SOIL, WATER, AND PEASANT FARMING IN THE IGUAQUE-MERCHÁN PÁRAMO: A STUDY OF CO-PRODUCTION, NOVELTIES AND SOCIO-TECHNICAL REGIMES

Master thesis

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Abstract:

Environmental conservation and agriculture are often framed as conflicting practices. In Páramo ecosystems in particular, peasant agriculture is frequently restricted, placing additional pressure on the livelihoods of local communities. A key challenge is to mitigate the ecological impacts of peasant farming without generating adverse conditions for these communities.

This study contributes to addressing this issue through exploratory analysis of how peasant farming practices influence and are influenced by soil and water aspects in the Iguaque-Merchán Páramo. A case study was conducted in the region of Iguaque-Merchán Páramo of Boyacá-Colombia, using surveys, semi-structured interviews, participant observation, and a literature review as data collection methods.

The findings indicate that the way in which farming tasks are performed distinguishes peasant agriculture from other types of farming. These distinctions are shaped by three socio-technical regimes identified in the research: Muisca, Colonial and Green Revolution socio-technical regimes. However, they are also influenced by novelty production and dissemination across peasants' farms. By examining these dynamics, the research contributes to understanding agriculture as a co-productive process in which society and nature are intertwined.

Dedication:

To my grandfather, Pepe Medina, my lifelong professor of agriculture, geography, and sociology. His stories and companionship gave life to this thesis.

Acknowledgements:

This thesis would not have been possible without the unconditional support of my family, Gladys, Jorge and Giorgio. I also owe sincere gratitude to my supervisor, Jannik Schultner, as well as to Jan Douwe van der Ploeg, Bibiana Duarte, and Bladimir Rodriguez, whose guidance was essential to this work. I am equally thankful to the people involved in the projects Riverhoods, Rivercommons, and Linking Páramos for the trust on this research. Last, but not least, I am profoundly thankful to Janhein, Tiny, Luz, Johan, Mario, Ángela, Duván and all the friends and peasant of El Convite Campesino who gave me strength to write and reflect on these topics.

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1. Introduction

The reconciliation between environmental conservation and agricultural production is not only a desire, but a necessity in today's world. While the agricultural sector contributes approximately one-third of the total global greenhouse gas emissions, food demand continues to rise (FAO, 2019; IPCC, 2022). This global challenge is reflected in the Colombian Andes, where both environmental conservation and food production depend on the páramo ecosystems and the peasant communities who inhabit them.

On the one hand, páramos ecosystem provides about 70% of Colombia's potable water supply and play a crucial role in sustaining agricultural water needs (Murad et al., 2024). On the other hand, peasants, which are the biggest social group living in páramos, produce approximately 80% of the food consumed by Colombian households (Colombian Ministry of Agriculture, 2016). Despite their individual importance, páramos conservation and peasant agriculture are often viewed as conflicting practices. Various studies, often framed within a biocentric approach, have documented the impacts of agriculture in and around Colombian páramos, with many recommending minimal or no agricultural intervention (Patiño et al, 2021; Estupiñán, et al., 2009; Cárdenas, 2016). These recommendations often carry the implication that peasant communities living in páramos zones should reduce, relocate or stop their farming activities (Osorio & Mazuera, 2024).

In contrast, perspectives from political ecology and critical agrarian studies emphasize peasants' historical contributions to environmental conservation (Martinez-Alier, 2013; Ploeg, 2023). From this perspective, it is understood that while some peasant practices may affect strategic ecosystems such as páramos, these impacts are closely linked to historical patterns of exclusion, including the displacement of communities from fertile valleys due to land concentration by large landowners (Osorio & Mazuera, 2024; Duarte-Abadía et al.,2021; Rincón & Sarmiento, 2002). Within this framework, the central challenge is to mitigate the ecological impacts of peasant farming without generating new forms of "nature enclosure" or "environmental dispossession" (Hoefle, 2020; Duarte-Abadía et al.,2021).

Building on this perspective, the present study addresses this challenge by analyzing how peasant farming practices influence and are influenced by the soil and water properties of the Iguaque-Merchán Páramo region. Specifically, it explores:

1. How do peasant farm labor processes influence and are influenced by soil and water properties of the Iguaque-Merchán Páramo region?
2. What is the influence of peasant farming socio technical regimes and novelties on soil and water properties in the Iguaque-Merchán Páramo region?
3. How do interactions and collaborations among peasant farms influence soil and water properties in the Iguaque-Merchán Páramo region?

Soil and water are at the center of this research as these two specific resources not only determine the productivity of crops and livestock but also play a crucial role in the water provisioning capacity of páramos ecosystems (details in section 3).

Regarding the first question, this study found that the way farm tasks are performed differentiates agricultural systems in how they interact with -and co-produce- soil and water dynamics. Conventional peasant farms rely on external inputs such as pesticides, which may threaten soil and water quality; agroecological peasant farms seek greater autonomy by understanding and reinforcing on-farm soil nutrients and water cycles; and the entrepreneurial farm, while dependent on external inputs, distinguishes itself from conventional farming by implementing techniques associated with more sustainable agricultural practices.

The rationale behind these distinctions lies in the socio-technical regime that shapes each farm, which connects to the second research question. Three main regimes were identified as influencing both peasant and entrepreneurial farming: the Muisca, Colonial and Green Revolution regimes, all rooted primarily in former Hacienda farming, but also in the learning processes developed during jornales on large agricultural farms outside the region (section 4 and 5).

Peasant farming, however, is not a passive recipient of these influences. Farmers actively adapt and combine elements from different regimes, creating novelties- new practices that respond to local conditions (see section 2 for definitions). Among the 256 tasks identified in this study, 20 were classified as novelties. Although limited in number, these practices were observed to be spread across the region through peasant social networks, underscoring the importance of interactions and collaborations among farms, which connects to the third sub-research question.

Understanding these interactions is key to explaining how farming practices evolve in the region. As shown in section 4.3, analyzing collaborations among peasant farms was essential to understanding how the Green Revolution regime spread in the past, and how novelties are shared today. Consequently, these interactions are also crucial for examining how socio-technical regimes and novelties influence soil and water dynamics in the region. The case of Association El Convite Campesino is presented as an example.

Each of these three sub-research questions relates to globally relevant debates. First, analyzing specific peasant tasks and their influence on soil and water in páramos informs discussions on whether environmental protection and food security can be reconciled in a context of global population growth (Fischer et al., 2017; Springmann et al., 2018; Wezel et al., 2013). Second, investigating socio-technical regimes and novelties contributes to analyses of grassroots, locally driven technical solutions for reconciling food production, peasants and environment (Rosset & Altieri, 2017; Rosset & Altieri, 1997). Finally, the third research question contributes to understanding how peasant social movements provide locally driven solutions to problems that are often addressed through top-down approaches (Rosset & Altieri, 2017; Ploeg, 2023).

To answer these questions, a case study with an explorative approach was conducted in the north-east part of the Iguaque Páramo region (figure 1 and appendix a), utilizing four data collection methods: surveys, semi-structured interviews, participant observation and literature review.

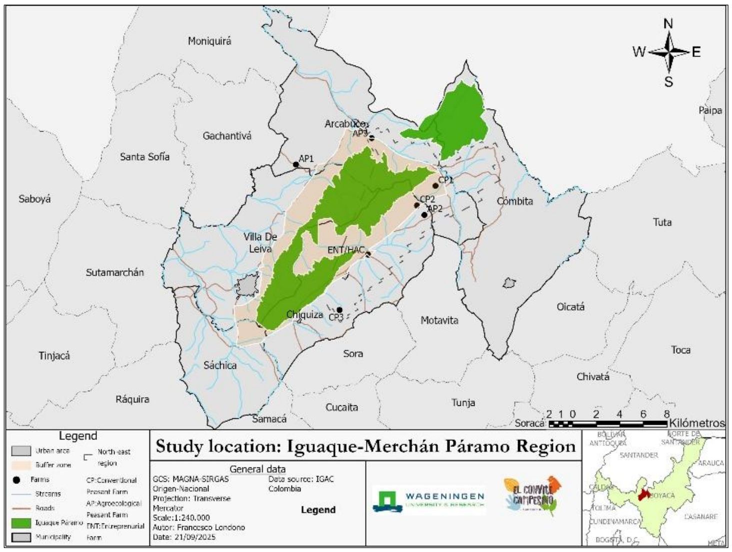

Figure 1. Map of Iguaque Merchán Páramo in the Boyacá, Colombia

The research was conducted with the support of the "El Convite Campesino Peasant Association", which is implementing the "Linking Páramos" project in collaboration with "SwissAid foundation" (section 3.2 and 4.3). This initiative is aiming to support agricultural transitions to a more environmentally sustainable systems in the Iguaque Merchán Páramo by promoting agroecology, gender equity and youth leadership in peasant communities.

This research contributes to these aims by providing insights into how peasant farming practices—whether agroecological or not—may influence and be influenced by the Iguaque-Merchán páramo ecosystem. It therefore contributes to informing decision-making and to answering the question of how this project could be a game changer in the region's environmental context.

Outline of the text

The thesis is structured into six sections. First section was already presented as an introduction. Section 2 presents the conceptual framework and defines the main analytical categories. Section 3 describes the methodology. Section 4 reports the results, followed by section 5 which discusses the main findings. Section 6 provides the conclusions and limitations of the research. Lastly, the thesis ends with the bibliography and appendix.

2. Conceptual framework

The aim of this section is to present the main concepts that form the basis of the study. It explains how each concept is defined and identifies the sub-concepts contained within them. Moreover, the framework provides an overview of how these concepts connect with one another, forming a structured theoretical interpretation of the collected data. First, the meaning of páramo is defined, along with how soil and water properties are understood in the context of the páramos. This is followed by an explanation of how peasant agriculture is conceptualized, as well as labor processes, novelties and interactions and collaborations between farms.

2.1 Páramo

There is no widely accepted interdisciplinary definition of what a páramo is. Nevertheless, a common aspect across most perspectives is that páramos are socio-ecosystems characterized by a shared dynamic of transition and co-configuration between human and non-human species (Osorio & Mazuera, 2024; Hofstede et al., 2003). These characteristics, however, are also widely debated. The first refers to a blurred boundary, since in most places there is no perpetual snow line, and the altitude of the páramos may not be a central defining aspect, as it varies according to other climatic and geophysical conditions. Similarly, the second is contested because humans are often not considered active agents in the production and reproduction of páramos ecosystems but rather as contributors to their disturbance (Osorio & Mazuera, 2024; Sarmiento, 2012; Rincón & Sarmiento,2002).

From an ecological perspective, páramos are grassland ecosystems located in the upper regions of the tropical Andes recognized for their capacity to store organic matter in the soil and retain water to create rivers (Cárdenas Agudelo, 2016). Their climatic conditions are characterized by low temperatures, high air moisture conditions, low evapotranspiration, and permanence of low clouds (Cárdenas Agudelo, 2016). These features determine a high runoff and leaching of soils (Cárdenas Agudelo, 2016). Ecologically, páramos are also divided into three altitudinal zones: the sub páramo, a transitional belt where the upper Andean forest transitions to shrubs and grasses; the proper páramo, dominated by shrubs, and frailejones; and the super páramo, the highest and coldest zone near the snow line, with sparse vegetation (Cabrera Pantoja, M. J., 2019).

From a socio-economic perspective, páramos have been used as a resource and instrument for agriculture and logging. Archeological evidence indicates anthropogenic influence in páramo vegetation boundaries since the Holocene, mainly in the last 11.500 years (Colinvaux et al 1997, Chepstow-Lusty &Johnson 2000, Horn 2001, Weng et al. 2006 cited in: Sarmiento, 2012). Even before the arrival of cattle, horses, donkeys, goats, sheep, and pigs during colonial times, herbivory roamers and grazers, such as tapir, bear, and deer, were held in Colombian páramos by Indigenous people (Sarmiento, 2012). Since then, páramos have been actively transformed with the inclusion of pasture species (*Panicetum clandestinum*)), potatoes (*R-12* and *pastusa*), and livestock (*Holstein* and *Normande*) on its landscapes (Hofstede et al., 2003).

Bridging these ecological and socio-economic perspectives is the concept of paramización, which complicates the definition of what is, and what is not, a páramo. This process occurs when abandoned agricultural or pasture lands that formerly deforested high Andean Forest acquire biotic characteristics of the páramo—even in areas not typically considered páramo by altitude (Rincón & Sarmiento, 2002). It begins with pioneer species such as Rumex acetosella, followed by small shrub formations dominated by Hypericum and grasses like Calamagrostis efusa (Mora-Osejo & Moreno, 1994). Over time, Frailejón (a unique plant species from páramo) establishes and eventually become dominant alongside taller shrubs, marking a process of plant succession (Mora-Osejo & Moreno, 1994) (Appendix b illustration 16).

As an example of how complex this can be, Laegaard (1992) suggested that most of the páramo surface area in Ecuador is a result of paramización processes. Similarly, during the participant observation conducted for this research, various paramización processes were found in between 2.900 masl and 3.100 masl in Chiquiza, Boyacá (Appendix b illustration 16). Moreover, it was found that, historically, indigenous, colonial and contemporary human settlements have been present in the area, transforming the high Andean forest and most likely leading to paramización processes, which makes it difficult to determine whether every location of what is today considered the Iguaque páramo were original páramo or the result of a paramización process (Bravo Monroy & Hammen, 2007).

Taking this to account, the adopted definition of páramo for this study was: A páramo is a high-altitude ecosystem of the tropical Andes that can be understood as (1) a variable altitudinal belt between the upper Andean forest and, where present, the snow line, subdivided into sub páramo, proper páramo, and super páramo; (2) an ecosystem characterized by unique vegetation such as frailejones and Calamagrostis efusa, low temperatures, and high moisture; and (3) an ecosystem shaped by biogeochemical cycles influenced by both non-human and human processes, including deforestation, agriculture, grazing, and paramización.

This aligns with Rincón & Sarmiento (2002) and Manosalvas et al. (2025) who argue that páramos cannot be classified solely by altitude but rather by their history of human occupation, making them complementary to the biogeographical perspective. While the biogeographical view emphasizes ecological and altitudinal traits, the anthropogenic perspective highlights the social construction of páramos. This is essential since processes as *paramización* can be highly influential in determining of where and what a páramo is. Therefore, classification requires attention to geo-historical scale: broad altitudinal belts offer general patterns, but local histories, conditions, and human interventions shape the specific boundaries and characteristics of each páramo.

2.2 Peasant farming and labor processes

2.2.1 Peasant

Defining what a peasant is also varies a lot depending on the theoretical framework. For example, peasants are usually referred to as smallholder-farmers or small scale-farmers by modernist agrarian theories (Ploeg, 2023). However, this definition leads to a simplification of the complexity of the peasant subject into marketable objects of the farm such as the size of the land or the amount of the harvest (Ploeg, 2023). For this research, as with páramos, a definition was adopted without seeking to resolve the conceptual conflict.

Two steps were taken to define what a peasant is. First, both the surveys and interviews included a question asking participants whether they and their families self-identified as peasants. Of the 119 survey respondents, 107 did so. In the interviews, 6 out of 8 participants identified as peasants, excluding the person who managed the entrepreneurial farm and the páramos expert who was interviewed.

