RESTRUCTURING THE AGRICULTURAL PRODUCTION IN THE TOTA LAKE BASIN (COLOMBIA): PROS AND CONS TO ACHIEVE THE CHANGE †

[RECONVERSIÓN PRODUCTIVA EN LA CUENCA DEL LAGO DE TOTA (COLOMBIA). PUNTOS A FAVOR Y EN CONTRA PARA LOGRAR EL CAMBIO]

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SUMMARY

Background. Moorlands are strategic ecosystems that provide regulation and provision of water, and that face serious effects due to agricultural activities. Productive reconversion (PR) is a mixed environmental, and economic strategy for managing change in agricultural systems towards sustainable agroecological models. **Objective**. To investigate the factors that favor and prevent the implementation of PR. **Methodology**. The paper analyzed 26 variables of the productive (14), socioeconomic (6) and environmental (6) dimensions of 172 producers of long onion and potato growers in the Tota lake basin, Tota-Bijagual-Mamapacha moorland, Colombia. **Results**. It was found that 44% of the variables are identified in favor and the remaining 56% against the PR, highlighting the advances in training, social organization, environmental awareness and disposition of the producers for the PR, but being forced to continue the activity due to the economic profitability. **Implication**. The economic profitability is against sustainability, it is related to the implementation of harmful practices such as the indiscriminate, inefficient, unplanned use of agro-inputs for fertilization and pest and disease management, with highly toxic pesticides, composting without maturity, which affect both human and ecosystem health**. Conclusion.** The main challenges are from the productive dimension, in which strategies are consolidated aimed at promoting: a) the adequate selection of quality seed, b) better soil management, c) the management of pests and diseases based on phytosanitary plans that integrate monitoring traps, preventive actions, and restrict the use of agro-inputs of chemical synthesis and d) promote the efficient use of water resources based on the strengthening of participatory agroclimatic monitoring networks.

Key words: sustainability; paramo; productive systems; reconversion; ecosystem services; indicators.

RESUMEN

Antecedentes. Los páramos son ecosistémas estratégicos que, si bien proveen servicios de provisión y regulación hídrica, enfrentan grandes dificultades asociadas a los efectos de las actividades agropecuarias. La reconversión productiva es una estrategia mixta ambiental y económica para promover el cambio hacia sistemas agropecuarios sostenibles. **Objetivo**. Investigar elementos que favorecen e impiden la implementación de la reconversión productiva. **Metodología**. Se analizan 26 variables de las dimensiones productiva (14), socioeconómica (6) y ambiental (6) en 172 agricultores de cebolla de rama y papa en la cuenca del lago de Tota, ubicada en el páramo de Tota-Bijagual-Mamapacha en Colombia. **Resultados**. Se encuentra que el 44% de las variables están a favor de la reconversión y el 56% en contra; se resaltan los avances en fortalecimiento de capacidades, organización social, y conciencia ambiental de los productores, quienes se ven obligados a continuar con la agricultura convencional debido principalmente a la rentabilidad económica. **Implicaciones**. La rentabilidad económica va en contra de la sostenibilidad, está relacionada con la implementación de prácticas nocivas como el uso indiscriminado, ineficiente y no planificado de agroinsumos para la fertilización y el manejo de plagas y

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enfermedades, con pesticidas altamente tóxicos, el compostaje sin madurar, que afectan tanto al ser humano. y la salud de los ecosistemas. **Conclusiones**. Los principales desafíos son de la dimensión productiva, en la que se deben consolidar estrategias encaminadas a promover: a) la adecuada selección de semillas de calidad, b) un mejor manejo del suelo, c) el manejo de plagas y enfermedades con base en planes fitosanitarios que integren trampas de monitoreo, acciones preventivas, y restringir el uso de agroinsumos de síntesis química y d) promover el uso eficiente de los recursos hídricos a partir del fortalecimiento de redes participativas de monitoreo agroclimático.
Palabras clave: sostenibilidad; páramo; sistemas productivos; reconversión; servicios ecosistémicos; indicadores.

INTRODUCTION

The strategic ecosystem of the moorland and the impact of productive systems

The moorlands are strategic high mountain ecosystems in the humid tropics in Colombia, Venezuela, Ecuador and Costa Rica mainly (Rincón-Garavito, 2015), and to a lesser extent in Asia (Indonesia), Africa (Papua and New Guinea) and Oceania (Rincón-Garavito, 2015), located between 2,700 and 4,200 m.a.s.l., on the border between closed forest and perpetual snow, characterized by the presence of open vegetation, in which soil, climate, biota and man interact (Hofstede *et al*., 2014). The moorlands provide various ecosystem services, highlighting the maintenance, regulation, and provision of water (Estupiñán *et al*., 2009). These services are especially important in the Andes Mountain range, where 99% of the world's moorlands are located, which supply nearby cities with between 70 and 100% of the water (Rincón-Garavito, 2015). However, the moorlands face serious effects due to mining, agricultural and livestock production activities (Buitrago and Rodríguez-Aparicio, 2021), which have affected the delimitation processes of the moorlands, ignoring the strategic nature of this ecosystem. It is estimated that of the total moorland area in Colombia (2,857,281 ha), 48% has agricultural uses (Arévalo and Flórez, 2021).

The removal of the vegetal layer, and the work of preparing the land that are carried out in agricultural activities are the most harmful actions on the soils of the moor (Estupiñán *et al*., 2009; Hofstede, 2001), especially in potato cultivation, which reaches altitudes close to 4,000 m a.s.l. (Hurtado *et al.*, 2022; van der Hammen and Otero, 2007) and long onion (Rodríguez-Robayo *et al.*, 2021) in sub-moor areas, where these practices are recognized as unsustainable in the long term (Hurtado *et al.*, 2022). In addition to this, artisanal, informal mining with little state control leads to the generation of leachate, the discharge of effluents with heavy metals and the elimination of the A horizon of the soil, which affects the water sources for the lower communities of the basin (Buitrago and Rodríguez-Aparicio, 2021). On the other hand, the constant trampling of cattle compacts the soft and loose organic matter of the first soil horizon, reducing the pore space to accumulate water, taking away its retention and infiltration capacity, hindering the flow of nutrients to the plants (Estupiñán *et al.*, 2009). Added to this, livestock droppings contaminate water sources, and carbon and nitrogen balances, which affects the natural physicochemical characteristics of the soil (Estupiñán *et al.*, 2009). Additionally, these livestock and agricultural activities have extended the sowing of introduced grasses, converting the moor vegetation into pastures (van der Hammen and Otero, 2007).

