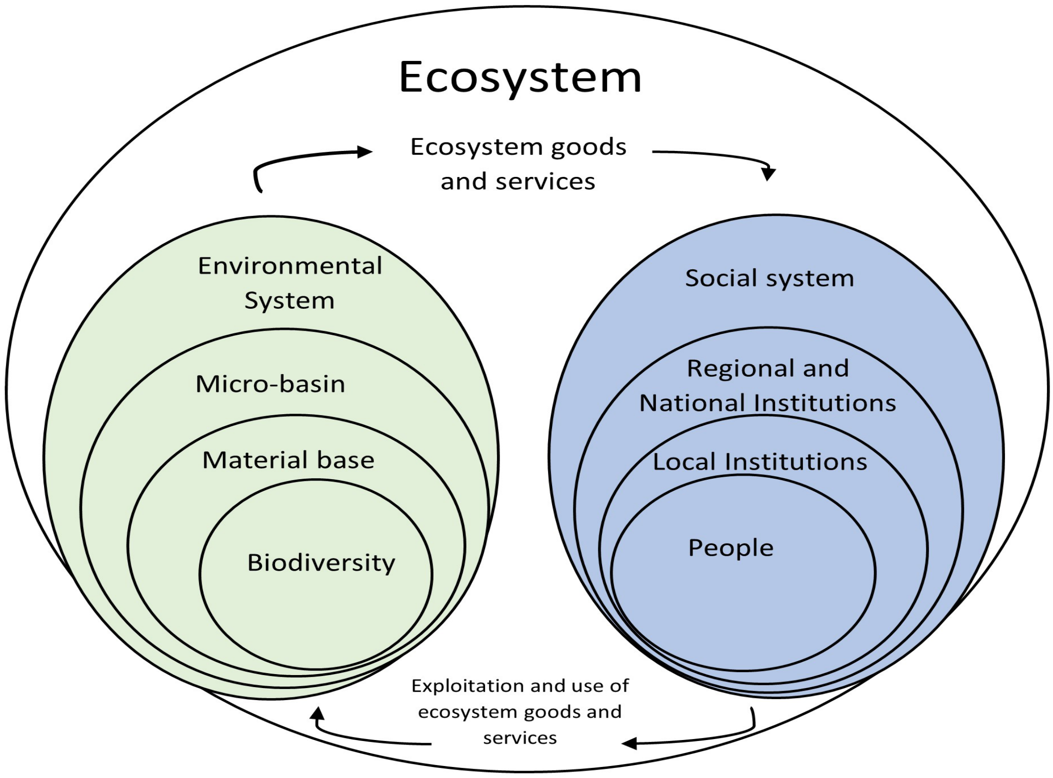

Figure 1. Conceptual scheme of the ecosystem.

The ecosystem services approach is the link in the theoretical-practical study of ecosystems, a bridge of interaction between the social dimension and the ecosystem (Andrade Pérez et al., 2011). This vision originated from the environmental movement's complains of the negative effects of pollution and deforestation (1960-1970); then, in studies on the importance of healthy ecosystems for human well-being (1970-1980) and, subsequently, in the evaluation of the benefit to humans obtained from natural resources (1980-2000). The use of this approach is supported by the urgency of recognizing the close relationship between ecosystem health and human health (Cerón Hernández et al., 2019).

3. Results and Discussion

3.1. General description of Cochapata

3.1.1. Location of the high altitude ecosystem - study area

The Cochapata high altitude ecosystem is located in the western Andean mountain range of Ecuador, in the province of Imbabura, in the rural mountainous area of the Urcuquí canton. It belongs to the Chachimbiro micro-region, upper Huarmiyacu micro-watershed, includes the Pucará and Huanga hills, an area abundant in natural resources, it is part of the buffer zone of the Cotacachi- Cayapas Ecological Reserve (Ministerio del Ambiente, 2014).

The study area covered the páramo between Huanguillaro, Taruga potrero to Los Corrales páramo at 4,050 m asl. Peasant farmers live in the Cochapata sub-páramo, at 3,700 m asl, and the Azaya and Ajumbuela communities are located in the intermediate zone, at 2,900 m (Figure 2).

For the research, the ecosystem was defined as a high micro watershed cut. Agroecological zoning was carried out based on altitude, landscape reading and land use: Zone A: corresponding to the paramo, contains natural vegetation of pajonal, CELEC E.P. infrastructure (Ministerio de Energía y Minas, 2019), and pine monoculture implanted by logging industries and the Añaburo ranch. Zone B: sub-paramo, contains high altitude crops and pastures managed by Cochapata's peasant settlers, pine and eucalyptus monocultures. Zone C:

the arid zones of the Azaya and Ajumbuela communes, non-irrigated crops, basic grains and small orchards (Figure 3).