Second, during the interviews with self-identified peasants, participants were asked what being a peasant meant to them. Autonomy, hard work, and a close connection to nature within rural life emerged as central themes. The following answers illustrate this:

> *1: "Being a campesina means being the owner of your life. There are other ways of living, but it's not the same, because the countryside gives you life — through the air. The city, when the air is bad, it takes life from you. The countryside gives it to you." (interview conventional farm 2, may 2025).*
>
> *2: "it's the best representation of what it means to be hardworking. Waking up early, being creative, resourceful, solving problems. That capacity—this word is a bit of a cliché—resilience. I mean, if I lost ten million pesos, I'd be depressed for a month. My dad, the next day, says, "We have to pull those potatoes out and plant again, what else can we do?" (interview agroecological farm 2, May 2025)*
>
> *3: "The peasant is a diverse and multicultural social group that lives an autonomous way of life, being the owner of their time and their labor. They have the privilege of feeling fulfilled with their work, of having chosen it, of doing it with joy and for their family. I would like to say they are also the owners of the land, but that is the reality of only a few and the repeated dream of many." (interview agroecological farm 3, April 2025)*

The centrality of labor in the responses aligns closely with Ploeg's (2018, p. 46) observation that "the peasant condition (or being a peasant) flows into, and sustains, the peasant mode of farming." In other words, what a peasant is depends both on what they do and on how they do it. In this sense, Ploeg (2018, p.22) highlights the multi-dimensional reality of peasant agriculture, with the means of production, the labor force, and governance as its core dimensions. This perspective resonates with the interviewees' emphasis on how peasant labor is connected to nature, and on the importance of autonomy as a form of governance.

2.2.2 Peasant farming

Building on this, Ploeg (2023) distinguishes between at least three modes of farming: peasant, capitalist, and entrepreneurial farming. Peasant farming in Ploeg's (2023) view produces wholly or partially for the market but relies minimally on external inputs, with labor, seeds, animals, and tools provided on the farm itself to maintain autonomy. In contrast, capitalist farming produces entirely for the market, relying fully on marketed labor, seeds, animals, and infrastructure to maximize profits. Entrepreneurial farming, on the other hand, depends on externally supplied resources and technologies, creating a dependency on external entities (e.g., financial, governmental, NGOs) that shape farm practices to fix a market-driven approach (Ploeg, 2023. Pg. 29-30).

Ploeg (2023) also suggest that these three modes of farming may be understood in terms of their relationship to labor and nature. Capitalist farming typically seeks complete control over both nature and labor to ensure integration into broader markets. Entrepreneurial farming usually relies on family labor and nature but is significantly shaped by external agencies (e.g., governments and NGOs). Peasant farming, by contrast, emphasizes on autonomy from broader markets and prioritizes care for both nature and labor (Ploeg, 2023, pg. 29-30).

2.2.1.1 Farm labor processes: tasks, labor force, objects of labor, and instruments

These three categories were used to differentiate between peasant and non-peasant farm labor processes. To identify which type of farming was pursued on each farm, labor processes were analyzed. Following Ploeg (2023), this analysis focuses on farming tasks, understood as the coordination between the labor force, the object of labor and the instruments.

During data collection, two different labor processes were identified: productive and reproductive. On the one hand, productive labor refers to tasks that transform objects of labor for either to be sold or reused on the farm (Ploeg, 2023). Reproductive labor, on the other hand, refers to tasks carried out exclusively to produce elements for internal use on the farm, with the purpose of maintaining daily life and enabling the continuation of productive labor (Ploeg, 2023).

The labor force, as defined by Ploeg (2023, p.39), refers to the humans who carry out the task (or subject of labor). Three sub-categories were distinguished: family, association and external. Family refers to individuals with kinship relations living on the same farm. Association includes extended family members living on other farms, as well as neighbors or peers from associations. External refers to both paid and unpaid hired labor.

The object of labor, in Ploeg's terms, refers to elements of living nature (crops, soil, animals, water, seed) that are both reproduced and transformed into useful products or services that contain value (Ploeg, 2023, p.39). No subcategories were established, as each analyzed task involved a unique object of labor. However, patterns were identified and will be presented in the results section.

Finally, instruments, as described by Ploeg (2023, p.39), are the objects that facilitate the conversion of nature into useful products and improve the labor process, sometimes making it less demanding. Multiple instruments were identified, and no subcategories were created since each analyzed task required its own specific instrument. Nevertheless, because instruments may be either built internally on the farm or obtained externally, instrument provisioning was added as a category. This distinction is important, as it may reveal aspects about the degree of autonomy of the farms in relation to their dependence on externally supplied and standardized tools.

2.3 Socio-technical regime, novelties, and niches

This aspect also reveals another dimension in which capitalist, entrepreneurial and peasant farming differ, and through which further distinctions can be made within these broad groups: the socio-technical dimension. The on-going development of tasks requires certain knowledge, procedures, and tools to transform the object of labor. That process is influenced by the so called, socio-technical regime, which is defined as "the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Kemp et al., 1998, p. 182). It is referred to as a regime because it is characterized by rules, procedures, and standardized mechanisms (Kemp et al., 1998).

In the Iguaque páramo region, three socio-technical regimes were found to influence peasant farming. First, the Muisca indigenous regime, represented by ancient techniques such as no-tillage farming practices and the cultivation of Andean tubers (Langebaek, 2019; Herrera Ángel, 2007). Second, the Spanish colonial regime, expressed through the use of hoes and/or livestock raising (Colmenares, 1998; Mörner, 1973). Finally, the modernist Green Revolution regime, reflected in the adoption of tractors and agrochemicals (Mazoyer & Roudart, 2006). Further development of this will be done in results section 4.2.

Based on the influence of these socio-technical regimes, two types of peasant farming were identified. The first is conventional peasant farming, which still employs procedures and instruments derived from the Muisca and colonial regimes but is strongly influenced by the Green Revolution regime. The second is agroecological peasant farming, which reintroduces techniques and objects of labor from the Muisca regime, combines them with procedures form the colonial regime, and incorporates selective instruments-mostly for soil disturbance-from the Green Revolution regime.

As no capitalist farming was found in the region, only entrepreneurial framing was analyzed. Entrepreneurial farming was found to be aligned most closely with the Green Revolution socio-technical regime but also shows the influence of a potential fourth socio-technical regime, which may be called the sustainability regime (Geels,2019).

2.3.1 Novelties

Socio-technical regimes create routines and specific farming methods that become established as rules. However, what Wiskerke and Ploeg (2004) call seeds of transition or novelties were also present. Novelties are modifications of, or breaks with, existing routines that are expected to improve the outcomes of farming tasks or labor processes (Kemp et al.,1998). They differ from innovations, as novelties arise directly from farm labor and local knowledge, whereas innovations usually represent exogenous developments linked to complex scientific procedures tested and developed in institutions outside the farm (Ploeg, 2023, p. 49).

Novelties may arise wherever a farming task is being developed, however, they need time and willingness to risk and fail in the process of building and testing the novelty. Thereby, some farms- often called niches- are needed to facilitate their emergence. In Ploeg´s (2023) words, niches are "protected spaces where novelties can germinate and they are cared for, allowing them to unfold further and show their potential". Similarly, for Kemp et al., (1998, p186) niches are "protected spaces for the development and use of promising technologies by means of experimentation".

2.4 Interactions and collaborations

Furthermore, these niches have shared novelties, which have been adopted by other collaborating farms. This highlights another important aspect of novelties identified in the Iguaque páramo case study: a novelty only becomes such when it is shared with other farms. As will be discussed in Section 4.3 of the results, collaboration among farms is central to challenging existing socio-technical regimes, and no socio-technical transition can be achieved without a collective process running. Thus a novelty cannot be understood as a modification of the existing rule unless it has been shared and adopted beyond the originating farm.

By farms collaboration it is meant that farms depend on one another to carry out one or several tasks. Such collaboration involves reliance on another farm for labor, instruments, or outcomes linked to the transformation of an object of labor. Not every interaction between farms, however, is collaborative. A farm may remain independent while interacting with another when it has other means to meet its needs—such as external income that allows it to hire workers or invest in machinery. In those cases, interaction takes place to improve a task, but it does not constitute collaboration, since the farm is not dependent on the other to carry it out.

3. Methodology

3.1 Study design, sample, population, and study approach

The study adopted a case study design with an explorative approach, utilizing four data collection methods: surveys, semi-structured interviews, participant observation and literature review. The sampling frame consisted of all farms included in the "linking páramos" project and the target population of which conclusions are aimed to be drawn are peasant farms located near the north-east part of Iguaque Páramo. The sub research questions were assessed with a two-step approach as follows:

Table 1. Steps approach sub-research questions

Sub-research question	First step	Second step
How do peasant farm labor processes relate to soil and river properties in the Iguaque-Merchán Páramo complex?	(a) How are the labor processes conducted	(b) how do they relate to soil & river properties?
What is the influence of peasant farming socio-technical regimes and novelties on soil and river properties in the Iguaque-Merchán Páramo complex?	(a) Which are the socio-technical regimes and novelties	(b) how do they relate to soil & river properties?
How do interactions and collaborations between peasant farming practices influence soil and river properties in the Iguaque-Merchán Páramo complex?	(a) Which are the interactions and collaborations	(b) how do they relate to soil & river properties?

Every data collection method addressed both steps with a mixed qualitative and quantitative approach. Additionally, the collected data was analyzed in relation to previous studies on agricultural practices in páramo ecosystems, which helped to understand how these practices may influence soil and river properties within the ecosystem. Literature reviews also helped the assessment of novelties and interactions and collaborations between farms.

3.2 Research context

3.2.1 Geophysical context

The research was conducted in the northeastern part of the Iguaque-Merchán páramo region, in farms that were located in the alluvial parts of the mountains between 2.500 and 3.100 meter above the sea level -masl- within or nearby the buffer zone of the protected area Flora and Fauna Iguaque páramo Sanctuary in the municipalities of Arcabuco, Chíquiza, and Cómbita in the province of Boyacá-Colombia (figure 1 or appendix A illustration 1).

The region's climate is shaped by tropical weather patterns, where annual variation in rainfall is more significant than variation in temperature (Osborne, 2012). Additional influences include, the "flying rives" -airborne moisture systems that move from east to west originating in the amazon and Orinoquía forests- and local condensation processes associated with lakes and rivers in the region (Londono & Rubio, 2025). In addition, during certain seasons evaporation from the Magdalena River pushes humidity into areas like Arcabuco, and parts of Villa de Leyva, producing a cloud wedge, known as the "Merchán wedge"(Londono & Rubio, 2025).

These environmental processes create a bimodal rainfall pattern, with rainy seasons from March to May (135-240 mm per month) and from September to November (150-327 mm per month). Dry seasons occur from December to February (77-122 mm per month) and from June to August (85-127 mm per month) (Villarreal et al., 2017). Temperatures are generally low with an annual average between 5°C and 15°C and marked variations between daytime and nighttime values. The region is classified as a humid cold climate (Villarreal et al., 2017).

The soils in this region have developed from alluvial sediments and are deep (more than 70 cm), well-drained, clay and clay loam soils, having medium to low organic matter content, low levels of exchangeable bases and phosphorus, and a very acidic pH (<4.6) (Villarreal et al., 2017).

Taken together, the soil and water characteristics of this region create soils with good water retention capacity under undisturbed conditions, strongly influenced by the Iguaque Massif, a folded mountain range of the Eastern Andes Cordillera uplifted by the interaction of the Nazca and South American plates and later shaped by folding and glacial erosion (Villarreal et al., 2017). The Massif plays a vital hydrological role, as the direction and dip of its structural sandstone allows water to infiltrate at higher elevations, move through the sub-surface, and resurface as runoff at lower points (Londono & Rubio, 2025). This process sustains numerous streams such as Chaina, San Pedro, and La Hondura, which provide water for many of the peasants in the area (Londono & Rubio, 2025).

3.2.2 Social context

In terms of the social setting, peasant farms in the Iguaque-Merchán páramo region were generally small-scale, averaging 2.5 hectares per farm, with a high prevalence of untitled property and limited access to basic public services such as health centers, wastewater disposal, garbage collection, internet, mobile networks, and proper roads (Villarreal et al., 2017). Regarding the surveys, electricity was available on all farms surveyed and interviewed, while drinking water was mainly supplied by municipal and community aqueducts. Basic educational centers were present in the surroundings areas, however, since no transportation was provided, children had to walk long distances to attend. Secondary and higher education services were provided in nearby urban centers, with the closest capital city, Tunja, approximately one hour by car (Villarreal et al., 2017).

Household income in peasants' families surveyed was primarily derived from the agricultural sector, including the production, processing, and commercialization of food (Villarreal et al., 2017). However, participant observation showed that multiple activities pursued by different family members outside the farm also contributed to household livelihoods. These included employment in construction services in urban areas, cleaning work in restaurants, and laboring for private companies. In addition, surveys revealed that rural tourism activities - such as guided tourism in the Iguaque Flora and Fauna Sanctuary, bed-and-breakfast accommodations, and adventure walks- have been expanding with the years.

3.2.3 The linking paramos project, El Convite Campesino and SwissAid

The sampling frame of the study consisted of the 119 families participating in the Linking Páramos project. According to the baseline survey conducted for the project, of these, 104 self-identify as peasants, 7 as neo-rural (individuals of urban origin who relocate to the countryside), 6 report no specific identity, 1 identified as peasant-Indigenous, and 1 as peasant-Afro-Colombian. These families belonged to five different peasant associations: El Hemitaño, ASOMORAL, ACIVI, Forest Brigades, Corazón de Frailejón, and El Convite Campesino.

The project has been running since 2024 led by El Convite Campesino in partnership with the Swissaid foundation with the goal of supporting agricultural transitions to a more environmentally sustainable systems by promoting agroecology, gender equity and youth leadership in peasant communities of the region. El Convite Campesino is an association of 62 families from Arcabuco, Cómbita, and Chíquiza, guided by young leaders that seek to promote agroecology and short food supply chains as pathways to food sovereignty (results section 4.3). Swissaid, which is an international organization, works to combat the global food crisis by promoting ecological and resource-preserving farming, supporting producers in developing countries, and ensuring access to healthy food for the poorest (Swissaid, 2025).

3.3 Data collection methods

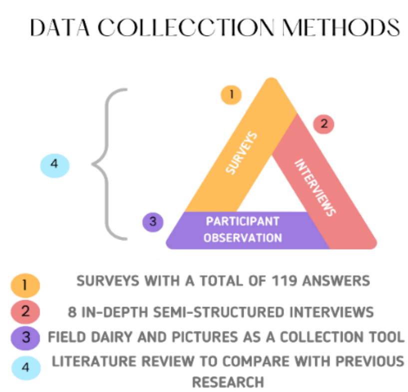

Figure 2. Data Collection Methods

Building on this contextual understanding, the research employed methodological triangulation to enhance the validity of the data. Surveys were used to gather general information of a macro-level scope that could be translated into numerical results. Interviews were conducted to understand participants' perspectives in a micro-level perspective which relates to the survey's responses and brings emerging topics. Participant observation enabled the researcher to engage directly with individuals and experience their practices, allowing for a more critical interpretation of interview and survey responses.

Additionally, the literature review was used to get insight into novelties and collaborations across farms, and to compare the findings with previous research on the impacts of agricultural practices on soil and water. This comparison allowed the study to draw exploratory conclusions on the potential impacts of peasant farm tasks on soil and water in the Iguaque Páramo zone.

3.3.1 Surveys

3.3.1.1 Surveys Questions-Macro level analysis-

The survey used in this research was originally designed for the implementation of the "Linking Páramos" project. A total of 119 surveys on three different municipalities -Chíquiza, Cómbita, and Arcabuco- were completed by the participants of the project, each containing 61 socio-economical questions. Out of these, 25 questions were selected for analysis based on their strong relevance to explaining farm labor processes (SRQ1). Of the selected questions, 22 were closed-ended and three were open-ended.

The questions chosen covered the following areas: personal information, agroecology appliances, animals, and productive labor. It asked for the farm representative name, municipality, sector where they live, gender of the representative and which organization they belong to. In terms of the agroecology section, it included questions about the farmer use of agroecological practices, including which crops and techniques were used, and which crop had the highest production. Questions about animals focused on what animals were on the farm and which ones produced the most. Finally, the labor section asked if workers were hired, how many workdays were needed per year, and what other farm activities or services were offered.