The process of adopting reconversion strategies

The processes of productive reconversion (PR) are not new, neither in Colombia nor in the world; however, there is no process standard that establishes a successful pattern to follow. In Latin America, the first documented agro-industrial PR processes show a forced nature of reconversion due to the low profitability of agricultural businesses. Such were the cases of Argentina and Mexico, whose productive matrices underwent abrupt changes in the eighties due to changes in local consumption patterns resulting from globalization (Beccaria and Quintar, 1995). These economies, larger and exposed to international exchange, experienced PR processes even without a defined direction. The trend continued in smaller Latin American countries, where the effects of globalization reached economies with late local exchanges. An example of this, was the intensive process of agro-industrial PR on the border between Nicaragua and Costa Rica in the middle of the first decade of the 21st century, where the productive models of domestic economies of internal trade quickly and abruptly migrated to agro-industrial systems with international destinations (Granados, Brenes and Cubero, 2005). The forced productive change eliminated traditional crops, and forced the migration of entire communities that were not prepared for the change. This markedly disruptive nature of the process, both in its causes and in its progress, has led several authors and sectors to question whether the productive reconversion is a development or a setback (Caldera, Torres and González, 2016). On the other hand, the productive reconversion is related to a reconversion oriented by the environmental and climate crisis that the world is facing, in which it is highlighted as urgent to achieve sustainability in agricultural production, especially in strategic ecosystems. This view of reconversion, focused on sustainability, has its origins, since the nineties, in the promotion of good agricultural practices (GAP), defined as a set of principles applied to production and post-production processes in the farms, which result in safe, healthy products that contribute to sustainability (FAO, 2016). However, since then its success and adoption have been limited (Auriol and Schilizzi, 2015;

Franco-Martínez, 2019, Rodríguez-Robayo *et al.*, 2022b).

In Colombia, the regulations of the moorlands define productive reconversion as a management strategy for agricultural systems integrating and directing actions to make sustainable use of the soil and water, increasing its sustainability and competitiveness, as well as reducing conflicts of use through the creation of added value, agricultural diversification, land adaptation, technological changes, crop changes, among others (Resolution 128 of 2017; Resolution 886 of 2018; Law 1930 of 2018).

Advances in productive reconversion in moorland ecosystems in Colombia

The advances in agricultural productive reconversion go back, partially, to ten experiences implemented in the country since 2015 in some places where the conservation of natural resources is perceived as relevant.

In the period 2015 - 2021, from the environmental sector developed the project "Moorlands: Biodiversity and Water Resources in the Northern Andes", implemented in Colombia in five moors complexes: Santurbán - Berlín, Rabanal, Los Nevados, Las Hermosas, Ángel – Chiles – Quitasol. This project had the specific objective of "strengthening the capacity of communities and institutions involved in the management of moors to conserve biodiversity and regulate water resources" (Galvis and Ungar, 2021; IAvH, 2020).

From the agricultural sector, in 2021, has advanced productive reconversion projects in the Tota lake basin and in the Santurbán moor complex. The projects focused on the long onion (Allium fistolosum), potato (Solanum tuberosum), and livestock. Table 1 summarizes the main advances.

Productive reconversion as a strategy for managing socioecological conflicts in the moorland

The ecosystemic and economic importance of the moorland has favored the development of socioecological conflicts, understood as the manifestation of inequalities that are generated from the relationship between actors and ecosystem services (Martínez-Alier, 2004). Contributing to its management and resolution is a key element in the search for development (Barli *et al.*, 2006), and the balance between protection actions and sustainable use of resources (Rodríguez-Robayo *et al.*, 2021a).

The reconversion then emerges as a mixed strategy: environmental and productive; since the conservation of ecosystems and their services, the impact of productive systems on them and the need to maintain the livelihoods of the communities that inhabit the moors are of great importance. The promotion, implementation and follow-up of the reconversion requires the design of instruments that facilitate its adoption. However, in Colombia, although conservation and mixed instruments have regulatory advances, implementation experiences are limited and insufficient for their consolidation (Rodríguez-Robayo and Ávila-Foucat, 2014).

As Caldera, Torres and González (2016) point out, there are different perspectives of the conflicts that PR raises, where it is imperative to investigate what are the factors that favor and prevent PR in communities, especially before its imperative application. In this way, the present article has the objective of analyzing elements of the productive, socioeconomic, and environmental dimensions of the long onion and potato producers in the Tota-Bijagual-Mamapacha moorland, thus offering elements that allow identifying the possibilities of moving towards models more sustainable production.

MATERIALS AND METHODS

Study zone

The study area is the Tota lake basin, located in Boyacá, Colombia (Figure 1). The basin with 22,370 ha is characterized by having the largest freshwater in the country located at 3015 m a.s.l. This system represents about 14% of the nation's water reserve (Rodríguez-Robayo *et al.*, 2021).

In addition to its hydric importance, the Tota lake basin is a refuge for approximately 135 species of birds, offers scenic beauty thanks to the confluence of the moors, the lake, the beaches and islands and, additionally, it is a center of agricultural production: it produces between 60 and 80% of the long onion consumed in the country and close to 12% of the national trout production (Rodríguez-Robayo *et al.*, 2021).

However, in 2012 the basin was recognized as one of the most vulnerable wetlands in the world through the Gray Globe, of the World Wetland Network (Bermúdez-Urdaneta and Avci, 2015) due to inadequate management of water resources and the coverages, which include the moorlands ecosystem, agroecosystems of mixed crops and the onion monoculture (Pontificia Universidad Javeriana, 2005; Raymond, 1990). On the other hand, in 2018, the lake is considered the third most attractive green destination in America, in one of the most important tourism fairs in the world, the ITB Berlin (Jiménez, 2022).

