UNIVERSIDAD POLITÉCNICA DE MADRID

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA AGRONÓMICA, ALIMENTARIA Y DE BIOSISTEMAS

Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales

Assessment of farmers' perceptions of the sustainable agricultural practices in the "Biocorridors for Living Well" program in Ecuador: Pisque Mojanda San Pablo and Cayambe Coca

Tesis Doctoral

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Tesis Doctoral

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Madrid 2021

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EL PRESIDENTE   LOS VOCALES

EL SECRETARIO

A Dios

A mi Familia, amigas y amigos

Acknowledgment

May each sunrise be the beginning to grow strong

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Agradecimientos

Que cada amanecer sea el comienzo para crecer con fuerza

Summary

Smallholder farmers play an essential role in the rural sector, the conservation of the environment, and the well-being of local territories in developing countries like Ecuador. However, climate change and structural socioeconomic problems characterized by a weak educational, health, road, and labor system have been affecting their livelihoods and their vulnerability to extreme weather events such as droughts, floods, frosts, among others. In Ecuador, public agencies and non-governmental organizations have carried out various programs and projects aimed at conserving soils and ecosystems, recovering native species, and promoting sustainable production in the hands of small farmers. In general, these actions have focused on generating environmental benefits in the territories and improving the quality of life of their inhabitants by promoting sustainable agricultural practices (SAPSs) as a crucial strategy to enhance adaptation and mitigation capacities in the face of climate change, and at the same time, improve the quality of life of smallholder farmers.

Despite the critical contributions of the government and international organizations for the incorporation of capacities in farmers, the adoption of SAPs continues to be a national challenge, and the studies addressing this issue are still limited. In this sense, the programs and projects focused on territorial rural development, such as the "Biocorridors for Living Well" program-BLW, continue to build technical capacities to improve environmental conservation and promote sustainable local economic growth. In the framework of BLW program, the objective of this thesis is to assess smallholder farmers perceptions, attitudes and actions towards the adoption of SAPs in Ecuador. To this sense, this research the following specific objectives are established: (i) to provide an empirical-based community-level analyses of the smallholder farmers' perceptions on the BFL program in comparison to the project managers perspectives, (ii) examine farmers' perceptions of the main environmental problems that affect their territory, contrasting them with climatic parameters and land use and land cover change, and (iii) to identify and asses the factors that determine farmers' adoption of SAPs. The scale of analysis of this research includes two bio-corridors of the BLW program: Pisque Mojanda San Pablo and Cayambe Coca.

In order to achieve these objectives, a methodological framework is carried out considering a combined approach, which is based on fuzzy cognitive maps and hierarchical cluster analysis to capture and analyze the perceptions of farmers, as well as decision-makers of the territories on the

conservation of the ecosystem. Second, farmers' perceptions of environmental issues are analyzed and compared with climatic stressors. This research also includes an analysis of land-use changes. Subsequently, an exploration of factors that influence the adoption of SAPs by farmers is carried out, performing an econometric analysis based on discrete choice models, for which four probit models are proposed. Thus, the methodological framework integrates qualitative and quantitative methods developed through participatory approaches. The research includes field work on the two intervention sites, where discussion groups were carried out, and 82 farmers were surveyed with the support of students from the National Polytechnic School in Ecuador. This information is complemented with geographic and meteorological data.

The study's main conclusions of the BFW program perceptions show that the program managers have a narrow perspective focused on the intervention measures. On the other hand, farmers' perceptions reveal a more complex system, highlighting the importance of developing capacities beyond technical sustainable agriculture. While the program managers highlight the contribution generated from the conservation of ecosystems to rural development, the farmers emphasize that their contribution and efforts to care for the environment have not been usually valued. Moreover, the analysis of farmers perceptions about the environmental issues reveals that farmers are concerned about the low fertility of the soil, and the contamination of the water in their local communities. Here, smallholders have identified the existence of external agents, such as intensive flower business, which are outside the program and generate negative environmental externalities at the territorial level. However, although farmers are worried about the soil, the analysis of land use and cover change shows that the agricultural frontier is continuously advancing in the study territories, which means that deforestation continue due to agricultural intensification where not only smallholders are involved in this trend. In fact, agriculture hold by big enterprises are involved in the advance of an intensive agriculture based on a highly capitalized model. Despite studies alert on the advance of climate change consequences in the territories, farmers did not highlight drought as a substantial concern, which is consistent with the analysis of climatic parameters where there is little variation in rainfall pattern. Additionally, this research reveals that the main determinant factors to adopt SAPs are education, local marketing channels and value-added processes. It is worth mentioning that the results highlight a significative negative effect on the involvement of women in agroforestry practices, which means that it is needed to influence in the adoption of this SAP, where women may constitute a change agent in the processes of biodiversity

conservation in agricultural systems. Factors as relationships of trust between local actors like institutions who promote agroecological fair should be strengthened to achieve a better impact on the territories. Moreover, the use of TICs in the agriculture such as WhatsApp should be monitored since our results show that farmers who use this social media show a lower probability to adopt SAPs, which could be related to their involvement in actions of intensive agriculture. Regarding the age, it is noted that older farmers are willing to continue adopting traditional practices as crop rotation. Finally, environmental concern and awareness is a relevant factor to support the adoption of SAPs from farmers.

As a result of this research, it is proposed that to improve the program's results, national and international institutions need to consider farmers' perceptions in their ecosystem conservation programs to guarantee the sustainability of actions in their local territories. Additionally, the introduction for the training of farmers in modern agricultural systems must be based on local knowledge of them. Finally, the strengthening of relationships of trust between local actors should be considered to support the management of SAPs within the communities.

Resumen

Los pequeños agricultores juegan un papel esencial en el sector rural, la conservación del medio ambiente y el bienestar de los territorios en países en desarrollo como Ecuador. Sin embargo, el cambio climático y los problemas socioeconómicos estructurales caracterizados por un débil sistema educativo, sanitario, vial y laboral han venido afectando sus medios de vida, y su vulnerabilidad frente a eventos climáticos extremos como sequías, inundaciones, heladas, entre otros. En Ecuador, organismos públicos y organizaciones no gubernamentales han llevado a cabo varios programas y proyectos dirigidos a la conservación de suelos y ecosistemas, a la recuperación de especies nativas, y al impulso de una producción sostenible en manos de pequeños agricultores. De manera general, estas acciones se han enfocado a generar beneficios ambientales en los territorios y a mejorar la calidad de vida de sus habitantes promoviendo la adopción de prácticas agrícolas sostenibles (SAPs en inglés) como una estrategia crucial para instalar capacidades de adaptación y mitigación frente al cambio climático y, al mismo tiempo, mejorar la calidad de vida de los pequeños agricultores.

A pesar de las importantes contribuciones gubernamentales como de organismos internacionales para la incorporación de capacidades en los agricultores, la adopción de SAPs continúa siendo un reto de dimensión nacional y las investigaciones siguen siendo limitadas. En este sentido, los programas y proyectos enfocados en el desarrollo rural territorial, como es el caso de los "Biocorredores para el Buen Vivir" – BFW en inglés, continúan construyendo capacidades técnicas dirigidas al cuidado del medio ambiente y al crecimiento económico local sostenible. El objetivo general de esta tesis es evaluar las percepciones, actitudes y acciones de los pequeños agricultores hacia la adopción de SAPs en el programa BLW en Ecuador. En este sentido, en esta investigación se establecen los siguientes objetivos específicos: (i) proporcionar un análisis a nivel comunitario con base empírica de las percepciones de los pequeños agricultores sobre el programa BFW en comparación con las perspectivas de los administradores del proyecto, (ii) examinar las percepciones de los agricultores sobre los principales problemas ambientales que afectan a su territorio, contrastándolos con los parámetros climáticos y el cambio de uso y cobertura del suelo, e (iii) identificar y evaluar los factores que determinan la adopción de los PAE por parte de los agricultores. La escala de análisis de esta investigación abarca dos biocorredores del programa BLW: Pisque Mojanda San Pablo y Cayambe Coca.

Con el fin de conseguir el objetivo mencionado, se lleva a cabo un marco metodológico considerando un enfoque combinado, el cual se basa en mapas cognitivos difusos y el análisis de conglomerados jerárquicos para capturar y analizar las percepciones de agricultores, así como de tomadores de decisión de los territorios sobre la conservación del ecosistema. En segundo lugar, se analizan las percepciones de los agricultores sobre los problemas relacionados con el medio ambiente, y se comparan con factores climáticos. Esta investigación también incluye un análisis de cambios de usos del suelo. Posteriormente, se lleva a cabo la exploración de los factores que inciden en la adopción de SAPs por parte de los agricultores, realizando análisis econométrico basado en modelos de elección discreta, para lo cual se plantean cuatro modelos probit. Así, el marco metodológico integra métodos cualitativos y cuantitativos, desarrollados a través de enfoques participativos. La investigación incluye información de campo de los beneficiarios de los dos sitios de intervención donde se desarrollaron grupos de discusión y se encuestaron a 82 agricultores, y para ello se contó con el apoyo de estudiantes de la Escuela Politécnica Nacional en Ecuador. Esta información se complementa con datos geográficos y meteorológicos.

Las principales conclusiones del estudio sobre las percepciones del programa BFW muestran que los gestores del programa BFW tienen un enfoque limitado y focalizado en las medidas de la intervención. Por otro lado, las percepciones de los agricultores revelan un sistema más complejo, destacando la importancia de desarrollar capacidades más allá de las técnicas agrícolas sostenibles. Mientras los gestores del programa resaltan el aporte generado desde la conservación de los ecosistemas al desarrollo rural, los agricultores enfatizan que su contribución y esfuerzos dirigidos al cuidado del medio ambiente no han sido la mayoría de las veces valorados. Además, el análisis de las percepciones de los agricultores sobre los problemas ambientales revela que los agricultores están preocupados por la baja fertilidad del suelo y la contaminación del agua en sus comunidades locales. Aquí los agricultores han identificado la existencia de agentes externos, como las empresas florícolas, que son ajenos al programa y generan externalidades ambientales negativas a nivel de los territorios. Sin embargo, aunque los agricultores están preocupados por el suelo, el análisis de usos del suelo y cambio de cobertura muestra que la frontera agrícola avanza continuamente en los territorios de estudio, lo que significa que la deforestación continua por intensificación agrícola para estas áreas, donde no solo los agricultores están involucrados en estas actividades. De hecho, la agricultura en manos de las grandes empresas participa de una agricultura intensiva, la cual está claramente marcada desde una visión de capital. Por otro lado, a pesar de los estudios que alertan

sobre el avance del cambio climático en los territorios, los agricultores no destacaron la sequía como una preocupación sustancial, lo que se justifica con el análisis de los factores estresantes climáticos recientes, donde no hay variación en el patrón de lluvia. Adicionalmente, esta investigación revela que los principales factores determinantes para adoptar SAP son la educación, los canales locales de comercialización y procesos de valor agregado. Cabe mencionar que los resultados resaltaron una falta de voluntad por parte de la mujer en adoptar prácticas agroforestales por lo que es necesario incidir en la aplicación de estas prácticas en campo, donde la mujer se podría constituir en agente de cambio sobre los procesos de conservación de la biodiversidad de los sistemas agrícolas. Factores como relaciones de confianza entre actores locales como instituciones que promueven la feria agroecológica deben fortalecerse para lograr un mejor impacto en los territorios. Por otra parte, el uso de TIC en la agricultura como WhatsApp debe ser monitoreado debido a que los resultados muestran que los agricultores que poseen esta red social muestran una menor probabilidad de adoptar SAP, lo que podría estar relacionado con acciones de agricultura intensiva. En cuanto a la edad, se observa que los agricultores mayores están dispuestos a seguir adoptando prácticas tradicionales como la rotación de cultivos. Finalmente, la preocupación y la conciencia ambiental es un factor relevante para apoyar la adopción de SAPs por parte de los agricultores.

Como resultado de esta investigación, se propone que, para mejorar los resultados del programa, las instituciones nacionales e internacionales requieren considerar en sus programas de conservación de ecosistemas las percepciones de los agricultores para garantizar la sostenibilidad de las acciones en sus territorios locales. Adicionalmente, la introducción para la formación de los agricultores en sistemas agrícolas modernos debe estar basada en el conocimiento local de los mismos. Finalmente, se debe considerar el fortalecimiento de las relaciones de confianza entre los actores locales para respaldar la gestión de SAPs dentro de las comunidades.

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Acronyms

ANOVA	A one-way analysis of variance
BLW	Biocorridors for Living Well
CaCo	Cayambe Coca
CEIGRAM	Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales
CEPAL	Comisión Económica para América Latina y el Caribe
CO2	carbon dioxide
ECOPAR	Corporation of Research, Training and Technical Support for the Sustainable Management of the Tropic Ecosystems
EQUIPATE	Technical Support, Evaluation and Monitoring Team at the territorial level
EQUIPATEN	Technical Support, Evaluation and Monitoring Team
FAO	Food and Agriculture Organization
FCMs	Fuzzy Cognitive Maps
FO5	Fifth Operational Phase
GDP	Gross Domestic Product
GHGs	Global GreenHouses
HCA	Hierarchical Cluster Analysis
LORSA	Ley Orgánica del Régimen de la Soberanía Alimentaria
LULCC	Land Use and Land Cover Change-
MAE	Ministry of Environment of Ecuador
NGO	Non-governmental Organization
NRM	Natural Resources Management
PiMoSaPa	Pisque Mojanda San Pablo
SA	Sustainable Agriculture
SAPs	Sustainable Agricultural Practices
SDG	Sustainable Development Goal
SEAE	Sociedad Española de Agroecología

SGP	Small Grants Program
UNDP	United Nations Development Programme
UNFCC	United National Framework Convention on Climate Change
UPM	Universidad Politécnica de Madrid
WFP	World Food Program

1. Introduction

1.1. Research context

This doctoral research was conducted within the Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM in Spanish) at the Universidad Politécnica de Madrid (UPM) over the period 2016-2020. The work was funded and developed within the framework of two national projects in coordination with the Corporation for Research, Training and Technical Support for the Sustainable Management of the Tropic Ecosystems (ECOPAR in Spanish), Escuela Politécnica Nacional University, and agricultural organizations.

- "Social capital in the conservation of biodiversity, climate change and poverty reduction in the rural zones: Case study of Cayambe-Coca, Pisque Mojanda San Pablo and Cotacachi Cayapas Bio corridors in Ecuador" was a project funded by the National Geographic Society during the period 2017-2020 to analyze farmers' perceptions regarding environmental conservation and climate change in the adoption of sustainable agricultural practices, considering the role of social capital and the level of household poverty. The project established a multidisciplinary approach, where experts and researchers from different fields took part in the process. For instance, agronomists, economists, mathematicians, and geographers, as well as key actors took part in this project to design different strategies in the rural development framework.

- "Biocorridors for Living Well" is a national linking project funded by Escuela Politécnica Nacional during the period 2018-2019. The project aim was to establish suitable methodologies for field data collection and support the data collection process through students' participation. In particular, the project attempts to involve young students to introduce them to the reality of the Ecuadorian rural context as well as to improve the understanding of quantitative and qualitative methods of data collection.

In order to strengthen the knowledge related to environmental management, a six-month research stay was undertaken at the Centre for International Postgraduate Studies of Environmental Management, Dresden, Germany as part of the Natural Resource Management for Developing Countries Postgraduate Course, from January 8th to July 13th 2020. As a result of this stay, I have

written a collaborative paper supervised by Jürgen Prestchz. This stay was funded under the CIPSEM fellowship.

1.2.   Problem description

Smallholder farmers in developing countries are vital for agriculture, rural economy, and worlds food production. They supply up to 50% of the world cereal, 60% of the world's meat and 75% of the world's dairy production (Kremen et al., 2012). However, they have to respond to environmental changes, as a consequence of climate change, by gradually changing their agricultural practices associated with environmental conservation. Climate change has led to a reduction in crop yields, impacts on human health and environmental degradation, which is damaging to small-scale plots (Below et al., 2012; IPCC, 2014). In addition, smallholder farmers are a vulnerable group because they are located in remote areas and are faced with low accessibility to essential services and market information, which restricts better economic opportunities. Given that farmers' livelihoods are strongly linked to agricultural production, farmers must look for sustainable and effective strategies to adapt to climate change patterns.

According to Molina (2006), by 2050, desertification and salinization will affect 50% of agricultural land in Latin America and the Caribbean. Furthermore, climate change is expected to not only lead to rising average temperatures but also extreme weather events, threatening ecosystems, wildlife population, human health and causing agriculture damage. All of these impacts represent a challenge for international and national institutions, non-governmental organizations (NGOs), academia and other society actors involved in policy-making to achieve sustainable development. It must be highlighted that, in 2015, the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States, established within SDG 13 the need to carry out urgent actions to combat climate change (United Nations, 2016).

In this strand, the Food and Agriculture Organization (FAO) argues that sustainable agriculture is a suitable pathway towards achieving the following: (i) resource conservation, (ii) redress environmental degradation, (iii) technification, (iv) economic and (v) social inclusion (FAO, 2016). By understanding that sustainable agricultural practices (SAPs) could achieve minimal soil damage, to increase the soil water retention capacities, control soil erosion, and improve soil

structure and texture (Menale Kassie et al., 2013; Twarog, 2006), it should be understood that its application would overall benefit farmers' well-being. Therefore, many countries around the world have engaged in efforts to mitigate emission of greenhouse gases (GHGs). In developing countries, many international development institutions have focused on the formulation and implementation of actions linked to SAPs such as agroecology, organic farming, and forestry systems (FAO, 2016; Hentschel & Waters, 2002). For example, Ecuador has integrated a resilience approach to promote these SAPs to protect the environment and ecosystem biodiversity (ECLAC, 2016; Morales et al., 2007). These practices have been implemented at a small-scale plot level amongst Ecuadorian smallholder farmers. The approach is mainly focused on agroecological production as a sustainable model, offering strong possibilities for maintaining biological biodiversity and supporting rural livelihoods (Ecuador, 2019).

In Andean countries such as Ecuador, these practices have recognized that local knowledge is a key element in sustaining the governance of ecosystems (Becker & Ghimire, 2003). In fact, valuable local knowledge and know-how have enabled farmers to adapt to the scarcity of resources, the value of which has been proven over centuries. Additionally, the "Pachamama" (a Quechua word that means "motherland" in English) has represented an element of respectfulness and environmental conservation among peasant farmers (Durán López, 2010; Gadgil et al., 1993), which provides them a knowledge management system, mainly dedicated to agricultural innovation and the management of natural resources. The human efforts, local know-how and the resources invested in protecting natural resources from diverse institutions have helped in part to reduce the pressure on ecosystems and to ensure sustainable economies at different levels. Given the aforementioned benefits related to ecosystem conservation from SAPs to the local territories, it is expected that the actions should be established in the local territories in the long-term. However, once the project ends, some farmers do not pursue further the actions implemented in the territory (Jansen et al., 2006; M Kassie et al., 2009; Satama & Iglesias, 2020; Somda et al., 2002).

Farmers in developing countries as Ecuador have received support from local, national, and international institutions to strengthen the support of SAPs. Given the economic and environmental benefits from SAPs (Adenle et al., 2015; Arslan et al., 2014; Lal, 2008), and the opportunities for mitigation and adaptation in the face of climate change, it is expected that the results from these

practices will materialize amongst farmers over the coming years. Nevertheless, once the programs or projects conclude their implementation processes, the continuity of their actions are not guaranteed (i.e. the effectiveness of the actions on the farmer's adoption decision). By considering that for over 30 years, smallholder farmers in developing countries have been involved in environmental management programs to encourage adoption of SAPs (M Kassie et al., 2009), it could be considered that the government's and international institutions' efforts to promote ecosystem conservation through SAPs have not been successful. The same is currently happening in Ecuador (Satama & Iglesias, 2020). As mentioned above, these programs can address a broad set of interests such as poverty alleviation, food security, and ecological management (Altieri, 2002; Keese, 2001; C. A. Meyer, 1993). However, although the presence of national and international institutions with rural development programs has generated substantial changes in the well-being of the local territories, in the long term is expected that the investment in sustainable intensification options reaches the expected results.

Thus, firstly there is a low adoption rate of SAPs from smallholder farmers; second, from a management perspective, national and international institutions do not reach the expected results of their program established. Given that the role of the government is crucial to enhancing knowledge and information exchange, as well as public and local training, there is a requirement for well-designed strategies to tackle environmental protection and support livelihoods based on farmers' perceptions.

1.3. Research objectives

By understanding the importance of sustainable transformation worldwide and the local need to provide local well-being in the territories, the BLW program in Ecuador seeks to establish a biodiversity conservation strategy by promoting agricultural practices by smallholder farmers that are friendly to the environment. In this context, the general objective of this Doctoral Thesis is to assess smallholder farmers perceptions, attitudes and actions towards the adoption of SAPs in the BLW program in Ecuador. The scale of analysis covers 2 biocorridors as a case study in the "Biocorridors for Living Well" program - BLW in Ecuador.

The specific objectives that are established to achieve the general objective of this thesis are:

- To provide an empirical-based community-level analyses of the smallholder farmers' perceptions on the BFL program in comparison to the project managers perspectives.
- To examine farmers' perceptions of the main environmental problems that affect their territory, contrasting them with climatic parameters and land use and land cover change.
- To identify and asses the factors that determine the adoption of SAPs by farmers.