3.3.1.2 Surveys sample and distribution

The survey had two versions (V2024 and V2025), both using non-random sampling that included all participants of the "linking páramos" project. The second version (V2025) excluded people who had already answered the first version. The survey was distributed via WhatsApp using Google Forms as the data collection tool. Each farm representative completed their own form. Later, to clarify unusual responses or fill in missing information, the project team contacted participants directly by phone.

3.3.2 Interviews -micro level-

3.3.2.1 Interviews questions and sampling

Eight in-depth semi structured interviews of approximately 2.5 hours each were conducted. One of them was conducted with a biologist who is a former director of the Flora and Fauna sanctuary of Iguaque and a recognized expert on páramo ecosystems. The remaining seven interviews were conducted on farms. Six of these farms were selected using a snowball sampling method, with the sample frame based on the list of participants from the "linking páramos" project- which means that they were also included in the surveys. The seventh farm was selected through convenience sampling to ensure the inclusion of a non-peasant farm that was not participating in the project. This last farm served as a control case, allowing for comparison between peasant and non-peasant farming contexts. The following table provides an overview of the farm interviewees:

Table 2. Interviewees overview

Farm	Location	Population description	Land size and property
Agroecological 1	Arcabuco	A couple middle-aged adults (man and woman)	Rented small land
Agroecological 2	Chíquiza	A family of a middle age, woman, a child and an elderly relative	Owned small land
Agroecological 3	Arcabuco	A young couple (man and woman) living with elderly	Rented small land
Conventional 1	Arcabuco	A couple middle-aged adults (man and woman)	Owned small land
Conventional 2	Chíquiza	A couple of middle-aged adults (men and woman) living with their young son	Owned small land
Conventional 3	Chíquiza	A couple of middle-aged adults (men and woman) living with their young son	Owned small land
Entrepreneurial	Chíquiza	A city dweller, not residing on the farm but visiting frequently	Owned big land

The interview conducted with the expert focused on: (a) his experience as former director of the Flora and Fauna sanctuary of Iguaque and how that role shaped the relationship between farming and the Iguaque páramo; and (b) the geophysical characteristics of the Iguaque Páramo and how they influenced, and influences, farming activities.

The farms interviews included a section that explicitly asked about: (a) conceptual perspectives about being a peasant; (b) daily, weekly and monthly farm tasks; the instruments used; how do they learnt to pursue each task; and who is involved in carrying them out; and (c) how people perceive their practices influence and depend on soil and river properties. In addition, the interview conducted on farm seven, also included a second part, focusing on the analysis of former "Hacienda Farming" which was conducted on the same farm as the "entrepreneurial farming" is happening nowadays. The grandson of the former owner of Hacienda Versalles, is today, the owner of "Hacienda Versalles-Entrepreneurial farming."

3.3.2.1 Interviews application and tools

Fieldwork was conducted to carry out the interviews. All of them, including the expert one, were done directly on the farms. In total, four interviews took place in the municipality of Chíquiza, specifically on Montes, Laguneta and Patiecitos sectors, and four in Arcabuco, specifically on Quirbaquirá, Rupavita and Montesuarez sector. Audio recordings were made during the interviews. Participants were informed about the purpose of the recording and verbal consent was obtained in each case. These recordings served to ensure accuracy in data transcription, coding, and analysis.

3.2.3 Participant observation

Participant observation was conducted on each farm prior to the start of each interview. Some of the activities carried out while doing participant observation were farming, animal care, building nurseries, collecting yields, cooking, sharing meals, attending community meetings, preparing bio inputs, and participating in local activities (appendix b). Farm labor tasks were performed before starting the conversation, providing insight from the researcher's perspective on (a) how peasant farming practices are done, and (b) how these practices both influence and are influenced by soil and river properties. The observations were collected in a field diary, supported by photographs that will be included in the appendix as complementary evidence.

While participant observation did not independently produced conclusions, it helped triangulating findings, enhancing credibility of the research process. Also, at the same time, the process of sharing experiences triggered rapport and trust, making interviewees more comfortable and open in their responses. It should also be noted that, in addition to this, the researcher has been working and volunteering with peasants in the study area for the past five years.

3.3.4 Literature review

Lastly, all collected data - particularly the farm labor tasks considered to have a direct influence on soil and water properties, as well as the data on hacienda farming- were analyzed and compared with previous research on the influence of agricultural practices on soil and water, to identify similarities or differences that either support or contradict the findings.

The researcher drew initial assessments about the influence of peasant farming tasks on soil and water properties. Later, these initial assessments were compared with the relevant literature to test and refine the researcher's interpretations. This process aimed to either confirm or adjust the categorization of practices as "directly related," weather by a) increasing soil and water aspects, b) decreasing soil and water aspects, or c) having no significant relationship. The following table shows which literature was used:

Table 3. Literature-influence of peasants farming

Type	Soil aspects Agricultural practices	Water aspects agricultural practices
Metha-analysis	Patiño, S, et al (2021). Influence of land use on hydro-physical soil properties of Andean páramos and its effect on streamflow buffering.	Mosquera, G, et al (2023). Frontiers in páramo water resources research: A multidisciplinary assessment.

Case Study in Páramos	Estupiñán, L. H., et al. (2009). Effect caused by agricultural activities on soil characteristics in the páramo El Granizo, (Cundinamarca - Colombia).	Rey-Romero, et al (2022a). Effect of agricultural activities on surface water quality from páramo ecosystems.
Case study in Andean forest	Ordoñez, M.-C., et al. (2015). Effects of peasant and Indigenous soil management practices on the biogeochemical properties and carbon storage services of Andean soils of Colombia.	Chará-Serna, et al. (2015). Understanding the impacts of agriculture on Andean stream ecosystems of Colombia: A causal analysis using aquatic macroinvertebrates as indicators of Biological Integrity.

As can be seen, although all the studies were conducted in Colombia and within similar high Andean ecosystems, none of the reviewed articles focused on the study area of this research. This required certain assumptions to be made. A similar situation occurred with the literature used to assess the influence of specific agricultural practices. The following table shows which sources were used for each practice:

Table 4. Literature: Influence of peasant farming practices

Practice	Article
Cover crops	Adetunji, A. T. et al. (2020). Management impact and benefit of cover crops on Soil Quality: A Review.
Suppresive soils	Kariuki, G. M., Muriuki, L. K., & Kibiro, E. M. (2015). The Impact of Suppressive Soils on Plant Pathogens and Agricultural Productivity.
Earthworms	van Groenigen, J. W., Lubbers, I. M., Vos, H. M., Brown, G. G., De Deyn, G. B., & van Groenigen, K. J. (2014). Earthworms increase plant production: A meta-analysis.
Soil biota	Creamer, R. E., Barel, J. M., Bongiorno, G., & Zwetsloot, M. J. (2022). The life of soils: Integrating the who and how of Multifunctionality.
No tillage	Ernst, G., & Emmerling, C. (2009). Impact of five different tillage systems on soil organic carbon content and the density, biomass, and community composition of earthworms after a ten year period.
Weeding	Upadhyaya, M. K., & Blackshaw, R. E. (2007). Non-chemical weed management: Synopsis, integration and the future.
pH correction	Zhang, S., Zhu, Q., de Vries, W., Ros, G. H., Chen, X., Muneer, M. A., Zhang, F., & Wu, L. (2023). Effects of soil amendments on soil acidity and crop yields in acidic soils: A world-wide meta-analysis.
Monoculture	Power, J. F., & Follet, R. F. (1987). Monoculture

The previously mentioned literature was neither conducted in high-altitude Andean ecosystems nor specifically focused on the cropping systems considered in this research. Therefore, assumptions had to be made. The selection of the literature was done using previous literature given on the courses “conservation agriculture- FTE50806” and “Environmental assessment of nutrient and pollution management -ESA31806” from Wageningen University.

Lastly, the literature review was also used to understand the “Hacienda” Socio technical regime complemented with the interview of Carlos Borrás, grandson of Miguel Borrás, former owner of Versalles Hacienda. This combination made it possible to compare perspectives and enrich the information gathered through the interviews.

3.4 Data processing: standardization, coding, and analysis

The survey and interview responses were coding using a hybrid approach: Ploeg's (2018) and Ploeg's (2023) conceptual categories of farming labor practices were applied deductively to the surveys, while interviews were coded both inductively to identify emerging themes, and deductively to identify regularities within the previous defined categories.

The analysis of the data combined quantitative and qualitative analysis from both the survey and interview material. Quantitative data was used to characterize proportions and patrons of productive and reproductive labor practices across farms, while qualitative data provided in-depth analysis of labor processes and allowed to find novelties and interactions and collaborations between farms. Together, these methods allowed for both measurable comparisons across farms and an interpretive understanding of a) how labor practices work in different peasant farms; and b) how they influence soil and water aspects within the Iguaque–Merchán Páramo complex.

3.4.1 Surveys: deductive coding and data analysis

The deductive codification of the surveys made it possible to determine which questions from the general survey from the "linking páramos" project were relevant for the research. The central concepts of the research - labor processes, socio-technical regimes, novelties, and farm interactions and collaborations- were assessed, resulting in a selection of 25 questions directly related to SRQ1 (labor processes and their relationship with water and soil properties) and SRQ3 (farm interactions and collaborations), though not specifically addressing soil and water properties. The following sub-categories were codified: association membership, type of farm, labor tasks, objects of labor, and type of labor force.

The standardization of the data gathered from the responses to the 25 selected survey questions was carried out using Excel. This process ensured that close-ended questions could be quantified and that patterns in the open-ended questions could be analyzed. Once the data was standardized, it was analyzed using the pivot table function in Excel. The combination of the name column with each of the columns containing information on labor processes and farm interactions and collaborations made it possible to identify patterns in the responses.

3.4.2 Interviews: mixed coding and data analysis

Eight in-depth interviews were codified using the following sub-categories for the assessment of labor process, novelties and interactions and collaborations: farming type; labor process (productive or reproductive); tasks (single response); object of labor (single response); type of labor force (family, external, family and association, or family and external); type of payment for external labor (formal payment or no payment); instrument (single response); instrument provisioning (external or internal); and learning (family, association, self-experience, or public campaigns).

To relate the categories of labor processes, novelties and interactions and collaborations to soil and water influences the following variables were considered: soil organic carbon, soil microbial biomass, soil porosity, soil bulk density, field capacity, infiltration rate, plant-available nutrient concentration, soil pH, nutrient load, salinity, organic matter in water, turbidity, and microbial pathogens. These variables were categorized according to their potential soil-water relation (direct or indirect) and classified as showing a potential increase, decrease or no effect. These variables were selected because they allow for comparisons with previous meta-analyses on the topic. These specific categories were founded as central on Patiño et al (2021) and Rey-Romero et al., (2022).

The assessment of influences (increase, decrease or none) was based on 1) The environmental context and its role in shaping these tasks; 2) the specific characteristics of the tasks as defined in the categories (e.g., who performs the task, what is being labored, and which instruments are used); and 3) previous research findings. Lastly, two main sources informed this assessment: 1) An interview with an expert on páramo ecosystems, specifically from the Flora and Fauna Sanctuary of Iguaque; and 2) a literature review.

To enable codification, the interview records were first transcribed using Google Pinpoint. The transcripts were then translated, followed by a careful manual review to ensure accuracy. Later, the codification was carried out using ATLAS.ti software, which served as the primary tool to codify the qualitative data in regards the categorization.

3.4.2.1 Interviews data analysis:

3.4.2.1.1 First step analysis: How are the labor processes conducted, which are the socio technical regimes, novelties, interactions, and collaborations.

The already coded data was transcribed into an Excel spreadsheet structured around a set of analytical categories, each represented as a column heading. These included: farming type; type of labor process; general and specific tasks (up to two levels of specificity and a unified task category); main object of labor and sub-objects of labor (up to three levels); type of labor force (familiar or external); type of payment for external labor (paid or unpaid); and instruments with their respective provisioning sources (up to two instruments). Additionally, learning sources (family, association, self-experience, or public campaigns) and location information (up to two entries).

The farming type column was defined by combining participants self-recognition as peasants with the analysis of labor processes-related data (task, object of labor, labor force, type of payment, instruments, and instruments provisioning), which indicated whether a farm operated as agroecological, conventional, or entrepreneurial (e.g., agroecological peasant farm 1, conventional peasant farm 1, entrepreneurial farm). The “type of labor process” column was derived from analyzing tasks to classify them as productive or reproductive.

This systematization allowed the data to be organized in a way that made it possible to grasp the complexity of each farming task. Similarly, by including variables related to knowledge transmission, labor relations, and instrument provisioning, the spreadsheet enabled to connect tasks and socio-technical regimes, and allowed the assessment of the presence of novelties, and the existence of interactions and collaborations with other farms.

3.4.2.1.2 Second step analysis: how do they relate to soil & river properties?

After the spreadsheet was completed, the analysis of how tasks were related to specific influence outcomes was conducted using Excel formulas. A color-coding system was applied to indicate whether each influence was categorized as increase (I) or decrease (D). Frequency counts of these coded outcomes were then performed, allowing the identification of patterns and the quantification of relationships between tasks, labor processes, and their potential impacts on soil and water properties within farms.

3.4.2.1.3 Comparison between farms

Lastly, to compare results between farms a heatmap was created using R studio. The tasks marked as directly influencing soil and water properties on the database were filtered. Later already standardized *Increase*, *Decrease* or *None* tasks were encoded as +1, −1 and 0, respectively. Every farm task-soil property combination was calculated as one single outcome, and then a sum up of all of them was computed as a single score for each farm. To get this done and ensure fair comparisons the net proportion was calculated using: total outcome=(Increases−Decreases)/Total Number of tasks, as a simple sum up without proportions would lead to confusion (farms with more tasks may look like more influential for a certain soil property and the way around). The resulting matrix was ordered with RStudio which used hierarchical clustering along rows (farms) and columns (soil and water properties) to group similar profiles.

4. Results

This section begins by addressing the first sub-research question, presenting survey results that provide a regional-level overview of the farming practices implemented by participants in the Linking Páramos project. It then draws on interviews' findings to examine how these practices are carried out and their implications for soil and water aspects. The rationale behind these practices is then analyzed by identifying the socio-technical regimes that are present and exploring how they, along with novelties, may influence soil and water. This analysis contributes to answering the second research question. Finally, the section addresses the third sub-research question by highlighting how collaboration and interaction among farms is central for the sharing and learning of agricultural practices, and their influence on soil and water.

4.1 Peasant Farming Labor Processes: Cases of Agroecological, Conventional, and Entrepreneurial Farming

This section addresses the first sub-research question by presenting survey results on how labor processes operate in the region. The data provide context for the subsequent interview analysis of agroecological and conventional peasant farms. Finally, it is presented a comparative analysis on how farms labor processes relate to soil and water aspects in the region.