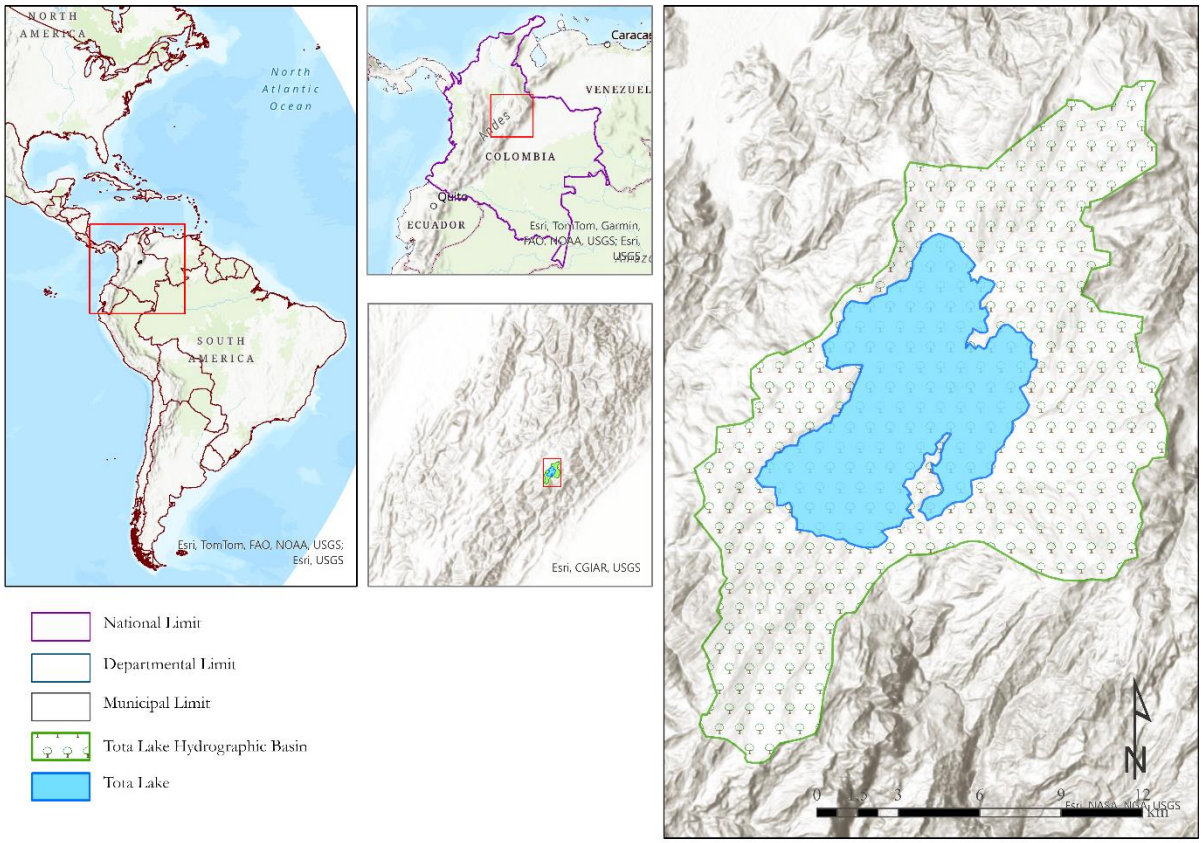

Figure 1. Location of the Tota lake basin. (Adapted from the branch onion (*Allium fistulosum* L.) participatory project in the Tota lake basin with permission from the author Diego Leonardo Cortés Delgadillo).

Variables of the environmental, socioeconomic, and productive dimensions in the Tota lake basin

During the period 2019-2022, the Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA) advanced in the productive reconversion of the long onion and potato systems (Rodríguez-Robayo *et al.*, 2021a; 2022b).

In the projects, various instruments were applied with the aim of characterizing mainly long onion and potato producers, considering the socioeconomic, environmental, and productive dimensions.

The instruments were two survey formats with semi-structured questions in the environmental, social, economic and productive dimensions in the Tota lake basin socio-ecosystem, which were applied in June-December 2020 and October-December 2021, following a non-probabilistic sampling by intention (Otzen and Manterola, 2017).

For the development of the article, the survey formats previously designed within the framework of the two phases of the reconversion project carried out by AGROSAVIA were analyzed, the central coincident variables were identified, and the databases were homogenized and integrated for 85 questions:

a) General information: date, name of the interviewer, community, trail, identification number and telephone number.
b) Socioeconomic dimension: number of household members, number of men and women, age and education, area and type of property ownership, most relevant economic activities, home garden and production of minor species, average monthly income, participation in organizations and home services.
c) Environmental dimension: perceptions of the moors and the lake in relation to changes in the last five years, benefits and associated ecosystem services, relationship between these resources and productive systems, actions for the protection of resources and knowledge of environmental regulations.
d) Agricultural productive dimension: motivations for cultivating, number of people in the household linked to agricultural activity, knowledge and implementation of good agricultural practices, seed origin, sowing, soil and fertilization, integrated management of pests and diseases, irrigation and drainage, harvest, post-harvest, and infrastructure.

Table 1. Main advances in productive reconversion in Colombia.