1.4. Related publications

Articles

- Satama, M., & Iglesias, E. (2020). Fuzzy Cognitive Map Clustering to Assess Local Knowledge of Ecosystem Conservation in Ecuador. Sustainability, 12(6), 2550.
- Satama, M., & Iglesias, E. (2021). Smallholder farmers' perception of environmental-related issues and sustainable agricultural practices adoption: Perspectives from Ecuador. (Draft in preparation, to be sent to a journal)
- Satama, M.; Andrea Urgilez-Clavijo; David Rivas-Tabares; Bélgica Normandi-Bermeo Jude Ndzifon Kimengsi (2021). Assessment of farmer's perceptions of sustainable agricultural practices and its responsive from environmental awareness in the Andean region of Ecuador. (Draft in preparation, to be sent to a journal)

Conferences

Satama Maritza, Blanco María, Vega Cristhian: Las ferias agroecológicas como iniciativas de desarrollo en el sector rural. Póster: II Foro regional de sistemas de innovación para el desarrollo rural sostenible, DOI: 10.13140/RG.2.2.35853.54247, Chile, 10/2016.

Satama Maritza, Iglesias Eva: Capital social y acción colectiva en la adopción de prácticas agrícolas sostenibles en los Biocorredores del Buen Vivir en Ecuador. Comunicación. XI Congreso de la Asociación Española de Economía Agraria: Sistemas Alimentarios y Cambio Global desde el Mediterráneo, Elche, 13-15 Septiembre de 2017

Satama Maritza, Blanco María, Vega Cristhian: Evaluación de impacto de las ferias agroecológicas en el Ecuador. Conferencia: XII Congreso de la Sociedad Española de Agroecología (SEAE). Leguminosas: Clave en la gestión de los agrosistemas y la alimentación ecológica., Lugo-España 2016

Awards

Grant for the development of "Social capital in the conservation of biodiversity, climate change and poverty reduction in rural areas of Cayambe Coca, Pisque Mojanda San Pablo and Cotacachi Cayapas" from the National Geographic Society.

1.5.   Structure of the thesis

Figure 1 presents the structure of the Thesis, which shows the seven chapters it consists of. Chapters 1 and 2 illustrate the introduction and state of the art, respectively. Chapter 3 provides the background of the study region. Chapter 4 describes the different methodologies used in the study. Chapters 5 and 6 set out the results and discussions of the investigation. Finally, Chapter 7 presents the general conclusions of the Thesis and lines for further research.
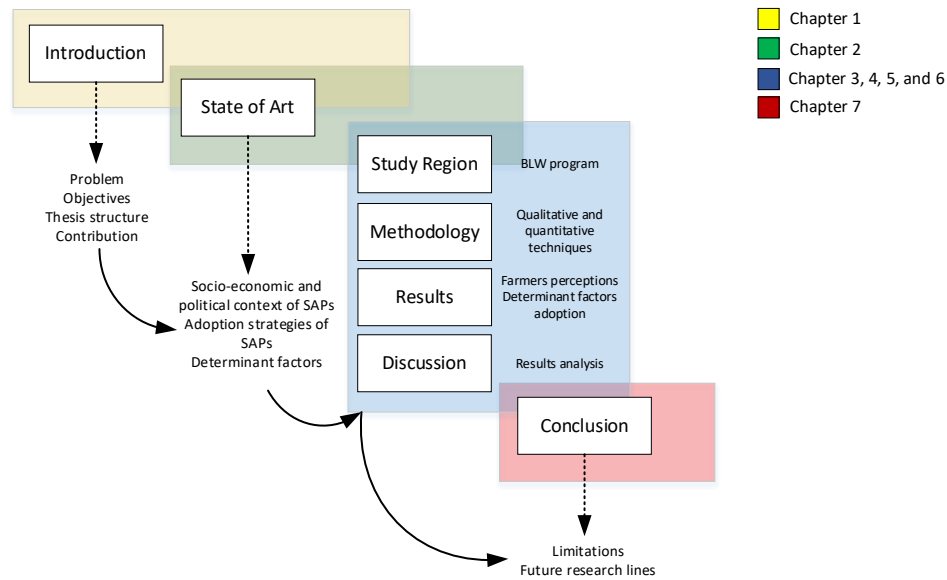
Figure 1. Thesis structure

As previously mentioned, Chapter 2 presents the state of the art, which summarizes the socio-economic and political context relating to the development of the SAPs. This section also offers some empirical contributions from previous studies relating to SAPs adoption strategies as well as a literature review on the determinant factors of SAPs amongst smallholder farmers.

Chapter 3 presents the study region that was established for this investigation with the description of the BFL program. In order to understand the work developed in the local territories at a national level, a brief history of the program is presented in the document. The objectives, strategies and results of this program are explained in detail. The definition of biocorridor used in the program is also presented.

Chapter 4 shows the different qualitative and quantitative techniques used in the development of the research. Field surveys and text analysis were used to explore the perceptions of the actors involved. The survey design and data field collection are presented in this section. Similarly, the study has used climate stressors and land use change analysis. In addition, the participatory approach Fuzzy Cognitive Map (FCMs) combined with the Hierarchical Cluster Analysis (HCA) was developed to analyze the farmers perceptions about program effectiveness. Finally, a probit model is presented to analyze the SAPs adoption factors.

Chapter 5 present the main results obtained in this research. Particular reference is made to the assessment of the perceptions of smallholder farmers and program managers. Likewise, the factors implied in the SAPs adoption are presented in the research, highlighting the role of environmental concern and social capital among farmers. This section also offers the results of climate stressors and land use land change in the study area.

Chapter 6 offers a discussion of the results arising from the application of each of the methodologies presented.

Finally, Chapter 7 presents, in brief, the main findings and the contribution of this Thesis as well as its limitations and identify future lines of research.

2. State of the art

2.1. Socio-economic and political context

2.1.1. Sustainable agricultural as a form of development: current status and future trends

Given that the Brundtland Report (also called Our Common Future) (Imperatives, 1987) established the term sustainable development; understood as meeting the needs of the present without compromising the need of future generations, since then, the sustainable agriculture (SA) concept has gained importance in the management procedures of crops and animal production practices (Congress, 1990). Its vision has been widely distributed based on the need to promote sustainable progress in the different contexts, and at different levels. However, its conception does not achieve harmonization in various fields of study (Velten et al., 2015). Although the attempts to define SA are not apparent, its potential benefits include halting natural resources depletion, and sustaining the economic viability of farm operations (Congress, 1990; FAO, 1989; Imperatives, 1987; MacRae et al., 1989). According to the FAO (1989), SA has several advantages, which include its ability to (i) fulfil human needs now and in the future, (ii) enhance environmental quality, (iii) efficiently use natural resources, (iv) economically sustained production, and (v) enhance the well-being of smallholder farmers. Conservation tillage, legume intercropping, legume crop rotations, improved crop varieties, use of animal manure, use of organic fertilizers, and soil and stone bunds for soil and water conservation are among the main practices linked to SA (Culleton et al., 1994; Koohafkan et al., 2012; Pierce, 1993; Tait & Morris, 2000). In addition, agroecology and organic production systems are linked to SA from an innovative point of view, which alongside the other practices propose long-term solutions regarding sustainable development.

In the hope of positively influencing environmental degradation, SAPs aim to increase agricultural productivity, accelerate local economic growth, and help to deal with climate change consequences that affect a million smallholder farmers worldwide. Nowadays, the world is concerned about the loss in the rates of biodiversity, land degradation through soil erosion, salinization and pollution, depletion and pollution of water resources. These are linked to poverty and high rates of

unemployment in rural areas; this outlook creates a challenge for SAPs adoption. Looking at the future of many rural communities, the natural resources will be threatened by the expected 20-40 per cent growth in population (IPCC, 2014). As a result of this growth, decision-makers must take significant measures to produce safe and healthy food, while ensuring economic sustainability and environmental protection. Moreover, the international research community needs to focus on how to cope with climate change effects at different levels; that is, from individuals up to authorities to work within public policies aligned with the concept of sustainability.

Over the past 30 years, the worldwide research on SAPs has been a growing trend in different countries, especially in USA, China, Germany, UK, Netherlands, India, Brazil, Australia and Italy (Aznar-Sánchez et al., 2019). In general, the studies have been focused on sustainable land use linked with crop management practices, where it is visible that topics related to sustainability in agriculture are becoming relevant worldwide. This is due to the fact that achieving sustainable goals should prevail in the different sectors, and especially in agriculture. Hence, a real and visible shift towards sustainable agriculture is required. However, according to FAOSTAT, although the share of the agricultural area allocated to organic agriculture has experience some significant changes, the adoption percentages are still low (Adnan et al., 2017; Lalani et al., 2016; Teklewold et al., 2013). For instance, in recent years, Europe shows a steady increase in organic agriculture. Indeed, data from 2017 shows that three per cent of the share of agricultural land is based on organic agriculture. In absolute terms, Spain, Italy, France and Germany occupied the top positions in the list of organically cultivated agricultural areas at a European level (Cristea et al., 2019).

On the other hand, areas such as Africa, Asia and America do not reach high levels of organic agriculture. For instance, Asia is facing critical challenges such as the increasing human population in India, accompanied by land degradations due to soil erosion and nutrient depletion (Srivastava et al., 2016). Here, the pressure toward cash crop cultivations is growing, while soil fertility is declining. Similarly, the low rates of SAPs adoption occur in Brazil. As mentioned by Caviglia-Harris (2003), this occurs due to imperfect information, income constraints, market failures, and cost adoption in the short-term, which are most common adoption barriers in South America. Furthermore, in this continent, political and economic forces have influenced the shift of production models devoted to large areas of monoculture, which in the long-term leads to economies of scale serving the national and international markets (Altieri, 2002). Thus, neoliberal

economic models have become the "best" way to promote export-led growth, while the depletion of natural resources persists. The intensification of food production based on the use of inputs such as capital-intensive technology, pesticides, and synthetic fertilizers have been the trigger negatively impacting to the environment and rural society in South America. Based on the urgent need to research alternatives to not only provide environmental opportunities, but also economic benefits to society, SA has demonstrated that its approach covers these aspects in a holistic manner.

Although some studies have criticized SAPs for reducing farm yields, other studies have stated that SA can become economically competitive compared to conventional agriculture (Altieri, 2000; Pretty, 1995). Additionally, in terms of yield, in most cases, it can be seen that SA is comparable to conventional farming (Edwards & Arefayne, 2007; Force, 2008). By understanding the need to produce food to feed the world with minimal harm to ecosystems, animals or humans, national and international institutions are aware of the importance of taking action to tackle the current situation. For instance, in Latin America and throughout Central America, NGOs have been working on efforts using an agroecological approach (Altieri, 2000) to help a significant number of smallholder farmers, directed at productive activities and environmental problems. According to Altieri (2000), in Honduras, hundreds of farmers have used velvet beans as green manure to be incorporated in the soil, with excellent results on erosion control, weed suppression while reducing land preparation costs. Similarly, through the farmer-to-farmer networks approach, Nicaragua has recovered degraded land by adopting cover cropping. In the Dominic Republic, some institutions have developed projects on the basis of agroecological strategies consisting of developing alternative production systems for local farmers. Elsewhere, in the Andes (Bolivia, Ecuador and Peru), the number of projects focused on agroecological schemes is still increasing.

By 2020, Latin America will reach 125 million inhabitants in rural areas (19 per cent of the region's population), of which 46.5 per cent of the rural population are in a poverty situation, and 20.5 per cent in extreme poverty, agriculture continues to be a central activity in rural areas, whose contribution to Gross Domestic Product (GDP) reaches 53% in South America (Córdova et al., 2018). However, activities linked to agriculture generates an economic impact of 60 billion dollars (Córdova et al., 2018) with the loss of biodiversity each year. On the other hand, Córdova et al. (2018) stated that agriculture contributes to 22.6% of regional gas emissions into the atmosphere, which put the food systems and ecosystems services under threat. In fact, Latin America and the

Caribbean present a worrying scenario regarding socio-environmental conflicts (Villafranca, 2018). All of this is compounded to cover the population's needs, and to achieve the desired sustainable goals.

Although Ecuador is not in the group of countries that have the lowest organic carbon stocks such as Argentina, Brazil, Chile and Mexico, it is not excluded from the scope (Trivelli & Berdegué, 2019),since agriculture in Ecuador employs about 62% of the labor force (76% of farmers are smallholder farmers) and contributes to approximately 14% of GDP (Córdova et al., 2018). If it is true, this sector has shown a significant contribution beyond smallholder farmers. However, employment, livelihoods, and agricultural land consolidation have become a significant environmental and socioeconomic problem. Climate change has been impacting food systems and the agricultural sector, where SA has become an alternative to local development. Nevertheless, at a global level, lack of land access, lack of awareness among policy-makers, and lack of alternative environmental technologies limit the adoption of SAPs, alongside farmers' day-to-day struggles with different economic shocks.

2.1.2. Strategies for the adoption of sustainable agricultural practices from farmers

The need for agriculture to adapt to climate change is inevitable due to the food that the population needs and the care for the environment. By 2050, the world´s population will reach 9.1 billion, 34 per cent higher than today (FAO, 2009); therefore, the impact on natural and managed systems becomes a focus area for both national and international institutions. By understanding that adaptation capacity could be defined as a vector of resources and assets that represent the asset base from which adaptation action can be carried out (Vincent, 2007), and also the way that communities and individuals react to climate variability events, the adaptation strategies become a pathway to enhance resilience to climate change at a global level. Indeed, under the framework of the 2030 Agenda for Sustainable Development (United Nations, 2016), some recommended actions are provided to combat climate change, including the need to integrate measures into national policies, strategies and planning. Furthermore, as outlined in the document, the promotion of SA is a crucial target that provides a more precise outlook for sustainable development at different levels.

According to the United Nations Framework Convention on Climate Change (UNFCCC, 1997) supporting developing countries in the adaptation to the risk of climate variability has to be considered within national and regional programs. These measures established will be focused on mitigating and facilitating the adaptation to climate change. In fact, the FAO strategy on climate change highlights the requirement to improve food security and nutrition through SA production systems for crops, livestock, forestry, fisheries and aquaculture. Indeed, the document promotes the prioritization of increasing and improving the provision of good and services from agriculture and forestry in a sustainable manner. By understanding that climate change compromises a variety of aspects such as food safety, market product prices, the nutrition of millions of people, and natural resources, UN agencies and programs act as international advocates for achieving the sustainable development goals, where agriculture is embedded in the action framework. According to the World Food Programme (WFP, 2016) the interventions of different bodies have to include social and economic dimensions to respond to the livelihood needs of local people and safeguard these resources for future generations.

The need to integrate SA production systems within national and regional policies is a crucial step to preserve ecosystem diversity and the well-being of local people (Mertz et al., 2007). However, the climate-related legal instruments used in most of the countries in Latin America are characterized as being too soft (Aguilar & Recio, 2013). Some countries such as Colombia, Dominican Republic, Mexico and Ecuador have included a climate change framework within their laws and regulations; while others have adopted some strategies and actions plans within their ministries. Only Peru and Guatemala have incorporated climate change strategies within their decrees or legal equivalent norms. Regarding the involvement of civil society, Colombia has designed some strategies to promote the participation of the population to tackle climate change. Other countries such as Argentina, Brazil, Mexico, Uruguay, Costa Rica and Chile have integrated specific contributions from society through ad hoc participatory processes (Science et al., 2015).

In the case of Ecuador, its National Constitution has incorporated aspects of environmental rights. For instance, Art. 413 and 414 of the Constitution highlight that the State will promote energy efficiency, the development and use of environmentally clean and healthy technologies and practices, as well as diversified, low impact renewable energy, that do not put food sovereignty, the environmental balance of ecosystems, or the right to water, at risk (Asamblea Nacional

Constituyente, 2008). On the other hand, it is important to highlight that in the period 2009 to 2013 in the "National Plan for Good Living" (Plan Nacional Del Buen Vivir 2009-2013, 2013), its policies emphasized the promotion of the adaptation and mitigation of climate variability with an emphasis on the climate change process. Additionally, the sustainable use of natural resources is a particular strategy in the agriculture sector called the "Good Rural Living". Similarly, the "Whole Lifetime" plan established for the period 2017-2021 has had the same focus as the other plan mentioned above (Secretaría Nacional de Planificación y Desarrollo, 2017), where the rights of nature and family farming are incorporated above all. In the agriculture area, development plans highlighted that agroecological production becomes a strategy for preserving food security and sovereignty, which is mainstreamed within the SA approach.

Although Ecuador has established a normative framework to support the development of sustainable strategies in the agricultural sector, the decision-making is reflected in the design of public policies that favor agribusiness. The boom in banana, flowers, and cacao export commodities represent the main crops at the national level, after the wheat, rice, and corn (Elbehri et al., 2015), whereas mentioned by Martínez Valle (2017), Ecuadorian agriculture continues to concentrate in the consolidation of capitalist agriculture based on the world market. It is supposed that agribusiness is portrayed to be a practical pathway to overcome poverty, unemployment, and migration in rural areas; however, the incorporation of sustainable practices in this "dominant" group is waiting in the background (Bergman, 2008). On the other hand, the advance of sustainable measures among smallholder farmers has been possible due to the adoption of concepts by agricultural organizations to respond to conventional agriculture (Intriago & Gortaire Amézcua, 2016).

The presence of indigenous people in the local territories, characterized by their strong social capital (Perreault, 2003) has played a critical role in the adoption of sustainable agricultural models. Moreover, their traditional wisdom and their respectfulness towards the "Pachamama" are the basis of the revitalization of degraded ecosystems (Altieri et al., 2008). Based on this vision, different NGOs have embraced this connection between local knowledge and biodiversity and emerged to carry out actions on the ground to face climate change consequences, rural poverty, and recover the vitality of the ecosystems. A variety of rural development projects have been promoted by NGOs, where it provided the impetus to the concepts of food sovereignty and

security. Nevertheless, studies on farmers strategies of decision-making on sustainable agriculture from farmers have not been well studied. For instance, few studies have focused on explaining adoption strategies of sustainable measures from smallholder farmers in Ecuador (Mauceri et al., 2005; Satama & Iglesias, 2020; Travis; Elli, 2015), which is vital due to the level of heterogeneity that rural areas present (Hentschel & Waters, 2002), and the possibility to generate public policies for small scale agriculture benefit.

2.2. Impacts of climate change on small scale agriculture and adaptation needs

2.2.1. Climate change-related issues on family farming

In Latin America, there are 15 million family farms, controlling 400 million hectares (Berdegué & Fuentealba, 2014). According to CEPAL (2010), in this region, the richest 20% of the rural population earn between 10 and 50 times more than the ranges for the poorest 20%. Indeed, the Gini coefficient of rural income is higher than 0.5, which confirms the high level of inequality that exists in the region (Schejtman & Berdegué, 2006). However, it is essential to have a better understanding of the definition of family farming because this concept is relatively distinct by nature. Berdegué & Fuentealba (2014) stated that there are three types of family farms, considering the asset endowment and context dimensions. The first group includes asset-poor farmers in territorial and regional contexts, known as subsistence farms (Baquero et al., 2007). The second group is known as smallholder agriculture with some limited assets in territorial and regional contexts, and the third group is the asset-rich smallholders, who are characterized as being located in environments where the conditions are not only positive for agriculture.

In this context, by understanding that around 11 million are subsistence farms (Berdegué & Fuentealba, 2014) and the characteristics mentioned above, the first and second group are essential for implementing adaptation measures to tackle climate change. As mentioned by Salcedo & Guzmán (2014), family farming has a relevant role in food security, leading to agriculture employment, poverty mitigation and biodiversity conservation. However, climate change becomes a latent threat for countries in Latin America, and thereby smallholder farmers. In fact, global warming in South America is projected to be above-average. On the other hand, CEPAL (2012) estimates a reduction of between 3% and 17% of the monetary value of assets and services in the agricultural sector in the different countries of Latin America and the Caribbean due to climate

change by the end of the century. Therefore, the effect of climate change on agriculture could be very severe, and even more so for subsistence agriculture, where the productivity of the farm labor and family health could be affected (Altieri et al., 2008; Olesen, 2010).