4.1.1 Peasant Labor processes in the northeast of the Iguaque-Merchán Páramo region

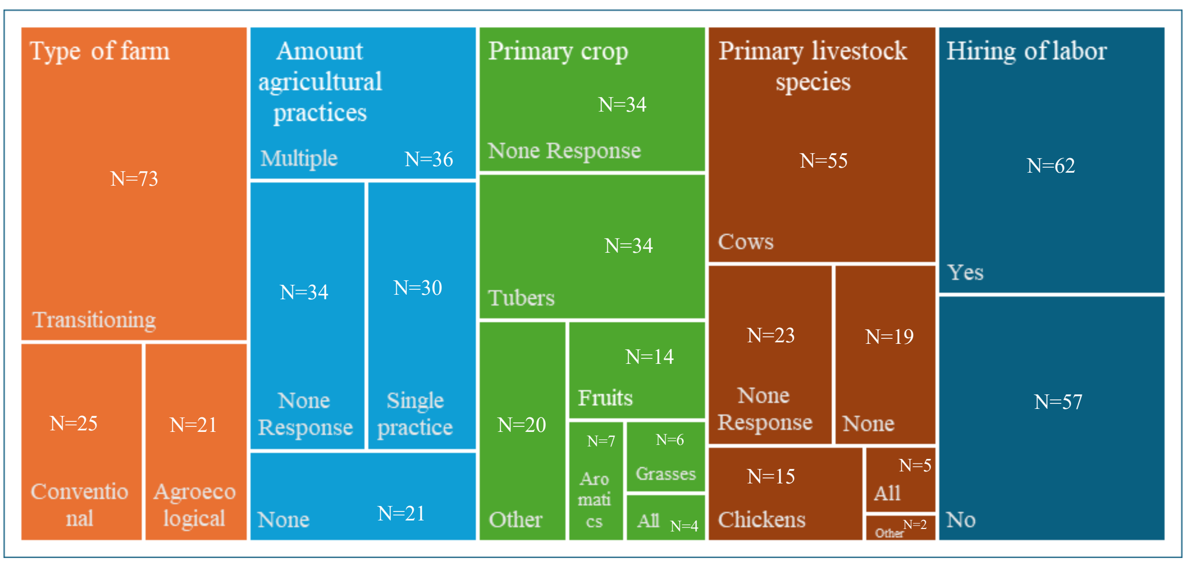

Figure 3.Surveys results on labor processes

As shown in figure 3, out of the 119 surveys conducted in the northeast of the Iguaque-Merchán Páramo region, 73 considered themselves as transitioning towards an agroecological farm. The remaining considered themselves fully conventional farms (25), followed by those identified as fully agroecological (21). The most frequently reported agricultural labor practices were the use of organic fertilizers (21 farms), live fences (20 farms), crop rotation (18 farms), and intercropping (18 farms). Additional mentions included native seeds usage, minimum tillage, non-chemical weed control, efficient water management, and, less frequently, no tillage and biological pest control. No specific conventional practices, such as the usage of chemical pesticides, were mentioned.

Across these farms, tubers were the most common object of labor (34mentions), followed by fruits (14), aromatic plants (7), and grasses (6) (figure 3). A smaller proportion mentioned cereals, legumes, and mushrooms and four farms stated that they produce tubers, fruits, vegetables, cereals, legumes and aromatic plants all together. A total of 34 respondents did not answer this question (figure 3).

For farms that produce tubers, the most common combinations of agricultural practices were: 1) intercropping with organic fertilizers, native seeds, live fences, and water management, and 2) crop rotation with intercropping and non-chemical weed control, each mentioned by two farms. The other farms reported only a single practice, with crop rotation (9 farms) being the most frequent labor practice. In the case of other production types, most fruit-producing farms (8) also reported using combinations of practices, while three out of five farms producing aromatic plants did the same. In contrast, none of the vegetables-producing farms reported combinations between practices.

Regarding livestock, when asked which animal has the highest production, cows lead (55 responses), followed by chickens (15), multiple (or all) (5), and rabbits and sheep which had one respondent each. A total of 23 respondents did not answer this question (figure 3).

In terms of hired labor, 62 farms reported hiring labor force for agricultural activities, while 57 do not (figure 3). Reported workdays per year vary widely: the median is very low (2 days), and the mode is 0, yet the mean is 25.7 days because three farms report continuous activity for around 200 to 300 hundred days per year, indicating high heterogeneity in labor intensity.

Overall, the results highlight that most of the surveyed farms recognized themselves as transitioning towards agroecological systems, though including isolated agroecological-like practices. Tubers are the dominant crop, followed by fruits and aromatics, while livestock production is led by the presence of cattle. These objects of labor are mainly transformed by family-based work with minimal hired labor. Interviews were conducted to deepen the understanding of how farms implement these mentioned practices and how they relate with soil and water aspects of the region.

4.1.1.1 Labor processes, agroecological peasant farms:

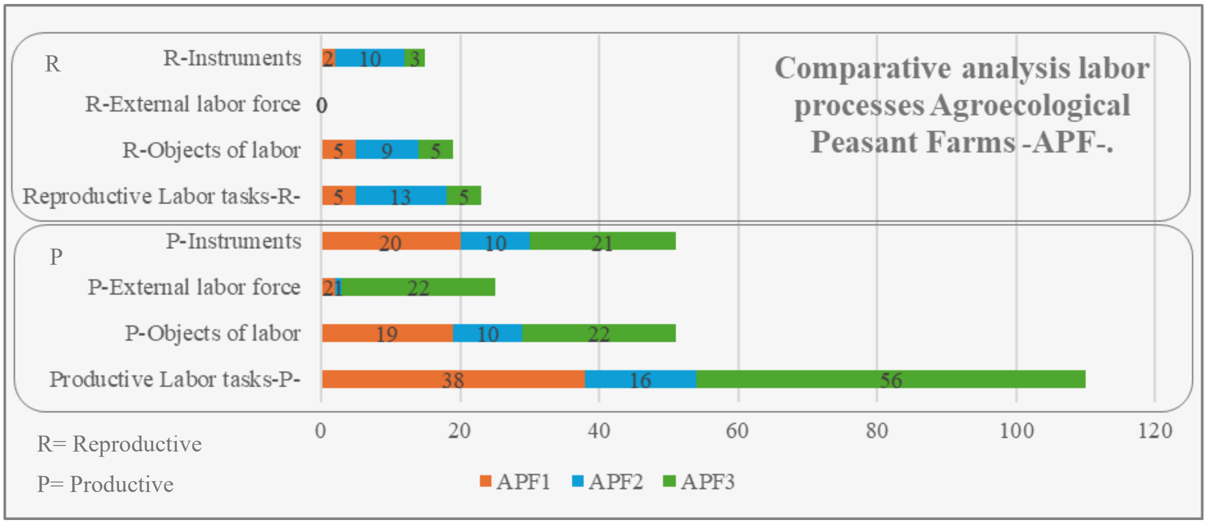

Figure 4. Labor processes on agroecological peasant farms

Figure 4 presents how the three agroecological peasant farms interviewed differed in the number of labor tasks, objects of labor, labor force and instruments, while also sharing some similar characteristics. In terms of productive tasks, farm 3 showed the highest number of tasks (56), followed by farm 1 (38), and farm 2 with the fewest (16). A similar pattern was observed in the diversity of objects of labor, with Farm 3 reporting 22, Farm 1 reporting 19, and Farm 2 only 10 (figure 4). Soil as an object of labor was central in Farm 1 (11 mentions) and Farm 3 (10 mentions), while water was central in Farm 2 (2 mentions). Farm 1 is also distinguished by the mentioned of Cuaresmero worm (5 mentions), while Farm 2 reported cows (3 mentions) and Farm 1 bio-inputs (also called organic agro-inputs) (13 mentions).

Regarding the labor force, all three farms relied primarily on family labor, but to different degrees (figure 4). Farm 3 was almost exclusively familiar (54 of 56 tasks), Farm 2 also depended largely on family (15 of 16 tasks), and Farm 1 showed greater diversity with tasks shared among family (22 of 38), family and association (9), association alone (5), and family with external support (2) (figure 4). External labor was minimal across the farms, being Farm 2 and Farm 3 the only ones that reported occasional paid tasks.

The number and type of instruments also varied (figure 4). Farm 3 recorded the highest number of instruments (21), followed by farm 1 (20), and lastly farm 2 (10) (figure 4). Manual agricultural tools were common to all three farms, but their relevance differed: hoes (5 mentions), and shovels (5 mentions) were most frequent in Farm 1, baskets (7 mentions), hoes (6 mentions) and shovels (3 mentions) in Farm 3, while Farm 2 relied more on tools linked to dairy and food processing such as milk pails (2 mentions), gloves (2 mentions), and rice (2 mentions).

Regarding reproductive labor processes, the farms showed contrasting patterns (figure 4). Farm 2 reported the highest number of reproductive tasks (13) carried out by family members, involving 9 nine objects of labor, most often breakfast, lunch and snacks (figure 4). Ten instruments were mentioned, mainly soap (4 mentions) and a cow's head for soup preparation (1 mention). In contrast, Farms 1 and 3 reported each only five tasks (figure 4), all performed by the family, involving 5 objects of labor each (figure 4). Both farms included breakfast and piquete (traditional snack) as objects of labor. Farm 1 reported two instruments -salt (3 mentions) and a horse chair for recreational riding (1 mention)-, while Farm 3 reported three instrument- salt, coffee, and soap-.

In summary, the three farms shared a strong reliance on family labor, the centrality of soil and water as objects of labor, and the use of manual instruments. However, Farm 1 and 3 showed a greater diversity in productive tasks and objects of labor, with hoes and shovels as common instruments, while farm 2 operated a smaller productive scale, with fewer task and instruments, but greater emphasis on reproductive labor processes.

4.1.1.2 Labor processes, conventional peasant farms:

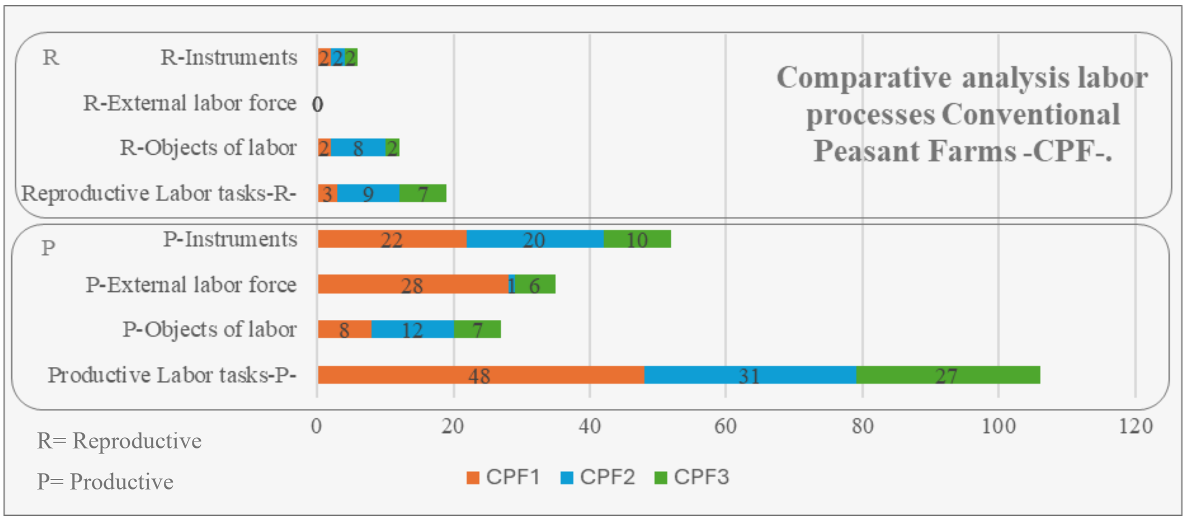

Figure 5. Labor processes on conventional peasant farms

The three conventional peasant farms interviewed shared a reliance on family labor, but they varied considerably in the number of tasks, diversity of objects of labor, instruments and reproductive labor tasks (figure 5).

In terms of productive tasks, Farm 1 recorded the highest number of tasks (48), followed by Farm 2 (31) and Farm 3 (27) (figure 5). The diversity of objects of labor was greatest in Farm 2 (12), compared to Farm 1 (8) and Farm 3 (7) (figure 5). Farm 1 was strongly oriented toward potato production (18 mentions), while Farm 2 emphasized dairy activities, particularly with the use of cows (9 mentions) to produce raw milk and cheese. Farm 3 showed a mixed profile, balancing soil (6 mentions), potatoes (4 mentions) and forest (4 mentions) as objects of labor.

The labor force in all three farms was predominantly familiar (figure 5), though the degree of diversification differed. Farm 2 was almost entirely reliant on family (30 of 31 tasks), with only one sporadic external paid job (figure 5). Farm 3 also depended mainly on family (21 of 27 tasks) but included family and association collaboration (4 tasks), and two sporadic external paid workers (figure 5). Farm 1 showed the broadest mix, with family (22 tasks), family and association (21 tasks), and external paid labor (7 tasks) (figure 5).

With respect to the instruments, Farm 1 reported the largest number (22 instruments), followed by Farm 2 (20 instruments) and Farm 3 (10 instruments) (figure 5). The types of instruments reflected the productive orientation of each farm: Farm 1 emphasized on external seeds (5 mentions), manual plows (3 mentions), and chemical pesticides (3 mentions); Farm 2 relied on tractors (3 mentions), buckets (2 mentions), and the use of care as a novelty instrument (section 4.3) (2 mentions); and Farm 3 reported backpack sprayers (4 mentions), tractor plows (3 mentions), and sacks (3 mentions).

Regarding the reproductive labor process, Farm 2 reported the highest number of tasks (9) involving 8 objects of labor (figure 5), most often snack (3 mentions), followed by lunch, followed by morcilla (traditional dish), coffee, lunch, and pigs (1 each). Farm 3 reported 7 reproductive tasks, with two objects of labor (figure 5) being birds to be rescued (5 mentions) and residues to be used in the wooden stove (2 mentions). Farm 1 recorded only 3 reproductive tasks (figure 5), involving potatoes and cows as objects of labor. Instrument use also varied: Farm 2 relied on water (5 mentions) and pots (3 mentions); Farm 3 reported boxes for bird rescue (2 mentions) and plastic bags to collect residues (2 mentions); Farm 1 used protein sourced externally.

In summary, all three conventional peasant farms shared the predominance of family labor, however, they diverged in productive focus (farm 1 on potatoes, farm 2 on dairy, and farm 3 on a mixed system), the scale of productive and reproductive tasks (farm 1 being the largest in productive terms and farm 2 in reproductive terms), and their use of instruments, with farm 1 being the most dependent on externally sourced tools.

4.1.1.3 Entrepreneurial farm:

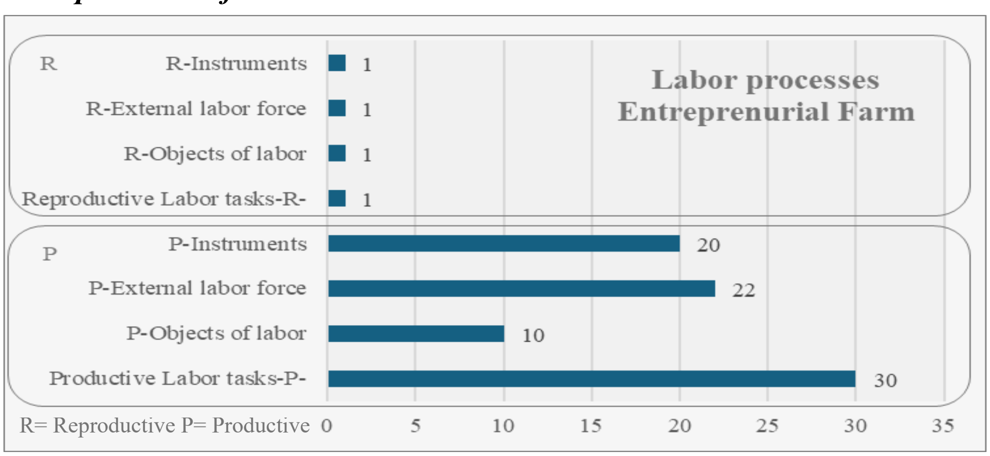

Figure 6. Labor processes on Entrepreneurial farm

A total of 30 productive tasks were identified on this farm (Figure 6), involving ten main objects of labor, the most frequently mentioned being cows (11 mentions), the house to be rented (7 mentions), and horses (5 mentions) (Figure 6). The labor force was predominantly external, appearing on 22 tasks, from which 20 had sporadically hiring with formal payment and two permanent formal jobs. Also, a combination of family and external labor was mentioned in 7 tasks. Twenty instruments were reported, with the most frequently mentioned being the stable (3 mentions), soap for productive spaces cleaning (3 mentions), and rope (3 mentions).