N°	Moorlands complex	Department	Institutions	Period	Production systems	Innovation theme or accompaniment
1	Santurban-Berlin	North of Santander	IAvH FAO Ministry of Agriculture	2015-2021	Long onion, potato, and dairy farming	Incorporation of productive reconversion criteria
2	Rabanal	Boyacá	IAvH Tropenbos-Foundation	2015-2021	Potato, Andean tubers, dairy farming	Sustainable management of systems, rescue of Andean tubers and local knowledge associated with biodiversity
3	Los Nevados	Caldas, Risaralda, Quindío, Tolima	IAvH	2015-2021	Livestock, potato	Sustainable management of production systems
4	Las Hermosas	Tolima, Valle, Cauca	IAvH	2015-2021	Dairy farming	Sustainable management of grasslands and establishment of live fences
5	Chiles-Quitasol	Nariño	IAvH	2015-2021	Potato and livestock	Sustainable management of potato cultivation and grasslands
6	Guerrero	Cundinamarca	Bio-Cuenca Foundation International Conservation	2015-2021	Vegetables and potatoes	Agroecological production of vegetables in high mountains, transformation, and commercialization (Páramo Farms)
7	Tota-Bijagual-Mamapacha	Boyacá	AGROSAVIA Patrimonio Natural French Development Agency Ministry of Environment	2019-2021	Long onion	Participatory environmental seals, good agricultural practices, efficient use of water
8	Tota-Bijagual-Mamapacha	Boyacá	AGROSAVIA CONDESAN Ministry of Environment	2021-2022	Long onion and potato	Participatory environmental seals, good agricultural practices, efficient use of water and participatory agroclimatic monitoring
9	Tota-Bijagual-Mamapacha	Boyacá	IDEAM MADR FAO	2022	Long onion	Incorporation of sustainable practices in the productive system
10	Las Hermosas Chili – Barragan Guanacas – Puracé Coconuco Chingaza	Valle del cauca, Nariño, Cauca, Cundinamarca	Ministry of Environment USAID Chemonics International	2022	Long onion, potato, livestock, vetch	Methodological proposal for the establishment of low-impact activities based on resilience indicators

Source: self-made.

The main variables are described below in Table 2.

Table 2. Variables selected for analysis.

Dimension		Variable	Description
Socioeconomic	**V1**	Scholarship	Number of years of formal education completed
	V2	Organization	Participation in agricultural and social organizations
	V3	Total area of the properties	Area in hectares of the properties managed by the producer
	V4	Economic activities	Perception of the activity that generates the highest income for the household
	V5	Average monthly income	Perception of the monthly income generated by the household, which includes all economic activities
	V6	Food safety	Households allocate an area on the land for agricultural production for self-consumption (home gardens and production of minor species).
Environmental	**V7**	Increase in the agricultural frontier	Perception of the increase in the agricultural frontier in the last five years in the Tota lake basin
	V8	Reduction of water resources	Perception of the reduction of water resources in the last five years for families and crops
	V9	Increase agro-inputs	Perception of the need to increase, in the last five years, the use of agro-inputs to maintain agricultural production
	V10	Ecosystem services	Recognition of the ecosystem services provided by Tota lake and the Tota-Bijagual-Mamapacha moorlands complex
	V11	Conservation areas	The household allocates part of a property for the conservation of natural resources
	V12	Knowledge of environmental regulations	The producer states that he is aware of the environmental regulations that govern the Tota lake basin
Productive	**V13**	Cultivated area	Area reported as cultivated under long onion or potato
	V14	Motivations to cultivate	The producer explains the reasons for engaging in agricultural production (tradition, lack of opportunities, profitability, taste, others)
	V15	Good farming practices	The producer states that he knows and implements good agricultural practices
	V16	Origin of the seed	The producer declares the origin of the seed used in the crop (farm, neighbors or friends, seed producer, supplier of certified seed).
	V17	Seed disinfection	The producer indicates to carry out the disinfection of the seed before sowing
	V18	Tillage	Type of tillage used for soil preparation (direct sowing, minimum, manual, animal traction, tractor)
	V19	Soil analysis	Use of soil analysis for the elaboration of fertilization plans in the last two years
	V20	Raw chicken manure	Use of raw chicken manure as organic fertilizer in onion and potato crops
	V21	Plagues and diseases	Report of the two most limiting pests and diseases mentioned by the surveyed producers for onion and potato crops
	V22	Pest or disease control decision	Reasons for selecting the time to control limiting pests or diseases (degree of crop affectation, preventively or by calendar, weather, technical assistant, recommendation of the commercial house)
	V23	Plague and illness management	Imported products for pest and disease management, along with the toxicological category
	V24	Irrigation	Criteria to apply irrigation (observation of plants, weather, shift assigned by the district)
	V25	Product quality	Aspects considered to define a good quality product (size, color and shape, taste, safety, performance)
	V26	Weather information	Climate information is used to make decisions about the crop, and its importance is valued

The values of the socioeconomic, environmental and productive variables, except V10, V12, and V15, correspond to a single perception response of the respondents. In the case of the exceptions, variables V10 and V12 of the environmental dimension, and V15 of the productive dimension, value scales with response options were established, as described in Rodríguez-Robayo *et al.* (2022).

In total, 172 surveys were registered (144 onion producers and 28 potato producers). The respondents are from three municipalities of Boyacá: Aquitania (47%), Tota (39%) and Cuítiva (14%).

RESULTS

Socioeconomic dimension

An average of four people live in the households surveyed, with one to two children, and parity in the average number of women and men. The average age of those surveyed is approximately 51 years, with an incomplete high school level (20%), complete high school (19%), and complete primary school (13%).

The average area of the properties is 2.2 ha. The activity declared as the most important in the area is onion cultivation (70%), followed by potato cultivation (17%) and livestock (5%).

The 53% of those surveyed state that they receive monthly income of less than US$ 266.7 (2021 dollars), 17% state that they receive between US$ 266.7 - 533.5 per month and 5% state that their monthly income ranges from between US$ 533.5 - 800.2. Potato growers state that they receive less monthly income than onion growers.
In relation to social organization, 45.4% state that they belong to some type of organization, among the most prominent are agricultural organizations, mainly onion, organizations around water resources called irrigation districts and community action boards.

Finally, when inquiring about home gardens and the raising of minor species, 22% of those surveyed stated that they had a home garden and 44.2% indicated that they raised backyard animals such as rabbits, chickens, sheep, or goats.

Environmental dimension

The 84% of those surveyed perceive that living near the moorlands or lake of Tota offers well-being to the family; 70% recognize that these ecosystems offer a beautiful landscape, symbols of cultural identity, spaces to strengthen physical, mental, and spiritual health, sources of oxygen and water for domestic use and crops.

On the other hand, the producers also widely recognize that, in the last five years, the agricultural frontier in the Tota lake basin has increased (66%), the water sources from which they are supplied have less water available for cultivation and the families (77%), and it has been necessary to increase the use of agricultural inputs to maintain agricultural production (73%).

Recognizing the relevance of the resources provided by the moor and the lake, 73% consider that they carry out some action for the protection of natural resources, 38% declare that they allocate land for conservation.