In the case of Ecuador, based on the context presented by Berdegue and Escobar (2002) it could be stated that the subsistence group of farmers included almost half a million farms, with approximately 2.5 million hectares of land, and with an average plot of 5.5 ha. On the other hand, transitional farms include 33% of all farms, covering 15% of the total farmland, with an average farm size of 7 ha. The asset-rich smallholder farmers contain less than ten thousand units that control 5% of the farmland, with an average of 66 ha. Figure 2 explains the landholdings in Ecuador in more detail, where it is possible to understand the significant impacts of climate change on the small-scale agricultural sector.
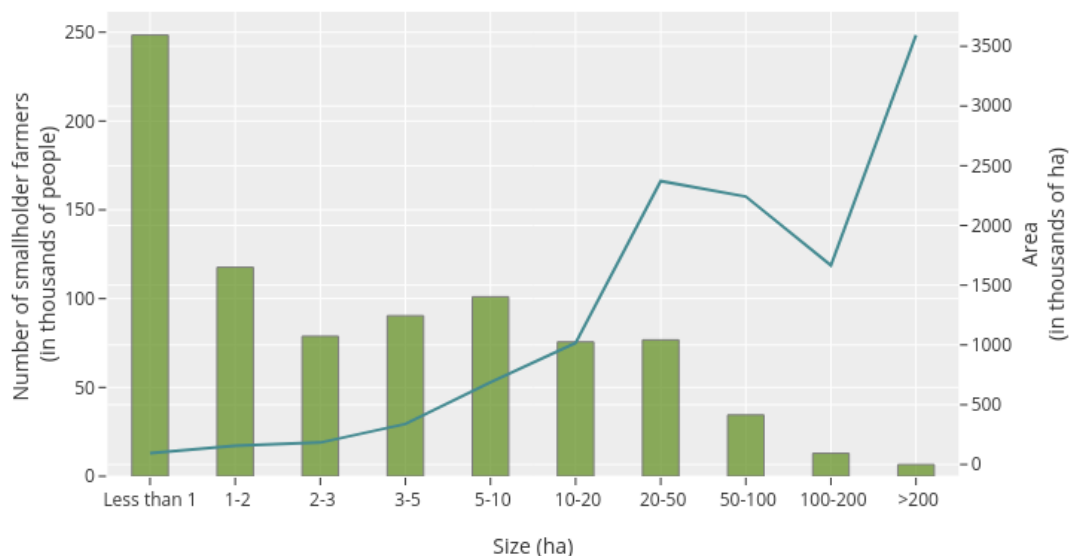
Figure 2. Landholdings in Ecuador. Source: Censo Nacional Agrícola 2000 (INEC, 2000)

According to Jiménez et al. (2012), climate change in Ecuador will have a negative impact on the agriculture sector between 2020 and 2030, and especially on its agrobiodiversity (Perez et al., 2010). In addition, moors (páramos in Spanish) will be affected, which act as a water sponge, generating ecosystem services for the local population, such as irrigation and drinking water (Camacho, 2014). In order to protect the ecological services that moors provide, large areas have been declared National Parks such as Cayambe-Coca (Perez et al., 2010). On the one hand, the main threats of climate change for the Andean zone including Ecuador is the high change in

seasonal distribution and regularity of water supply. On the other hand, climate variability may affect farmers' ability to control pests due to the reduction in the effectiveness of pesticides in high temperatures, where crops such as corn, beans, potatoes and rice will be affected, while exportation products such as bananas and cocoa will benefit by up to 11% during the year 2020 (Berdegué & Fuentealba, 2014).

By understanding climate change, it has become one of the major global concerns, and its manifestation may cause a pressing threat on natural and human systems (IPCC, 2014). The increase in the number of greenhouse gases, especially carbon dioxide (CO_2) in the atmosphere, is causing ongoing anthropogenic climate change. The release of greenhouse gases, which absorb reflected solar energy, will lead to an increase in the Earth's temperature. The potential consequences of this rise involve complex interactions and diverse impacts on the whole economic system. The changes in climate have caused different impacts on natural and human systems all over the world. According to IPCC (2014), some impacts from climate change have had major or minor influences on social and economic factors. However, the impacts on natural systems have been the strongest. As a result, in terms of national income and employment, these rely on agriculture, especially in developing countries, and are directly affected by climate change. In fact, agriculture is a sector in which the effects of climate change might be more evident (Mertz et al., 2009).

Considering that the acceleration of environmental degradation and climate change has direct effects on agricultural productivity and food security, agronomic adaptation responses can be part of the solution by contributing to climate change adaptation and mitigation. At different levels, climate change poses risks for local populations and natural ecosystems (See Figure 3). Thus, the importance of strengthening the agricultural systems based on a sustainable approach will help to avoid the depletion of natural resources and will create livelihood opportunities for the rural population. In this sense, agriculture production systems need to be adapted to the present and future circumstances caused by climate change. By understanding that agriculture constitutes an important sector in developing countries, climate change impacts could be more severe for smallholder farmers. Different experts have expressed their concerns for smallholder farmers, who have limited economic resources to pursue the strategies required to adapt to the different circumstances as a results of climate change consequences (Mertz et al., 2007). As mentioned by

Barbier (2003), undoubtedly the vulnerability of the agricultural sector in many Latin American countries is caused by poverty and limited economic resources.
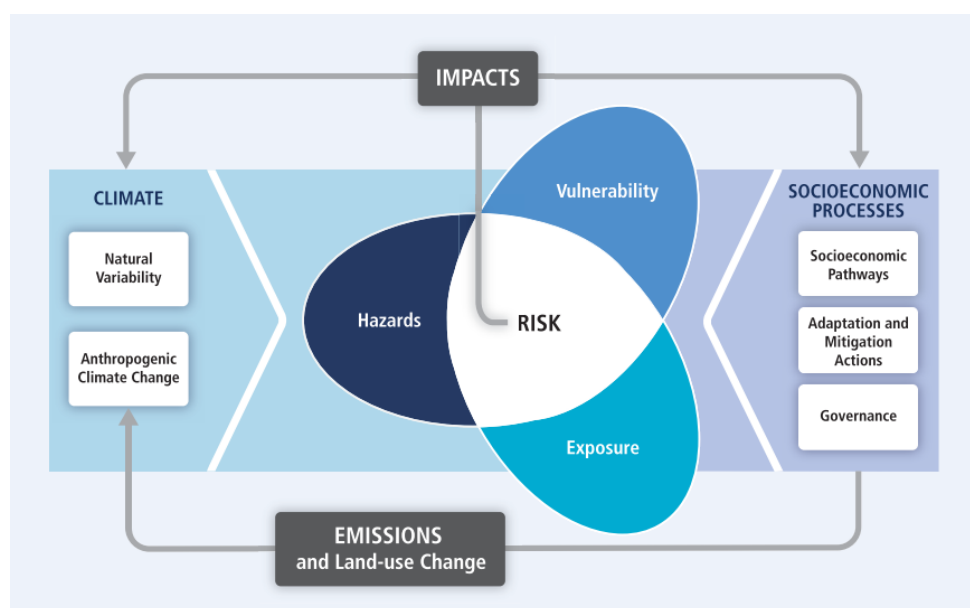
Figure 3. Risk of climate-related impacts resulting from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems[1].

2.2.2. Climate change adaptation needs for smallholder farmers

Until now, the climate change impacts have urged the need to include adaptation actions to pursue climate-resilient pathways for sustainable development. In general, adaptation seeks to reduce risk and vulnerability through seeking opportunities and building people's abilities at the different levels to cope with climate impacts. The adaptation process is directed at natural systems as well as humans. On the one hand, the biological systems can adapt through multiple processes (e.g., phenology changes, migration, compositional changes, phenotypic acclimation and genetic changes). On the other hand, humans may act as agents of change by directing their environmental awareness towards adaptation and mitigation strategies. In terms of environmental concern,

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[1] Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. Source: IPCC (2014)

encouragement had been a tipping point for conventional practices to benefit local communities in developing countries (Ma et al., 2009; Min et al., 2018a). Different forms of capacity building such as training in workshops and promotion campaigns have been carried out to promote environmental awareness, and to ensure the protection of the environment (Kapoor, 2011; Salafsky & Wollenberg, 2000; Shiferaw et al., 2009; Uzunboylu et al., 2009). However, in the long-term, the SAPs adoption has a level of uncertainty from farmers (Jansen et al., 2006; M Kassie et al., 2009; Satama & Iglesias, 2020; Somda et al., 2002). Therefore, environmental education has been examined as a way of making informed decisions and raising awareness about the environment (Fishbein and Ajzen, 1977; Stern et al., 1985; Sanera, 1998; Özden and Ozden. 2008; Uzunboylu et al., 2009; Hassan et al., 2010). Some studies have stated that environmental awareness has a positive correlation with attitudes towards improving the state of the environment (Fishbein & Ajzen, 1977; Gomera, 2008; Pasek de Pinto, 2004). From the perspective of local ecosystem protection programs, Min et al. (2018) documented that environmental awareness influences farmers' willingness to participate in ecosystem conservation programs. Based on the above arguments, it is understood that environmental awareness acts on the behavior of the individuals (Du et al., 2018), involving environmental knowledge, attitudes and concerns (Sullivan et al., 1996). Thus, local institutions such as local governments, NGOs, and civil society organizations, are key actors in advancing adaptation and in the process of enhancing the adaptive ability and resilience of different stakeholder groups.

Adaptation goals are commonly expressed within a resilience framework, which seeks to capture the complex interactions between humans and the environment. In the case of rural areas in developing countries, the adaptation process must be linked with the viability of agricultural activities (Bosello et al., 2009) in an attempt to harmonize the actions in the territories with local people welfare. As a result, there are some options regarding adaptation such as raising awareness, extension, community meetings and other training programs for knowledge dissemination (Birkmann & von Teichman, 2010). Furthermore, building social capital at a community level becomes a crucial strategy for supporting social resilience. Nevertheless, it is important to emphasize that the adaptation process faces several limiting factors which put ecosystem services under threat.

The barriers mentioned above delay and impede the overall process of institutions and civil society adopting SAPs (Caswell et al., 2001). Overall, economic, cultural, political and social needs are

involved in the framing of adaptation. Governmental and local institutions pursue the implementation of actions at different levels by identifying the social conditions, in which the engagement of different stakeholders is required; however, more often than not, the establishments' lack of resources and ability hinder the creation of adaptation processes. Moreover, at a community level, factors such as traditional versus scientific knowledge in the framing of cultural preferences play an important role in influencing adaptation (Jones & Boyd, 2011). For instance, traditional knowledge is linked to social and cultural factors, which is associated with social values, norms and behaviors. As mentioned by Wolf & Moser (2011), these social and cultural factors can influence the perceptions of risk, where the decision making will depend on what adaptation options are considered useful or not. In addition, it is important to highlight that, economic disruptions have a disproportionate effect on sectors that are vulnerable to climate change, especially in the rural areas of developing world (Füssel, 2010).

In the rural areas, smallholder farmers have faced adverse circumstances due to climate change, which significantly has affected their demographic, social and economic factors (IPCC, 2007; Paul et al., 2016). For instance, land degradation has become one of the main concerns and challenges, which is being accelerated due to anthropogenic influence (Lal, 2000). Inappropriate agricultural practices, steepness of the farmland, erratic rainfall, low vegetation cover and weak land resource management are some of the main causes that produce negative consequences for the well-being of people (Lal, 2000; Scherr & Yadav, 1996).

In Ecuador, mitigation and adaptation activities are considered a priority in the legal framework. The facts show that mitigation and adaptation to climate change is considered as state policy, with the Ministry of Environment being the entity that is in charge of formulating and executing the national strategy in terms of climate change. By 2011 there were around 9 initiatives, 17 projects and 185 studies related to vulnerability and climate change adaptation in the agriculture, risk management, and infrastructure sectors (Cáceres et al., 2011). However, despite the past and ongoing efforts, on the one hand, the institutions do have not adequate coordination and prioritization for the analysis they have carried out, which means there is weak institutional ability (Ludena et al., 2012). On the other hand, institutions cannot overlook social, cultural, economic, political and technological factors that influence adoption decisions at an individual level. In this sense, from a position of decision-making, the development of strategies, and urgent measures

must be taken considering environmental and social aspects, where farmers could adopt production alternatives that allow them to adapt to the challenges of climate change while supporting their well-being.

2.3. Social, economic and demographic factors in agricultural decision-making behavior to tackle climate change

At a local level, agricultural decisions are made based on external factors, state of well-being and the availability of resources. Within the adaptation process in the face of climate change, environmental perceptions, feelings and attitudes about nature and its understanding influence individuals' decision-making behavior (C. Singh et al., 2016). In terms of land, smallholder farmers are the ones who decide which practice to select, which means that the adoption of any agricultural practice is up to them. However, as previously highlighted, the connection between attitudes and behavior in farm practices not only considers this linkage but also takes into account several factors such as the local context and socio-economic dynamics that reinforce decisions. However, climate change impacts are a strong reason to adopt sustainable measures to reduce the effects on the land, and reduce the vulnerability of livelihood assets; the adoption of these practices is a response to household needs.

In the literature, the adoption of SAPs depends on several demographic, socioeconomic and environmental factors, which could explain the low adoption by smallholder farmers (C. Singh et al., 2016; Zeweld et al., 2017). For instance, credit constraints, women's education, household assets, distance to markets, number of relatives, age of the head of the household, size of the family and plot size are some of the factors that influence the adoption of SAPs (Menale Kassie et al., 2013; Teklewold et al., 2013). In addition, social capital is understood as a form of membership of rural institutions, and also contributes to the SAPs adoption processes. In fact, the collective action of institutions also has an effect on smallholder farmers' decision-making (Menale Kassie et al., 2013). With respect to environmental variables such as rainfall, pests and disease are also factors that impact farmers' decision to adopt SAPs. Moreover, mass media, training, and outreach workers, can make that smallholder farmers aware of sustainable practices, and reduce uncertainty about the advantages and disadvantages of the practices.

The factors that influence the SAPs adoption process have been studied in different countries and continents such as Africa (Menale Kassie et al., 2013; Teklewold et al., 2013), Asia (Tey et al., 2014), United States (D'souza et al., 1993; A. Munasib & Jordan, 2011; Mutekwa, 2009), Central America (Wollni et al., 2010) and Ecuador (Gonzalez Gamboa et al., 2010; Mauceri et al., 2005; Raes et al., 2017). While it is true that Gamboa et al. (2010) shows that an interesting perspective about social network effects on the adoption of agroforestry species between ethnic groups; however, perceptions and behavior response face to adopt these practices are not analyzed. On the other hand, although Mauceri et al. (2005) have explored various factors to adopt integrated pest management technologies among potato farmers, social capital and environmental awareness need to be explored further. In addition, despite the interesting framework presented by Raes et al. (2017), farmers' preferences for alternative types of contracts for payment for ecosystem services are analyzed. It is important to highlight that it is only considering farmers willing to participate in payment for environmental services, which means a cost-sharing from programs. Most of the rural development programs in Ecuador are focused on building capacities that improve smallholder farmers' decision-making process for adopting SAPs. Thus, this doctoral research brings an integrative picture of the implementation of the program through a participative modeling approach, and comprehensive methodological frame to analyze the decision-making process on SAPs from farmers, where there is the potential to scale up the program's actions, and improve the livelihoods of the rural poor in Ecuador.

3. Study region: Biocorridors for Living Well (Ecuador)

With a decentralized and participatory approach, UNDP's Small Grants Program (SGP), which forms part of the Global Environment Facility implemented locally by the United Nations Development Program seeks to achieve global environmental benefits through community initiatives and actions. In Ecuador, the SGP has been implemented since 1994 and its fifth operational phase (FO5, acronym in Spanish) represented a qualitative leap with the development of "Biocorridors for Living Well"- BLW, based on three strategic approaches: ecological connectivity, productive landscapes and associativity. The objective of this new territorial management strategy is the conservation of biodiversity and Ecuadorian rural areas, promoting their social, environmental and commercial interrelation to generate strategic alliances in the management of each biocorridor. The 16 biocorridors were established in four regions at national

level. Five are located in the Costa, three in the Sierra Norte, five in the Centro-Sur, and three in the Amazon. To manage the program, the National Coordination of the SGP has the support of a Technical Support, Evaluation and Monitoring Team, made up of a national team (EQUIPATEN) and four teams at a territorial level (the so-called EQUIPATE, in charge of four regions: Costa, Sierra Norte, Sierra central-south and Amazon). In the Sierra Norte (where the Cayambe-Coca, Pisque -Mojanda-San Pablo and Cotacachi-Cayapas biocorridors are located), the EQUIPATE is ECOPAR. This corporation monitored the FO5 projects, in which 23 associations of agricultural producers participated in the development of community projects in two biocorridors mentioned above. For over 20 years, the SGP has been working in Ecuador, and it has implemented six operational phases, with the seventh phase currently in progress. The fifth phase, implemented in 2012, represented a qualitative leap with the development of the BLW program.

Biocorridors refer to conservation and local development, which means that they promote agricultural activities by smallholder farmers that are friendly to the environment (PPD, 2012), and at the same time they reduce the risk of threatening the ecosystems around them. Although the term biocorridor accounts for the effects of habitat loss and fragmentation (Bennett & Mulongoy, 2006); which are the primary causes of biodiversity loss worldwide, this term also involves social dynamics patterns since the ecosystem services are available for local inhabitants. This means that conservation actions coexist with socio-economic activities as a holistic framework to achieve sustainable development. This program has been promoting the adoption of SAPs by smallholder farmers as an alternative to enhance people's well-being, while incorporating environmental considerations in agricultural activities (PPD, 2012).

The BLW program has been implementing activities such as reforestation, restoration and conservation campaigns, SAPs, products with territorial identity and marketing networks to benefit 79,808 inhabitants in both sites (direct and indirect influence). The main objective of this program is the conservation of biodiversity and the rural Ecuadorian areas through the strengthening of the social, environmental and commercial interrelationship to create strategic alliances in the management of each biocorridor. The improvement of socio-ecological adaptation and resilience amongst smallholder farmers through sustainable consumption and production (PPD 2012) is also an aim of the program, which are mostly taught in the sustainable production framework.

The data for this thesis was derived from the beneficiaries' sample of the BLW program in two biocorridors; namely the Pisque Mojanda San Pablo-PiMoSaPa, and Cayambe Coca – CaCo biocorridors. The PiMoSaPa biocorridor has an approximate extension of 64 034 ha located for the most part in the province of Pichincha, in the parishes of Tupigachi, Tabacundo, La Esperanza, Tocachi and Malchinguí of the Pedro Moncayo canton. The remainder is located in the province of Imbabura, Otavalo canton, in the parishes of, Eugenio Espejo, San Rafael and González Suárez. The southwest area of this biocorridor belongs to the Metropolitan District of Quito, corresponding to the Parishes of Perucho, Atahualpa (Chavezpamba), and Puéllaro, including the Jerusalem Dry Forests. Its diversity of geographical factors allows the development of dominant plant formations such as the herbaceous moors, the high montane evergreen forest, and the humid montane scrub. Likewise, the social dynamics of the sector have given rise to the appearance of agricultural landscapes that are the seat of the economic and productive activities of its inhabitants. In this biocorridor, there were training processes on the advantages of agroecological production, the conservation agrobiodiversity, and its value in food. These technical assistance processes were based on a research approach to promote permanent project innovation.

On the other hand, the CaCo biocorridor is located in the north of the province of Pichincha in the Cayambe canton, with an approximate extension of 127 806 ha. Due to biophysical and natural factors, it has many species and surface areas inhabited by various associations of flora and fauna typical of the Andes and its western foothills towards the inter-Andean valleys and east towards the Amazon and its forests. At a general level, it contains a great diversity of ecosystems. Approximately 20% of the biocorridor surface is within the Cayambe Coca National Park (PNCC), and, in turn, much of this territory is in the buffer zone of this protected area. Its core area is the buffer zone of the Cayambe Coca National Park, specifically the moors from which the water sources that are the object of conservation of this biocorridor come. The actions of the associative projects are carried out. The actions done in the territory were focused on the conservation of moorlands, which were carried out through agroecological production, and commercialization processes. Additionally, the rescue of ancestral seeds and organic agriculture was promoted to strengthen food security.

Previous works (ECOPAR, 2015; GAD Pichincha, 2015; PPD, 2012) have identified these areas as being vulnerable to the climate events such as frosts, and dust storms that have occurred, which makes it essential to be considered for the research. Furthermore, the ecosystem-services (e.g., water provision, water regulation, and soil erosion prevention) provided in the protected areas located in these zones such as Mojanda and Cayambe Coca National Park are of high value. Figure 4 presents the location of surveyed farmers in the two study sites.
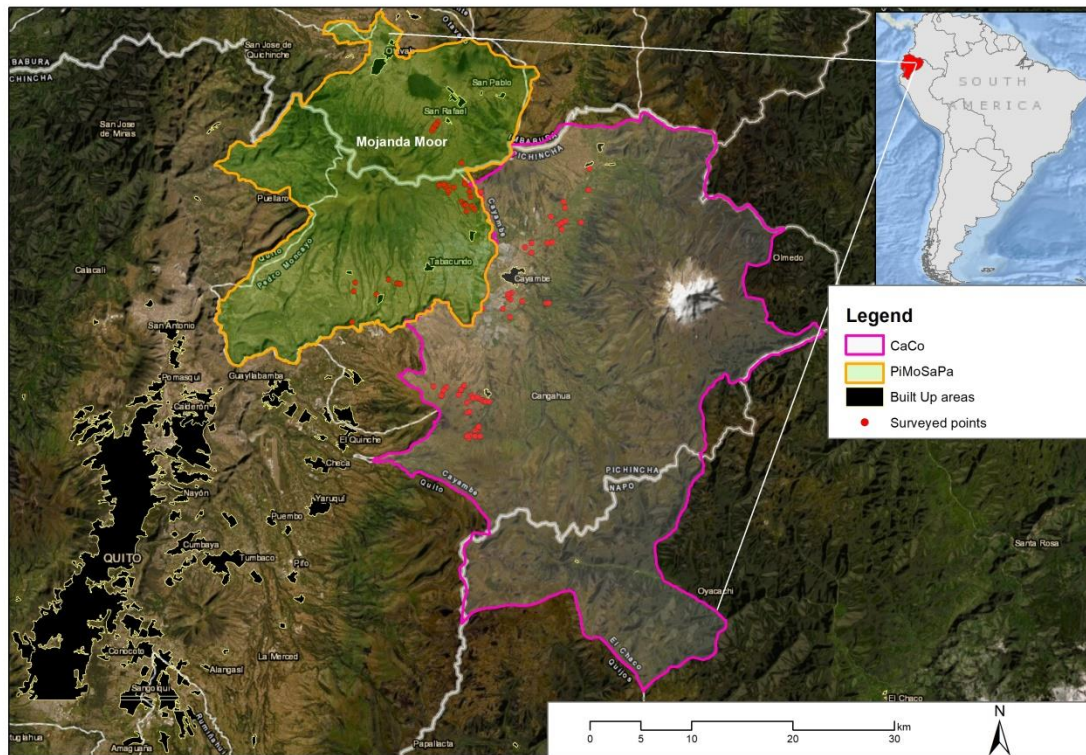
Figure 4. Geographical scope of the study. The geographical positions of the surveyed points are indicated.