Regarding reproductive labor processes, one task was documented for this farm, involving a single object of labor (Figure 6). It was carried out by an external worker under a formal payment, using one instrument – a horse- provided internally (Figure 6).

In comparison with the previous conventional and agroecological farms, the entrepreneurial farm relied heavily on external labor and showed a strong focus on cattle and horses as part of its productive system, as well as on tourism through house rentals. Moreover, stables were mentioned only on this farm, and the centrality of soap in its productive activities underscores the importance of sanitary practices.

4.2.2 The relationship between labor processes and soil and water aspects in the northeast of the Iguaque-Merchán Páramo region

4.2.2.1 Soil-related labor processes

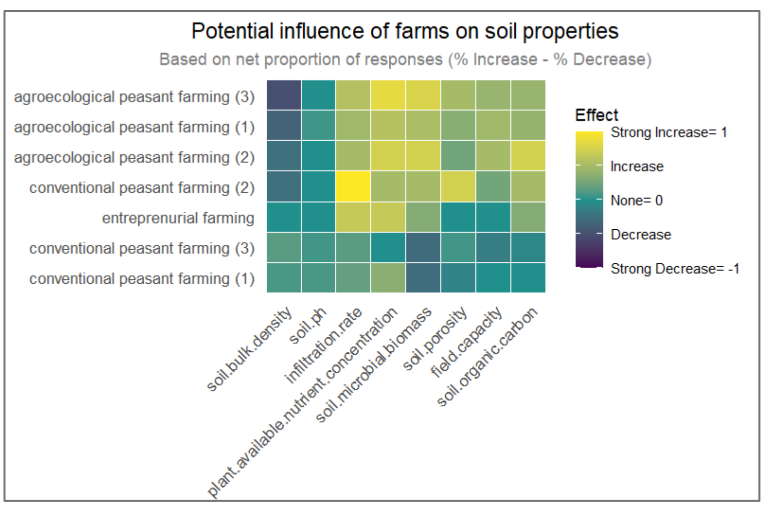

Figure 7. Comparison of the potential influence of farms on soil properties

Figure 7 illustrates how taken together Agroecological Peasant Farms -APF-, are the group of farms with the largest potential of increases in every soil property, except for soil bulk density that decreases sharply and soil pH which shows no effects. Although the emphasis of how properties are influenced varied by farm. In terms of number of tasks influencing soil properties, APF3 showed highest influence with 13 tasks directly influencing, followed by

APF1 with 17, and APF2 with 4 (appendix c table 1, 2 and 3). APF3 showed 49 potential increases against 7 decreases, APS1 had 44 increases against 7 decreases, and APS2 documented 14 increases against only 1 decrease (appendix c table 1, 2 and 3).

On the one hand, APF1 recorded increases on nutrient availability (11 tasks) and infiltration (9 tasks), while APF2 concentrated its effect on organic carbon, microbial mass, and nutrient availability (3 tasks each) (figure 5 and appendix c table 1 and 2). APF3 demonstrated the broadest influence, with nutrient availability (12 tasks) and microbial mass (11 tasks) most frequently increased, alongside infiltration (8 tasks), porosity (7 tasks), organic carbon (6 tasks), and field capacity (6 tasks) (figure 5 and appendix c table 3). On the other hand, decreases across every agroecological peasant farm concentrated on bulk density (figure 5 and appendix c table 1,2 and 3).

In APF1, manure applications (goat, horse, cow) and the increase of organic matter to create pests' suppressive soils, contributed to increases across nearly soil properties while reducing bulk density (appendix c table 1). In APF2, mulching was the most influential tasks, enhancing almost all soil properties while reducing bulk density (appendix c table 2). In APF3, the strongest contributions came from green manures, Bokashi and manure applications, which improved nearly all soil properties and decreased bulk density (appendix c table 3). Other practices such as low disturbance plowing and furrow making contributed to porosity and infiltration improvements across APF1 and 3 (appendix c table 1 and 3).

In contrast, Figure 7 illustrates how Conventional Peasant Farms -CPF- present more mixed results, with conventional farm 2 showing a more neutral trend compared to conventional peasant farms 1 and 3. In terms of number of tasks influencing soil properties, CPF3 recorded the highest influence with 13 tasks directly influencing, followed by CPF1 with 11 and CPF2 with only 4 (appendix c table 4,5 and 6). CPF1 showed 10 increases and 6 decreases, CPF2 had 15 increases and 2 decreases, and CPF3 documented 13 increases and 12 decreases (appendix c table 4,5 and 6).

CPF1 reported the largest number of increases in plant available nutrient concentration (4 tasks) and infiltration (3 tasks) (figure 7 and appendix c table 4). CPF2 concentrated on infiltration (4 tasks) and porosity (3 tasks), with additional increases in organic carbon, microbial biomass, and nutrient availability (2 tasks each) (figure 5 and appendix c table 5). CPF3 also showed infiltration (4 tasks) and porosity (3 tasks) as the most improved (figure 5 and appendix c table 6). CPF1 showed decreases on microbial biomass, while CPF2 reported only two decreases, both linked to bulk density (figure 5 and appendix c table 5 and 6). CPF3, decreases were influencing microbial biomass (5 tasks), porosity (2 tasks), infiltration (2 tasks), organic carbon (2 tasks), field capacity (2 tasks), nutrient availability (2 tasks), and bulk density (2 tasks) (figure 5 and appendix c table 6).

In CPF1, increases were linked to furrow making with tractors or horses and to agrochemical fertilization, while decreases were driven by the use of pesticides and compaction of cattle during grazing (appendix c table 4). In CPF2, rotational grazing and manure fertilization were highly influential, contributing to improvements across every soil aspect, though bulk density also increased under tractor and animal plowing (appendix c table 5). CPF3 presented a more widespread range of activities influencing, tasks such as loosening, plowing, and hilling potentially increases porosity and infiltration, and tree planting increases soil organic carbon and microbial biomass in forested areas. However, flagstone extraction for arepas making and agrochemical use may lead to decreases across all soil properties (appendix c table 6).

Lastly, entrepreneurial farming as shown in Figure 7 presents a generally neutral influence on soil properties, particularly in relation to soil bulk density, soil pH, soil porosity and field capacity. In this farm, 3 tasks were found directly influencing soil aspects. Across these tasks, 6 potential increases and no decreases were found (appendix c table 7). Rotational grazing was the most influential task having potential impacts on soil organic carbon, soil microbial mass, infiltration rate, and plant available nutrient concentration (figure 5 and appendix c table 7). Bringing cattle back to the stable daily may lead to an increase on infiltration rate, while applying the proper, site-specific agrochemical load may lead to an increase on plant available nutrient concentration (appendix c table 7).

In general, across both agroecological and conventional farms, labor processes predominantly generated increases on soil aspects, though through different instruments and techniques. Agroecological peasant farms emphasized practices such as manure application, suppressive soils, mulching, and different bio-inputs like Bokashi and green manures. Conventional farms also showed increases, particularly where manure fertilization and rotational grazing were applied, but they were more likely to generate decreases and increases in bulk density due to tractor plowing and cattle compaction. Entrepreneurial farming sits somewhere in between, avoiding decreases but also lacking the potentiality of agroecology to increase certain soils aspects.

4.2.2.2 Farms comparison: water related labor processes.

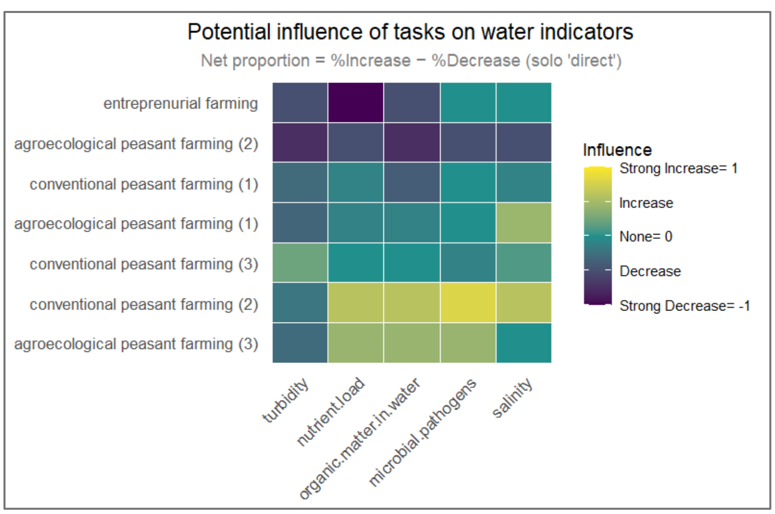

Figure 8. Comparison of the potential influence of tasks on water indicators

Figure 8 illustrates how Agroecological Peasant Farms-APF- generally show a mix of increasing and decreasing effects on water aspects. In terms of number of tasks, APF1 reported the highest with 9 tasks directly influencing water, followed by APF3 with 7 and APF2 with only 4 (appendix c table 1,2 and 3). APF1 documented 14 increases and 15 decreases, APF2 recorded 2 increases and 14 decreases, while APF3 reported 13 increases and 6 decreases (appendix c table 1,2 and 3).

In APF1, decreases were observed in nutrient load, organic matter in water, turbidity, and microbial pathogens, mostly linked to low disturbance plowing, fishbone crop shaping (appendix illustration 17), rotational grazing, and suppressive soils (figure 8 and appendix c table 1). APF2 showed a stronger decreases profile, with nutrient load, salinity, organic matter, turbidity, and pathogens all decreased, mainly through planting in forested areas, water-cleaning practices, and mulching (figure 8 and appendix c table 2). APF3 also presented decreases in nutrient load, organic matter in water, and turbidity, primarily from cover crops and mulching (figure 8 and appendix c table 3).

In APF1, increases in nutrient load, organic matter in water, and pathogens were tied to manures application, while furrow making raised turbidity and phosphite application increased salinity (appendix c table 1). APF2 showed fewer increases, tied to nutrient load and salinity, associated with agrochemical fertilization of potatoes (appendix c table 2). APF3, concentrated its increase in nutrient load and organic matter in water, both linked to intensive manure and bokashi application, which may also include microbial pathogens in water (appendix c table 3).

Conventional Peasant Farms -CPF- also display variability as can be seen in figure 8. In terms of number of tasks, CPF1 reported the highest with 7 directly influencing water, followed by CPF3 with 5 and CPF2 with only 2 (appendix c table 4,5 and 6). APF1 documented 5 potential increases and 17 decreases, APF2 showed 3 increases and 3 decreases, while CPF3 presented 6 increases and 4 decreases (appendix c table 4,5 and 6).

CPF1 showed the strongest pattern of reduction, with three environmental protection and site clean-up tasks lowering nutrient load, salinity, organic matter in water, turbidity, and microbial pathogens, complemented by fire alerts near springs that reduced turbidity and organic matter (figure 8 and appendix c table 4). CPF2 decreases only came from rotational grazing, which reduced nutrient load, organic matter in water, and turbidity (figure 8 and appendix c table 5). CPF3 reported decreases linked to tree planting, which reduced nutrient load, organic matter, turbidity, and microbial pathogens in streams nearby protected forested areas (figure 8 and appendix c table 6).

By contrast, in CPF1, tractor furrowing increased turbidity, while fertilizer placement into furrows and hilling raised nutrient load and salinity (appendix c table 4). In CPF2, cow manure applications increased nutrient load, organic matter in water, and microbial pathogens (appendix c table 5). CPF3 showed a wide range of increases: tractor plowing elevated turbidity, fertilizer spraying raised nutrient load and salinity, and flagstone extraction contributed to higher organic matter and turbidity (appendix c table 6).

Entrepreneurial farming presents a different profile as seen in Figure 8. In this farm 2 tasks were identified as directly influencing water properties. Across these tasks, no increases and 4 decreases were found (appendix c table 7). Rotational grazing potentially reduced nutrient load, organic matter in water, and turbidity, with salinity and microbial pathogens unchanged. Applying proper, site-specific agrochemical load may lead to decreases on nutrient load, while leaving salinity, organic matter in water, turbidity, and pathogens unchanged (appendix c table 7).

In general, across both agroecological and conventional farms, labor processes highly influenced water aspects through diverse practices. Agroecological farms reduced impacts through mulching, rotational grazing, and forest planting, but manure, Bokashi and agrochemicals raised nutrient load, organic matter in water and pathogens. Conventional farms followed a similar pattern. These farms showed consistent decreases from water protection tasks, tree planting and rotational grazing, but also increases from chemical fertilizers, mechanization and pesticides inputs. Entrepreneurial farming systems tend to present overall decreases across most aspects.

4.2 The rationale behind peasant farming labor processes: socio-technical regimes, hacienda farming and peasant novelties

Comparative analysis across farms showed that different types of farming labor processes generate distinct ecological outcomes (figure 7 and 8). Findings from the interviews and literature review show that peasant farming labor processes in the north-east sector of the Iguaque páramo region derive from a combination of three socio-technical regimes: the ancient Muisca Indigenous socio-technical regime, the Spanish colonial socio-technical regime, and the Green Revolution socio-technical regime. These regimes were inherited from diverse sources, with hacienda farming emerging as the most influential.

This chapter explains hacienda farming, how it transmitted socio-technical dynamics to peasant farming, and how peasants have generated novelties that differ from hacienda promoted socio-technical regimes. Finally it considers the implications of novelty production for soil and water aspects.

4.2.1 Socio-technical heritage: La Hacienda

The hacienda was an institution born in the colonial period and reinforced during Colombia's early independence around early 1800s (Bravo Monroy & Hammen, 2007). As noted by Magnus Mörner (1973), it demonstrates "semi-feudal" or "half-feudal, half-capitalistic" characteristics. Three features identified by Jesús Antonio Bejarano (1987) are especially relevant for contextualizing the case studied here: 1) Labor relations were extremely oppressive and based on the monopoly of land. 2) Settlement on the hacienda gradually led to family and economic autonomy of tenants (workers) in relation to the haciendas, while simultaneously pressuring them to prevent their access to the monetary market. 3) The implementation of peculiar forms of labor almost always responded to the need to secure scarce labor and to minimize costs.

In this research, Hacienda Versalles, located in the municipality of Chíquiza in the San Pedro de Iguaque sector, was studied. However, multiple other haciendas were mentioned during the interviews as having existed throughout the Iguaque Páramo region, including Hacienda El Molino in San Pedro de Iguaque and the former hacienda of the Corredor family in the municipality of Arcabuco.

Hacienda Versalles operated until around the 1960s under the ownership of Miguel Borrás. It was created from the division of a larger hacienda (whose name is unknown in this research) into two new haciendas: hacienda Versalles and hacienda El Molino, the latter owned by Carlos Rivadeneira. This original hacienda had belonged to Concepción Neira Pinzón, who inherited it from her father, Antonio Rivadeneira. Antonio, in turn, received it from Lucrecia Rivadeneira -whose kinship is uncertain- who was the owner of Hacienda Iguaque considered the primary hacienda.

Hacienda Iguaque has been studied as a colonial hacienda, formed in the 17th century through the transformation from Indigenous settlements into haciendas (Fals Borda, 1957). However, the oldest notarial record identified in this research (dated 1890), indicates that Lucrecia Rivadeneira inherited Hacienda Iguaque from her father, Timoteo Neira, who was likely its owner since the early nineteenth century (Borrás y compañía,1890). In that sense, the hacienda may also be considered an “hacienda decimononica” (nineteenth-century hacienda) stablished for agricultural and livestock production as suggested by the instruments listed in the notarial record: a weighing scale, six tables, four sofas, a canopy, four boxes, eleven hoes, three saws, six stools, three axes, and five ropes (Borrás y compañía,1890).