Finally, 81% state that they are unaware of the environmental regulations that describe the importance and restrictions on the use of the resources offered by the moorland and lake Tota.

Productive dimension

In this dimension, it is evident that the average cultivated area is 2.1 ha, the average area reported for onion cultivation is 1 ha ± 1.5 ha, and for potatoes, 2.6 ha ± 3 ha. The 66.3% point out that they own less than 2 ha of land.

Half of the surveyed producers state that they know good agricultural practices (GAP) and 34% say they implement them. When inquiring about the meaning and implications of GAP, the main responses highlight the lower use of agrochemicals, environmental protection, better crop management, and the health of agricultural products. The 86% say they are interested in implementing them.

Regarding the seed, 47% state that it comes from neighbors or friends, 37% from the same farm, and 6% from a seed producer. 60% indicate that they disinfect it prior to sowing.

In land preparation, the two most used methods are plowing with a tractor (41.3%) and animal traction (36.6%).

Regarding soil fertilization, 8.7% of those surveyed state that they do soil analysis. 73% of farmers say they apply chicken manure or poultry manure to the soil, 98% raw, and 2% processed. On average, per year, per hectare of onion planted, 74.5 tons of raw chicken manure are applied; and per hectare of potatoes planted 69 tons. These decisions on fertilization are made mainly from the experience of the producers (47%), orientation of the agricultural store (24%) and 14% indicate consulting a technical assistant.

Regarding pest and disease management, the main disease reported for long onions is mildew (*Peronospora destructor*) (31%), followed by the slug plague (Gastropoda class molluscs) (26%) and the yellow disease (*Alternaria porri* and other fungi) (26%). Powdery mildew occurs both in summer and winter, mainly from the third to fifth stage of the

crop. For its management, the producers state that they use Dimetomorph (toxicological category II), Propamocarb + Metalaxil (category III), Fenamidone + Propamocarb (category II), or Mandipropamid + Oxathiapiprolin (category I) every eight days. Secondly, Fitoraz Propineb + Cymoxanyl (category III), Tebuconazole + Trifloxystrobin (category III), Oxathiapiprolin (category IV), or Propineb (category III) are reported. The slug occurs both in summer and winter, with an increase in the latter season. It occurs at all stages of cultivation, due to excess moisture. Its management is mainly with chemicals such as Metaldehyde (category III), every 8, 15 or 30 days, and diatomaceous earth.

For potatoes, the main pest is the Guatemalan moth (*Tecia solanivora*) (50%), followed by gout (*Phytophthora infestans*) (18%). For the management of these pests and diseases, 54.7% of the producers indicate that they always apply the same mixture of products. The Guatemalan moth is a summer pest, which occurs mainly in the final stages of the crop. Its management is traditionally chemical. The agrochemicals that are used every 15 or 20 days are Permethrin (category III), Chlorpyriphos (category II), Bifenthrin + Zetacypermethrin (category II), Profenofos (category II), and Profenofos + Cypermethrin (category IB). On the other hand, gout, a disease mainly in winter, occurs mainly in the third stage of the crop due to variations in the climate. Its management is chemical, with Propineb + Cymoxanil (category III), Dimethomorph (category III), Fluopicolide + Propineb (category I), Mancozeb (category III), or Pyrimethanil (category IV).

In relation to the waste generated in the plots, 83% of the surveyed producers state that they do proper handling, triple washing, and perforation, of the containers used; On the other hand, 47% indicate that they incorporate the harvest residues into the lot, 39% remove them to one side of the lot, and 2% compost them.

Regarding irrigation, the main criterion for the application of irrigation referred to by those surveyed for both onion and potato is the observation of the crop plants (43%), followed by the weather (30%). Irrigation per assigned shift is only reported in the onion production system, where this application criterion is referred to by 22% of those surveyed in the system.

Although approximately 80% of all surveyed producers consider climate information important, only 33% state that they use it. In potatoes, 71% say they do not use it, and in onion, 63% say they do not use it.

For and against productive reconversion

Based on the results obtained for each of the dimensions. Next, Table 3 describes which variables are in favor or against productive reconversion in the Tota lake basin.

DISCUSSION

Pros: In favor of productive reconversion in the Tota lake basin

Of the 26 variables selected, 12 are in favor of reconversion: three socioeconomic, four environmental, and five productive. In the socioeconomic dimension, the following are identified: i) the level of education of the producers, evidencing that about 40% have completed and incomplete high school; this reflects that the levels of schooling have increased, since the 2005 census highlights that both in the department of Boyacá and in the community of Aquitania only 16% had basic secondary education (DANE, 2005). These results agree with the findings of Puentes-Puentes (2020), who found that the producers of Tota lake mostly have basic primary and even secondary education, but not the municipal residents, who reach up to 50% of higher education (from technical to postgraduate), product of the bonanza of the onion activity. The higher the level of schooling, the greater the capacities of households and the greater the commitment to engage in new productive activities (Ávila-Foucat and Rodríguez-Robayo, 2018; Mora Rivera and Cerón Monroy, 2015), as pointed out by Bermudez Londoño and Prada Florez (2021), who found that the higher the educational level there is a greater appreciation and knowledge of the conservation and protection of the environment.

ii) The organization of producers in the Tota lake basin is another variable that stands out today in favor of reconversion, although in the 1990s a reduced organizational capacity was highlighted (Raymond, 1990); the results show that 45% state that they are part of an organization, which highlights the possibilities of cooperating, reaching agreements and working collectively. Despite the multiple socio-environmental conflicts present in the basin, especially around water resources (Rodríguez-Robayo *et al.*, 2021b), the number of social organizations, productive, environmental and water use has increased. In agreement, there is ample evidence of the positive relationship between community organization and the proper management of natural resources (Rodríguez-Robayo and Merino-Pérez, 2017; Rodríguez-Robayo *et al.*, 2016; Bennett and Dearden, 2014; Bremer *et al.*, 2014; Bouma and Ansink, 2013).

Table 3. Summary of the results.