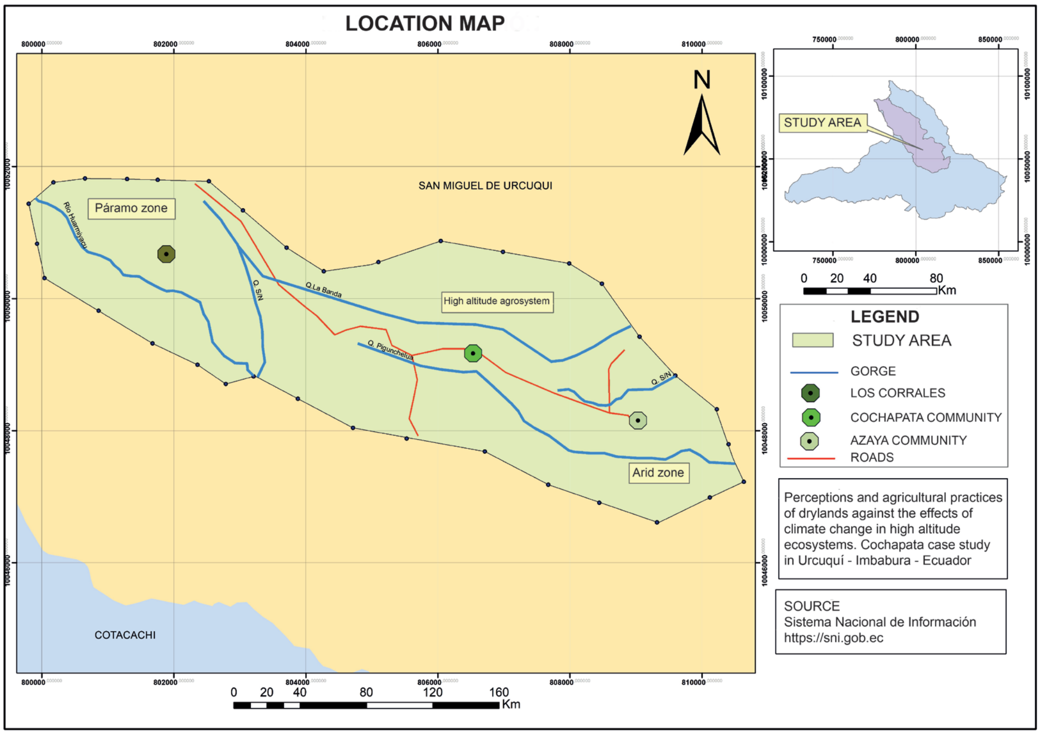

Figure 2. Location of the study area (Modified from National Information System).

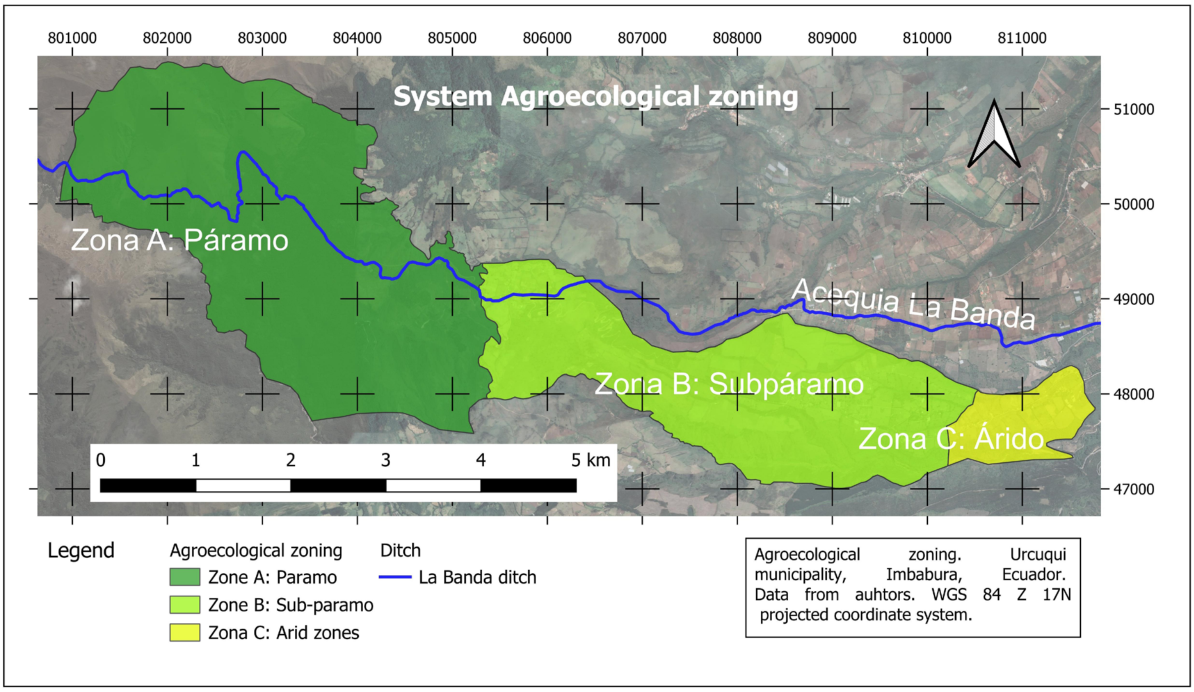

Figure 3. Agroecological zoning of the system.

3.1.2. Brief history of the Cochapata high altitude ecosystem

With the information collected, a concise representation of the transformations of the ecosystem was elaborated. It describes the period, the main characteristics of the ecosystem, the production technologies and the socio-political characteristics. This table includes external levels of the system, i.e., the situation of the environment and the national institutional framework (Table 1).

Table 1. History of Cochapata.

Períod	Local ecosystem	Local socio-political characteristics	Technology, crops, local breeding
Pre-Hispanic	Abundant native forest, abundant rainfall.	Crop exchange between different ecological levels.	Biological agriculture, deer hunting for food.
Spanish invasion (1570-1820)	Co-opted pre-Inca irrigation canals, large estates produce cereals and sheep extensively.	Strong hacienda system, models of exploitation of native peoples: mitas, concertaje.	Changes in crop patterns, introduction of species (sugar cane, beans, cattle, sheep), high level of tillage - use of yuntas.
Liberal revolution (1830-1960)	Hacienda Añaburo in the name of José María Pérez y Calixto.	Peasant movement seeks land for those who work it: smallholdings.	Extensive wheat and barley plains and extensive cattle and sheep farming.
Agrarian development law: latifundismo (1960-1990)	Implementation of machinery and agrochemicals.	Land grabbing is reaffirmed. Water as a national asset, delivery of water concessions.	Formation of peasant orchards in the huasipungos (potatoes, ocas, mellocos).
Neoliberalism: Plutocracy (1990-2000)	Añaburo is sold to Gloria Mesías. Implementation of timber industry in the páramo and subpáramo.	Allocation of water sources to agribusiness.	Logging industries are outsourced (no jobs are offered to locals).
Extractivist capitalism: global war for commodities (2007-2022)	Implantation of camps (geothermal and timber) in the Cochapata páramo, handing over of rural territories to mining transnationals.	Technocracy Clientelism Concession of rural territories to extractivism; large-scale transnational mining.	Decrease in stream flow, Climate variability, Increase in crop pests.