Nevertheless, weather understood as a colonial or a decimononica hacienda, the temporal gap suggests that colonial socio-technical was still present on its farming practices. Moreover, drawing on the studies of other haciendas (Bejarano, 1987 and Colmenares, 1969), it is likely that indigenous workers were employed on the hacienda Iguaque. This would indicate that both colonial and Muisca (Indigenous) socio-technical regimes were combined in daily labor practices, which were later inherited by the peasant workers of hacienda Versalles.

Bravo Monroy & Hammen (2007) provides an illustrative example of how these antique labor processes shaped contemporary peasant agricultural labor practices. In the 17th and 18th centuries, the mita (a colonial labor system requiring Indigenous people to work in exchange for symbolic wages) replaced the encomienda (a system that obliged Indigenous people to provide tribute to colonists), giving rise to what is now known as the jornalero (day laborer). Mitayos received wages, small plots of land inside the haciendas, and sometimes tools and seeds. In return, the hacienda received half of the production from these plots, and workers were also obliged to labor in the commercial fields.

Indigenous people who entered the haciendas as laborers worked in both productive and reproductive systems. In doing so, they adopted hacienda practices while also incorporating their own inherited traditions. Over time, these Mitayos—which included not only Indigenous people but also poor whites—evolved into what are now known as peasants (Fals Borda, 1975). These peasants cultivated their own plots, where they were forbidden from growing commercial crops, while also working in hacienda fields dedicated to market production (Bravo Monroy & Hammen, 2007).

Through this dual experience, peasants gradually learned to manage both self-provisioning and commercial farming. They inherited an ancient socio-technical regime from local Muisca traditions and reproduced mostly in their self-provisioning plots, while simultaneously adopting a mainstream regime introduced by colonizers in the commercial plots. In doing so, they not only acquired techniques for using tools but also new methods for dividing and organizing agricultural labor (Fals Borda, 1975; Bravo Monroy & Hammen, 2007).

This peasant farming style continues to exist today in the Iguaque páramo region. This is exemplified in the coexistence of self-consumption crops and commercial crops in most of the lands visited during this research and the "Linking Páramos" project. In these lands, especially in the conventional farms, self-consumption plots are still managed using techniques closer to those of the Muisca and early colonizers, while commercial plots reflect the socio technical influence of both early and late hacienda farming (up to the 1950s) when Green Revolution was already present.

4.2.1.1 Green revolution socio-technical heritage: La Hacienda

A testimony collected by Bravo Monroy & Hammen (2007) illustrates this transition from Colonial to Green Revolution technical regime in Hacienda Versalles. Former workers mentioned Bravo Monroy & Hammen (2007) that, in the hacienda, chemical fertilizers were not initially used. Instead, they were told to collect sheep and cow manure to apply potato crops. However, around the early 1950s, agronomists introduced chemical fertilizers and new potato seeds, initiating the "Green Revolution" in the hacienda farming.

Not long after, the process of parcellation (the subdivision and sale of rented hacienda lands to peasants) began. This research records its start in 1954, preceding the national Agrarian Reform Law of 1961. Notarial records of Hacienda Versalles indicate that 208 parcellations were carried out between 1954 and 1991 (Superintendencia de Notariado y Registro, 2025). This process enabled 208 peasants to acquire small plots, gradually reshaping patterns of land property and land management in the region.

After the partitioning of the land, peasants were required to pay for their plots by selling agricultural products. The lands acquired generally corresponded to the plots they were already given as a rent, which were often located closer to the páramo zones of the former haciendas (Bravo Monroy & Hammen, 2007). Interviews indicate that, consequently, and for other socio-economic reasons, peasants sought to maximize the profitability of their plots. They did so by exploiting available wood for sale in Tunja (the nearest big city), expanding farming and cattle grazing into the páramos, and using agrochemicals, practices they had learned from commercial crop production on the haciendas and jornales in big potato production farms (section 4.3).

4.2.2 Similarities between Versalles hacienda farming and today's peasant farming: Socio-technical regime and productive-reproductive labor tasks

In Hacienda Versalles, a total of 50 productive and reproductive tasks were documented, being mostly classified as administrative (23 tasks related to marketing and territorial governance), followed by recreational (2 tasks related to hunting dogs and horses), and a high number of productive and reproductive tasks carried out outside the family (25 tasks). Bravo Monroy & Hammen (2007) also conducted interviews with former workers (not owners) of the hacienda, and found tasks such as tiling with tractors, storing corn and cereals in silos, cooking, and cleaning.

These tasks involved 15 different objects of labor. The most frequently mentioned were cows (11 mentions), the hacienda itself (8 mentions), and water (3 mentions). Bravo Monroy & Hammen (2007) also found that cows, potatoes, corn, and fava beans were raised and cultivated in the hacienda.

The labor force was mainly composed of unpaid external labor (25 tasks), followed by family labor (16 task) and a combination of family and external labor (9 tasks). The payment system was known as "obligations," which required each worker living in the hacienda to contribute one full month of labor to its productive, marketable systems every few months, without official pay. Bravo Monroy & Hammen (2007) collected testimonies about this system and conclude that some people reported not being paid at all, while others recalled that children received 5 centavos and adults 10 centavos per week (equivalent USD 0.004 converted from 1950s COPS to 2024s COP). In some cases, even this symbolic payment was retained, as the cost of renting land was deducted from wages.

The most common instruments were the hacienda map (7 mentions, used for territorial governance and water management), rope (6 mentions, used for animal-related tasks), the hoe (5 mentions, used for productive farming tasks), and the páramo (3 mentions, used for water management). Of these instruments, 24 were externally sourced and 21 were internally sourced. Bravo Monroy & Hammen (2007) also noted that páramo was used as an instrument for cattle ranching. Cows, sheep and goats, mostly owned by the hacienda owners, were taken there to graze and drink water from the lagoons. Moreover, they highlighted the importance of páramo for wood provision.

Out of 50 hacienda tasks, the interviews documented 17 that were common with those practiced by current peasant farming. In terms of cattle management, seven tasks were notably similar: providing cattle with salt, ensuring sufficient grazing space, selecting cattle breeds, defining pastures, allowing cattle to graze for several days, rotating pastures, and taking cows to the pastures.

Two milking tasks also overlapped: separating cows and calves for milk production and applying the proper technique of manual milking. Moreover, both systems shared the practices of selling milk and selecting and selling potatoes. Bravo Monroy & Hammen (2007) noted the use of agrochemicals in hacienda farming as well as in conventional peasant farming; however, this was not explicitly mentioned in the hacienda interview conducted for this research.

Reproductive and household tasks also showed overlap. Five such tasks—gathering wood from the forest for kitchen use, washing dishes, making butter, slaughtering animals for labor and family consumption, and preparing puntal for laborers—were shared, with most centered-on kitchen and household care. Finally, recreational practices also reflected similarities: horseback riding was present in Agroecological Farm 1, while hunting was practiced in Conventional Farm 1 as well as in hacienda farming.

Overall, despite differences in who performed the tasks in Hacienda Versalles compared with peasant farms, 17 tasks overlapped with present-day peasant farming -particularly in cattle management, milking, household care, and marketing- showing continuities in practices that link the hacienda farming system with current peasant ways of carrying out tasks.

4.2.3 Novelties in Today's Peasant Farming in Relation to the Socio-Technical Regime Inherited from Hacienda Farming and Its Implications for Water and Soil aspects.

Excluding the 17 similar tasks, within 256 productive and reproductive tasks analyzed on 7 different peasant farms, 20 were considered novelties of today's peasant farming in relation to the haciendas farming inherited socio technical regime.

In the case of Conventional Farm 2, milking involved allowing both the milker and the cow to relax before the process began. The relaxation of the cow was considered an important factor for improving milk quality. This could only be achieved by deepening the relationship of care with the animal, tending to it with food and gentle treatment. Such a relationship challenges the notion of humans as subject and cow as object by fostering a subject-to-subject interaction.

Novelties on animal feeding practices included giving cattle potato residues in Conventional Farms 1 and 2 and, in Agroecological Farms 1 and 3, feeding rabbits with competing plants or low-quality harvested vegetables. These practices illustrate how animal management can also be shaped by crop management, effectively closing the cycle between the inputs and outputs of both systems. By feeding cows and rabbits with potato residues and weeds, crop waste is reduced, and the leftovers are instead used into animal feed. In turn, this generates outputs such as manure, which can be reintegrated into the cropping system soils. Moreover, this practice may reduce the amount of crop residues and organic matter that would otherwise enter water sources.

Fertilization practices also revealed significant novelties. Agroecological farms employed multiple methods, including maintaining living cover crops, incorporating crop residues, and applying organic inputs such as Ortimeg, purines, bokashi, and efficient microorganisms. In addition, Agroecological Farm 2 reported fertilizing with kitchen residues, while Agroecological Farm 1 also applied ash coming from the kitchen as a soil amendment. These practices rely on manures, crop residues, decomposed weeds, and household waste to enhance soil properties that facilitate nutrient uptake by plants. Although these techniques were learned from other farms, they were adapted and tested according to the resources available and the specific production context of each farm. The influence of these practices on soil and water is generally tending to increase soil properties (except for bulk density) and to reduce exogenous components in water. Their specific potentialities are discussed in Results 4.1.

Manual weed extraction was also practiced in the agroecological farms (1 and 3) and was observed sporadically in Conventional Farm 2. This practice was considered a novelty because it was carried out not only to control competing plants in crops but also to selectively collect weeds for other purposes. Kikuyu grass was dried and left on the crop, huacas, lengua de Vaca (tongue of cow), and dandelion were used as rabbit feed, nettle was fermented for use as fertilizer, and carreton was collected as cattle feed. Moreover, through this practice, peasants on these have recognized the need to avoid certain grazing pastures when toxic weeds for cows and sheep are present. By applying this novelty, soils aspects such as plant nutrients availability and soil organic carbon content may be increased.

Disease control also presented novelties. Agroecological Farm 3 and especially Agroecological Farm 1 reported using a wide variety of techniques to manage plant diseases, including the application of phosphate rocks, Trichoderma, chili ferments, garlic–alcohol mixtures, and phosphates, as well as enhancing soil organic matter to promote suppressive soils. These methods, which are mainly preventive, emphasize on the agroecosystem itself to reduce the risk of harmful organisms affecting crops. This approach shifts disease management from the reactive, post-disease treatments promoted during the Green Revolution to more nature-based solutions (Kesavan and Malarvannan,2010).

In terms of water management, Agroecological Peasant Farm 1 implemented a fishbone crop design (illustration 17), which was used to improve water retention while ensuring its proper distribution. This practice helps maintain adequate soil moisture conditions, enhancing the solubility of nutrients for plants while also reducing the transfer of nutrients and organic matter into water sources.

Environmental protection related tasks were not mentioned in hacienda farming, whereas they were reported in peasant farming. Some of these could be considered novelties, but perhaps they are not since the absence of environmental protection in hacienda farming may simply reflect the lack of an in-depth analysis of this topic on interviews. Similarly, some of the novelties identified may resemble earlier hacienda techniques, where colonizer and Indigenous knowledge were combined. However, they are considered novelties because the instruments and the techniques used may have changed within time. The similarity between them must be further studied.

Finally, in Agroecological Farm 1, the novelties reflected necessary innovations in response to the presence of a harmful caterpillar (Cuaresmero worm) that, during the interview period, was affecting the harvest. The peasant described having to experiment with multiple strategies to control the worm and was particularly engaged in explaining how the trial-and-error process was.

In general, 20 novelties were identified in today's peasant farming compared with the socio-technical regime inherited from haciendas. These novelties were evident in animal care and feeding, fertilization, weed management, disease control, water management, and environmental protection. They reflect practices adapted to local resources and context, often emphasizing care, prevention, and circular use of outputs. In most cases, they resembled earlier socio-technical regimes, while emerging as responses to new challenges.

4.3 Interactions and collaborations between farms: relevance on peasant farms and their influence on soil and water aspects.

Building on the previous sections, this chapter explains how interactions and collaborations between farms are central to the transmission and expansion of socio-technical regimes and novelties, and how these processes influence soil and water aspects in the Iguaque-Merchán region. It begins by showing why interactions and collaborations are key to socio-technical regimes and novelties and concludes by analyzing their prospective importance in shaping the influence of novelties and regimes, using Association El Convite Campesino experience as an example.

4.3.1 The centrality of interactions and collaborations in transmitting socio-technical regimes and novelties.

Interviews revealed that changes in soil and water conditions in the Iguaque Páramo Region, driven by novelties and socio-technical regimes, have only been achieved through the massification of labor practices facilitated by peasant interactions and collaborations in on-going farm labor. For example, interviews on Conventional Peasant Farm1 and 3 highlighted that the Green Revolution socio-technical regime expanded in the region not only through hacienda farming but also through the practice of jornales (agricultural day labor). During participant observation and interviews, peasants explained that they learned how to use agrochemicals while working on other farms with both relatives or peasant friends and non-peasant farmers who were already using them.

This pattern is also reflected in the results on knowledge sharing of labor processes. Across both agroecological and conventional peasant farms, learning to perform agricultural tasks was primarily transmitted by the family. On Agroecological Peasant Farms-APF-, family teaching dominated but was complemented by peasant associations and self-experience. APF1 reported 10 tasks learned from family, nine from peasant associations, and self-experience 1; APF2 reported family (14), and self-experience (2); APF3 reported family (45), self-experience (6), and associations (5). On Conventional Peasant Farms -CPF-, learning was almost exclusively familiar, though self-experience and, in one case, public campaigns also played a role in learning acquaintance. CPF1 reported family (40 tasks), self-experience (9), and public campaigns (1); CPF2 reported only family learning; and CPF3 reported family learning for all 27 tasks.

Familiar teaching and association -including neighborhood relations- were found to be central in transmitting knowledge about how to perform tasks and use instruments. No references were made to schools or formal education services. This highlights the importance of peasant-to-peasant methodologies in sharing socio-technical regimes and novelties.

By contrast, when asked about where their parents had first learned to use Green-Revolution type of instruments, peasants during interviews pointed to two main locations: the municipality of Ventaquemada in the department of Boyacá (around one hour by car from the Iguaque Region) and the metropolitan area of Bogotá (around three hours away). In these places, people worked as jornaleros (daily workers) on big farms and learned to use transgenic seeds, agrochemicals, tractors, and other modern agricultural tools, particularly for potato cultivation.

Today, however, when asked about how novelties are being expanded, interviewees emphasized family labor, neighborly collaboration, and convites (collective work gatherings). Two farms -APF1 AND APF3- were identified as agroecological niches. Peasants mentioned these farms as examples of socio-technical transitioning farms that generate novelties by building up on former Muisca socio-technical regime. These two farms have also been deeply involved in the creation and development of “El Convite Campesino,” the peasant association that manages the “linking páramos project.” Moreover, the peasants running these farms have participated in multiple convites on other farms and have organized free workshops for associated peasants interested in learning about the novel production methods practiced there.

Entrepreneurial farming showed a lower reliance on associative and familiar learning processes. While, out of 256 peasant farming tasks, family members were involved in 238 tasks and associations in 43 tasks, entrepreneurial farming reported only 1 out of 30 as learn within the family. No associative processes nor collaborative tasks were mentioned on this farm. Instead, the entrepreneurial farm primarily interacts with other farms by employing peasants from the region, thereby increasing peasant participation in off-farm labor activities.