4. Methodology

4.1. Methodological framework

This thesis was structured in two consecutive and interrelated studies. The first study considered a perception assessment of sustainable actions in small scale agriculture between beneficiaries of the BLW program and program managers. The second one exploring the decision making on SAPs. In addition, it is important to highlight that in this second study, this research considered the analysis of meteorological data and a Land Use and Land Cover Change- LULCC analysis. Thus, the methodological framework of this research was based on combinations of qualitative and quantitative methods, which were developed through participatory approaches (See Figure 5). The scale of the research analysis is based on the BLW program framework, where PiMoSaPa and CaCo biocorridors are the study sites in this thesis.
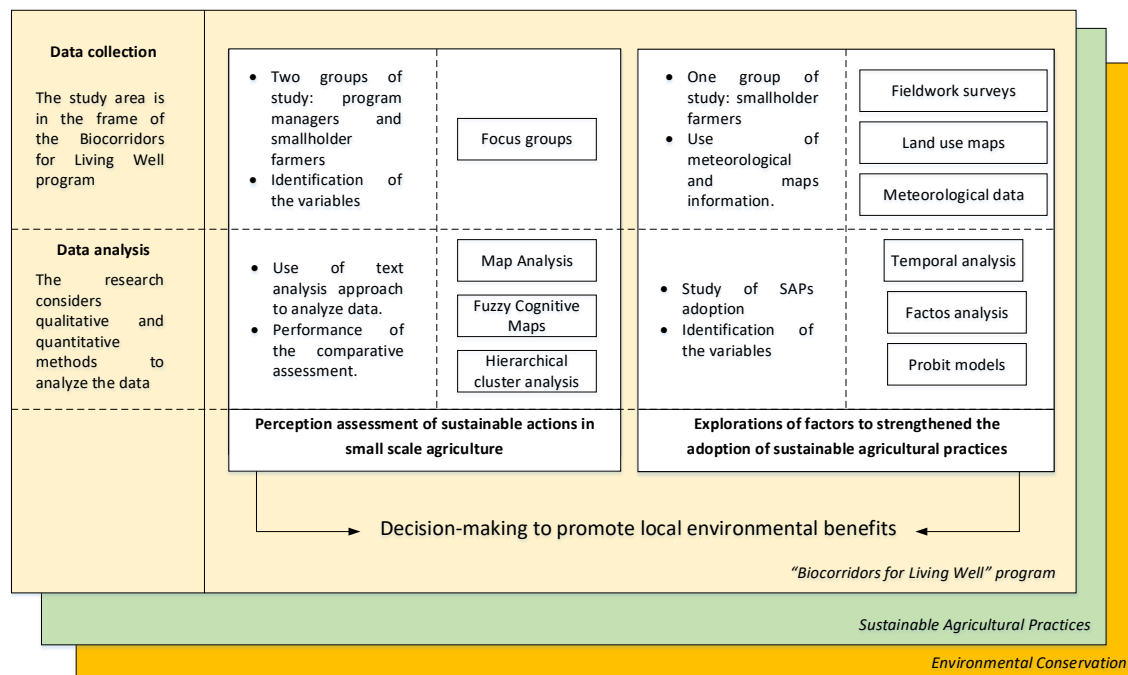
Figure 5. Methodological framework of the thesis research

4.2.   Research methods

In this research, the engagement of key stakeholders from the program through the development of focus group enabled the collection of qualitative data, where implementation of text analysis and FCMs methods to understand and analyze the perceptions of the different groups of interest. Smallholder farmers which were beneficiaries of the program and program managers were the groups of interest for this thesis. On the other hand, in this thesis quantitative analysis provided an understanding of decision-making on SAPs adoption, which will be supported by land use and land cover change, climate stress analysis, and discrete choice models.

4.2.1.   Qualitative Methods

One of the main advantages of qualitative research is the great deal of information that can be obtained about the field of interest (Gibbs, 2012). The objective of qualitative methods is to understand the events in their natural environment, allowing an in-depth study of the reality being investigated. Although these methods could be considered atypical from a positivism point of view, the study of perceptions, motivations and valuations of studied population can help to understand social phenomena and their relationships (Gibbs, 2012).

In this research, the focus group approach was used to gather information on the current knowledge of the group of interest. This method is useful for exploring people's knowledge, perceptions and experiences, which leads to an understanding of how people think and why they think in that way (Bagnoli & Clark, 2010; Kitzinger, 1995). Once carried out, the group discussion has to be analyzed through textual analysis, which presents a wide range of techniques that have emerged to analyze the information collected (Kathleen Carley, 1993).

In the case of textual analysis, its approach establishes a way of gathering and analyzing information in academic research. For researches working in cultural and media studies, and social science fields in general, textual analysis becomes a useful research method in their academic disciplines. A textual analysis is valuable in research because it allows researchers to comprehend connotations and ideas expressed through written words (Kathleen Carley, 1993). There are many techniques for conducting a textual analysis. For instance, counting the number of times certain phrases or words appear in the text, which allows the essence of the text to be examined and

interpreted. There are a variety of techniques within textual analysis, historically allowing a variety of problems to be solved, where content analysis has enabled the analysis of historical document and narratives. This approach enables a quantitative analysis of a large number of texts, where the frequency of words is studied (Fernández, 2002). In particular, the concepts are the focus of study within this analysis. Similarly, Katheleen Carley & Palmquist (2011) present the map analysis technique, which in contrast to content analysis, acknowledges the meaning contained within the text, whilst the study of the relationships between the main concepts studied is considered in the analysis.

Map analysis was effectively used in this research. This technique followed three basic steps in the representation scheme of the map analysis: (1) Definition of concepts through discussion with program managers; (2) relationships between the concepts in the record statements; and (3) directionality and strength in the causal relations between two concepts (Katheleen Carley & Palmquist, 2011). During the first step, data transformation from the pre-recorded sessions must go through a rigorous transcription, interpretation and assessment by the researcher. This interpretative process marks the quality of the analysis. As mentioned by Gibbs (2012), this process could be time-consuming; nevertheless, this work could be automated if the researcher uses a document management tool. Management tools for qualitative data analysis, such as NVivo and Atlas.ti, have been used to analyze unstructured text, audios, video, and image data, including interviews, focus groups, surveys, social media. Nevertheless, excel has proven to be a practical tool for data crunching, where the data manipulation and display features can be utilized for qualitative analysis (D. Z. Meyer & Avery, 2009).

Moreover, the first phase considers the categorization of text aligned to research objectives. For this reason, to make the categorization an interactive and visual process for the researcher, the data collection technique has to consider a systematic design, and data triangulation among the interested parties. It is likely that the creation of categories emerges during the process as well as before the data collection based on the research question. Once the categories are determined, the second phase includes the counting operations, determination of relationships and statistical processing. Finally, the researcher establishes the directionality, strength and sign between concepts.

Participative modelling approaches

The participatory approaches have been gaining momentum across social science disciplines, where researchers collaborate with each other for achieving action-orientated goals (Bagnoli & Clark, 2010). By the 1970s and early 1980s, participatory methods and techniques were carried out in response to research and planning (Pimbert & Pretty, 1997). This approach aimed to answer research questions by collecting and interpreting data (C. L. Gray, 2009). The main idea of this research method is to democratize knowledge building, allowing people to give their own opinions through their subjective perceptions (Diez, 2001; Özesmi & Özesmi, 2003). As mentioned by Ahnström et al. (2009), this approach is a powerful method within the social sciences and, indeed, it has been applied in other fields of study. For instance, this approach has been implemented in health care (Pyett, 2002), evaluation processes (Diez, 2001), and for supporting conservation efforts to tackle climate change up to the present day (Ericson, 2006; S. A. Gray et al., 2015; Özesmi & Özesmi, 2003; Satama & Iglesias, 2020).

In the climate change framework, participatory approaches enable the incorporation of formal and informal knowledge, which facilitates the implementation of policy scenarios for decision-making (Walker et al., 2002). By the early 1990s, institutions such as NGOs, national governments, and academic institutions started to develop an interest in stimulating local participation based on this approach in order to support conservation interests. As indicated by Diez (2001), developing awareness, facilitating learning and empowering the different stakeholders to face the different challenges at various levels are some of the advantages of this approach. The need to involve key stakeholder groups in decision making will allow successful conservation and sustainable development to take place. By understanding the need to take urgent actions in the face of climate change, the participation of necessary stakeholders creates a space for debate, enabling a collectively and socially desirable outcome to be achieved (Walker et al., 2002).

Participatory approaches are possible at different levels; for instance, they could easily be implemented at a regional and local level using an evaluation framework (Diez, 2001). Moreover, many methods have been developed around this approach. For instance, working with stakeholders, policy exercises, participatory learning action (Pretty, 1995), and participatory integrated assessments (Satama & Iglesias, 2020). In fact, participatory modelling has offered a

broad field of analysis in the ecosystem conservation framework. Essentially, the different methods around participatory approaches, as mentioned above, have created the opportunity to share ideas, values and aspirations among people, where the evaluation process could become successful for policy makers for identifying adaptation strategies for local people in the face of climate change.

A wide variety of participatory approaches and methods for participatory planning and decision making in natural resource management (NRM) have been developed (Basco-Carrera et al., 2017; Bots & Van Daalen, 2008; Grimble & Chan, 1995; Özesmi & Özesmi, 2004). These participatory methods have emerged due to the need to integrate solutions and strategies to address certain challenges in the ecosystem conservation and NRM fields. One of the advantages of these participative approaches is that they provide the effective participation of each stakeholder group, making their ideas and positions visible to support the planning and decision process. It is important to mention that these participatory methods take place in the qualitative research, where focus groups, Delphi method, and Participatory Rural Appraisal, among others, have been used to drive involvement from the interest groups. To provide a more integrated assessment from stakeholders, modelling tools have been applied into modelling participatory processes.

Within these participative approaches, the modelling tools are central to the development of a technical analysis. However, these models have to be understood by the stakeholders and decision-makers involved. There has been a growing trend in the development of computer-based models in the NRM field, as well as socio-ecological decision-making (S. Gray et al., 2014) to provide a more integrated assessment and a better understanding of the uncertainties of the complex nature of participatory processes. Among the participatory models, FCM is described as a qualitative or semi-quantitative modelling, which describes the system in term of its categories and relationships. Development of FCM is based on the information collected by questionnaires, interviews and focus groups (Özesmi & Özesmi, 2004). In this research, focus groups were used to obtain information from the stakeholders. As FCMs need to identify the relationships of the key concepts, which are linked with the objective of the research, map analysis was used to construct causal relationships, and thus an analysis system. In different fields of study such as water management (Mouratiadou & Moran, 2007), ecosystem conservation (Armah et al., 2010; Martinez et al., 2018; Özesmi & Özesmi, 2004), FCMs are proven to have been very useful, and also suitable for

comparing stakeholders' perspectives (S. Gray et al., 2014; Halbrendt et al., 2014; Satama & Iglesias, 2020).

4.2.2. **Quantitative methods**

Quantitative methods provide a wide range of tools and techniques used to describe and interpret quantitative data. Statistical methods have proved useful in analyzing all kinds of data in some fields like social and behavioral sciences, agriculture, and spatial analysis (Somekh & Lewin, 2005; Wang, 2014). Moreover, statistics has become a mathematical tool for analyzing experimental and observational data in the twentieth century, allowing drawing reliable conclusions from empirical results. Fundamentally, quantitative methods in this research involve, on the one hand, the collection of data on the ground about smallholder farmers and their social context by a range of techniques, bringing us a vision to the interpretations of facts was central to the work of decision-making on SAPs. For this, discrete choice models were implemented to analyze determinants of SAP adoption. Also, this research is complimented with a land use and land cover change, and a climate stressors analysis.

The social dimension that considered in this study has led this research to develop elaborate methodological fortresses in which particular understandings of knowledge, behavior, and values for research design and provide an exciting approach that has been crucial for decision-making during the program intervention. The following sub-section give a brief summary about the quantitative methods applied in this research.

Land use and land cover change - LULCC

On the one hand, land use change is defined as having physical, biological or chemical alterations caused by management, which may include changes for growing food crops, cutting trees, drainage improvements or cities built by humans (Ali, 2009). These changes have contributed to the issue of climate variability, and these activities have resulted in the emission of heat-trapping greenhouse gases. On the other hand, land cover is defined by the characteristics of the land surface, which could be modified due to agricultural activities affecting natural systems (Verburg et al., 2006). The decisions on land use and land change can either have positive or negative effects

on climate change and its impacts. In particular, LULCC is focused on agriculture, forests, rural and urban communities. Humans have had control over land use and land cover over years, where NGOs and governments can make decisions to adapt or reduce the effects of climate change. SAPs to increase carbon storage in soil are amongst the adaptation options. However, land-use decisions are in the hands of smallholder farmers, therefore, the effective interventions of different institutions could increase awareness, motivations and intentions to adopt sustainable practices which can be weak.

In this thesis, LULCC analyses were conducted to provide complementary information on the complex interactions between human and physical environments (Manandhar et al., 2010). Thus, environmental change can be evaluated based on LULCC. The analysis of land cover transitions could indicate the effectiveness of land management strategies (Carmona et al., 2010). The implementation of this analysis has considered a cross tabulation matrix based on LULCC, which allowed the change in land categories to be quantified between two points in time. The rows in the matrix indicate the categories at an initial point in time and the columns show the categories at a subsequent point in time. The entries in the matrix show the sizes of the areas that transition from the initial category to the subsequent category (Huang et al., 2012).

Logistic regression models in the determinations of affecting factors

The discrete choice models have been useful in different fields of study such as medicine (V. Singh et al., 2020; Talukder & Hossain, 2020), economy (Moh'd Anwer, 2019; Niaki et al., 2019), education (Albright et al., 2019; Mashenene, 2019), and agriculture (Abadi et al., 2017; Teklewold et al., 2013; Tey et al., 2014). Regarding the last study field mentioned, where we focus on SAPs adoption, several empirical studies have tried to capture the influence of socio-economic, and environmental variables on SAPs adoption by farmers (Caviglia-Harris, 2003; D'souza et al., 1993; Menale Kassie et al., 2013; Saltiel et al., 1994; Teklewold et al., 2013; Zeweld et al., 2017). For the analysis, the binary logistic regression (when Y is binary in nature) (Tranmer & Elliot, 2008), multinomial logistic regression (when Y has two or more unordered levels) (Böhning, 1992) and ordinal logistic regression (when Y is ordered) (O'Connell, 2006) have been applied to obtain the determinant variables of the SAPs adoption. In most of the cases, the use of logit or probit models was applied to calculate or predict the probability of a binary outcome (or dependent

variable). In this research probit models were suitable since the dependent variable is binary. Four probit models were performed taking into account the characteristics of the studied variables. The empirical model will be explained later.

4.3.   Understanding the causal interconnection of the local actors

The first study presents a semi-quantitative approach which was developed in three subsequent phases: i) Focus Group Discussions and Map Analysis in the Program Intervention, ii) FCMs application, and iii) Perception assessment by Hierarchical Cluster Analysis - HCA. This method is presented to assess peasant farmers' and project managers' perceptions about environmental conservation and livelihood in the BLW program.

4.3.1. Focus Groups and Map Analysis in the Program Intervention

A qualitative focus group technique (Kitzinger, 1995) was performed to gather information on current knowledge of the BLW program from smallholder farmers and project managers (see Figure 6). Both groups were analyzed in a separate way to ensure their precise understanding (S. Gray et al., 2012) of the outcomes and reflections.

As a preliminary step, a workshop was established with program managers, where a discussion was done to gather the key concepts (keywords) that underlie the actions taken in the BLW program. Based on the reports available for the program intervention, an interactive discussion was maintained about the keywords, which allowed it to obtain up-to-date knowledge. The reports available on the program intervention were studied. In addition, some peasants' plots in the study area were visited to gain initial insight into the project activities implemented in the area, as well as into the implications for their daily lives. Subsequently, focus group sessions were conducted using semi-structured interviews to gather data on current agricultural activities and to discuss the challenges, drivers, and impacts within the program framework. Interview questions targeted for local peasants contributed to understanding current outcomes and thinking about possible strategies for the next stage. Local peasants were selected and recruited with the help of a local leader and the project coordinator in each biocorridor. Several aspects were considered, such as meeting attendance, participation in environmental management training, and farmers that applied SAPs on their plots. Essentially, peasants that participated in the workshops had actively

participated in activities related to the biocorridors. A semi-structured approach was developed in five sessions with different focus groups. The focus groups were separated by agricultural organization in such a way that allowed us to reach a balanced dialogue with smallholder farmers.

Figure 6. Focus group sessions with the peasants.

Another focus group was conducted with the territorial project coordinators to identify the main dimensions of the program intervention. Discussions were voice recorded and analyzed through map analysis (Katheleen Carley & Palmquist, 2011; Jetter & Kok, 2014). This technique focuses on the concepts of relationships in a quantitative way. Three basic steps were employed in the representation scheme of the map analysis: (1) Distinction of concepts through discussion with program managers; (2) relationships between the concepts in the record statements; and (3) directionality and strength in the causal relations between two concepts. In the next section, we explain in detail the map analysis process in connection with FCM construction. Exploratory analysis of statements took place using the voice recordings, and map analysis was conducted using Excel worksheets.

The sample was not designed to be representative of the farmer population in each biocorridor, but instead aimed to capture in-depth insight into a small set of local peasants. Not all farmers who were selected and contacted from the two biocorridors participated in the workshops. The number of participants in each workshop was as follows: 7 belonged to the PiMoSaPa biocorridor, 13 to the CaCo biocorridor, and 4 participants were program managers who worked in both biocorridors. The focus group sessions took place in November and December 2018. On average, each session lasted one hour.

4.3.2. **Fuzzy Cognitive Maps application**

FCMs were constructed using map analysis (Katheleen Carley & Palmquist, 2011; S. A. Gray et al., 2015) to codify results from the focus groups sessions. As the name indicates, FCMs are based on cognitive mapping and allow for semi-quantitative analysis (S. A. Gray et al., 2015; Kosko, 1986; van Vliet et al., 2010). This methodology was based on the work of Axelrod (1976) and Kosko (1986). Fuzzy cognitive mapping has been widely used in a large number of fields, where sustainable development is addressed by Dodouras (Dodouras & James, 2007). He linked the existing local knowledge or ancestral knowledge to scientific knowledge, which is an essential area of inquiry in this study. FCM is based on the establishment of an adjacency matrix (Langfield-Smith & Wirth, 1992), which represents causal relationships between variables. As a first step of map analysis, the main concepts (variables or nodes) were identified in a parallel way between program managers and peasant groups. The causal relationships and their strength between two variables were assigned through Carley and Palmquist's methodology (Katheleen Carley & Palmquist, 2011; Kosko, 1986). The directionality was established by positives edges, which represented a causal increase, whereas negative edges represented a causal decrease (Axelrod, 1976; Novak & Cañas, 2008). A discrete range of values in the interval [–0.75,0.75] was used to denote whether the relationship was implied in the text (0.25), stated explicitly (0.50), or emphasized (0.75). A positive (negative) value indicated a positive (negative) relationship. Finally, 0 was assigned when no relation was identified. For example, a peasant said that "production factors such as land, seeds, water, and commercialization are the most important." This statement clearly involves four variables (land, seeds, water, and commercialization) which were coded as having a positive link with agricultural production. Also, the phrase "the most important" emphasized the level of importance, which, in this case, was 0.75.

Subsequently, identified variables were reduced by combining them into common variable categories for both peasants and project managers. The idea was to allow a comparison between both groups. These results were averaged by category in each study group considering the strength values previously established. Finally, using the adjacency matrix (Langfield-Smith & Wirth, 1992) between variables in the interval [–0.75,0.75], FCMs were constructed for each focus group session, making five in total. Four cognitive maps were obtained from the farmer groups and one by the program manager group. To obtain the opinions of the stakeholder groups, the FCMs of

farmers were subsequently aggregated. In the process of combining farmers' maps, each map was given equal weight.

Once the FCMs were obtained, and following the calculation procedure explained by Özesmi & Özesmi (2004), the connection indices were calculated: Outdegree, indegree, and centrality. The outdegree index (od(vi)) is defined by the row sum of the absolute values of coefficients in the adjacency matrix (i.e., the total strength of influence on other variables), where a_{ik} represents the weight in rows as in Equation (1):

$$od(vi) = \sum_{k=1}^{N} a_{ik}. \tag{1}$$

The indegree measurement (id(vi), see Equation (2)) was calculated from the sum of the values in the column in the adjacency matrix (i.e., the total strength of influence on the variable), where a_{ki} represents the weight in columns.

$$id(vi) = \sum_{k=1}^{N} a_{ki}. \tag{2}$$

Finally, the sum of the indegree and the outdegree of a variable is a centrality measurement (c). This measurement represents the importance level of individual variables (C. L. Gray & Bilsborrow, 2014; S. Gray et al., 2014). According to the connection indices, the type of variable (Bougon et al., 1977) was identified as shown in Equation (3).

$$X = \begin{cases} \text{transmitter,} & [od(v_i)]>0 \ \Lambda \ [id(v_i)]=0 \\ \text{receiver,} & [od(v_i)]=0 \ \Lambda \ [id(v_i)]>0 \\ \text{ordinary,} & [od(v_i)]>0 \ \Lambda \ [id(v_i)]>0 \end{cases}. \tag{3}$$

To assess the level of the participation variable within the system, the centrality index, complexity, density, and hierarchy (h) index were analyzed. The complexity index represents the ratio of the receiver-to-transmitter variables, where a higher complexity shows complex systems thinking (Eden, 2004; S. Gray et al., 2014). The number of connections divided by the maximum number of all possible connections represents the density index. A higher density index offers potential management policies within the model (Eden, 2004; S. Gray et al., 2014). On the other hand, the h index depends on the total number of variables (N), as shown in Equation (4):

$$H = \frac{12}{(N-1)N(N+1)} \sum_{i=1}^{N} [od(v_i) - (\sum [od(v_i)]/N]2. \tag{4}$$

When the index is equal to 1, the map is fully hierarchical, and when it is 0, the system is fully democratic (Özesmi & Özesmi, 2004). For the graph theory indices, FCMapper (Papageorgiou & Kontogianni, 2012), based on a Microsoft Office Excel spreadsheet, and Visual Basic for Applications were used.