Dimension		Variable	For	Against
Socioeconomic	**V1**	Scholarship. Complete and incomplete high school	39%	
	V2	Being part of a social or productive organization	45%	
	V3	Total area of the properties	2.2 ha	
	V4	Onion production as the most important economic activity		70%
	V5	Average monthly income less than or equal to one million pesos		53%
	V6	The home has a home garden		22%
Environmental	**V7**	Perception of the increase in the agricultural frontier in the last five years	66%	
	V8	Perception of the lower availability of water resources in the last five years	77%	
	V9	Perception of the increase in the use of agro-inputs to maintain production		73%
	V10	Recognition of ecosystem services	70%	
	V11	Manifests carrying out conservation actions	73%	
	V12	Declares knowledge of environmental regulations		19%
Productive	**V13**	Cultivated area < 2ha	66%	
	V14	Profitability as the main motivation to cultivate		39%
	V15	Declares knowledge of GAP	50%	
	V16	The seed comes directly from local seed growers		6%
	V17	Perform seed disinfection	60%	
	V18	Carry out tillage with tractor		41%
	V19	Use of soil analysis		9%
	V20	Use of chicken manure and raw chicken manure as fertilizer		98%
	V21a	Main onion pest: slug	26%	
	V21b	Main onion disease: powdery mildew		31%
	V21c	Main potato pest: Guatemalan moth		50%
	V21d	Main potato disease: gout		18%
	V22	Decision to apply agro-inputs preventively or periodically to control disease or limiting pests		49%
	V23	Use of agro-inputs of toxicological category I and II (extremely dangerous)		25%
	V24	The main criterion for applying irrigation is the observation of the plants		43%
	V25	The size of the product as a determinant of quality		46%
	V26	Recognizes the importance of climate information	80%	
		Total number of variables	12	15

iii) The total area of the properties, close to 2 ha, is a variable that can be considered in favor of conversion, since the condition of small producers favors the change to diversification and new forms of production. In agreement, Navarrete (2015) points out that the greater the amount of land, the less interest in diversifying into sustainable activities.

In the environmental dimension, there are four variables that highlight the perceptions of those surveyed and that coincide with national figures such as iv) the increase in the agricultural frontier, v) less availability of water resources, vi) the recognition of the ecosystem services provided by the territory and vii) the implementation of conservation actions in the territory. These perceptions with percentages higher than 65% in the four variables reflect that the producers are aware of the importance of the ecosystems of the basin, as well as the affectation and impact that the productive systems have on natural resources, particularly the long onion; which allows inferring a greater willingness to change and productive reconversion, as long as this process is accompanied by the entities of the Ministries of Environment and of Agriculture, as established by Law 1930 of 2018.

These results agree with what was stated by Moreno *et al.* (2020) and the Rural Agricultural Planning Unit - UPRA (2018; 2021) who show the change in vegetation cover mainly due to agricultural uses, for the country and for the basin. Likewise, Corpoboyacá – Pontificia Universidad Javeriana (PUJ) (2005), the project Adaptation to the Impacts of Climate Change on Water Resources in the Andes (AICCA) (2020) and the Food and Agriculture Organization of the United Nations (FAO) (2021) affirm that the affectation in quantity and quality of the water resource is the result of inefficient use in agricultural work and contamination due to the intensive use of synthetic inputs. Chemical and organic matter (chicken manure) without

composting. These elements highlight the urgency and importance of updating and implementing territorial planning instruments and environmental determinants.

Regarding conservation actions, it is important to analyze in detail what producers understand as conservation actions, since the basin has multiple connectivity problems between the remnants of natural ecosystems, and the protection of springs and water rounds is deficient (Corpoboyacá - PUJ, 2005; AICCA, 2020). The most frequent conservation action is associated with planting trees, this highlights the importance of reflecting on quantities, species, and patterns in these reforestation processes; since it is clear the need to incorporate landscape management tools, ecological restoration actions and diversification of productive activities with a prospective vision of the territory (MADS *et al.*, 2022).

The five variables in favor of reconversion in the productive dimension are:

viii) The cultivated area both general average (2.10 ha) and by crop (1 ha for onion and 2.6 ha for potatoes) corresponds to smallholdings of traditionally managed family farming that have gradually incorporated technification processes. This tendency towards smallholdings, which is a constant for countries such as Peru, Ecuador, Mexico, Nicaragua, El Salvador, Brazil and Bolivia (Namdar-Irani *et al.*, 2020, Salcedo and Guzmán, 2014), has led to the fact that in countries that present the phenomenon, linked to family farming, prevail in the design of policies for this productive sector, especially those of promotion, replacement of bad agricultural practices, and reconversion (Namdar-Irani *et al.*, 2020, Salcedo and Guzmán, 2014). In Colombia, where the smallholding is the majority for these crops (DANE, 2016), the productive reconversion policies concern small agricultural production units settled in moorland ecosystems.

ix) On the other hand, there is a growing knowledge and implementation of GAP in the Tota lake basin, especially among long onion producers. Its acceptance and use contribute to improving production conditions. However, as Rodríguez-Robayo et al (2022b) state, they are not a guarantee of sustainability, and their implementation, although it is an important step, is not the end of a process towards sustainability, but depends on the joint action of many more variables.

x) One of these variables is the disinfection of the seed, which allows to alleviate the uncertainty of a provenance free of pests and diseases in favor of the establishment of a healthy crop and with a homogeneous phytosanitary management (Segura *et al.*, 2015). Most of the onion and potato producers state that they disinfect the material prior to planting, with bactericidal and fungicidal products mainly based on iodine and sulfur, in accordance with the recommendations of Huertas-Carranza *et al*. (2020).

xi) The slug is reported among the main pests of onion and vegetable crops (Sánchez *et al.*, 2012), whose management in the region by producers is currently conditioned to the use of agroecological practices, due to that agrochemicals such as Methiocard and Metaldehyde-based molluscicides have been banned in the country. Thus, the impact of these on other organisms of the agroecosystem such as mammals, birds and insects that play the role of natural controllers of this pest, has been reduced. The practices currently implemented include the establishment of pitfall traps, the use of diatomaceous earth, the use of inputs based on wormwood, manual collection and destruction, baits based on astromelia buds, moistened sisal sacks, application of wood ashes, use of agricultural lime or dolomite, application of mineral salts and proper management of irrigation and drainage.

xii) The last variable in favor of the reconversion is the wide recognition of the importance of climatic information in crop management. Most producers (80%) consider climate information important to bring their production to a successful conclusion. Barrientos *et al.* (2009) point out that climate change has affected onion crops, mainly in the increase of pests and diseases and in the increase in irrigation needs. In this regard, Altieri and Nichols (2008) indicate that farmers adapt and even prepare for climate change, minimizing losses by recording and analyzing climate information to support decision-making. In this way, just as a producer learns and prepares for the impacts of climate change, he can learn and prepare for productive reconversion.