3.1.3. Biophysical factors

The study area has several climates, a humid cold climate towards the central zone (3,400 m a.s.l.) and the cold Andean paramo climate in the highlands at 4,100 m a.s.l. The temperature varies between 0 °C and 18 °C, depending on the altitude. Rainfall is from November to May; the dry season is from June to October. The main rivers in the lower basin are the Palacara, Huarmiyacu, and Tababara. There are deep streams such as the Chachimbiro, Turucucho, Pijumbí and Azufral and ditches Pisangacho, Mindaburlo (López Males & Zura Quilumbango, 2013, p. 104). In the upper basin are the Nambal slopes, Nambal and Chimborazo irrigation ditches (which form the La Banda irrigation ditch) and the Huarmicocha irrigation ditch. Soils are black, shallow, silty (2-3% organic matter), with a moisture retention capacity of 10 to 20 %, pH 7 to 7.5. Slopes greater than 70 % in 48.83 % (mountainous slope) not suitable for agriculture (GADP San Blas, 2015). The level of erosion caused by productive activities reaches 67%. According to Mafla Pantoja (2015), the potential land use in the Huarmiyacu micro-watershed is as follows: class IV, determined by land with severe limitations (3.06%); class V, with arable land with intensive management methods (10.54%); Class VI, with non-arable land, with severe moisture limitations, suitable for pasture and non-arable land, suitable for forestry purposes (86 %); and Class VIII, suitable for wildlife conservation (Table 2).

There are 3,400 species of vascular plants and 1,300 species of non-vascular plants in the paramo, distributed in 127 families and 540 genera, of which 14 are endemic to the northern Andes. In general, paramo and subparamo have suffered great landscape transformation (deforestation of the Andean forest zone), and the transition zone between forest and paramo in Ecuador is quite affected (Luteyn, 1999).

3.1.4. Social context

Cochapata is a human settlement made up of 27 families from the highlands, formerly the large Coñaquí hacienda. According to the political administration of Urcuquí, the commune is not categorized within the parish council. The population is organized under a political-administrative model of Community Committee, registered with the Ministry of Social and Economic Inclusion since 2007, complying with regular contributions, but without development projects. The committee's board of directors is renewed every year at the assembly, and is in charge of managing water for human consumption and other issues related to the population's future. According to the local census, 85 people currently live in Cochapata. The census indicates that in 2014 there were 150 inhabitants living in the area. Families migrating from the highlands settle in the communes of zone C (Azaya and El Tablón), areas which have transportation to educational centers.

Table 2. Land use and vegetation cover, Huarmiyacu micro-watershed.

Land use and vegetation cover - micro-watershed	Current land use	Surface área	
		(ha)	(%)
1	Native forest	543.04	35.73
2	Annual crop	361.18	2.05
3	Paramo	915.43	60.23
4	Pasture	18.22	1.20
5	Shrub vegetation	16.05	1.06
Total		**1.519.95**	**100.00**

Source: Mafla Pantoja (2015).

The occupation of Cochapata's paramo by timber extractivism is evident. Photographs of the Pucará paramo in 1980 and 2022 show the transformation of the ecosystem (Figure 4).

Figure 4. Change in land use, "Los Corrales" paramo.

3.1.4. Social context

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3.1.5. Agricultural context

Around 1964, in the context of the agrarian reform, the Huasipungueros of Cochapata obtained plots of 0.3 to 1.8 ha. Since then, they have been cultivating the land mainly for subsistence. However, limited access to land means that the plots have been divided into 500-2,000 m plots. Even so, 12% of the farmers lease plots in distant areas, or plant under the "*al partir*" modality, dividing the profits with the landowner. The new families, children and grandchildren of the huasipungueros, have reached agreements to cultivate small plots (1,000-2,000 m) in the highlands, even though they have migrated to the middle zone where they also cultivate. In this way, they guarantee family's food supply with products from both zones, maintaining the model of micro-verticality of cultivation. Twenty percent of those interviewed indicated that they need to rent land to graze their cattle, especially during the summer season. They indicated that the rental price per block fluctuates between US$15 and US$30 per month, depending on the quality of the pasture. Other landowners within the study area are: landowners with between 10 and 50 ha for extensive cattle ranching and tourism, Hacienda Añaburo with 5,000 ha, a logging company with 755.80 ha, and CELEC E.P., with the Chachimbiro geothermal project that occupies 400 ha. A summary of the information gathered is shown in Table 3.

Table 3. Access to land - Cochapata.

Land size (ha)	Owners
0,5 - 2,5	39
2,5 - 5	5
10 - 50	4
100 - 1.000	2
1.001 - 5.000	1

Agriculture in Cochapata is artisanal, survivalist. The traditional crops are potato (*Solanum tuberosum*), oca (*Oxalis tuberosum*), melloco (*Ullucus tuberosus*), fava bean (*Vicia faba*), Chocho (*Lupinus mutabilis*). Potato cultivation is predominantly of the violet, chola, capira, and única varieties. The land is prepared manually, even the use of oxen is restricted, due to the economic availability and the small size of the plots. The seed is the reserve of each family, but, according to the interviews, in recent years a plague has killed the native seed (Figure 5).