4.3.3. Perception assessment by Hierarchical Cluster Analysis - HCA

This research aimed to analyze the different perspectives of the program intervention from the point of view of the peasants and the program managers, and to identify potential strategies for the next stage of the program. HCA (Murtagh & Legendre, 2014) was performed based on the resultant metrics of the FCMs of each studied group (m for managers and p for peasants). For this purpose, new variables were proposed and defined as the difference between the outdegree and the indegree metrics, as shown in Equations (5) and (6).

$$sim = od(v_i^m) - id(v_i^m), \text{ where i } = 1,...,N \tag{5}$$

$$sip = od(v_i^p) - id(v_i^p), \text{ where i } = 1,...,N \tag{6}$$

According to the resultant sign of sim and sip, the variables were explained. For example, a positive sign belongs to a cause group, and a negative sign belongs to the effect variable (Alizadeh et al., 2008). Then, differences between the variables c and s were taken. This difference is between program managers and peasants. Equations (7) and (8) show the formulas applied:

$$Dc = cmi - cpi, \text{ where i } = 1,...,N; \tag{7}$$

$$Ds = smi - spi, \text{ where i } = 1,...,N. \tag{8}$$

A condition of Equations (7) and (8) is that the groups of the study share the same variables. Also, if dc is negative, it belongs to the managers' group. On the other hand, to analyze the variable ds, we analyzed the behavior of smi and spi, and so identified the position of the group.

HCA was conducted to define the clusters, and Euclidean distance was used to identify the similarities between different variables. The appropriate number of clusters was chosen according

to the objectives of the analysis (Romesburg, 2004). Subsequently, ANOVA was carried out to test for significant differences among the clusters in each group. Then, descriptive statistical analysis was conducted by calculating the mean and the standard deviation of each cluster obtained. The main objective was to understand the position of the studied groups regarding the program intervention. The data were processed with RStudio using the package FactoExtra (Kassambara & Mundt, 2017).

4.4. Exploring the decision-making on sustainable agricultural practices

In this subsection, the second study presents a four-step procedure approach, which was developed in four subsequent phases. These methods are aimed at understanding the decision-making process on the adoption of SAPs by smallholder farmers in the frame of the BLW program in Ecuador. The next subsection explains the sources of information considered for this research.

4.4.1. Survey design and data collection

This study incorporates data from three sources: (i) survey of beneficiaries of the program, (ii) land use and land cover data evolution from 2000 to 2018 for a total of 13 parishes that make up PiMoSaPa and CaCo areas, and (iii) historical records (between 2012 and 2015 period) of rainfall and average maximum and minimum.

The first source of information was based on a random sample of the program beneficiaries. The data collection considered 418 participants registered as direct program beneficiaries in both biocorridors, taking into account the density of farmers' participants by each biocorridor. In the study, a sample from a random selection of farmers in each biocorridor was extracted. The survey samples included 103 farmers, 38% for PiMoSaPa and 62% for CaCo areas. Although it has made some formal agreements with community leaders to gather information from selected farmers, during the data collection some farmers did not collaborate in the process and others were not in their houses. In total, 80% of the sample households were conducted, which represents a total sample size of 82 smallholder farmers. The unit of analysis was the participant of the program, which in some cases was household head.

Between April and May 2019, data were collected using face-to-face questionnaires. The questionnaire for householders was designed to capture different points of view of farmers'

perceptions regarding SAP adoption, which was designed into three parts. The first part incorporates detailed information on farmer's socio-economic characteristics. The second part involves questions of commercialization, social capital and collective action. The third part of the survey included questions about farmer's adoption level for five known SAPs, as a measure of environmental behavior. The five sustainable practices were agroforestry, cover crops, crop rotation, trees nurseries, and mixed crops (See Table 1). These variables were measure using adoption or non-adoption. Annex 1 outlines the questionnaire structure. The survey was previously tested with success without any change for its application. The test considers 12 respondents to ensure the adequacy of the information and to avoid any ambiguity in the questions. For this, data collection was done in collaboration with 25 undergraduate students of Escuela Politécnica Nacional university. They were previously trained to carry out fieldwork in the frame of the social bonding project established with the Science Faculty of the university.

Table 1. Adoption (%) of sustainable agricultural practices adopted by smallholder farmers

SAPs[a]	Adopt	Don't adopt
Agroforestry	39.02	60.98
Crop rotation	84.15	15.85
Mixed crops	97.56	2.44
Cover crops	48.78	51.22
Tree nurseries	24.39	75.61

[a]The SAPs represent the five dependent variables that are going to be estimated by the model

The second data set corresponds to land use and land cover maps of the Ministry of Environment of Ecuador – MAE (for its acronym in Spanish). We select the years 2000 and 2018 for the analysis. This interval is coupled to the program's lifetime in Caco and PiMoSoPa areas. The maps include six categories of land use and land cover: Forest, agricultural land, scrubland and pastures, water bodies, built-up, and others (fallow land and glaciers). Finally, the third data set was obtained by Otavalo meteorological station provided by the Instituto Nacional de Meteorología e Hidrología (2015).

4.4.2. Relating farmers' perceptions of environmental issues to climate trends and land use and land cover change

The methodologies used for this research were (i) farmers perceptions of environmental issues analysis, (ii) map analysis using Geographic Information Systems-GIS, and (iii) climate stressors analysis. Using the results obtained from farmers perception of environmental issues a discussion was established in comparison with LULCC (land use and land cover change) and meteorological data.

The spatial analysis was performed to understand whether the perceptions of smallholder farmers matched their activities within their plots. LULCC analyses were conducted to provide complementary information about the complex interactions between human and physical environments (Manandhar et al., 2010). Thus, the environmental change can be evaluated based on LULCC. The analysis of land cover transitions could indicate the effectiveness of land management strategies (Carmona et al., 2010). A cross tabulation matrix was established as the main basis of the LULCC, which allows the quantification of change among land categories between two points in time. The rows in the matrix indicate the categories at the initial point in time and the columns show the categories at a subsequent point in time. The entries in the matrix show the sizes of the areas that transition from the initial category to the subsequent category (Huang et al., 2012).

Based on the data obtained from farmers perceptions of environmental issues, the study compared face to evidence in meteorological records to establish a comparison between human perception and the physical environment. More detailed information about these steps is outlined below.

Climate stressors analysis

Meteorological data were collected from the study sites providing recent records (for the period between 1994 and 2015) on rainfall and average maximum and minimum temperatures. Monthly data collected at the Otavalo meteorological station were provided by the Instituto Nacional de Meteorología e Hidrología (2015). Although two other meteorological stations were located in the study area, information was not available on their websites. In addition, while the Otavalo station has relatively consistent historical records, it does not provide data from 2016 to 2019.

A t-test was performed using STATA 12.1 to assess the trend over time in terms of temperature and rainfall data over the studied periods. Finally, percentage change analysis was calculated to determine the rate of changes in temperature and rainfall between years.

Map analysis using Geographic Information Systems-GIS

For LULCC analysis, data were studied from 2000 to 2018. Based on the two sites of the study, two maps were cross-tabulated to identify the spatial changes (i.e., gains and losses) derived from temporal analysis for the CaCo and PiMoSaPa areas. This is reported in a cross-tabulation matrix to identify net gains at the end of the columns and losses at the end of the rows. The main diagonal of the matrix from the top-left corner to the bottom-right corner, represents the land use and land cover persistence (Pontius Jr et al., 2004). In contrast, the bottom part of the matrix represents the area gained for each category in the second period, represented by the column's headers.

4.4.3. Determinants of adoption of sustainable agricultural practices among farmers

The identification of the relationship between endogenous and exogenous variables was enabled through the empirical models proposed. Four models were considered using the adoption of SAPs as endogenous variables. Although the four agricultural practices share a sustainable approach, the choice to adopt one or the other is not limited. Hence, the four models were considered separately to see if any factors studied relating to the adoption decision still hold and explore the role of environmental concern and trust among farmers. More detailed information about this step is outlined below.

Empirical model: Probit Models

Since our database includes categorical independent variables, and the dependent variable has a dichotomous nature, a Probit model was selected as a suitable tool to assess the relationship between SAP adoption and the variables of interest. These type of models have been extensively used in other studies to assess adoption (Case et al., 2017; Deressa et al., 2011; Fischer & Qaim, 2012; Hunecke et al., 2017) . The Probit model enables the analysis of factors that influence the probability of SAPs adoption. Although there are two alternative model specifications, such as Probit and Logit and, only the former was selected since the results of the Logit model were only slightly different. The following Probit is proposed to explain the adoption of SAPs.

$$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + u_i \qquad u_i \sim IN(0,1)$$

Where x_{ij} denotes a set of explanatory variables j $(j = 1, ..., k)$, i for farmer and u_i is the error term. The dependent variable y_i^* is unobserved. However, we observe whether participation takes place, that is:

$y_i = 1,$ if $y_i^* > 0$ (farmers i adopted sustainable practice), and

$y_i = 0,$ 0, otherwise

The Probit model is estimated for the adoption of SAPs using maximum likelihood techniques programmed in STATA version 12.1 (Hamilton, 2012). Table 2 shows a description of the independent variables and expected signs for the SAPs adoption level model. We estimate four Probit models for each SAP.

5. Results

5.1. Understanding the causal interconnection of the local actors

5.1.1. Focus Groups, Text Analysis, and FCM

Using text analysis, a total of 38 concepts were identified in the Project managers focus group session, whereas 155 concepts came up in the farmers' focus group. Figure 7 illustrates an example of concept categorization from farmers and program managers. Data processing resulted in four FCMs for local peasant farmers and one for program managers. One aggregated map was obtained for the peasant farmers. The total number of variables in the map was 155, and these were combined into 24 categorical variables. Thus, around 57% of the variables were common among both groups (see Annex 2 and 3 for the variable aggregation list).
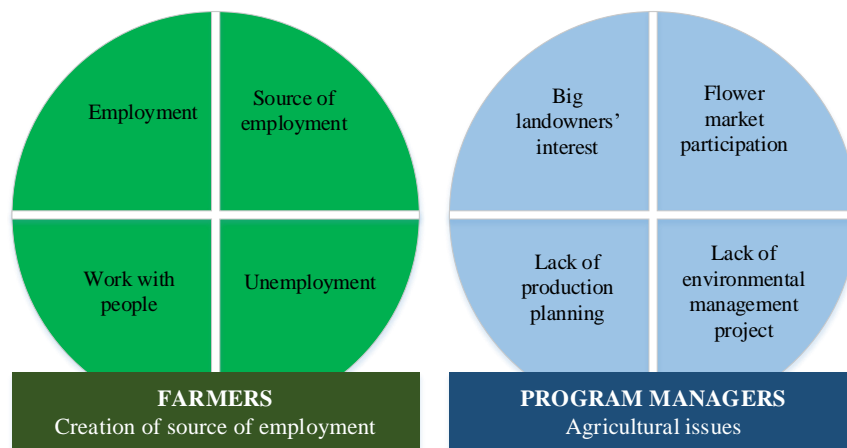
Figure 7. Visual representation of concept categorization from farmers and program managers. Note: "Creation of source of employment" and "Agricultural issues" are the categorized concepts.

Table 2 provides farmers' FCM metrics (average values) and the aggregated maps (peasant farmers' and program managers' maps). The average number (±SD) of variables in the agricultural organizations' map was 17.25 (±1.71). The mean number of connections between variables was 48 (±6.38). After FCM data processing, peasant farmers' concepts resulted in 106 connections, whereas project managers presented a total of 20 concepts and 54 connections in their map. Peasant farmers presented a value of density index close to 0.18, whereas the project managers were close to 0.14. Furthermore, the project manager map had more receiver variables than the peasant farmer group. Hierarchy indices show values close to 0 for both groups, in particular the peasant farmers.

Table 2. Mean and standard deviation of the FCM indices by organization group.

Index [1]	Agricultural Organizations	Peasant Farmers	Managers
Number of maps	4	1	1
Number of participants	20	20	4
Number of variables (N)	17.25 ± 1.71	24	20
Number of connections (C)	48 ± 6.38	106	54
C/N	2.13 ± 0.19	4.42	2.70
Density	0.16 ± 0.03	0.18	0.14
Number of transmitter variables (T)	3.25 ± 1.70	3	4
Number of receiver variables (R)	2.5 ± 1	3	5
Number of ordinary variables	11.5 ± 2.08	18	11
Complexity (R/T)	1.17 ± 1.23	1.00	1.25
Hierarchy index, h	0.06 ± 0.03	0.01	0.05

[1] Except for the number of maps and the number of participants, all values are mean and standard deviation of the indices.

Figure 8 illustrates the connections between the eight most central variables in the managers' and the peasant farmers' maps. The most central variable for both groups was social capital and collective action, understood as trust and teamwork. Indeed, farmers emphasized the importance of this variable during the focus group sessions: "…if the organization among us were good, we could improve production planning, commercialization, and our well-being." SAPs were another central variable perceived by the managers and peasant farmers. Moreover, in a focus group session, one of the peasants said: "…the best way to express love to the Pachamama is by using organic fertilizer." On the other hand, capacity strengthening affected the SAPs positively, whereas household welfare had a negative effect (see adjacency matrix in Annex 4). A peasant farmer indicated that "we are thankful for the training of the project in how to sow, how to make organic fertilizers; however, it is crucial to know the nutritional and medicinal properties of the products and how to promote them."

Additionally, household welfare was identified among the most central variables in the peasant farmers' cognitive map. According to map analysis, the local peasant farmers linked welfare with income, animal feed, and mainly emotional stability. A female peasant farmer said that "there are harmful things which undermine self-esteem, and we cannot work. However, with this program, I became more empowered in my household, and also with the partners of my local community." Furthermore, within the program managers' map, commercialization was another central variable (see adjacency matrix in Annex 5). Nevertheless, in the peasant farmers' map, this variable was not presented within the eight most central variables. On the other hand, peasant farmers paid attention, during the program intervention, to agricultural production and the issues affecting their daily lives. Both study groups agreed that the lack of agricultural planning remains a problem, whereas associativity is perceived as part of the solution.

As expected, ecosystem conservation was also distinguished as a central variable in the managers' cognitive map, although they mentioned that gender played an essential role in conservation. A project manager said that "the women work in the area of production landscape, whereas the men work in ecosystem conservation." On the other hand, although the ecosystem conservation variable does not appear in the group of most central variables for peasant farmers, they have strong concerns relating to environmental conservation. Indeed, a peasant farmer said that "Our soils need feeding and care. We have cared for the Pachamama for many years."

Program managers   Peasants

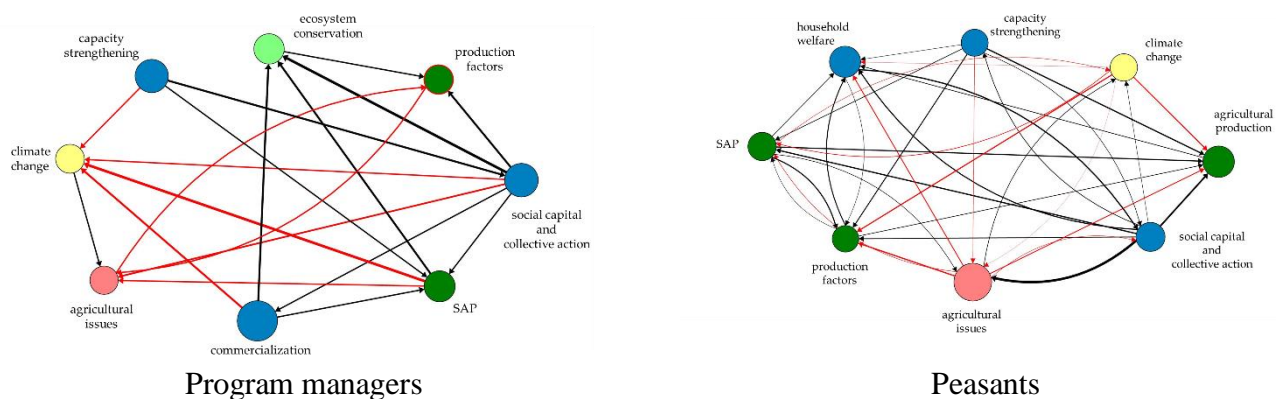**Figure 8.** Visual representation of a subset of managers' and peasant farmers' maps, showing the eight variables with high centrality.[2]

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[2] The black lines represent positive connections, and the red lines show the negative connections. The circles represent the variables of the system, and the colors refer to the program sector (green for agriculture, light green for

5.1.2. Perception assessment by Hierarchical Cluster Analysis - HCA

The HCA results are shown in the dendrogram in Figure 9. Three clusters were obtained. Cluster 1 was denominated "activities during the program intervention," considering the core activities explained in the program reports. Cluster 2, "program framework," containing the objectives pursued by the program. Finally, Cluster 3, "building knowledge and welfare," characterized by social strategies during the program intervention.
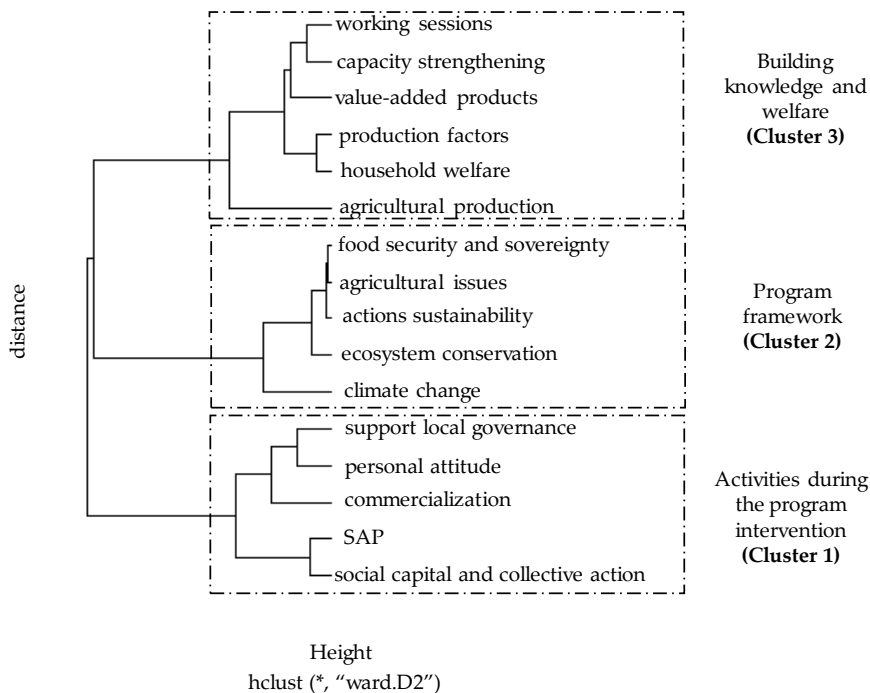
Figure 9. Dendrogram of the clusters of the program intervention. SAP, sustainable agricultural practice.

Highly significant differences were found between clusters for the dc variable (p-value was 5.53e-05). On the other hand, the findings reveal no significant differences among both groups on the ds variable due to the dimensions identified being similar. Looking at Figure 10, the findings confirm that program managers believed that Cluster 1 followed by Cluster 2 were the most important dimensions in the "Biocorridors for Living Well" program, whereas local peasant farmers

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conservation, blue for socioeconomic aspects, red for issues, and yellow for climate). SAP, sustainable agricultural practice.

perceived Cluster 3 as a central dimension (representing 60% of the central variables in the peasant farmer FCM). In the case of the ds variable, a positive sign illustrates an effect variable (driver), whereas a negative sign represents a receiver variable.
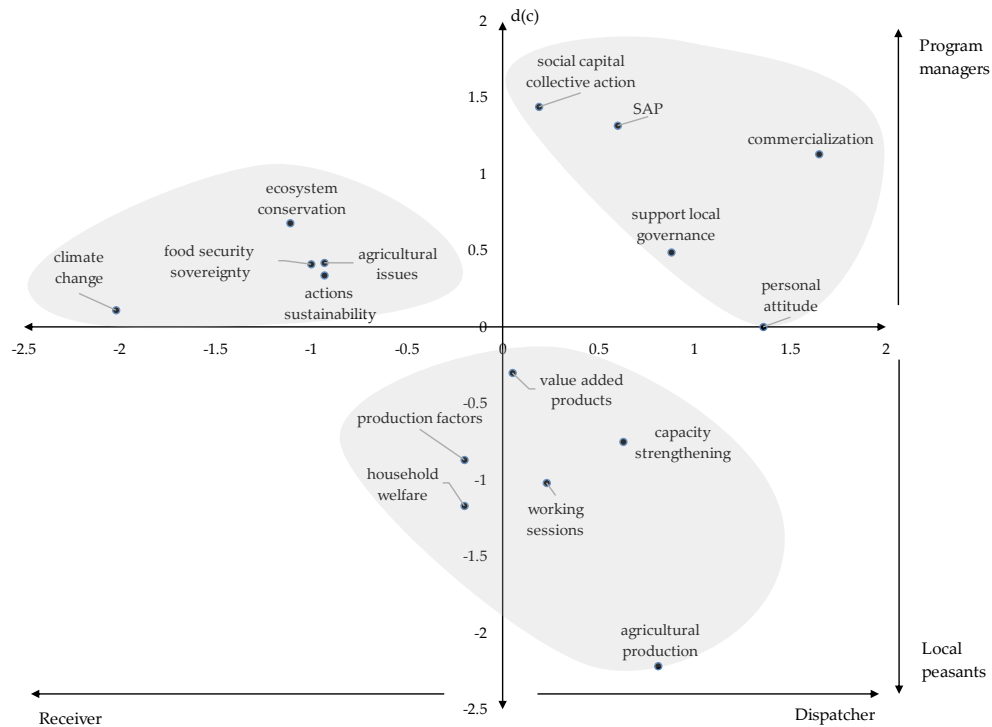
Figure 10. Comparison assessment between managers and peasant farmers. Clustering nodes by FCM indices. Mean value of performance variables in the three established clusters. Dc, differences in the centrality variable between the study groups; ds, differences in the s variable between the study groups.