Cons: Against the productive reconversion in the Tota lake basin

Of the 26 selected variables, 15 are against conversion: three socioeconomic, two environmental, and nine productive.

In the socioeconomic dimension are: i) that onion cultivation is the main activity for 70% of the producers, indicating the strong perception of the profitability of the system and the fear of venturing into new productive activities. These results are associated with the fact that the basin provides between 60 and 80% of the long onion produced in the country (DNP, 2014; AGRONET, 2020) and although the livelihood has been introduced, there is roots for more than 90 years in the development of this activity (Rodríguez-Robayo *et al.*, 2021).

ii) Additionally, half of the producers stated that they received an average monthly income less than or equal to a minimum wage (US$ 266.7), which, in line with the previous variable, may reflect fear of changing their activity, since there is evidence that higher income levels are associated with better

results from the implementation of environmental programs (Jones *et al.*, 2012; Neitzel et al., 2014). According to Rodríguez-Robayo *et al.* (2022a) one of the main impacts of onion cultivation in the region was the displacement of traditional crops such as potatoes, which represents only 20% of the profitability compared to onion cultivation.

iii) Only a quarter of the producers stated that they had a home garden or set aside a space on their property to produce food for the home, crops that are characterized by the absence of applications of chemical synthesis agro-inputs. This reduced percentage reflects the lack of interest in the consumption of safe food at home, the strong dependence on the consumption of food bought in supermarkets, and that the family effort is concentrated in production mainly associated with monoculture.

From the environmental dimension, the following stand out:

iv) The strong perception of the need to increase the use of agro-inputs to maintain crop production, a variable that is associated with the reduction of agrobiodiversity in the region, and the impact on the resilience of productive systems, making them increasingly more susceptible to pests and diseases, which in turn translates into a greater use of inputs with little effectiveness or with undesirable side effects (Rodríguez-Robayo *et al.*, 2021; Altieri and Rosset, 2018; Rodríguez-Robayo *et al.*, 2022). According to CELIA (2020), the effectiveness of pesticides is less than 1%, which has implications for production costs and the health of ecosystems, by generating resistance from populations of unwanted organisms, in addition to collateral damage on natural resources.

v) The widespread ignorance of environmental regulations is a huge intersectoral challenge and even more so its implementation, which is why socioecological conflicts are increasing more and more (Rodriguez-Robayo *et al.*, 2021) and highlight the urgent need to implement environmental practices low environmental impact that enables productive reconversion. This lack of regulatory clarity is a common fact among producers and institutions, due to the multilevel disarticulation in intersectoral and territorial terms, which makes it difficult to implement productive reconversion actions, and favors the affectation of ecosystems.

In the productive dimension, the greatest number of variables against reconversion is identified:

vi) First, there is the paradigm of monetary profitability as a decisive factor in the selection of monoculture. The very high profitability of the onion and potato monoculture, which Rodríguez-Robayo *et al.* (2022b) place at 15,032 and 2,930 US$/ha, respectively, against other alternatives such as the cultivation of native tubers. It is important to consider in the analysis of costs and benefits the environmental impact of production systems associated with ecological disturbance, and the contamination of soil and water resources.

vii) Secondly, at the moment of beginning the productive activity, the seed or plant material is a key element for the success of the crop and for the incidence of pests and diseases; therefore, the acquisition of the best quality seed, from vigorous parents, free of pests and diseases, is an imperative (Segura *et al.*, 2015). The seed of both onion and potato is usually clonal (asexual), and to ensure that it meets the required conditions, it is necessary to go beyond the knowledge of its origin, reaching the standard of obtaining it. In this sense, the seed from neighbors or friends, or from the farm itself, must follow protocols that guarantee the quality of the planting material; Likewise, in the basin there are producers who, although they are not certified, are characterized by the production of quality seed, with good agricultural practices for more than 10 years.

viii), ix) and x) Three variables associated with the edaphic component stand out against reconversion: (1) plowing, which is mainly carried out with a tractor and which has been documented as detrimental to physical (rupture of the porous soil structure) and biological fertility of the soil (exposure of the sublayers to oxidizing environments, which mineralizes the organic matter, and of the photosensitive edaphic microbiota) (Labrador, 2002), and whose counterpart is the minimum or zero tillage, with better results on the properties of the soil at long term (Resquin *et al.*, 2010); (2) the reduced use of soil analysis, the lack of which prevents a directed, conscious and planned fertilization that integrates useful elements to the requirements of the crop and the soil; and (3) poor fertilization, which again due to a bad practice, seeks to be ensured with the inadequate and exacerbated use of organic matter without proper processing, such as poultry feces known as raw chicken manure (Rodríguez-Robayo *et al.*, 2022). In this way, the variable use of chicken manure and raw poultry manure as fertilizer is considered against the productive reconversion where it is shown that 98% of the producers make use of this input to carry out the fertilization practice, in this regard Campos (2014) indicates that the producers consider that, in order to obtain a greater productivity of onion, the use and application of raw chicken manure has become necessary, which has led to its inappropriate and indiscriminate use. Likewise, Gutiérrez (2020) indicates that because onion production around Tota lake is increasingly high, producers have increased and intensified the use of this fertilizer, becoming an essential input to produce the vegetable.