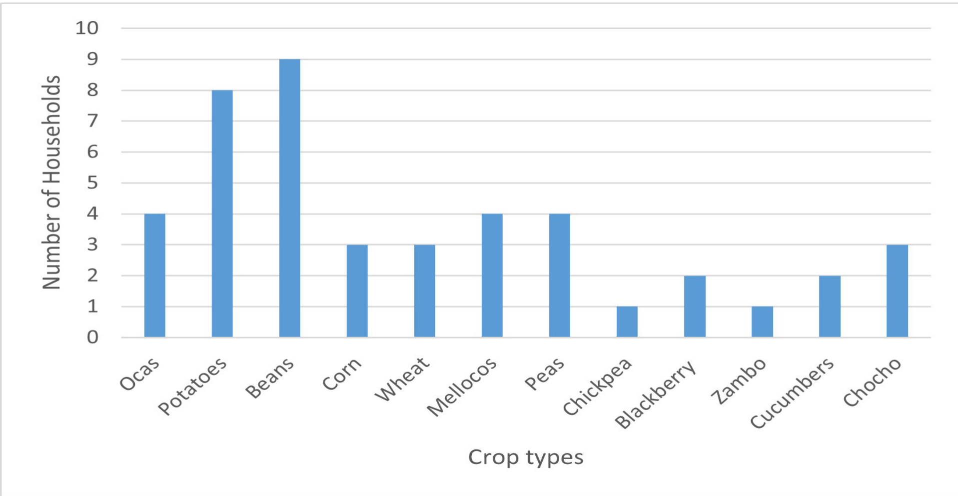

Figure 5. Crop representation, last 10 years.

They try to maximize the use of land space with polycultures and associations between potatoes, beans and vegetables (functional diversity). Another practice is crop rotation, transforming unproductive pasture into plots for planting potatoes, either manually or with a yoke. Pastures are renewed after 5-10 years.

Another aspect that was observed is the emergence of new non-traditional crops in the area: blackberry (*Rubus ulmifolius*), cucumber (*Cucumis sativus*) and uvilla (*Physalis peruviana*). The reasons for this, according to the interviews, are: low potato productivity, low prices, increased pests, lack of rainfall, and excessive heat from the sun.

Potato planting begins in June, when the soil has adequate moisture for germination, and staggered planting is done to increase the availability of food for the family. The planting calendar is different from that of the arid zone where the planting season begins in October, a month with abundant rainfall.

Cattle ranching in Cochapata is *Criollo*, with small herds depending on the availability of pasture for each family (four cattle on average). Based on field observation, (it can be said that) this is the main economic investment in land use. In the past, they choose to raise cattle instead of sheep because of the high mortality of sheep due to parasitosis. Another modality for cattle ranching in the past was the communal use of the Paramo (located 4 km away) together with farmers from neighboring areas (Cahuasquí and Pablo Arenas). However, this component has been forgotten.

The small farmers' cattle are raised and fattened for sale to middlemen, who come to the Comuna to buy the merchandise and move it to the fair. The little milk production (due to poor pastures and the practice of leaving the calves to late weaning) is intended for family consumption and cheese production; few families commercialize cheese at the cost of sacrificing their own consumption. Other backyard livestock are: guinea pigs, poultry and pigs. Horses (mules, mares and donkeys) are important for farming, pack and mobility.

As to the problems in bovine breeding, the interviewees pointed out to the increase in diseases. In 2015, bovine vesicular stomatitis affected livestock in the region; they indicated that in the Azaya commune mortality was high, but not in the cold zone, because they acquired antibiotics and topical disinfectants in a timely manner (Helena V., interview 7). In 2021, interviewees reported increased mortality in neonatal calves with symptoms of pneumonia. Another community member (Rigo Ch., interview 11) reported that, in recent years, infectious diseases caused by ticks (*A. ixodidae*) have also become more virulent in the highlands, as well as recurrent cases of diarrhea due to stagnating water, since water flows are now scarce to the point of flooding.

The interviewees state that they have never received technical assistance in agricultural production. Preventive practices for infectious diseases, such as anthrax, are carried out through agreements with local ranchers who organize sporadic vaccination campaigns, but these are not constant. Thus, producers must deal with the incidence of new livestock diseases, which implies an increase in expenses.

3.1.6. Economic context

Cochapata's families base their economy on agricultural production, subsistence livestock and the sale of labor as day workers in nearby areas, and migrating temporarily to other regions, by relying on friends or relatives to guide them in their search for job openings. Survival agriculture and livestock breeding are integrated activities, that imply permanent dedication on the part of the family, and represent a way of life for local farmers (Figure 6).

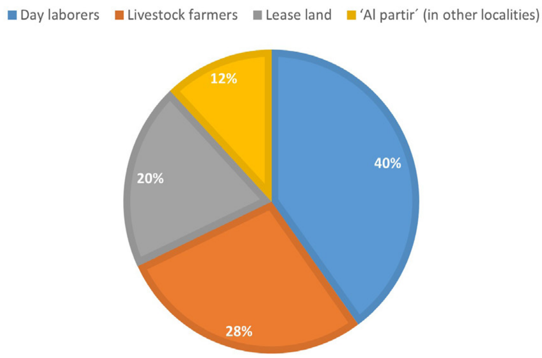

Figure 6. Economic means.

Cochapata's inhabitants maintain kinship, mobility, exchange, housing, production and labor relations with the populations of the middle zone: Azaya, Ajumbuela, Pisangacho, and El Tablón. The socioeconomic characteristics of these communities are similar; however, a difference can be found in the pattern of cultivation of sandy soils, and high water deficit of the latter.

Another existing 'exchange relationship' between families in the middle altitude zone and those in the high altitude zone is based on the harvesting of products adapted to different soils. In the middle zone they produce grains, with corn being the product of greatest interest. In the past women bartered for geese and maize, nowadays they buy and sell. During fieldwork, observed that some of the Azaya farmers take their crops to the highlands to store them in small huts, thus prolonging the conservation of the corn due to low temperatures.

The men, from a very young age, sell their labor. In the big cities they are employed as masons' helpers with an average income of $100.00 per week; while on the haciendas, they are paid $60.00 on average. During the Choclo harvest season, the region's middlemen hire young farmers as stevedores, who work up to 18 hours a day for a weekly wage of $100 per week. When in distant cities, in order to save money for the household, they restrict their food and lodging expenses, sharing and enduring precariousness. The income deriving from the sale of labor force is occasional, so an average of $1,924.00 per year is estimated.