The profile of Cluster 1 (Figure 11) indicates a close agreement between managers and peasant farmers on the "personal attitude" variable regarding the level of importance. Also, both groups considered personal attitude as a causal variable. Although peasant farmers emphasized the importance of this variable during the focus group sessions, the results show a low score impact of this variable in the whole system. On the one hand, as described earlier, both groups considered the "social capital and collective action" variable an important causal force. On the other hand, looking at the emphasis on the "SAPs" variable by project managers and peasant farmers shows that the program pays attention to these production systems.

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Figure 11. Cluster 1 variations of the variables c (centrality variable) and s (difference between the outdegree and indegree variables).

Both groups agreed that commercialization of baskets of agricultural products and agroecological fairs are key variables in the success of the BLW program. On the other hand, local peasant farmers saw commercialization as part of the effect group of variables. Regarding the support of the local government during program intervention, the results show that local peasant farmers and managers did not perceive a significant presence of local public institutions.

In the case of Cluster 2, as seen in Figure 12, denominated as "program framework," its main features focus on the concerns of agricultural issues. Managers perceived that the program was focused on not only working on ecosystem conservation, but also on integrating solutions for resolving issues facing the agricultural sector. On the other hand, both groups also placed the most importance on the "climate change" and "ecosystem conservation" variables. According to the behavior of the s variable, and as expected, these variables were perceived as response variables by project managers. The program had among its main objectives the restoration of ecosystems and the reduction of vulnerability of farmers' households. On the other hand, the smallholder farmers recognized both variables as driver variables.
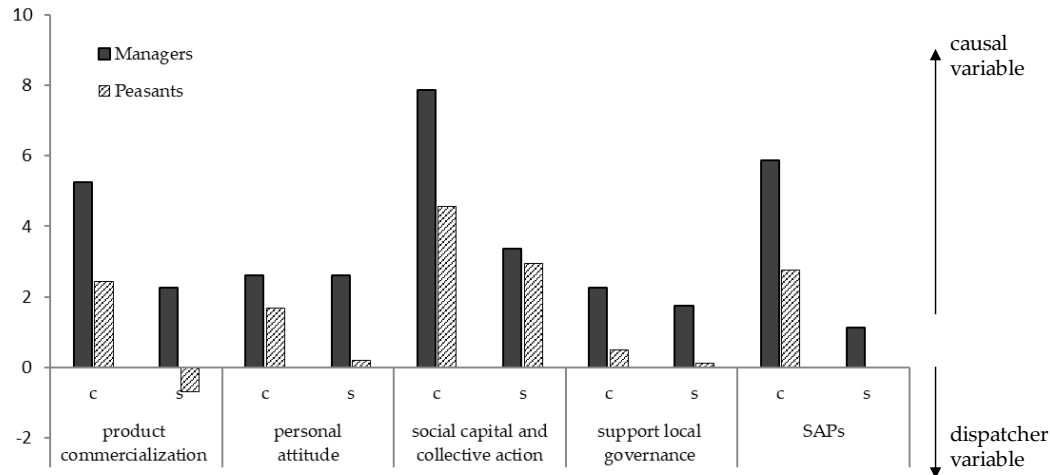
Figure 12. Cluster 2 variations of the variables c (centrality variable) and s (difference between outdegree and indegree variables).

The results also show "actions sustainability" and "food security and sovereignty" within the program framework. Project managers paid attention to these variables. However, peasant farmers' perceptions revealed that further efforts are necessary and include new strategies to incentivize SAP adoption by farmers. Finally, the main features of Cluster 3 in Figure 13, which was denominated as "building knowledge and welfare," obtained the highest score by peasant farmers. Figure 13 clearly shows the importance given by peasant farmers to the "agricultural production" and "production factors" variables within the program. In addition, both groups characterized these concepts as response variables. Project managers and peasant farmers also placed great importance on the "capacity strengthening" variable and considered it a driver. Here, education and technical assistance played a crucial role in the program. On the other hand, within the program implementation strategies, we found that the "household welfare" variable had a high centrality score from both groups, particularly farmers. In addition, the behavior of the s variable showed that household welfare was an effect variable.
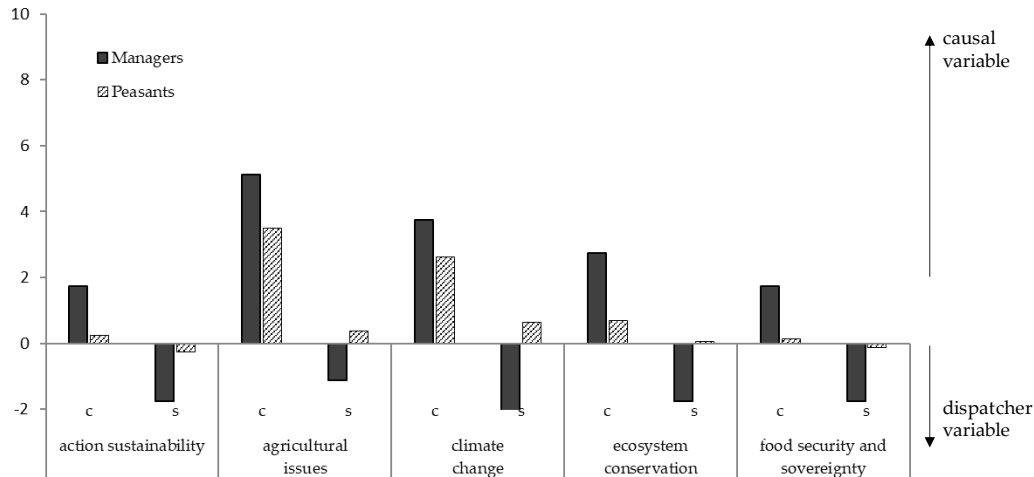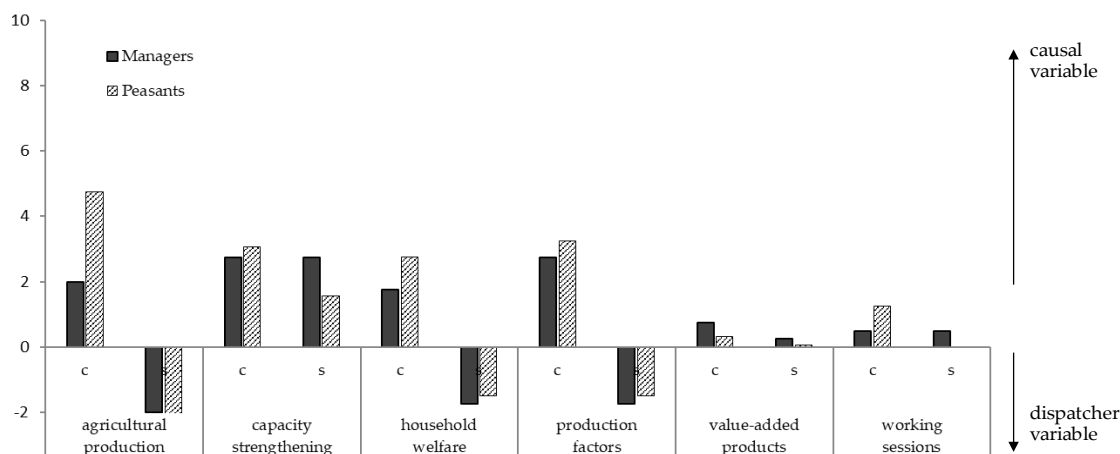
Figure 13. Cluster 3 variations of the variables c (centrality variable) and s (difference between outdegree and indegree variables)

Regarding the "value-added products" and "training sessions" variables, both groups showed that the program might not have had a significant impact. On the other hand, "mingas" (indigenous tradition of informal collective actions) have allowed the creation of spaces for discussion among stakeholders in the local territories. The results show that peasant farmers perceived that these meetings helped to comply with the activities in the program. Voluntary engagement and social media were also perceived as important in the program implementation.

5.2. Exploring the decision-making on sustainable agricultural practices

5.2.1. Socio-economic characteristics of smallholder farmers

The results of the descriptive summary of the smallholder farmer's socio-economic characteristics are presented in Table 3. The survey that was directed at smallholder farmers indicated that 68% were women, and 32% were men. The age profile of the surveyed group was 47 years old (±12.8). Within the surveyed group, the average family size was on average six members (±4.75). In addition, the number of children in the household was four (±1.94). Over 47% of respondents revealed that they had a secondary education level. An expected result was that over 78% of the farmers' group surveyed have identified themselves as indigenous. In all, 46% of the sample had taken part in agro-ecological fairs, with women being more involved in this activity. On the other hand, 17% of respondents mentioned that they have incorporated value-added agricultural

products. Flours, pies, juices, and dairy products were some of the products that they produced, selling them mainly at markets for agroecological products. Regarding the size of landownership, the group of surveyed farmers have on average 1.47 ha (±1.18) per household.

Table 3. Socio-economic characteristics from the surveys in Pisque Mojanda San Pablo-PiMoSaPa, and Cayambe Coca-CaCo zones.

Independent Variables	Definition	Statistics		Expected Sign
		Mean **(% were noted)**	**s.d.**	
Category: Socio-demographic characteristics				
Education	Farmers' level of education			
No		10.98%		
literacy		17.07%		+
primary education		23.17%		
secondary education		48.78%		
Gender of the participant	dummy, 1 if farmer is female and 0 otherwise	31.71%		+
Age of the participant	age of the farmer in years	47.27	12.8	+
Poverty	perception of poverty			-
	not poor	3.66%		
	more or less poor	86.59%		
	poor	9.76%		
Household size	number of household members	6.07	4.75	+
Community years	family members linked to agricultural activities	3.43	2.28	+
Ethnic identifier				+

Independent Variables	Definition	Statistics		Expected Sign
		Mean (% were noted)	**s.d.**	
	indigenous	79.27%		
	mestizo	20.73%		
Land size	farm land holding, ha	1.47	1.18	?
Category: Commercialization				
Agro-ecological fair	dummy, 1 if the farmer participates in the fair and 0 otherwise	46.34%		+
Value-added	dummy, 1 if the farmer adds value to the products	17.07%		+
Category: Social capital and collective action				
Trust in SAPs	dummy, 1 if farmers trusts their colleagues regarding the adoption of SAPs and 0 otherwise	71.95%		+
Minga	dummy, 1 if farmer participates in this collective activity and 0 otherwise	82.93%		+
Category: Social capital and collective action				
Environmental concern	likert scale environmental awareness			?
likert=1	lowest score	8.54%		
likert=2	middle score	12.20%		
likert=3	highest score	79.27%		

SAPs refers to Sustainable Agricultural Practices

5.2.2. Relating farmers' perceptions on environmental issues to climate trends and land use and land cover change

Smallholder farmers' perceptions of environmental issues

Figure 14 summarizes the farmers perceptions related to climate variability: air, water and soil pollution, soil fertility issues, and drought in five communities. Over 49% of respondents indicated that there is an evident decline in soil fertility. In addition, the results showed that 41.46% of smallholder farmers surveyed considered that there is high soil damage in their local territories. Furthermore, 31.71% and 26.83% of farmers perceived the existence of a problem in their territories regarding air and water pollution. For instance, our results highlighted that smallholder farmers are most concerned about soil fertility, soil pollution and water pollution in their local communities.

Finally, drought does not appear as an important concern since most respondents ranked the threat of drought as low importance (53%) or even not important at all (21%). Only 26% of respondents consider it a threat of moderate importance.
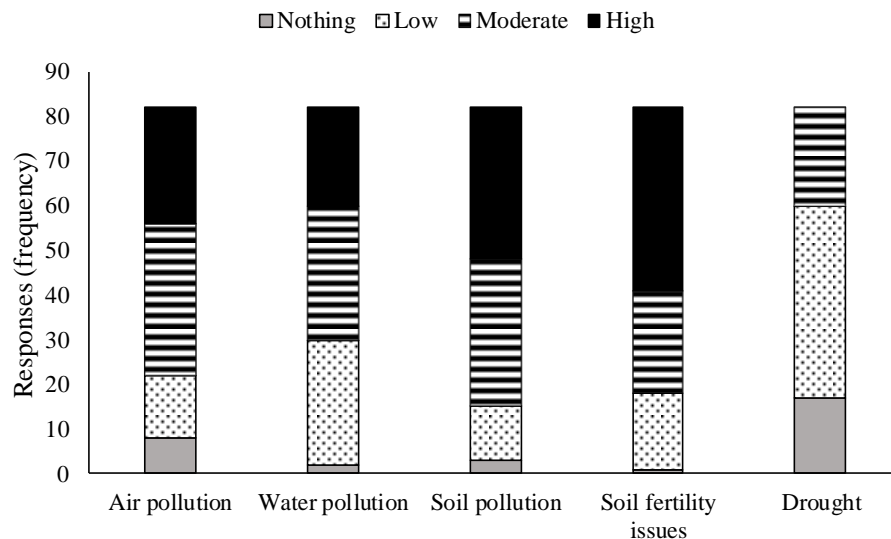

Figure 14. Smallholder farmers' perceptions of the climate change-related issues in the CaCo and PiMoSaPa biocorridors in Ecuador

On the other hand, the results of the descriptive analysis of the climate stressors in the study area is presented in the Table 4. The t-test reveals that the mean annual rainfall has presented

homogeneity in the periods 1994-2008 and 2009-2015, while for the maximum annual temperature, the opposite occurred. Looking at the descriptive statistics of the climate variables, the period 1994-2008 has the least mean annual rainfall, while 2009-2015 had the highest maximum temperature. It was also observed that there was a significant difference between the two periods analyzed.

Table 4. Descriptive statistics of climate stressors in the study area

Pooled data (1994-2015)	
Mean annual rainfall (mm)	74.18
Mean of rainfall days	11.99
Mean annual temperature (°C)	14.53
Mean annual maximum temperature (°C)	21.74
Mean annual minimum temperature (°C)	7.77
Sub period I (1994-2008)	
Mean annual rainfall (mm)	73.05
Mean of rainfall days	11.25
Mean annual temperature (°C)	14.19
Mean annual maximum temperature (°C)	20.73
Mean annual minimum temperature (°C)	7.84
Sub period II (2009-2015)	
Mean annual rainfall (mm)	76.62
Mean of rainfall days	12.73
Mean annual temperature (°C)	14.87
Mean annual maximum temperature (°C)	22.75
Mean annual minimum temperature (°C)	7.7
t-test	
Change in annual mean rainfall between 1994 and 2008 and 2009–2014	3.57
Change in annual mean rainfall days between 1994 and 2008 and 2009–2015	1.48
Change in annual mean temperature between 1994 and 2008 and 2009–2016	0.68
Change in average maximum temperature between 1994 and 2008 and 2009–2015	2.02
Change in average minimum temperature between 1994 and 2008 and 2009–2016	-0.14
t-test for rainfall	-1.21
t-test for days of rainfall	1.37
t-test for temperature	-1.53
t-test for maximum temperature	-2.78***
t-test for minimum temperature	0.14

Note: **significant at 1% level of testing

Source: Instituto Nacional de Meteorología e Hidrología (2015)

Map analysis using Geographic Information Systems-GIS

Table 5 shows the transition matrix comparing land use and land cover maps in the *CaCo* area for the period from 2000 to 2018. showing that the area of this diagonal did not change during the selected period. The penultimate column of the table indicates the total area for 2000 by category and the total area of *CaCo* is in the last cell of the table. The main land use and land cover in 2000 in the area was scrubland and grasses followed by agricultural land with both categories accounting for 88% of the area, and forest only representing 8% of the total area. At the 2nd point in time, 2018, *CaCo* also confirms this situation in which agriculture, scrubland, and grasses account for 87% and forest remains at 8% of the total area. The main important LULCC is attributable to the scrubland and grasses land gain followed by agriculture, which is typical for agricultural-livestock rotational schemas in the Andean region. Other important changes are attributable to an increase in built-up areas to 2,358 ha. Forest loss of 1,762 ha in the area is compensated by 1,491 hectares in a shifted area.

Table 5. Cross table for land use and land cover maps in Cayambe Coca-CaCo zone in Ecuador for the period 2000 to 2018, values in hectares.

| | **2018** | | | | | | | |
Land Use/Land Cover	Agricultural land	Scrubland and grasses	Water Bodies	Built-Up	Others	Forest	**Total**	Gross Loss
Agricultural land	26,688	4,669	8	2,260	58	1,161	**34,842**	8,155
Scrubland and grasses	3,278	74,249	26	86	232	330	**78,200**	3,951
Water Bodies	9	54	350	0	0	0	**413**	63
Built-Up	0	0	0	913	0	0	**913**	0
Others	10	610	1	0	2,230	0	**2,852**	622
Forest	1,149	534	6	12	60	8,826	**10,588**	1,762
Total	**31,133**	**80,115**	**392**	**3,271**	**2,579**	**10,317**	**127,807**	
Gross Gain	4,446	5,867	41	2,358	349	1,491		14,552

(The left side of the table is labelled **2000** vertically.)

Note: Values are shown in hectares (integer) and minor differences of 1 ha can be expected across the table because of number rounding, but cross-validation values agree in the total summation between 2000 and 2018 (green cell)

Table 6 shows the results of LULCC in the PiMoSaPa zone. In terms of global change, PiMoSaPa changed land use and land cover in 1 2,741 ha (20%) of the total area, whereas the overall CaCo land change was 14,552 ha (11%) of the total area. The PiMoSaPa zone as well as the CaCo zone are agricultural and livestock suitability areas between 2000 and 2018 in terms of land-use and land cover. PiMoSaPa presents a forest loss of 2,055 ha, but such loss is compensated by reforested

areas from agriculture and scrubland and grasses of 1,380 ha. However, there was a loss of 675 ha (9%) of forests. Another major change in the area, similar to CaCo, is the increase of built-up area to 2,636 ha (4%) of the total area. Both zones represent areas that have shifted from agriculture to scrubland, and grasses, typical for the Andean region in which animal grazing is part of long-term crop rotation schemas to generate profit from the disposal of manure from grazing activity.

Table 6. Cross table for land use and land cover maps in Pisque Mojanda San Pablo-PiMoSaPa zone in Ecuador for the period 2000 to 2018, values in hectares.

	Land Use/Land Cover	Agricultural land	Scrubland and grasses	Water Bodies	Built-Up	Others	Forest	**Total**	Gross Loss
				2018					
2000	Agricultural land	25,486	1,948	8	2,313	0	1,017	**30,772**	5,286
	Scrubland and grasses	4,541	17,510	13	286	30	364	**22,744**	5,234
	Water Bodies	10	26	1,037	1	0	0	**1,073**	36
	Built-Up	0	0	0	1,633	0	0	**1,633**	0
	Others	37	92	0	0	0	0	**129**	129
	Forest	1,564	448	2	36	6	5,628	**7,683**	2,055
	Total	**31,638**	**20,023**	**1,060**	**4,270**	**36**	**7,008**	**64,035**	
	Gross Gain	6,152	2,513	23	2,636	36	1,380		12,741

Note: Values are shown in hectares (integer) and minor differences of 1 ha can be expected across the table because of number rounding, but cross-validation values agree in the total summation between 2000 and 2018 (green cell)

5.2.3. Determinants of adoption of sustainable agricultural practices among farmers

Table 7 illustrate Probit models' results with P-Values and estimated coefficients. The Chi-Square test shows that the likelihood ratio statistics are highly significant ($P<0.01$), for the explained variables except for mixed crops ($P>0.05$). Here, the values of the Chi-square test suggest that the models that were applied have a strong explanatory power.

Our findings show that the education coefficient is statistically significant for the adoption of agroforestry and crop rotation, where the low education levels appear to be associated with the low adoption rates of both these practices. We found a negative gender effect in the adoption of agroforestry and crop rotation practices, indicating that women are less likely to adopt agroforestry practices. Further, higher age is related to greater adoption of the agricultural practices of crop rotation among smallholder farmers. On the other hand, in terms of poverty status, our results show

that most of the surveyed group are characterized as being poor. However, the results show that the influence of the age variable in the adoption of agroforestry practices is not significant. Furthermore, the number of years that farmers have been living in the community appears to be associated with the adoption of both practices.