Overall, the findings indicate that interactions and collaborations are central to the spread of both socio-technical regimes and novelties and are therefore crucial for understanding their influence on soil and water aspects. Green Revolution practices entered mainly through off-farms wage labor, while agroecological novelties are driven by family teaching, neighborhood relations and convites. By contrast, entrepreneurial farming showed little reliance on associative or familiar processes.

4.3.2 Potential influence of peasant farms interactions and collaborations in socio-technical change and soil and water aspects: The example of Association El Convite Campesino

From a prospective perspective, socio-technical change, and consequently changes in how peasant farms influence soil and water aspects, was observed to occur only through collaboration and interaction within peasant farming. The above-mentioned findings indicate that altering how peasant farming tasks influence soil and water -whether increasing, decreasing or none- requires novelties not only in how tasks are performed but also in how they are shared through collaborative and interactive practices.

In line with this, associative processes were found to be already taking place in the region. Of the 119 farms surveyed, 93 reported belonging to an association. Ten associations were identified, all of which listed environmental protection as one of their main objectives. Eight of those, also reported aiming to transform the agricultural sector in line with local realities.

The El Convite Campesino Association was among these and was found, during interviews and participant observation, to be developing novelties in associative processes that contribute to socio-technical change. The association initially emerged during the COVID-19 pandemic to market agricultural surplus products at fair prices, but its objectives expanded toward strengthening members' food sovereignty. To achieve this, a model was created to ensure household self-consumption while generating surpluses for commercialization. The strategy relied primarily on the agroecological transition of farms, supported by short food supply chains, and reinforced through the implementation of an "agroecological corridor".

The agroecological transition was observed to depend on peasant-to-peasant methodologies, including workshops held during collective work gatherings (convites) and training sessions on niche farms described in section 4.2. Interviews indicated that these gatherings were particularly relevant, as reduced use of agrochemicals increased labor intensity and facilitate hands-on learning.

Regarding the short food supply chains, three main channels were identified: (1) exchanges or low-cost sales among associated farms, (2) direct sales at local markets, and (3) a structured marketing food supply chain with Tunja, the closest city. In the latter, food baskets containing diverse products were offered through social media platforms at accessible prices to consumers while still covering profits and production and distribution costs for producers. This system reduced dependence on external market actors, ensured year-round supply, and enhanced the sustainability of food distribution by shortening transport distances.

Lastly, the association is building an "agroecological corridor", described as a mechanism to expand the number of agroecological farms while fostering ecological and social relationships among them. According to interviews in agroecological farms 1 and 3 (representatives from El Convite Campesino), the corridor is aimed to restore connectivity between fragmented ecosystems around and inside páramos, while enhances the flow of exchanges of labor, instruments and knowledge in the region.

Participant observation and interviews showed that these strategies applied by El Convite Campesino were also present in the other nine associations, participating in the "Linking Páramos project". These findings highlight the importance of interactions and collaborations among farms for a broader socio-technical transition in the region.

Overall, findings demonstrate that socio-technical change in the Iguaque Páramo Region depends fundamentally on collaboration and interaction among peasant farms. The case of El Convite Campesino illustrates how associative processes are contributing not only to food sovereignty but also to different ecological outcomes from peasant farming. Importantly, these strategies are spreading through other associations, indicating a collective process of transition.

5. Discussion

As stated above, the objective of this research was to analyze how peasant farming practices both influence and are influenced by the soil and water properties of the north-east Iguaque-Merchán Páramo region, focusing on labor processes, farming novelties, and collaborations and interactions among farms. The study found that different types of farming produced distinct outcomes, shaped by varying socio-technical regimes and novelties that guided how productive tasks were carried out. Interactions and collaborations between farms proved essential for understanding how these socio-technical regimes spread and how they may foster socio-technical change. This section discusses these results and outlines the identified contributions to the knowledge.

5.1 How peasant farm labor processes influence and are influenced by soil and water properties.

Peasant farming labor processes in the Iguaque Páramo region are deeply influenced by the climatic and geophysical conditions of this high Andean ecosystem. The soils characteristics of páramos and alluvial valleys on the region and the abundant rainfall and low temperatures strongly influence the conditions under which farming plants develop. The importance of these environmental factors on farming is well documented in páramo studies (Hofstede et al., 2003; Osorio & Mazuera, 2024; Ordoñez, M.-C., et al., 2015; Chará-Serna, et al., 2015) and, more broadly, in research interested in the reconciliation between agriculture and environment (Fischer et al., 2017; Springmann et al., 2018; Wezel et al., 2013), as well as in international assessments such as FAO's (2019) report on the world's biodiversity for food and agriculture.

In this research, water emerged as essential for daily household needs, and agricultural productive activities. The natural abundance of rainfall in the region, combined with the sandstone soils dual properties of porosity and water retention, has historically allowed farming and households to remain largely independent of artificial irrigation. This situation is not unique to the north-east part of Iguaque-Merchán páramo region. Similarly, studies such as the meta-analysis by Mosquera et al., (2023) and the Santurbán Páramo case study by Duarte-Abadía et al., (2021), emphasize the central role of water in páramos communities and its importance for sustaining livelihoods.

The centrality of water also explains why farms in the region have adopted water protection practices, reflecting a recognition of water not only as an instrument but also as an object of labor that must be safeguarded even through religious rituals (illustration 10). Bravo Monroy & Hammen (2007) further develop the analysis of peasant water protection practices and their relation to local conceptions of what a páramo represents for the people of the Iguaque-Merchán páramo region.

Peasants' awareness about water protection in the region corresponds with scientific and technical assessments of climate change impacts on páramo ecosystems. For instance, Rubiano et al., (2025), conclude that humid high-elevation tropical ecosystems (included páramos) in Northern South America -where Iguaque-Merchán páramo is located- will experience the largest increase in temperature and decrease in precipitation due to climate change. Similarly, the management plan of the Iguaque Flora and Fauna Sanctuary, on its climate change scenarios for the region, mentions this situation (Villarreal et al., 2017).

In contrast, soil conservation was found to be central only in agroecological peasant farming, even though its properties are closely linked to farming success in general. Various studies have done research about this. For instance, the meta-analysis of Young et al., (2021) on the implications of sustainable agricultural management on crop, soil, and environmental indicators, and the exploratory study of Macintosh et al., (2019) on the relationship between soil phosphorus and agricultural management.

In this research, peasant agroecological practices were found to potentially improve soil properties while reducing bulk density, and certain loads to water (section 4). By contrast, peasant conventional practices were associated with declines in soil quality, increases in bulk density, and overall higher loads to water (section 4). Entrepreneurial farming caused fewer negative effects on soil and water but lacked the soil-building potential of agroecology (section 4).

These findings on the relationship between peasant farming tasks and soil and water aspect align with the meta-analysis by Patiño et al (2021) on the influence of land-use changes in Andean Paramos on hydro-physical soil properties (i.e. Soil Organic Carbon; Soil Organic Matter; Porosity; Bulk density; saturated hydraulic conductivity; and water retention capacity). They also resonate with the analysis by Rey-Romero et al., (2022) on spring onion (Allium fistulosum), potato (Solanum tuberosum), and livestock farming on water aspects (i.e. nutrients, salts, organic matter, sediments, and pathogens) in páramo ecosystems.

However, while these studies provide valuable insights into agricultural influence on soil and water in paramos, their analysis was done at bigger scales that overlook the complexity of farming practices inside the farm. Building on previous academic assessments (e.g. Murad et al.,2024; Patiño, S, et al 2021; Mosquera, G, et al, 2023) and policy-oriented reports such as the management plan of the Iguaque Flora and Fauna Sanctuary (Villarreal et al.,2017), this research instead contributes by focusing on on-farm labor processes and their potential influences at the task level, offering a perspective that complements large-scale analysis.

5.1.3 Co-production

This research also highlights the importance of a dialectical analysis of on-farm practices and páramo ecological processes. Farming depends on the intertwining—or co-production—of labor processes and natural resources (or objects of labor), while soils and waters are simultaneously shaped by farming practices (Rosset & Altieri, 2017; Ploeg, 2023). Most studies that have assessed agriculture in páramos only examine either influence of soil and water aspects in farming or the influence of farming in soil and water aspects of paramo, but rarely the co-relation between them (Murad et al.,2024; Patiño, S, et al 2021; Mosquera, G, et al, 2023; Rey-Romero et al., 2022).

These interactions vary across entrepreneurial farming, conventional peasant farming, and agroecological peasant farming. Entrepreneurial and Conventional farming relies on external inputs (seeds, agrochemicals, knowledge) and tends to show limited awareness of local biogeochemical cycles. In contrast, Agroecological farming seeks greater autonomy by closing ties with the objects of labor (e.g. water, soil, animals) (section 4). Another key distinction lies in labor relations: peasant farming depends mainly on family work, while entrepreneurial systems hire workers (section 4). Although both groups may work in the same land for years, peasants' direct management of land builds a more intimate relationship with soil and water.

5.2 Influence of peasant farming socio-technical regimes and novelties on soil and water properties

The rationale behind these distinctions was found in the socio-technical regime guiding each farm. Three socio-technical regimes were found to be present in the explored farms: the Muisca, Colonial and Green Revolution socio-technical regimes. Conventional peasant farms often overuse Green Revolution–based agricultural inputs. By contrast, agroecological farms are closer to Colonial and Muisca socio technical regime having a lower detrimental impact in soil and water aspects. The Entrepreneurial farm, meanwhile, is somewhere in between Green Revolution regime and the transition toward more sustainable approaches.

Within peasant farming, despite the differences between them, both groups continue to rely on manure and other residues coming from inside the farm (section 4). Such sustainable practices were found to be often driven by conditions of scarcity, aligning with Martinez-Alier's concept of the environmentalism of the poor, and Altieri's (2002) view of agroecology as a science of natural resource management for poor farmers in marginal environments.

This differentiation between different farming types has not been adequately addressed in previous research on agriculture in páramo regions. Most studies treat agriculture as a unique activity, overlooking the diversity of farming systems. Rural geography, agronomy and rural sociology studies have deepened the analysis of farming systems differentiation and could help to further bridge these insights with environmental assessments of farming systems (Hidalgo et al. 2014; Ploeg, 2023; Therond et al., 2017).

Understanding this diversity also requires looking beyond contemporary differences to their historical foundations. Many of the labor practices observed today -especially within peasant farming- can be linked to tools, objects of labor and labor relations inherited from the

Hacienda systems. After the partitioning of the Hacienda, peasants -now landowners- tried (and some still try) to replicate hacienda style of farming on a smaller scale (section 4.2). Similar analyses have been conducted by agrarian historians and sociologist in other former haciendas territories (Colmenares, 1998; Mörner, 1973; Bejarano, 1987; Fals Borda, 1975).

In addition to the historical legacy of the hacienda system, knowledge circulation has also been shaped by more recent labor dynamics, particularly through jornales (day labor). Although Green Revolution-type technologies and practices were present to some extent in Hacienda farming, peasants primarily learned them while working as jornaleros on large farms outside the region. These techniques later spread through peasant social networks, highlighting the role of peasant- to- peasant exchange in the dissemination of socio-technical regimes (section 5.3).

However, peasants are not passive inheritors of these regimes and these sources. Instead, they actively create novelties that reshape farming practices and generate new influences in soil and water aspects (Wiskerke and Ploeg 2004). Novelties were identified in both agroecological and conventional farming, with Agroecological farms 1 and 3 driving a potential transition towards a peasant-driven socio-technical regime. Conventional farming, while more closely aligned with Green Revolution socio-technical regime, also shows novelties mostly driven by "care" as an instrument for labor. Lacayo (2024) further develops this idea.

The potential agroecological transition, nevertheless, follows a different logic than the already mentioned entrepreneurial one. Agroecology is primarily driven by a pragmatic environmental awareness aimed at reducing external dependencies through stronger on-farm environmental services (about this: Martinez-Alier, 2013; Altieri, 2002). In contrast, entrepreneurial farming is shaped mainly by external market and policy trends tied to what is called the 6^{th} Kondratiev long-term economic cycle, characterized by a global shift toward sustainability (about this: Allianz, 2010; Geels, 2019).

This difference between peasant-agroecological transitions and market-driven sustainability transitions has been widely discussed by agroecologists and social movements engaged in agroecology (Rosset & Altieri, 2017; Rosset & Altieri, 1997). Recognizing this difference is important for future research and policy development on farming and environment, as homogenization may lead to misinterpretations and inaccurate policies.

5.3 Interactions and collaborations among peasant farms and their influence on soil and water properties

Research on socio-technical regimes and novelties in relation to environmental protection should also consider farm interactions and collaborations, as these are central to how regimes and novelties spread. In the Iguaque-Merchán páramo region, as mentioned, the Green revolution originally expanded mainly vertically through wage labor and market-oriented farms, while novelties currently spread primarily locally and horizontally through family labor, neighborly exchanges, and convites (get togethers), also known as traditional peasant to peasant methodologies (Rosset et al., 2011; ANAP et al., 2016).

The case of El Convite Campesino illustrates the role of peasant associations in driving wider socio-technical transitions, enabling both ecological and social transformations in the region. The development of an agroecological corridor and the replication of strategies through the nine other associations in the Linking Páramos project reveal how collective practices expand beyond farms scale. This supports the view that ecological transformations in rural context are not merely technological but also are influenced by social aspects. It aligns with academic debates on whether a modernization and techno-centered approach to sustainable transitions is sufficient to achieve environmental goals at global, regional and local scales (Spaargaren, 1997; Ulloa, 2015).

Lastly, this study highlights that interactions and collaborations between farms are important for environmental assessments in peasant communities, as understanding how these interactions function is central to identifying how and why peasants adopt and spread harmful or beneficial labor practices, and how these practices can be transformed or strengthened.

6. Conclusions

This thesis explored the relationships between peasant farming practices and soil and water aspects in the north-east region of Iguaque-Merchán Páramo region. By analyzing labor processes, novelties, and interactions and collaborations among farms, the study contributes to:

1. Understanding agriculture as a co-productive process in which nature and society are intertwined in distinct ways depending on the type of farming implemented.
2. Exploring the active socio-technical regimes operating within peasant farming and their relationship to soil and water use; and
3. Highlighting the importance of collaborations among farms for the analyzing socio-technical regimes and processes of socio-technical transition.

The findings show that soil and water are active elements in shaping which crops and animals can be raised, while, in turn, they are transformed by farming practices. However, the ways in which this co-production unfolds differ across agroecological, conventional, and entrepreneurial farming. Peasant agroecological farming emerged as the most conscious of the reciprocity between local soil and water conditions and farming practices. Conventional peasant farming reflected a strong dependence on external inputs, with limited awareness of how these inputs influence soil and water. Entrepreneurial farming, by contrast, is beginning to transition toward a sustainable system, though this shift is driven mainly by external market and policy influences rather than by local awareness of how co-production occurs on the farm.

These differences were found to be rooted in the socio-technical regimes underlying each farm. While all share a historical origin in Hacienda farming, they diverge in who performs the tasks, how techniques are applied, and why specific practices are chosen. Peasant farming (agroecological and conventional) relies largely on family and associative labor, whereas entrepreneurial depends on hired labor. Conventional farming is strongly linked to Green Revolution socio-technical regime, while entrepreneurial and agroecological are moving toward a socio-technical transitioning.

The study also highlights the importance of novelties and collaborations among peasant farms. Novelties are not only new techniques but also locally aware shifts in farming practices that can benefit harvests while improving soil and water conservation. However, novelties were found to be unfruitful if they are not disseminated through family networks, neighborly exchanges, and peasant associations. Therefore, the research highlights the importance of recognizing interaction and collaborations when assessing the environmental impacts of peasant farming. The central role of family and associative structures is crucial to understanding why peasants perform certain labor practices and how these practices, in turn, shape soil and water dynamics.