For the study of the economic aspect, the following annual income was added: the solidarity bonus of $70.00 (always in the woman's name), the man's income as a day laborer in the low area $240.00, the sale of fattened cattle $70.00 (one head of cattle per year), while the small sales of annual harvests are not significant in the monetary income. It was estimated that the family (with one member as a day laborer) was able to obtain a monthly income of $385.00. This income is related to the cost of the basic family's budget [CBF - Canasta Basica Familiar in spanish], which -for the year 2021- was $716.14. This income is transformed in in-kind: purchase of basic grains from producers on other floors, or those that the family did not grow during the season, purchase of livestock for the new fattening cycle, seed, fertilizers, pack animals, tools. Figure 7 shows a schematic of the above.

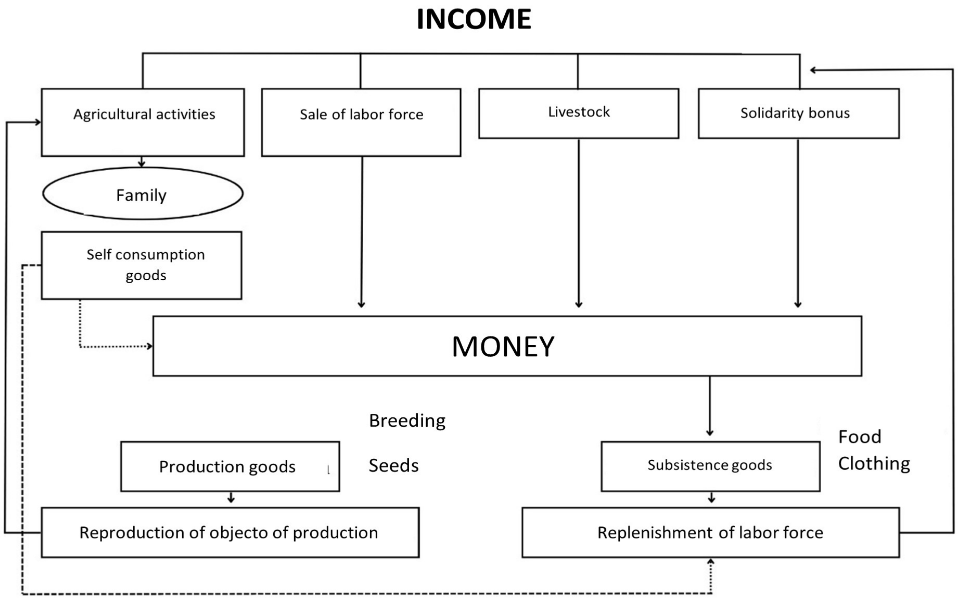

Figure 7. Survival economy.

3.1.7. Hydrological structure in the ecosystem

The study of matter, energy and water flows corresponds to the study of ecosystems. Since the paramo fulfills the function of collecting, preserving and supplying water to the region, its availability, distribution and demand are described below. The report reflects the use of water that originates in the upper basin, and is distributed in the towns of Cochapata, Azaya, Ajumbuela, Chachimbiro, Tumbabiro, and San Francisco.

The SENAGUA report shows that 84 % of the water is used for irrigation, 8 % for the tourism industry, and 0.51 % for food sovereignty. The report quantifies 57 authorizations, 15 of which (26 %) ranging between 10 to 50 l s^{-1}, and 42 (74 %) between 0.04 to 9 l s^{-1} (Table 4).

Table 4. Water distribution originating in the ecosystem.

Water use	Liters/second	%
Irrigation	319.17	84.21
Thermal water	32.69	8.63
Household	12.16	3.21
Tourísm	13.05	3.44
Food Sovereignty	1.93	0.51
	379	100.00

Source: Ministerio del Ambiente, Agua y Transición Ecológica. (2022).

3.2. Perceptions of climate change

Villagers stated that changes in the climate have been evident in recent years. Most of them mentioned that, in the area, the climate tends to be hot and this causes the soil to lose moisture very quickly. The inhabitants of the middle zone indicated that they will be forced to abandon the fields for good, and look for livelihoods alternatives in the cities.

The effects of climate change perceived by producers in both the highlands (B), and the arid zone (C) coincide as to the increase in temperature, and the uncertainty concerning the arrival of rainfalls. As to the effect of the changes observed in crops they indicate that the increase of pests and diseases is notorious: cattle fly (*Haematobia irritans*), tick infections (*Acari ixodidae*), potato pests (which increased drastically since 2018). Anothwer frequent answer emerging from our interviews regards the little moisture that soil can conserve, resulting in impoverished grass and water stress in crops.

3.3. Perceptions on water distribution

Perceptions were also gathered from local stakeholders on the distribution of water from the Paramo, water conflicts, irrigation needs, interest in rain harvesting practices, and changes related to climate change. It was found that local people posess a deep knowledge of, and attribute important value to their environment: springs, streams, rivers, irrigation ditches, histories, injustices, conflicts, appropriation, uses and qualities of the springs.

Most answers concerned the inequity in water distribution on the part of state agency, favoring the haciendas, logging companies and the geothermal project. The old landowners practice of co-opting one community member as a guardian of the irrigation ditches, in order to instill fear against a potential informal use of water by community members, was also reported. This employee, indoctrinated to "guard" the water in favor of the landowner, thus becomes within the commune a sort of 'policeman" of the hacienda. Another diffuse practice of local large landowners is to easily obtain authorization to take water from the springs and pipe it to the haciendas, thus disturbing the ecology of the landscape and the uses that other actors can give to the springs (watering places).

Regarding water conflicts, during this research it was possible to observe the loss of the Nambal watershed, through bureaucratic practices that mistreat the peasants by ignoring the processes that (peasant) communities propose to the water agency.

As to the perceptions of irrigation and watering rights for subsistence agriculture, twelve people responded that they did not know that they had rights; that, they considered that only landowners have a right to water. Five farmers refrained from answering.

On the benefits of rain harvesting methods, the response of twelve community members was positive, they reasoned about the implications of the rainfall capturing infrastructure, and about the material for pond manufacturing. The three arguments against this technology were based on the rainy climate in the high altitude zone, emphasizing that this is not the case for the lowlands, where dry seasons are prolonged, and agriculture is affected.