Regarding the use of technology by farmers, the use of WhatsApp seems to be significantly and positively related to the adoption of agroforestry, while for crop rotation there does not seem to be any particular pattern. The results also suggest that linking farmers to agroecological fairs could promote greater adoption levels of agroforestry practices. Furthermore, although our results have showed show that the value-added chain is still underdeveloped in this surveyed group, the ordinal logit model shows that farmers who have started to add value to their agricultural products appear to be associated with a higher adoption level of both practices.

In addition, trust among smallholder farmers is significantly and positively associated to the adoption of crop rotation practices. This could mean that within close local communities there is an increased likelihood that more farmers adopt this practice in their plots. Similarly, our findings revealed that participation in collective actions, such as minga, is not associated with greater adoption of mixed crops and tree nurseries. Finally, our results revealed that environmental concern is associated with higher adoption of SAPs for both practices in the study group.

Table 7. The results of the probit models

Variable	Y = Agroforestry		Y = Crop rotation		Y = Cover crops		Y = Trees nursuries	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Socio-demographic variables								
Education (secondary©)								
Iliteracy	-0.65	0.62	-2.38	1.09	-0.55	0.63	-0.4	0.67
Literacy	-1.93**	0.6	-1.4**	0.98	-0.24	0.53	-1.97**	0.81
Primary	0.06	0.46	-0.9	0.65	-0.43	0.45	-1.29	0.59
Gender	-1.01**	0.45	0.19	0.58	-0.39	0.42	-0.68	0.49
Age	0.02	0.02	0.07**	0.03	0.02	0.02	-0.02	0.02
Biocorridor (1=CoCa-Caco, 0=PiMoSaPa)	-0.13	0.4	0.49	0.53	0.21	0.36	0.77	0.52
Household_size	0.02	0.03	0.15	0.14	0.03	0.04	0.07*	0.04

Variable	Y = Agroforestry		Y = Crop rotation		Y = Cover crops		Y = Trees nursuries	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Communication media								
WhatsApp (1=Yes, 0=No)	-0.42	0.4	-1.56**	0.7	-0.29	0.38	-0.85*	0.46
Commercialization								
Agroecol_fair (1=Yes, 0=No)	0.81*	0.43	0.1	0.61	-0.04	0.41	-0.27	0.48
Value_added (1=Yes, 0=No)	0.65*	0.52	-	0	0.72	0.5	0.02	0.53
Social capital and collective action								
Trust_SAP (1=Yes, 0=No)	0.32	0.41	1.41**	0.62	0.91**	0.4	0.37	0.49
Minga (1=Yes, 0=No)	0.07	0.54	0.2	0.73	-0.35	0.49	-1.31*	0.6
Community_years	0.02**	0.01	0.01	0.02	0.02*	0.01	0.03**	0.02
Environmental awareness								
Environmental concern (much©)								
Nothing	0.16	0.69	-2.89***	1.11	-1.51**	0.76	0.36	0.81
Low	0.38	0.62	0.73	0.89	-0.06	0.56	-0.7	0.7
constant	-2.11*	1.14	-2.98	1.96	-2.04	1.07	-0.02	1.12
Log likelihood	-39.56		-20.79		-44.19		-33.76	
Wald$_x^2$	30.58		24.78		25.25		23.58	
Pseudo R^2	0.28		0.37		0.22		0.26	
Num. Observations				82				

***,**,* Stand for values statistically significant at 0.01, 0.05, and 0.1 levels, respectively. © Reference category

6. Discussion

This research was structured in two consecutive and interrelated studies. The methodological approach applied combines the i) implementation of participative modelling supported by FCM and HCA, and ii) a decision-making analysis, which environmental issues analysis from farmers, map analysis using GIS, climate stressors analysis and probit models, and these methodologies aimed at understanding the local actors' causal interconnection, and exploring the decision-making on SAPs, respectively. Both studies were located in the BLW program framework in the Coca-CaCo and PiMoSaPa zones.

The **participative modelling approach based on FCM and HCA** enabled perceptions of ecosystem conservation to be captured, and the impact of the BLW program to be assessed amongst program managers and smallholder farmers. To achieve an understanding of what has been happening within the program, FCM and HCA were used to explore and analyze the outcomes achieved by the program, considering the perceptions of the actors involved.

In contrast with other studies (Ostrom, 1990; Vasslides & Jensen, 2016), FCM results show that the peasant farmer group represented a large value on the density index compared to the program managers. Besides, program managers perceived program intervention as a complex system, in which many components interact in this type of program. On the other hand, the farmers' results show that their maps were fully democratic, which means that all the actor had the opportunity to presents their point of view. This finding reveals that the work can be seen as a participatory approach, where the decision-making in the program does not only concentrate on one group of participants. As indicated by both groups, social capital and collective action are highly connected to other variables in the system, and are considered as key elements for achieving the program's conservation goals (Woolcock & Narayan, 2000), and creating positive biological biodiversity on farms. Moreover, peasant farmers perceived that sustainable practices promote the conservation of natural resources and guarantee food supply (Mehrabi et al., 2018; Salafsky & Wollenberg, 2000). However, they perceive that the educational training implemented in the program framework is becoming a recurring theme.

Undoubtedly, farmers' perceptions show that welfare is an essential factor for active participation in the program, where activities focused on it could empower the participants. In addition, as highlighted in the results, commercialization was not present in the most central group of variables. One explanation for this could be that the agroecological fairs still presented a gap between the costs of production and sales (Loconto et al., 2018), causing farmers' dissatisfaction with the perceived net profit. On the other hand, the production surplus could be another explanation, because farmers mentioned that their current production output was not enough to be sold at fairs, contrary to the Heifer report (HEIFER, 2014), which mentioned that there is production surplus to the market. In this sense, although some authors stated that sustainable agriculture guarantees food supply (Altieri et al., 1998; Mehrabi et al., 2018), it is not clear to what extent these systems would provide enough food for the population and whether the price of products guarantees the long-term sustainability of the agricultural system

In terms of agricultural production, the result from peasant farmers shows that the problem in the agriculture sector includes the whole production chain. As Polan (2005) suggests, the critical point in the agricultural sector is organization and rural education. Issues such as access to credit, lack of technification, and irrigation access are perceived as important barriers by farmers, and these issues would be resolved with strengthened organization. In this sense, NGOs should continue actions to strengthen associativity, and coordinate work with stakeholders in the local territories. On the other hand, the results show the role of women in ecosystem conservation, in which, according to Ahmed (2001), a woman is responsible in terms of natural resource management. For this reason, it is advisable that the program continues focusing on access to knowledge and on improving women's skills to enhance local community development (Seferiadis et al., 2017).

The farmers' FCMs results show that they have prioritized agricultural production within the conservation process of natural resources, where their agricultural practices have roots in their culture and traditions. The vast local knowledge about the nature and ecological characteristics of the region that they inhabit (Gadgil et al., 1993; Pohle & Gerique, 2006; Walshe & Argumedo, 2016) has allowed them to face extreme events (Hobbs et al., 2011) and to demonstrate care and respect for the "Pachamama."

As a next step to assess local knowledge of ecosystem conservation amongst farmers and program managers, the results of the HCA show that there is no agreement between both groups in terms

of the level of importance of the following dimensions: building knowledge and welfare, program framework, and activities during the program intervention. However, it is important to highlight that peasant farmers and program managers understood that the program was focused on improving adaptation to climate change, supporting ecosystem conservation and production factors, and trying to overcome agricultural barriers, safeguard food security and sovereignty, guarantee the long-term sustainability of actions, and improve the livelihood of the local people. Globally, local government and NGOs are working to respond to the existing food security emergency and poverty challenge through these types of programs (Romero et al., 2012).

In addition, both groups indicated that personal attitude influences the participation in the program (Ahnström et al., 2009). Nevertheless, not all of the participants of the program felt motivated during the development of the activities. The results are also in accordance with the FAO (2016), which suggests that agroecology helps to sustain a wide range of production, socio-economic, nutritional, and environmental benefits. Nevertheless, despite the importance given to this variable, there has been no positive effect on peasant farmers' attitudes; that is, these practices do not seem to have any implications for the involvement of farmers in this program. However, there has been increasing interest from national and international institutions in providing technical assistance to sustainable farming practices. In this sense, the support of the local government, national and local governments must be focused on establishing policies that incorporate the concept of sustainable development, and this support must direct invest towards human capital. As mentioned by Romero et al. (2012), public investment has to leave aside neoliberal dogma, and instead focus on human and social capital to secure long-term sustainable development. However, according to Lalander (2016), if economic interests in Ecuador are still prevailing, natural resource management programs will not receive proper attention. It is not new that the tightening of the link between livelihoods and ecosystem conservation seeks to create social impacts on local people (Keese, 2001). Nevertheless, although conservation and poverty alleviation pursue different objectives, there could be an overlap of these concept in practice from a sustainable approach (Adams et al., 2004).

This research shows that the commercialization of baskets of agricultural products and agroecological fairs are incentives for adopting conservation practices (Wollni et al., 2010). This could suggest a strategic pathway for program managers to ensure the long-term sustainability of

the program. This finding is based on the fact that local peasant farmers feel motivated to participate in the fairs, while they are producing using agroecological systems on their plots. Undoubtedly, peasant farmers and managers are aware of the relevance of the program objectives despite farmers giving climate change and ecosystem conservation low scores. Indeed, farmers considered that social and environmental changes have been experienced in their territories for a long time; it has allowed them to gain experience in the face of extreme climatic events (Pretty & Smith, 2004).

It is important to mention that the BLW program is aligned with the vision of the Ley Orgánica del Régimen de la Soberanía Alimentaria (LORSA in Spanish) (COPISA, 2009) and Sumak-Kawasay (GEF Small Grants Programme, 2014), where program managers' attention is focused on establishing agrifood public policies to link production, conservation, and livelihood. In this case, the program has totally routed its objectives to the preservation of local products (GEF Small Grants Programme, 2014). However, according to the local peasant farmers' perceptions, further work is still required for safeguarding food sovereignty. According to the results, managers and peasant farmers believed that the actions developed during the program intervention had direct implications on the likelihood of supporting the actions over time. However, peasant farmers' perceptions revealed that further efforts are necessary focusing on strategies to incentivize SAP adoption by farmers, where mingas (indigenous tradition of informal collective actions) could be considered as a pathway for creating discussion spaces among stakeholders in the local territories (Hoogesteger, 2013).

Given that farmers cited agricultural production and production factors as being important variables for them, and their well-being is linked with their welfare, which could support the sustainable environment (Rieckmann et al., 2011), the program should seek to incorporate integral solutions linked to the agricultural sector. In addition, the findings revealed that program managers noted that education and technical assistance sustain conservation actions in the long term (Keese, 2001; Saltiel et al., 1994). However, a diversification of the technical assistance topics is needed. For instance, topics on nutritional quality, marketing strategies, and so on could be considered based on farmers' perceptions. This is because the farmers did not pay much attention to the value-added products, which could be due to the fact that it was an innovation introduced in the Sixth Operational Phase of the program, and there is still work to be done.

It is important to emphasize that the results of this study have been shared with stakeholders during workshops in the communities developed by institutions that carried out the program. The results have been presented to both groups: agricultural organizations and program managers, where they have mentioned that the results seem interesting and it has been helpful to continue working in the different actions planned in the subsequent phases of the BFW program.

On the other hand, according to the results of the **perceptions of smallholder farmers relating to environmental issues applied in this research**, it could be stated that smallholder farmers are aware of the current environmental issues that their communities face. In fact, they are concerned about what would happen to the production factors such as land, seed and water, which are crucial for agricultural livelihoods. According to ECOPAR (2018), the program's intervention sites are relevant to the floricultural sector, and over many years have suffered from environmental damage to soil and water resources (Bergman, 2008; Tenenbaum, 2002). The chemicals used for flower production have ended up in rivers and this threatens smallholder farmers' livelihoods. In fact, the results of the **spatial analysis applied in this research shows** an expansion of the agricultural frontier which could be related to the growth of the floricultural sector in this area. Also, the deforestation continues to advance as a result of agricultural intensification, where not only farmers are part of it. In fact, big enterprises are involved on intensive agriculture, where their priority is the capital. Also, the scrubland and grasses associated with moors have decreased in PiMoSaPa, the opposite was detected in the CoCa zone where they were gained from abandoned marginal farmland. Because of the classification accuracy of land use and land cover maps (around 80%), the slight difference in the class (water) cannot be a source of interpretation regarding the change in water bodies. Moreover, the forest category shows that there was deforestation of the primary forest despite there being recoveries in other places. This situation demonstrates that there is a commitment to recovering forest, although forest degradation remains a subject of conservation study in this area. Another important change is the increase in built-up areas that are located in the central part of the program's intervention area. This is the beginning of an urban corridor, that is consistent with most of the farm holder locations in our survey. Even increasing the settlement of rural communities in this built-up area, looking for services that are scarce in the highlands. Moreover, even though some authors alert about the advance of climate change in the same geographical context (Córdova et al., 2019), the findings regarding environmental perceptions highlighted that farmers do not raise droughts as their major concern despite droughts

may bring devastating consequences to smallholder farmers (IPCC, 2014). This behavior can be explained due to farmers not having recently experienced a decrease in rainfall patterns in their community, although as precipitation can act erratically. Indeed, the findings demonstrated that smallholder farmers have maintained direct perceptions related to community issues, except precipitation pattern. This finding is also justified with the **climate stressors analysis**, where there is no variation in the rainfall pattern. It was also observed that there is a significant change of the max temperature in the geographical area, where the values indicate an increase of the temperature in the period of 2009-2015. The rise of temperature has presented as a new threat for moors in Andean countries as Ecuador (Buytaert et al., 2014), where once again the results of this research alerts that the geographical area studied has currently this pressure, which is a clear evidence of climate change consequences.

Finally, regarding the **study of the determinants of SAPs adoption amongst farmers**, the Probit models' results show that lower levels of education are associated with decreases the probability of adopting agroforestry, crop rotation, and trees nurseries practices. On the one hand, these findings may be due to the fact that these three practices have been considered in the program's workshops. Thus, their adoption will be linked to education and understanding of their importance for their plots. On the other hand, although agroforestry and trees nurseries practices have existed for centuries to protect the soil and water resources (Current et al., 1995; Nair, 1998; Sanchez & Leakey, 1997), farmers considered them as novel practices that were introduced in their territories. In this sense, this finding may provide evidence that the educational training process to foster the adoption of the three practices amongst smallholder farmers has been successfully scaling-up thanks to the BLW program.

Furthermore, we found a significant negative gender effect in the agroforestry model, which suggests that the BLW program has not successfully incorporated women in the adoption of the aforementioned practice. These results could be related to cultural reasons due to the role played in administration and in the preparation of food for the family and workers. As mentioned by Colfer et al. (2015), men tend to play a more active role as farmers than women despite the important contribution of women in managing and harvesting the plot. In this sense, as mentioned by Fisher (2019), it is important to suggests that program managers within the projects have to consider the integration of women since the well-being of the household is in women's hands

(Colfer et al., 2015; Kiptot & Franzel, 2012). Considering that the woman is responsible for household planning and the management of natural resources within the plot, women participation and empowerment becomes a strategic element in sustainable development programs. On other strand, the results highlight that the extent and likelihood to adopt traditional practices such as crop rotation is higher for older farmers, which is in line with the findings from Montúfar and Ayala (2019).

The results also show that people who have WhatsApp accounts have a lower probability of adopting crop rotation and trees nurseries practices. Although social networking has been considered a strategy for supporting agriculture activities and a convenient communication channel for developing a management system between farmers (Naruka et al., 2017; Singh Nain et al., 2019), this could represent a challenge for farmers to use it. Indeed, rural areas in developing countries have limited internet data packs available, where farmers do not have wide access to communicate with each other, and news or activities sent in this way take time to arrive. Considering that WhatsApp could present pros and cons for sustainable agriculture, it would be interesting to properly study the access to these mass media in the rural areas, where academia would play an important role as a linkage actor between rural areas and technology access.

Our results are also in line with Wollni et al. (2010) and Gomez et al. (2016) who find that the involvement of farmers in commercialization channels such as agroecological fairs could provide a significant incentive for agroforestry practices, generate employment and income, and also become a space to exchange knowledge and strengthen women's skills. In Ecuador's case, the participation of smallholder farmers in these associative experiences to promote SAPs has increased (Macas and Echarry, 2009). Although our results have not shown a level of significance in the rest of the models, we could consider it as a strategy to encourage the adoption of agroforestry practices. In fact, since the program has introduced technical training on agroforestry practices in the intervention area, farmers have considered linking these short marketing channels as a way of connecting producers to the market.

The coefficient for the value-added variable was found to be significant in the adoption of agroforestry practices. This finding is related to the range of possibilities of adding value to an agricultural product, which has been implemented by the BLW program. The link between SAPs adoption and the value-added chain based on agricultural production will represent a more

significant income for rural families (Gazolla & Pelegrini, 2011), and an improvement in the farmers' welfare. However, it is important to consider that there is still a challenge in terms of market competition for smallholder farmers but this does not mean that there are no ways to find niche markets that directly link smallholder farmers and consumers.

Furthermore, our results are consistent with other studies which contend that the existence of networks among farmers can help to reduce uncertainty about the application of SAPs (A. B. a Munasib & Jordan, 2011; Teklewold et al., 2013; Zeweld et al., 2017). This is the case for the adoption of crop rotation and cover crops, which is considered to be traditionally known by farmers. On the other hand, in our results, the minga variable negatively affected the adoption of trees nurseries. This finding could be because this practice is carried out in each farmer's plot, which enables the provision of seedlings to the plot. It is important to highlight that the minga represents community-wide efforts for centuries (Korovkin, 1997), involving community work to strengthen skill-building, trust among farmers, and therefore increasing the adoption of SAPs.

Another result that we found was related to the time that farmers live in their communities, which is associated to a greater likelihood of SAPs adoption (Munasib and Jordan 2011). This result highlights that farmers who have lived in the community for several years may have a significant concern for their communities. They have been mainly involved in the different management processes of grassroots organizations, which are linked with social capital strengthening, and protecting the environment, and providing welfare for the community. In this sense, agroforestry and tree nurseries imply a high level of understanding amongst farmers in terms of the benefits that SAPs adoption could provide. People who have recently arrived in the local community need time to learn and understand how the SAPs will impact their welfare in the long term.

Regarding environmental concerns, this variable was significant in crop rotation and cover crops practices, which indicates that these practices, as highlighted before, are traditionally accepted by the farmers. In addition, these results could be interpreted as farmers' perception of trust towards these practices that have been carried out in their plots for many years, which could be linked to the program performance in the territory.

7. Conclusions

7.1. **Major findings and research contributions**

This research established an understanding of the causal interconnection between local actors based on the participatory methodological approach established, which illustrates the level of complexity in the implementation of environmental management programs. The strength of this methodological approach is that it allows the exploration and analysis of the need to strike a balance among strategies aimed at ecosystem conservation for improving livelihoods of communities. For instance, the research revealed that capacity building continues to be essential for enhancing sustainable development in the communities. However, aspects such as nutritional factors and marketing of agricultural products may be also considered under a holistic educational training approach in the communities. Besides, there is clear evidence that trust is a crucial element for improving the processes of production planning, commercialization, and therefore well-being in the community.

On the other hand, the application of the HCA analysis demonstrated the importance given by the program managers towards the SAPs, where agroecology is highlighted as linking social and environmental aspects in the local territories. However, national and international institutions must be aware of duplicating program activities, and devise strategies that are tailored to the context of the community and that embrace farmers' perceptions.

Although the methodology proposed does not intend to carry out a comparison of the program's report assessment methodology, it does provide a strategic pathway for exploring the stakeholders' perceptions in greater depth. For instance, the FCM approach revealed linkages and provided a better understanding of the inherent complexity of environmental management programs, where findings suggest that the combination with HCA enables the dimensions of the program intervention to be understood. This semi-quantitative technique is tailored to programs implementation and is a helpful tool to provide a diagnostic of a project and an inclusive assessment integrated approach (ex-ante, mid-term, and ex-post).

With regard to exploring decision-making on sustainable agricultural practices approach, from a local development vision, governmental institutions and NGOs have launched a series of programs and projects focused on rural development, where one of the components has addressed environmental conservation through the adoption of SAPs. However, the adoption rates of these practices are still low in developing countries, and Ecuador is not an exception. Our study was focused on, seeking which factors are involved in the SAPs adoption—considering that the decision-maker on the plot of what to do, what to sow and how to do it is the farmer. Here, as researchers, our intention in this study is to advise policymakers about strategies to encourage farmers to adopt sustainable practices. In this case, our study has encountered that farmers are not strongly concerned about climate issues, but they care about the soil condition. However, although farmers are worried about the soil, the analysis of land use and cover change shows that the agricultural frontier is continuously advancing in the study territories, which means that deforestation continue due to agricultural intensification where not only farmers are involved in this trend. In fact, agriculture hold by big enterprises are involved in the advance of an intensive agriculture where it is clearly marked from a capital vision. Also, farmers did not highlight drought as a substantial concern, which is consistent with the analysis of climatic parameters where there is no variation in rainfall pattern. This result was aligned to the analysis of climate stressors showing that there has been no recent annual rainfall variation in the area.