xi), xii) and xiii) The management of pests and diseases of productive systems includes three elements. On the one hand, the presence of diseases

such as powdery mildew (*Peronospora destructor)* and the complex bacteria (*Pseudomona sp*.) nematode (*Ditylenchus dipsaci*) in onion distributed in cultivation areas surrounding Tota lake, causing losses of over 50%; as well as the Guatemalan moth (*Tecia solanivora*) and late blight (*Phytophthora infestans*) on potatoes; phytosanitary disturbances that are limiting and require the use of agro-inputs such as Methiocard, Metaldehyde, Mancozeb, Fluazinam, Propineb, Chlorothalonil, Mandipropamide, Cymoxanil, Fluopicolide, Dimethomorph, Propamocarb, Metalaxil, Benalaxil, Fluopicolide, Dimethomorph, Cyazofamid and Fluazinam which are of chemical synthesis and present negative impacts such as the immediate contamination of the abiotic environment such as air, soil, surface and groundwater, also affecting different species of insects that play the role of natural enemies of pests or that are considered beneficial for the agroecosystem (ICA , 2012).
In line, it is highlighted that the decision to apply agro-inputs is carried out mainly preventively and periodically, where 54% of the producers always apply the same mix of products. According to Segura *et al.*, (2015) this can be dangerous because it contributes to the increase in resistance to these substances by some pathogens, the contamination of soil, water and food resources that have turned out to be a threat to health, since these substances they can be absorbed by the human body through different routes.

Finally, it is noteworthy that the use of toxicological category I and II agro-inputs persist, which are extremely dangerous and shocking. One in four products used is highly toxic (32/127). At this point it is important to mention that the toxicological classification of the products varies in the different countries of the world, the active ingredients most reported by the producers are highlighted in table 4.

Because pesticides are substances with great toxic potential, worldwide there are entities that regulate their registration, commercialization and use in different countries. Each country adapts the regulations generated worldwide and establishes the policies and requirements for registration, approval, use and restriction of new molecules year after year.

Countries like the United States are increasingly strict in approving the registration of new molecules for use as pesticides for agricultural use; however, in contrast, countries like Brazil have been registering new pesticide products, making it a paradise for pesticides where molecules that have been prohibited in other countries can be freely marketed, this type of behavior at the level of government policies goes against the productive reconversion since it opens the doors for the large international agrochemical companies to be able to commercialize in large quantities these chemical molecules that are being prohibited or they have already been vetoed in other countries, resulting in effects on human health and the environment.

xiv) Irrigation is a variable that also needs to be strengthened. Most producers (81%) report having a sprinkler irrigation system and of these, 72% belong to an organized irrigation district. However, when inquired about the criteria that producers consider for the application of water resources to their crops, less than half emphasized the observation of the state of the plants, followed by the observation of climatic conditions. It is important that these percentages increase and that, at the same time, the percentage of producers that irrigate according to the assigned irrigation shift is zero. It is relevant to reflect on the importance, in the Tota lake basin, of having agronomic and hydraulic designs and localized irrigation options that reduce the amount of water

Table 4. Comparison of toxicological category in 5 countries of the Americas.

Active ingredient	Toxicological category			
	Colombia	Mexico	Brazil	Unites States
Thiamethoxam+ Lambda-cyhalothrin	II- Highly toxic	4- Caution	4 – Little toxic product	I- Hazard
Cypermethrin+profenofos	IB- Extremely toxic	-	-	II- Warning
Chlorpyrifos	-	3- Hazard	-	-
Methamidophos	IB- Extremely toxic	I- Hazard	-	-
Permethrin	III Moderately toxic	3- Hazard	-	-
Dimethomorph	II Highly toxic	4- Caution	5 - Product unlikely to cause harm	II- Warning
Propineb	III Moderately toxic	4- Caution	5 - Product unlikely to cause harm	III- Caution

-: its commercialization in the country is prohibited.

used in crops by up to 30% (FAO, 2018); these systems accompanied by the monitoring of the plant and the climate, would promote the efficient use of the resource.

xv) Among the main determinants of the quality of the final product is the size of the product, more than 50% of the producers agree on the relevance of this variable for both potato and onion crops. For onion, the Colombian Technical Standard - NTC 1222 classifies it as extra, long a, long b and current; Regarding the potato, NTC 341 classifies it according to its size as very large (zero), large (thick), medium (couple) and small (riche). However, according to Arispe and Tapia. (2007), more than size is safety, one of the most relevant variables to consider in product quality, safety is essential in public health; Henceforth, the importance of aligning quality standards, guiding consumers in this regard and consolidating markets that, more than size, recognize the value associated with the safety of products, is highlighted.

CONCLUSIONS

It is worth highlighting the progress that exists in the region in terms of the elderly: levels of schooling, social organization, and environmental awareness by recognizing the various ecosystem services offered by the territory, as well as the growing scarcity of water resources and the increase in actions of conservation associated with reforestation. Likewise, there is wide recognition of good agricultural practices, and of important practices such as seed disinfection.

However, challenges are identified, mainly from the productive dimension, in which strategies are consolidated aimed at promoting: a) the adequate selection of quality seed, b) better soil management in which minimum tillage or farm animal traction is privileged, as well as the development of fertilization plans based on soil analysis, which guide the way in which the excessive use of raw chicken manure is discouraged, c) the management of pests and diseases based on phytosanitary plans that integrate monitoring traps, preventive actions, and restrict the use of agro-inputs of chemical synthesis of toxicological categories I and II, under international standards and d) promote the efficient use of water resources based on the strengthening of participatory agroclimatic monitoring networks, the collaborative work to improve irrigation on the properties.

Finally, the last challenge is associated with the analysis and consolidation of markets for differentiated products, in which it is possible to educate consumers and producers, clarifying that the best quality onion and potato, is the one that it is innocuous and that it has been produced under alternative models to the conventional one, contrary to the reality in which only thickness and color are privileged.

Thus, the challenges of productive reconversion at the local and national level transcend the technical scenario to challenges of intersectoral articulation, regulatory harmonization, compliance with court rulings, development of impact identification methodologies and implementation strategies of productive reconversion with a holistic and systemic approach to find specific solutions to the various types of moorland farmer. Both this analysis and the application of methodologies for determining the impact of productive activities in moorlands contribute to implementing agri-food systems with a strong component of sustainability, security and food and nutrition sovereignty of all people without jeopardizing their economic, social, and environmental foundations or those of future generations.

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