Finally, we gathered perceptions on the need for irrigation. Thirteen community members responded positively as to the need for irrigation water, which would increase the productivity of both pastures and crops. Four interviewees indicated that seasonal agriculture is better for them.

3.4. Agricultural practices

Producers plan crop strategies based on the availability of resources, climatic conditions, local knowledge and technologies, and the destination of the harvest. Producers in the highlands use the crops for family consumption, and very little for sale in the surrounding area (neighbors and family buy the few surplus harvests), also the classification of the potatoes harvested is different from that required by the market. Farmers in the arid areas try to obtain uniform and good-sized products (peppers) for wholesale markets by using more pesticides, despite this, yields are low because the soil is sandy, with little organic matter, eroded by runoff and scarce rainfall.

Table 5 summarizes the main agricultural practices currently used by the inhabitants of the cold zone.

Next, we elaborated a scheme that summarizes the transformation of practices that informants over 60 years of age in the upper zone recall and explain, and the motivation that promotes change (Table 6).

Table 5. Agricultural practices in Cochapata - highland zone.

Identify adequate soil moisture to achieve high germination.
Knowing the suitability of the soil and crops adapted to biophysical conditions
Test new crops (market oriented: grape, cucumber, blackberry)
Polycultures, association and crop rotation (functional diversity).
Dividing the farm into small plots (food for a longer period of time).
Manual tillage and in few occasions with animal traction.
Make sangraderas (drainages)
Low use of pesticides (due to their high cost).
Ensure food availability from crops (potatoes, beans, wheat).
Maintain the tradition of "prestamanos".
Use guinea pig manure for backyard gardens (vegetables).

Table 6. Transformation of agricultural practices - highland zone.

Prior	Current	Motivation
Crops adapted to the climate	New crops	Pricing and marketing
Production without pesticides	Use of pesticides	Many pests appear
Conservation of traditional seeds	Seed purchase/conservation with pesticides	Pests appear
Estimation of the rainy season using ancestral knowledge	Rainy season cannot be predicted	
Consumption, barter and sale of harvests	Crop consumption	
Mingas and "prestamanos" for agriculture	"Prestamanos".	Functional ancestral practice and human relationship
Clearing and burning for crops (trocha)	There are no more spaces to make agricultural land	They know the benefits of controlled burning
Farms with extensive wheat and beef cattle cultivation	Pine and eucalyptus monocultures, companies and megaprojects, burning of páramo for pine plantation	Extractivist capitalism, technocracy, no regulation
Availability of water in irrigation ditches for drinking water	Cement pond that stores the leftover water for watering	Shortage of water in irrigation ditches, livestock fall sick
Fewer crop pests	Purchase synthetic fertilizers and pesticides	Pests increase every year
Fewer animal diseases (treatments with native plants)	Purchase antibiotics, mineral supplements	New livestock diseases

The informants in the arid zone have different agricultural practices due to different climatic conditions, but with similar socioeconomic conditions, which are summarized in Table 7.

Table 7. Rainfed agricultural practices - arid zone (C).

Waiting for the rains to prepare the land
Bean, lentil, chickpea, maize, bell pepper and fruit orchards for wholesale markets
Little functional diversity
Hillside terrain without runoff containment
Use of agrochemicals (herbicides, insecticides)
Tillage with heavy machinery
Heirs sell land at low prices (lack of irrigation makes land cheaper)

Similarly, past practices, current practices, and motivation to transform these practices were summarized (Table 8).

Table 8. Transformation of practices arid zone (C)

Prior	Current	Motivation
Seasonal crops (beans, lentils, chickpeas, corn)	Emigration, sale of land	Low yields, eroded soils, high cost of inputs
Production without pesticides	Dependence on pesticides	They have proven that the soil does not produce without pesticides.
Less crop pests	Pests increase every year	Buying insecticides and other pesticides
Community seed conservation	Purchase of seeds according to market demand	Older adults have no other life options
Rainy season changes and shortages	Request access to irrigation from SENAGUA	They know that there is unused water, water stress in crops, example of other communes
Barter and sale	Selling in wholesale markets	They hope to get a good price for their harvest.
Mingas and “prestamanos” for agriculture	- Hiring labor forcé	The custom has been lost
Extensive wheat farms	- Farm and timber company grow eucalyptus	Unregulated extractivist capitalism

3.5. Shortage of water in the springs

In Cochapata, here emerged a perception coincidence in describing a decrease in the water flow of the irrigation ditches over the last few decades. The interviewees reported that the Nambal and Huarmiyaku springs are diminishing, such is the scarcity in the irrigation ditches that they have been forced to build ponds near the springs to capture and store the remaining water in order to water their livestock (Figure 8).

Figure 8. Pond used to find a solution of water shortage in the irrigation ditches.

When asked about the causes of this scarcity, the answers referred to the implementation of eucalyptus and pine plantations in the water recharge zone. The interviewees perceived the relationship between the state of maturity of the timber trees and the water supply in the springs (stages of pine renewal - increase in flow and vice versa). Additionally, we observed the existence of a small alder forest (Alnus acuminata) planted by a farmer near the watershed to attract water.

This section interprets the structure, function, disturbance, ecosystemic goods (soil and water), and functional diversity from the agroecological dimensions of the landscape and the structure (distribution) of water.

The object of study - Cochapata high altitude ecosystem - is conceived as a complex system made up of people and nature deeply intertwined and evolving. This, in turn, contains subsystems, whose flows produce interactions that result in socio-environmental alterations, different interests, power relations and conditions of vulnerability. The subsystems, environment, agro-productive (peasant and industrial) and hydrological, are related internally and with the environment (which was left outside the system). Thus, matter (biomass), energy (labor, inputs) and water flow in and out of the ecosystem, in favor of one or the other claimant.

This reflects that the populations studied do not constitute harmonious societies; on the contrary, we observe scenarios where the different actors assume different objectives and degrees of power, and in this environment they deploy their actions, shaping social systems in disequilibrium and transformation.