On the other hand, our research identifies a set of factors, which offer insights about the complex and specific dynamics in the adoption process of SAPs. Here, the influence of factors such as age and household size are associated to some specific practices, which also will depend on the local circumstances. However, it is essential to highlight the role of the social capital in the adoption of these practices, where SAP's trust, collective effort, and the number of years living in the community have been found as factors that play a critical role in the interaction to reach rural development. Thus, strengthening social capital may play a decisive role in promoting the adoption of SAPs and become a sustainability driver influencing organizational development.

On the other hand, considering the importance to balance supply and demand, the promotion on the demand side with consumption campaigns should consider responsible consumption, where agroecological fairs present a paradigm shift to preserve the security and sovereignty of food. Also, it is important to highlight that program has made several efforts to integrate women participation

in the different SAPs, who have been very proactively involved during the implementation with positive outcomes. Our study provides empirical evidence that the role of women are less likely to adopt agroforestry practices; however, the role of them in agriculture should not be dismissed to ensure the program's effectiveness, since they have can become agents of sustainable change in local development. Moreover, the use of TICs in the agriculture such as WhatsApp should be monitored. The use of social media to promote environmental awareness and provide program information may become an opportunity to improve program results incorporating farmers who are currently less likely to adopt SAPs.

The environmental concern among farmers is attached to traditional practices and grounded on a historical process, providing solutions for the local communities to preserve their yields and food security. Here, there is a need to continue promoting awareness towards environmental care, with a particular focus on agroforestry and trees nurseries practices. Both practices are prominent traditional agricultural practices, but in our case, farmers have considered them as novel practices introduced in their territories. In this case, at the level of policymaking regarding a specific SAPs adoption, it is suggested to continue working to encourage the SAPs taking into account farmers' trust and environmental concern towards these SAPs. Such effort is crucial since these practices are the least adopted.

Differentiated policies in the rural sector, targeting at smallholder farmers as a priority, will improve the chances to reach the desired sustainable development goals through sustainable agriculture takes part of this aim.

7.2. Limitations and further research

While our two-case study approach is not representative of regional or national trends we highlight the need to develop further research on the relation between local commercialization channels and adoption strategies at a national level. Nevertheless, this research may serve as a reference for local institutions, central governments, and NGOs, who could adopt the proposed approach during the inception and of the overall assessment of ecosystem conservation programs.

Our field survey was limited to the biocorridors Coca-CaCo and PiMoSaPa in Ecuador. Although the sample was relatively small compared to the total rural population of each parish located within the sites, the survey was inclusive considering od all social conditions, including gender

considerations and representing the smallholders' communities at the different sites. It is important to mention that the conclusions presented are particular of this study area and should not be generalized at a national level. Nevertheless, the case study was designed to present a rich picture of the smallholder farmers response-actions in the face of ecosystem programs based on the factors involved in the adoption process. Further research is needed to explore the interactive effects between territorial characteristics and individual socio-economic features on SAP's adoption at multiple scales. We also note that the combination of the FCM model and HCA can be further expanded to present future scenarios to describe possible strategies for decision makers.

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Annexes

Annex 1. Questionnaire structure

Sección B: Caracterización hogar

REGISTRO MIEMBROS DEL HOGAR

1. ¿Cómo se IDENTIFICA (…) Dentro de su hogar?

- ○ 1 Jefe de hogar
- ○ 2 Cónyugue
- ○ 3 Hija(o)
- ○ 4 Amigo(a)
- ○ 5 Familiar

2. ¿Cuál es su estado civil (........)?

- ○ 1 Casado
- ○ 2 Unión libre
- ○ 3 Separado
- ○ 4 Divorciado
- ○ 5 Viudo
- ○ 6 Soltero

3. Actualmente, ¿Usted trabaja en el sector?

- ○ 1 Agropecuario
- ○ 2 No agropecuario
- ○ 3 Ambos
- ○ 4 Ninguno

4. ¿Cuántos personas de su hogar trabajan en actividades agrícolas?

[____] personas

5. ¿Cómo se IDENTIFICA (…) según su cultura y costumbres?

- ○ 1 Indígena
- ○ 2 Negro/a
- ○ 3 Mulato/a
- ○ 4 Montubio/a
- ○ 5 Mestizo/a
- ○ 6 Blanco/a
- ○ 7 Otra, cuál?.......................

EDUCACIÓN

6. ¿Sabe leer y escribir?

- ○ 1. Si
- ○ 2. No

7. ¿Cuál es el nivel de instrucción y año más alto que aprobó?

- ○ 1 Ninguno
- ○ 2 Alfabetización
- ○ 3 Primaria
- ○ 4 Secundaria
- ○ 5 Universidad
- ○ 6 Maestría
- ○ 7 Doctorado

ACTIVIDADES ECONÓMICAS

8. ¿Ha recibido alguna vez el Bono de Desarrollo Humano?

- ○ 1. Si
- ○ 2. No

9. Durante los ÚLTIMOS 12 MESES ¿cuál fue su último ingreso o ganancia neta que obtuvo de trabajo?

Agrícola _____ dólares

No agrícola _____ dólares

10. ¿Vende Usted algún producto en una feria agroecológica?

- ○ 1. Si ──¿Cuáles?▶ a.................
  - b.................
  - c.................
  - d.................
  - e.................
  - f.................
- ○ 2. No

11. ¿Hace algún proceso de sus cultivos (productos con valor agregado, artesanías, textiles,…)?

- ○ 1. Si ──Cuál?▶ a ....
  - b ....
- ○ 2. No
  - c ....
  - d ....
  - e ....
  - f ....

COMUNICACIONES

12. ¿Tiene USTED TELÉFONO CELULAR ACTIVO?

- ○ 1. Si
- ○ 2. No

13. ¿Posee USTED cuenta de WhatsApp?

- ○ 1. Si
- ○ 2. No

14. ¿Posee USTED cuenta en alguna red social (Facebook, twitter, youtube, instagram?

- ○ facebook
- ○ twitter
- ○ instagram
- ○ telegram
- ○ Ninguna

15. ¿En los últimos 12 meses ¿Qué tan activo(a) ha estado usted con el uso de redes sociales?

	1 Totalmente activo(a)	2 Activo(a)	3 Medianamente activo(a)	4 No activo(a)
facebook	○	○	○	○
twitter	○	○	○	○
instagram	○	○	○	○
telegram	○	○	○	○

16. ¿Utiliza USTED equipos tecnológicos tales como?

	SI	NO
1 Computadora		
2 Tablet		
3 Celular		
4 Celular inteligente		
5 Televisión		
6 Radio		
7 Equipo de sonido		
8 Otra, cuál?		

2

Sección C: Capital social y Acción coletiva

CAPITAL SOCIAL

17.- ¿Confían que dentro de su comunidad/vecindario las y los compañeros llevan a cabo prácticas agrícolas sostenibles?

○ 1 Confían

○ 2 No confían

18.- ¿Qué tan de acuerdo está Usted con las siguientes afirmaciones?

	1 Totalmente de acuerdo	2 De acuerdo	3 En desacuerdo	4 Totalmente desacuerdo
La gente de su comunidad/ vecindario es honesta y confiable	○	○	○	○
Los miembros de su comunidad/vecindario son más confiables que otros	○	○	○	○
Las personas de su comunidad se preocupan principalmente por el bienestar de sus familias y no por el bienestar de la comunidad	○	○	○	○

19.- En relación al resto de sus compañeros de su comunidad, considera Usted que es:

○ 1 No pobre

○ 2 Más o menos pobre

○ 3 Pobre

○ 4 Muy pobre

20.- Piensa Usted que en los últimos años el nivel de confianza frente a las personas de su comunidad:

○ 1 Ha mejorado

○ 2 Está igual

○ 3 Ha Empeorado

21.- Acorde a su percepción, califique la siguiente afirmación: se siente .... dentro de su comunidad?

○ 1 Totalmente aceptado(a)

○ 2 Aceptado(a)

○ 3 Medianamente aceptado(a)

○ 4 No aceptado(a)

22. Para solucionar un problema ambiental Usted acude a:

○ 1 Gobierno

○ 2 ONGs

○ 3 Comunidad

○ 4 Otro.................................... .

23.- En los últimos 12 meses, ante problemas de salud Usted acudió a:

○ 1 Centro/ subcentro de salud

○ 2 Médico particular

○ 3 Clínica

○ 4 Ninguno

○ 5 Otro.................... ..

ACCIÓN COLECTIVA

24.- ¿Ha sido Usted miembro activo de alguno de los siguientes grupos o asociaciones en su barrio o comunidad?

○ 1 Grupos Religiosos

○ 2 Clubes Deportivos

○ 3 Asociaciones Sociales

○ 4 Cooperativas o Asociación de producción

○ 5 Comités Barriales o Comunitarios

○ 6 Organizaciones de mujeres

○ 7 Grupo Político

○ 8 Otro, cual?...........................

25.- ¿Ha participado usted de alguna minga comunitaria?

○ 1 Si   ¿Cuáles? → Limpieza de asequias ☐

○ 2 No

Construcción de vías ☐

Reforestación ☐

Otras:........................ ☐

CONCIENCIA AMBIENTAL

26.- ¿Qué tanto le preocupa a USTED la situación del medio ambiente a su barrio o localidad:

○ 1 Mucho

○ 2 Medianamente

○ 3 Poco

○ 4 Nada

27.- Acorde a los siguientes problemas que se mencionan a continuación, otorgue un puntaje pensando en su comunidad.

	Alto (1)	Medio (2)	Bajo (3)
1 Contaminación del aire			
2 Contaminación del agua			
3 Contaminación del suelo			
4 Contaminación por basura			
5 Contaminación por ruido			
6 Pérdida de fertilidad del suelo y aumento de plagas			
7 Falta de lluvias			
8 Falta de animales			
9 Muchas sequías			

28.- De las siguientes acciones, ¿cuáles Usted ha llevado a cabo?

	SI	NO
1 Colaborar con alguna organización en defensa del medio ambiente		
2 Participar en voluntariados ambientales		
3 Manifestarse contra alguna situación perjudicial para el medio ambiente		
4 Denunciar personalmente algún problema ambiental que haya identificado		

3

Sección D: Percepción del nivel de vida, capital social y retorno migratorio

PRÁCTICAS AGRÍCOLAS

29.- ¿Este hogar cuenta actualmente con terrenos:

○ **1** Si ⟶ ¿Cuántos? [ ]

○ **2** No

[Fin de la encuesta]

30.- ¿Cuál es la superficie del terreno?:

	ha	metros	valor
Terreno 1			
Terreno 2			
Terreno 3			

31.- El/los terreno(s) de los miembros de este hogar son:

	1 Tierras propias	**2** En arriendo	**3** Al partir
Terreno 1	○	○	○
Terreno 2	○	○	○
Terreno 3	○	○	○

32.- ¿Los miembros de este hogar adoptan o no las siguientes prácticas agrícolas en su finca, terreno, parcela,...?

	Adopta	No adopta
Aplicar estiércol de animales/ abono orgánico	○	○
Uso de abono inorgánico	○	○
Uso de pesticidas	○	○
Viveros	○	○
Agroforestería	○	○
Rotación de cultivos	○	○
Cultivos mixtos	○	○

	Adopta	No adopta
Cultivo de verduras	○	○
Cultivos de cobertura	○	○
Cultivos resistentes a la sequía	○	○

33. ¿Durante los ÚLTIMOS 12 MESES, los miembros de este hogar tienen o tenían cultivos de:

	1 Mucho	**2** Medianamente	**3** Poco	**4** Nada
Verduras	○	○	○	○
Legumbres	○	○	○	○
Arroz	○	○	○	○
Tubérculos	○	○	○	○
Frutas	○	○	○	○
Otro 1…………………….	○	○	○	○
Otro 2…………………….	○	○	○	○

34. ¿Durante los ÚLTIMOS 12 MESES, los miembros de este hogar, tuvieron alguno de los siguientes animales?

	Si	No	¿Cuántos?
Vacas, toros, terneros	○	○	[ ]
Ovejas, cabras, chivos	○	○	[ ]
Llamas, llamingos	○	○	[ ]
Cerdos o chanchos	○	○	[ ]

	Si	No	¿Cuántos?
Cuyes y conejos	○	○	[ ]
Gallinas y pollos Pavos	○	○	[ ]
Patos	○	○	[ ]
Caballos, asnos y mulas	○	○	[ ]
Otros animales……………………	○	○	[ ]

FUERZA DE TRABAJO

35.- ¿Dentro del trabajo de su terreno, finca, parcela le apoyan:

○ **1** Familia

○ **2** Vecinos

○ **3** Contrato

_____

ENCUESTADOR

_____

ENCUESTADO

4

Annex 2. The overview of categories, as taken from the variable aggregation list from peasants.

Variable	Qualitative aggregation	Sign [1]
knowledge transfer	exchange of knowledge	+
local laws and regulations	local laws and regulations establishment	+
	laws of community leaders	+
savings bank	banks	+
ONGs support	ONGs	+
value-added products	added value	+
	process products	+
ecosystem conservation	nature	+
	work for nature	+
action sustainability	native crop maintenance for many years	+
food security and sovereignty	food security and sovereignty	+
social media	use of WhatsApp	+
	Facebook	+
support local government	credit	+
	low interest rate	+
	appropriate grace period	+
working meetings	meetings	+
	assemblies	+
personal attitude	awareness to take care of the land	+
	personal interest	+
research	research by academy	+
	involvement of students	+
agricultural production	agriculture	+
	livestock	+

Variable	Qualitative aggregation	Sign [1]
	Small-scale agricultural production	+
	production	+
	family farming	+
creation of source of employment	employment	+
	source of employment	+
	work with people	+
	unemployment	−
	water	+
	appropriate technology	+
	water needs	+
	need of water	+
	irrigation access	+
	land access	+
	Pachamama	+
	soil fertility	+
	demand of labor hand	+
	fertilizer and agricultural chemical	+
production factors	transporting of agricultural products	+
	machinery	+
	commercial seeds	−
	irrigation access	+
	pogllos use	+
	lack of water sources	−
	loss of water sources	−
	soil	+
	bioles production	+
	cost of tools	−
commercialization	agroecological fairs	+

Variable	Qualitative aggregation	Sign [1]
	prices of agroecological products	+
	prices of organic products	+
	prices of agricultural products	+
	challenging process in the market	−
	household income	+
	welfare	+
		+
household welfare	broken houses	−
	cooking and animal feeding	+
	indebtedness	−
	participation	+
	family involvement	
	lack of interest in collaboration	−
	willingness to participate	+
	self-call	+
	lack of team work	−
	divide the machinery among neighbors	+
	organization and team work	+
	interaction between partners	+
social capital and collective action	organization	+
	collective initiatives	+
	trust	+
	weak linkage of universities	−
	lack of organization	−
	neighborhood support	+
	exclusive organization	+
	team work	+
	inside the fair organization is necessary	+

Variable	Qualitative aggregation	Sign [1]
	water district	+
	collaboration	+
	agricultural organizations	+
	community leaders	+
	mingas	+
	precipitation	−
	drought	+
	rain	−
	climate	+
	summer season	+
	climate variation	+
	adverse weather conditions	+
	act of good	−
	climate change	+
climate change	effects of greenhouse gases	+
	pollution in the environment	+
	pollution	+
	no rainfall	+
	climate variability	+
	upper reaches	+
	strong wind	+
	weather	+
	effects of the climate	+
	rain	−
	ice	+
	monitoring and following of the projects	−
process management issues	lack of financial resources	+
	political issues	

Variable	Qualitative aggregation	Sign [1]
	malfunction of water reservoirs	+
	elevated costs	+
	process management strategies	−
	issues with local government	+
sustainable agricultural practices (SAPs)	vegetable production	+
	local seed preserve	+
	organic matter	+
	local crop sustainability	+
	organic fertilizer	+
	organic production	+
	organic fertilizer	+
	building beds for cultivation	+
	preservation of local seeds	+
	compost use	+
	agroforestry	+
	seeds	+
	native crops	+
	lack of local seeds	−
	manure of animals	+
	agroecological systems	+
agricultural issues	lack of technification	+
	building structures in rural zones	−
	issues with tractor use	+
	issues with agricultural hand tools	+
	issues with motorized plough use	+
	lack of technology	+
	lack of reservoirs	+
	eucalyptus owners	+

Variable	Qualitative aggregation	Sign [1]
	credit access	−
	lack of production planning	+
	migration	
	delay in crops	+
	big landowners' interests	+
	lack of environmental management projects	+
	lack of irrigation access	+
	lack of greenhouses	+
	eucalyptuses	+
	lack of appropriate technology	+
	florist	+
	training in water use	+
	water use	+
	education	+
	water collection	+
	capacity strengthening	+
capacity strengthening	lack of knowledge of the composition and properties of products	−
	lack of knowledge of local finances	+
	lack of knowledge of promotion and publicity measures	+
	storage and utilization of rainwater	−
	trainings	−

[1] "+" indicates a positive relationship with the concept aggregated, whereas "−" indicates otherwise.

Annex 3. The overview of categories, as taken from the variable aggregation list from program managers.

Variable	Qualitative aggregation	Sign [1]
support local government	organization of walks and bicycle routes	+
	water resource laws	+
capacity strengthening	technical assistance	+
	capacity strengthening	+
personal attitude	personal interest	+
conventional production	conventional production	+
indigenous knowledge	indigenous knowledge	+
working sessions	working sessions	+
concentration of information	concentration of information	+
consumer awareness	consumer awareness	+
value-added products	value-added products	+
social capital and collective action	organization	+
	team work	+
	work at community level	+
commercialization of agricultural products	agroecological fairs	+
	baskets of agricultural products	+
sustainable agricultural practices (SAPs)	agroforestry	+
	tubers	+
	changes in land use	+

Variable	Qualitative aggregation	Sign [1]
	organic production	+
	local seeds	+
ecosystem conservation	conservation	+
	activities of environmental management	+
production factors	irrigation access in vulnerable communities	+
	land	+
agricultural production	production	+
	small scale agricultural production	+
household welfare	decrease in household income	−
	drinking water access	+
	self-consumption	+
actions sustainability	actions in the long term	+
food security and sovereignty	food security and sovereignty	+
agricultural issues	big landowners' interest	+
	flower market participation	+
	lack of production planning	+
	lack of environmental management projects	+
climate change	frost	+
	variation of weather conditions	+

[1] "+" indicates a positive relationship with the concept aggregated, whereas "–" indicates otherwise.

Annex 4. The final adjacency matrix of the local peasants obtained by focus groups using text analysis.

	actions sustainability	agricultural issues	agricultural production	capacity strengthening	climate change	commercialization	creation of source of employment	ecosystem conservation	food security and sovereignty	household welfare	knowledge transfer	local laws and regulations	ONGs support	personal attitude	process management issues	production factors	research	saving banks	social capital&collective action	social media	support local governance	SAP	value added products	working sessions
actions sustainability																								
agricultural issues			-0.25		0.25	-0.31	-0.25		-0.13	-0.19				-0.19		-0.25						-0.13		
agricultural production							0.31			0.19						-0.13								
capacity strengthening		-0.25	0.63		-0.06	0.19				0.19						0.31	0.19		0.19			0.19	0.13	
climate change		0.19	-0.63				-0.13			-0.06						-0.38						-0.25		
commercialization		-0.06	0.19							0.25				0.19	-0.13							0.06		
creation of source of employment			0.19							0.19														
ecosystem conservation					-0.19											0.19								
food security and sovereignty																								
household welfare		-0.06	0.25											0.13	-0.06							-0.13		
knowledge transfer				0.13																				
local laws and regulations																								
ONGs support				0.13	-0.06																	0.06		
personal attitude			0.25			0.13				0.06						0.13						0.19		0.19
process management issues	-0.19	0.25	-0.06		0.13	-0.06		-0.19		-0.25						-0.44			-0.13			-0.06		
production factors			0.44	0.06	-0.06	0.19	0.06			0.06														
research		-0.13	0.13	0.19					0.13					0.06		0.06								
saving banks																					0.19			
social capital&collective action	0.06	-0.44	0.69	0.13	-0.13	0.38	0.19			0.44		0.19	0.06			0.13						0.31		0.31
social media															-0.06						0.13			0.13
support local governance		-0.06		0.13																	0.13			
SAP		-0.13	0.44		-0.13	0.13				0.25						0.31								
value added products						0.19																		
working sessions														0.19	-0.19				0.25					

Annex 5. The final adjacency matrix of the program managers obtained by focus groups using text analysis.

	actions sustainability	agricultural issues	agricultural production	capacity strengthening	climate change	commercialization	concentration of information	consumer awareness	conventional production	ecosystem conservation	food security and sovereignty	household welfare	indigenous knowledge	personal attitude	production factors	social capital&collective action	support local governance	SAP	value added products	working sessions
actions sustainability																				
agricultural issues			-0.50						0.50			-0.50			-0.50					
agricultural production																				
capacity strengthening	0.25				-0.50							0.50				0.75		0.50	0.25	
climate change		0.50																		
commercialization	0.50		0.50		-0.75			0.25	0.50	0.50	0.25							0.50		
concentration of information																				
consumer awareness						0.50														
conventional production		0.50	-0.50																	
ecosystem conservation															0.50					
food security and sovereignty																				
household welfare																				
indigenous knowledge					-0.50															
personal attitude		-0.50					0.50		0.25							1.00		-0.38		
production factors		-0.50																		
social capital&collective action	0.75	-0.63	0.50		-0.50	0.50			1.00			0.25			0.75	0.50	0.25	0.50		
support local governance						0.50		0.25			0.25				0.50			0.50		
SAP		-0.50			-1.00				-0.25	0.75	0.50	0.50								
value added products	0.25														0.25					
working sessions																0.50				