Practically, this research offers contributions to both the Linking Páramos project and public institutions aimed to conserved páramos. For the project, the findings provide a clearer understanding of the potential environmental impacts of peasant labor practices involved in the project and the rationale behind them. For public institutions, the research offers insights into peasant farming practices and their connections to páramo conservation goals, thereby informing more context-sensitive policies.

Methodologically, this research contributes to future studies on the environmental impacts of agriculture, particularly in páramos where peasants' communities remain active. It demonstrates a pathway for analyzing differences between farming types and understanding how each one influences environmental aspects. In addition, it shows how Ploeg's (2023) conceptual framework can be applied within environmental sciences (and vice versa), while also providing insights of how to assess the dialectic relationship between humans and non-human species. In doing so, the research engages with academic and methodological debates on environmental assessment, socio-technical regimes, peasant farming, and páramo ecosystems.

Limitations and recommendations

However, like any study, this research has limits. First, while the influence of farming tasks on soil and water aspects was examined, the reverse influence -how soil and water conditions shape labor processes- requires further study. Out of 336 tasks identified, 236 were marked as being influenced by soil and water factors without specifying the nature of these relationships. This suggests that a substantial amount of data remains to be analyzed in greater depth. Second, this study did not experimentally test practices directly or developed a complex understanding of the underlying social processes. Although this limitation was recognized from the beginning and accepted given the explorative nature of the research, more accurate types of assessments and measurements should be conducted in future studies.

Other limitations also need to be acknowledged. The analysis of labor processes was compared with only a limited set of soil and water aspects, even though the framework and methodology allow for the inclusion of many variables. In addition, the information collected may also reflect either long-term practices or short-term conditions on farms. For instance, in Agroecological Farm 1, the main object of labor identified -the Cuaresmero worm-, was linked to a specific pest concern that the farmer had at the time of the interview. Additionally, a more in-depth study of hacienda farming, novelties, socio-technical regimes and farms interactions and collaborations is needed to clarify their role in shaping current and future peasant farming practices.

Finally, it is important to note that the tables and figures presented in this document are meaningful only within the context of this research. Given the exploratory nature of the study, drawing definitive conclusions about the influence of farming tasks on soil and water aspects is not recommended.

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Appendix:

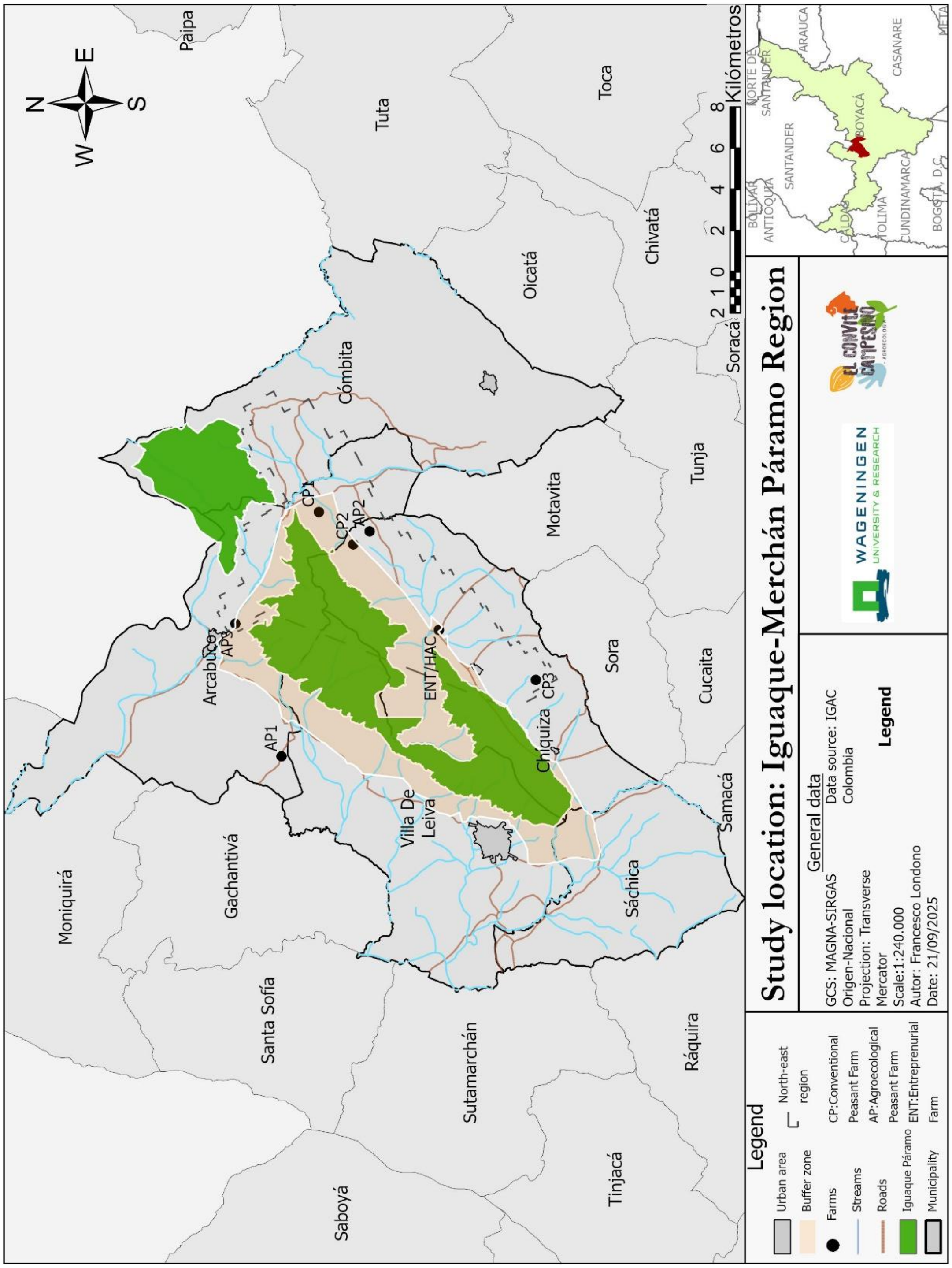
Appendix on the use of Artificial Intelligence (AI):

Artificial Intelligence was used to support (1) grammar and spell checking, and (2) code refinement with AI-assisted tools to generate a plot comparing the potential influences of agriculture on soil and water aspects.

Regarding the first use, paragraphs were provided to ChatGPT (OpenAI), and a grammar check was requested using the following prompt: “please check for grammar errors and provide a suggested change”. This process allowed for comparison and correction directly within the text, meaning that no copy-pasting was performed.

For the second use, ChatGPT (OpenAI) served as support for error checking while running code in R, as well as for organizing the codde in a logial way. Two prompts were used: 1. For error checking: “R is showing this error in relation to the code and data I am running. Please suggest how to fix it”. 2. For code organization: “this is the code I built. Please suggest how to organize it logically so I can obtain a plot”.

Appendix A- Figure 1/Map 1:



Appendix b- Pictures:

Illustration 1. Intercropping conventional peasant farm.

Illustration 2. Crop agroecological peasant farm

Illustration 3. Hunting dog

Illustration 4. Former hacienda farm

Illustration 5. Conventional potato crop in páramo

Illustration 6. Crops and páramo landscape

Illustration 7. Páramo landscape

Illustration 8. Peasants' nursery collective construction

Illustration 9. A horse: Peasant tool for carrying and transport

Illustration 10. A peasant protected stream with religious figures

Illustration 11. Collective work in a agroecological peasant crop nearby páramo

Illustration 12. Peasant making cheese

Illustration 13. A calf in a peasant's house door. Representation of care practices

Illustration 14. Collective production of bio-inputs in agroecological peasant farm

Illustration 15. Stream and flies on a stream in Agroecological peasant farm

Illustration 16. Frailejones in a former arable land, non-considered paramo area. Representation of paramización.

Illustration 17. Fishbone crop shaping

Appendix C- Tables:

Appendix C. Table 1. Task x soil and water aspects, Agroecological Peasant Farm 1

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Plowing with low soil disturbance	-	-	↑	↓	-	↑	-	-	↓	-	↓	↓	-
Manually making furrows	-	-	-	-	-	↑	-	-	-	-	-	↑	-
Manually Pilling up	-	-	-	-	-	↑	-	-	-	-	-	-	-
Manual weed extraction in vegetables	-	-	-	-	-	-	↑	-	-	-	-	-	-
Fertilization-Ortimeg	-	↑	-	-	-	-	↑	-	-	-	-	-	-
Fertilization-Phosphate rocks	-	-	-	-	-	-	↑	-	-	-	-	-	-
Fertilization-Goats manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Fertilization-Horse manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Fertilization-Cows manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Fertilization-Efficient microorganism	-	↑	-	-	-	-	↑	-	-	-	-	-	-
Diseases control-Diatomaceous earth	-	↓	-	-	-	-	-	-	-	-	-	-	-
Diseases control-Trichoderma	↑	↑	-	-	-	-	-	-	-	-	-	-	-
Diseases control-Increasing organic matter(suppressive soil)	↑	↑	↑	↓	↑	↑	↑	-	↓	-	↓	↓	↓
Diseases control-Ash	-	-	-	-	-	-	↑	↑	-	-	-	-	-
Diseases control-phosphite	-	-	-	-	-	-	↑	-	-	↑	-	-	-
Crop water retention-Fishbone crop shape	-	-	-	↓	-	↑	-	-	↓	-	↓	↓	↓
Rotating pastures	↑	↑	-	-	-	↑	↑	-	↓	-	↓	↓	↓
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 2 Task x soil and water aspects, Agroecological Peasant Farm 2

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient Load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Fertilizing with agrochemicals	-	-	-	-	-	-	↑	-	↑	↑			
Fertilizing with organic residues from kitchen	↑	↑	-	-	↑	↑	↑	-	-	-	-	-	-
Mulching	↑	↑	↑	↓	↑	↑	↑	-	↓	↓	↓	↓	-
Environment protection-Planting in a forested area near watersheds	↑	↑	-	-	-	-	-	-	↓	↓	↓	↓	↓
Environmental protection-Keeping water clean for own and animal consumption	-	-	-	-	-	-	-	-	↓	↓	↓	↓	↓
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 3 Task x soil and water aspects, Agroecological Peasant Farm 3

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Plant green manures- Cover crops	↑	↑	↑	↓	↑	↑	↑	-	↓	-	↓	↓	-
Mulching	↑	↑	↑	↓	↑	↑	↑	-	↓	-	↓	↓	-
Plowing with low soil disturbance	-	-	↑	↓	-	↑	-	-	-	-	-	-	-
Manually making furrows	-	-	-	-	-	↑	-	-	-	-	-	-	-
Provide inputs for plants strength while rainy season	-	↑	-	-	-	-	↑	-	-	-	-	-	-
Applying Purines	-	↑	-	-	-	-	↑	-	-	-	-	-	-
Applying Bokashi	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	-
Applying Phosphate rocks	-	-	-	-	-	-	↑	-	-	-	-	-	-
Applying Goats manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Applying Horse manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Applying Cows manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Applying Efficient microorganism	-	↑	-	-	-	-	↑	-	-	-	-	-	-
Irrigate when dry season	-	↑	-	-	-	-	↑	-	↑	-	↑	-	-
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 4 Task x soil and water aspects, Conventional Peasant Farm 1

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Opening furrows with tractor	-	-	-	-	-	↑	-	-	-	-	-	↑	-
Opening furrows with horse	-	-	-	-	-	↑	-	-	-	-	-	-	-
Soil Ph correction-lime application	-	-	-	-	-	-	↑	↑	-	-	-	-	-
Diseases control- preventive fungicide application	-	↓	-	-	-	-	-	-	-	-	-	-	-
Apply fertilizer in the furrows with seeds inside	-	-	-	-	-	-	↑	-	↑	↑	-	-	-
Manually Pilling up	-	-	-	-	-	↑	-	-	-	-	-	-	-
Apply fertilizer while hilling	-	-	-	-	-	-	↑	-	↑	↑	-	-	-
Apply herbicide while hilling	-	↓	-	-	-	-	-	-	-	-	-	-	-
Diseases control-curative fungicide application	-	↓	-	-	-	-	-	-	-	-	-	-	-
Harvesting- fungicides to pre-mature	-	↓	-	-	-	-	-	-	-	-	-	-	-
Grazing-Taking cattle to graze after potato crop	-	↑	↓	↑	-	↓	↑	-	-	-	-	-	-
Environmental protection-Pick up trash from the spring	-	-	-	-	-	-	-	-	↓	↓	↓	↓	↓
Environmental protection-Stop people from causing water pollution	-	-	-	-	-	-	-	-	↓	↓	↓	↓	↓
Environmental protection-Alert when fires are happening in the surroundings of the spring	-	-	-	-	-	-	-	-	-	-	↓	↓	-
Environmental protection-Picking up trash from forest areas to prevent fires	-	-	-	-	-	-	-	-	↓	↓	↓	↓	↓
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 5 Task x soil and water aspects, Conventional Peasant Farm 2

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Rotating pastures	↑	↑	-	-	-	↑	↑	-	↓	-	↓	↓	-
Plowing with animals	-	-	↑	↓	-	↑	-	-	-	-	-	-	-
Plowing with tractor	-	-	↑	↑	-	↑	-	-	-	-	-	-	-
Applying Cows manure	↑	↑	↑	↓	↑	↑	↑	-	↑	-	↑	-	↑
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 6 Task x soil and water aspects, Conventional Peasant Farm 3

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Loose the soil using a tractor	-	-	↑	↓	-	↑	-	-	-	-	-	-	-
Plowing with the tractor	-	-	↑	↑	-	↑	-	-	-	-	-	↑	-
Making furrows mechanically	-	-	-	-	-	↑	-	-	-	-	-	-	-
Apply fertilizer in the furrows with seeds inside	-	-	-	-	-	-	↑	-	-	-	-	-	-
Spraying fertilizer with two wings machine	-	-	-	-	-	-	↑	-	↑	↑	-	-	-
Apply Herbicide with two wings machine	-	↓	-	-	-	-	-	-	-	-	-	-	-
Manually Pilling up	-	-	↑	-	-	↑	-	-	-	-	-	-	-
Increase pesticides load due to resistance increase	-	↓	-	-	-	-	-	-	-	-	-	-	-
Applying fungicides	-	↓	-	-	-	-	-	-	-	-	-	-	-
Harvesting- fungicides to pre-mature	-	↓	-	-	-	-	-	-	-	-	-	-	-
Protect forest from firewood selling	↑	↑	-	-	-	-	-	-	-	-	-	-	-
Planting new trees	↓	↓	↓	↑	↓	↓	↓	-	↓	-	↓	↓	↓
Arepas making-flagstone testing with fire at the páramo	↓	↓	↓	↑	↓	↓	↓	↑	-	-	-	↑	-
Reproductive task: Lower pesticide loads for bird rescue	-	↑	-	-	-	-	-	-	-	-	-	-	-
Legend	↑: Increase ↓: Decrease -: None												

Appendix C. Table 7 Task x soil and water aspects, Entrepreneurial Farm

Task	Soil properties								Water aspects				
	Soil Organic Carbon	Soil Microbial Mass	Soil Porosity	Soil Bulk Density	Field Capacity	Infiltration Rate	Plant Available Nutrient Concentration	pH	Nutrient load	Salinity	Organic Matter in water	Turbidity	Microbial pathogens
Rotating pastures	↑	↑	-	-	-	↑	↑	-	↓	-	↓	↓	-
Daily bring cattle back to the stable	-	-	-	-	-	↑	-	-	-	-	-	-	-
Applying the proper load of agrochemical on the specific space needed	-	-	-	-	-	-	↑	-	↓	-	-	-	-
Legend	↑: Increase ↓: Decrease -: None												