The interpretation of the structure, function and evaluation of the ecosystem shows how the extractive companies established in the paramo deployed a large infrastructure contingent, exploit ecosystem goods and services, cause environmental degradation, disrupt the paramo by planting 475 ha of forest species with high water demand, erode the soil, alter and divert water flows (local water privatization modes). As a result, peasant societies do not have access to sufficient land, irrigation or watering places, they hardly use the soil for food in conditions of survival and vulnerability to the effects of changing climates.

Additionally, the impact of the timber industry on water storage causes a decrease in the water flows which benefited small cattle ranchers in the Cochapata community. According to similar research, there is a relationship between the decrease in water flow and the timber industry. The extractive industry, established since 1980, at the same time, had the power to forge authorizations from the springs and drive the irrigation ditches to the farms, thus making the irrigation ditches disappear from the landscape, and leaving the farmers without watering places for their animals.

All of the above occurs in contexts of global warming that reflect rural societies previously made vulnerable by socioeconomic structures of inequity, with no possibility to face the adverse effects of the climate phenomenon (Figure 9).

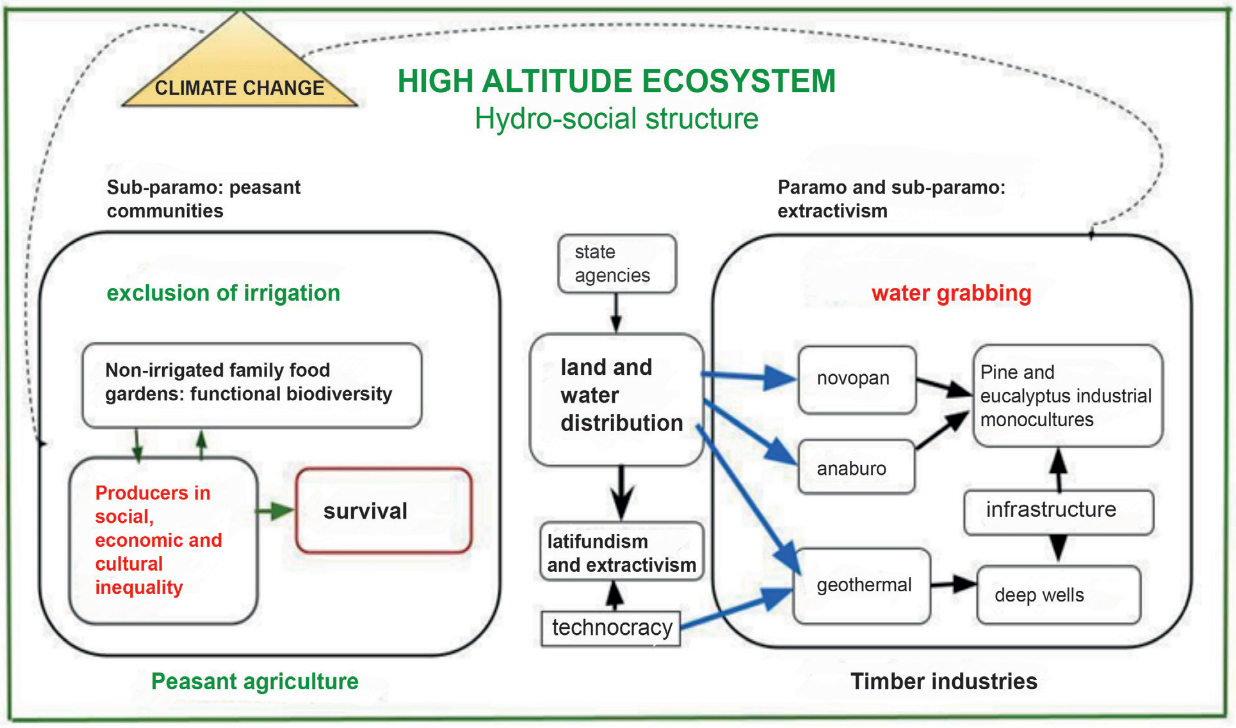

Figure 9. Water distribution in the Cochapata ecosystem.

4. Conclusions

The study of perceptions and practices in the face of the effects of climate change leaves some conclusions.

Studies at regional level show that the area has a heterogeneous climatology, with a change of trend in precipitation and temperature indexes, starting in the 1990s, Andrango (2018) concluded, with 95% confidence, that significant changes occurred in the behavior of temperature during the last two decades. Specifically, minimum temperature values are increasing from 0.6 to 12 ºC (Andrango Quisaguano, 2018). Accordingly, the villagers perceive the effects in their daily lives, but do not contextualize the phenomenon as such since other worries of their work as farmers predominate: perverse markets, unemployment, migration, low crop productivity, increase of pests. The increase of pests in crops and livestock was the generalized concern; however, the incidence of climate changes could not be related in a unidirectional way with the increase of pests, since agriculture and the health of individuals are complex multifactorial systems, non-linear and far from equilibrium. It is concluded that climate variability is present, being a factor that makes agricultural activities and the life of small farmers, in general, more complex.

Farmers' adaptation to climate change in Latin America and the Caribbean is limited by institutional practices and agricultural policies. This weak institutional capacity would cause dramatic impacts in the face of extreme climate events in terms of frequency, intensity and/or duration. A more active role of governments is required to remedy these conditions. Public policy has yet to face the challenge of integrating climate variability into its practices and policies (Conde-Alvarez & Saldaña-Zorrilla, 2007).

Thus, theories regarding the variables that affect small farmers' intention to adapt to climate change indicate that these are classified into three groups: socioeconomic, demographic and psychological. Within the socioeconomic variables, the following prevail in the intention to adapt: gender, age, formal education, agricultural experience, land ownership and material capital, form of land tenure, access to credit and land size. With these variables, Ladines Zambrano (2022) concluded that 68.5% of small farmers do not have the intention to adapt to climate change; his descriptive study suggests that the intention of small farmers to adapt to climate change increases with higher levels of schooling, greater agricultural experience, land ownership and access to credit. On the contrary, those who suffer from low availability of resources, and information about climate change find it difficult to take adaptive strategies.

Income from land exploitation is insufficient for subsistence, which forces small farmers to seek external income by selling their labor force. These characteristics place the peasantry as the object of multiple exploitation: in the price that the market imposes on their crops, in the price they must pay for the goods they acquire, and in the physical force they are obliged to deliver to the labor market. This subsystem is diluted in the national economic system as a whole (Ladines Zambrano, 2022).

As Mendoza Ospina (2017) points out, "The peasantry is constituted as the most relevant social actor of the rural reality and of the national economy, but at the same time, it is established as one of the main victims of the dispute over the distribution, tenure and use of land". This constitutes a social and political debt owed by the State to the rural sector, since the peasantry is one of the most vulnerable actors in terms of exclusion by the State, its institutions and society in general. State neglect is one of the main causes of their vulnerability (Mendoza Ospina, 2017); consequently, the peasantry is forced to seek capacities that allow them to survive in different contexts and situations.

Another conclusion arises from the fact that within the social system under study there is no access to communal land production for planting or grazing. The survival logic of the communities in the past was directed towards the communal organization of land for grazing and crops. At present, small landowners, retailers, restrict production to family subsistence (limiting market exchange of complementary goods). This reflects the fact that in the rural area studied there is a category of '' *landless* peasants, those who do not possess material elements of unification; therefore, they disintegrate both as members of the comunas - and as human beings - being forced to join other forms of survival in exchange for a salary, or simply to emigrate (Comisión Económica para América 'Latina [CEPAL], y Programa die las Naciones Unidas para el Medio Ambiente [PNUMA], 1983). This indicates that peasant communities are excluded from ecosystem goods, land and water, which are abundant in the ecosystem, but inequitably distributed since colonial times, thus concluding that the survival situation is caused mainly by redistributive injustice, which increases the risk of imminent climate change.

The study of the hydrological structure of the high altitude ecosystem found that the source of the La Banda irrigation ditch, located in the deep paramo, has abundant flow, but not the sources near the pine monocultures. It was also found that the extractive timber companies, the hacienda system, and the geothermal project are direct beneficiaries of the water ecosystem good. It was found that official agencies, local governments and other institutions allow water grabbing, excluding small farmers from water for irrigation and watering.

Therefore, it is concluded that the effects of climate change affect populations that have been excluded, whose previous vulnerability is high, due to these exclusionary socio-political structures.
Indeed, it was found that the sources of the middle basin (Nambal ditch, Guarmiyacu source) show scarcity. According to the perceptions and analysis of land use, and the processes of water grabbing by the large estates there is water scarcity in these springs. Villagers associate water scarcity with the period when the timber industry was established. Therefore, it is likely that the decrease of water in the springs is directly associated with the implementation of pine and eucalyptus monoculture plantations that were installed in the ecosystem from 1980 onwards, and which are advancing on intensive and extensive scales without any regulation whatsoever.

In addition, the same extractive companies divert the irrigation ditches to their private facilities, depriving the local inhabitants of their watering uses and customs, and altering the landscape. This provoked local conflict and an unequal dispute with the water agency. The ex-SENAGUA officials ignored and mistreated peasants for two years, after which the irrigation ditch was piped to the hacienda's facilities. This case demonstrated clientelism and technocracy as failures to recognize the peasantry as subjects with rights, reinforcing social inequality. To deny institutional support, to bow to the contradictions of neoliberal economic policy with an economistic vision is to strip and exclude the peasantry of its capacity as a social subject (Milán Pérez & Zúniga-Gonzalez, 2021).

Regarding land use, it was found that the paramo is occupied by timber industries with pine and cypress monocultures in the paramo and eucalyptus in the subparamo zone, and in the arid zones; these plantations are characterized by their high water demand. There is also the Chachimbiro-CELEC E.P. geothermal project, with great infrastructure in its location (camp, pond, water conduction, well drilling, roads, etc.) (Ministry of Energy and Mines, 2019). The sub-paramo is inhabited by the community of small landowners who use the land to provide for family sustenance based on their labor force. In the arid zone there are peasant communities that carry out marginal agriculture. The soil in this area is quite eroded by runoff.

Land use for the timber industry, implemented since 1980 by the large landowner haciendas and by the timber company during the last decade in the paramo ecosystem, is not regulated by state entities. This demonstrates the institutional weakness of the government, which systematically favors large landowners by allowing capitalist power to overlook environmental care in fragile ecosystems such as the paramo.

As to what concers the relationship between water supply and industrial forestry, the hydrological regulation of the paramo is provided by the soil and its high organic matter content. In humid paramo, organic carbon contents of more than 40% can be found; in younger moorlands, contents of between 2 and 10 % (3.5-10 kg m-2) are found, similar to those found in drier moorlands. Research reports that soils under pine plantations recorded reductions in water retention and soil organic carbon content. The upper and lower soil horizons under 25-year-old pine plantations had respectively 35 and 57 % less organic carbon than soils with grasslands. While soil moisture content for saturation moisture, field capacity and wilting point decreased by 14, 55 and 62 %, respectively. The saturation moisture is similar between grassland and pine cultivation, while there is a significant reduction in the soil under pine trees for field capacity and wilting point moisture. These data indicate a change in pore size distribution and, perhaps, a reduction in fine pores. The loss of soil organic matter may be the cause of the reduction in its water holding capacity (Llambí et al., 2012).

Pine plantations, while contributing to the accumulation of carbon in the trees, reduce the amount of carbon stored in the soil. The disturbance is in the transfer of carbon from the soil reservoir to the wood of the monoculture. Thus, the impact is negative when the plantation is harvested, since even the litter layer is usually burned before a new plantation is planted (Llambí et al., 2012).

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Contributor Roles

- Nancy Beatriz Saltos Fernández: conceptualization, investigation, methodology, resources.
- José Luis Flores De la Torre: validation, writing- review & editing.

Ethical Implications

The authors state that for the application of the structured interviews a consent of participation was obtained from the interviewees, following the concepts proposed in Retamal et al. (2011).

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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