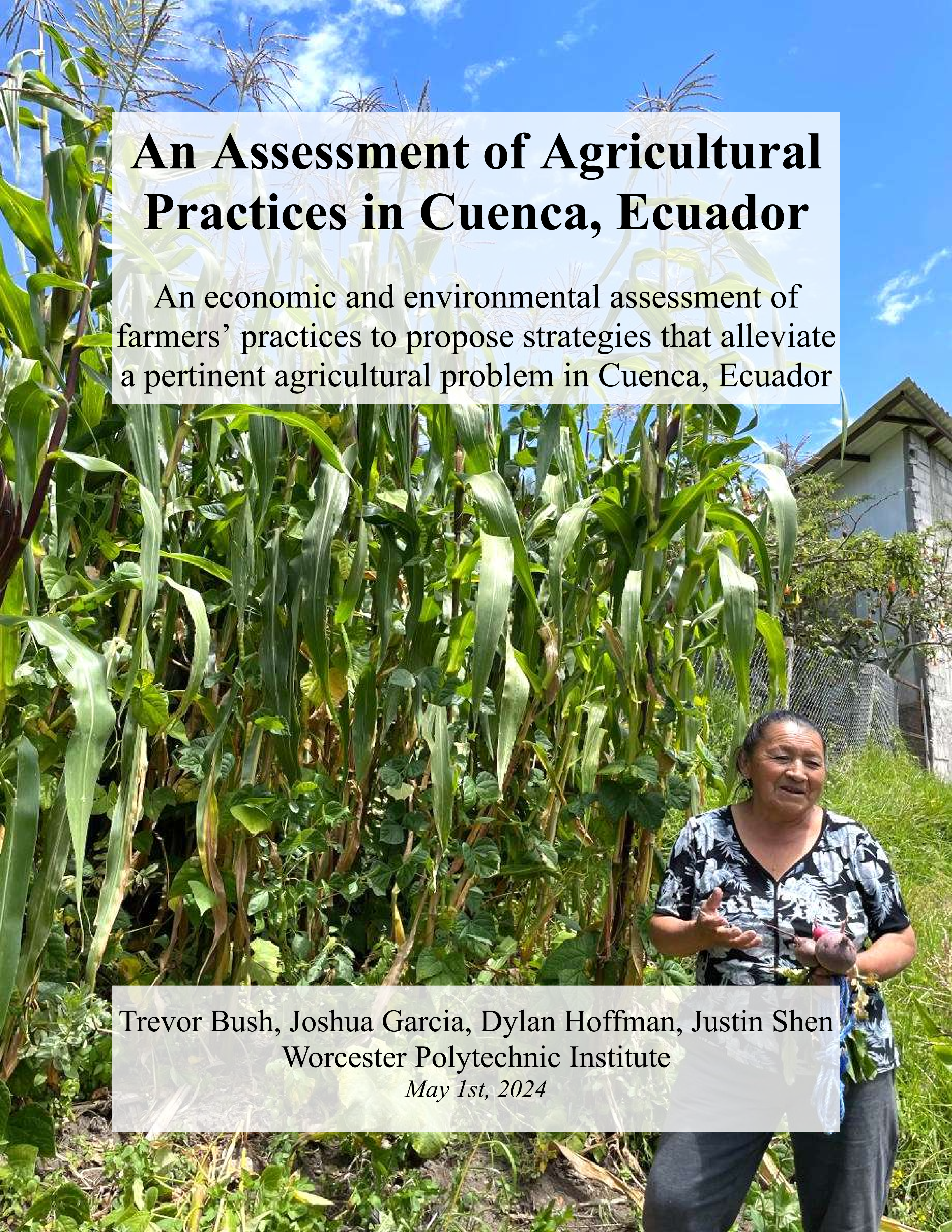

An Assessment of Agricultural Practices in Cuenca, Ecuador

An economic and environmental assessment of farmers' practices to propose strategies that alleviate a pertinent agricultural problem in Cuenca, Ecuador

Trevor Bush, Joshua Garcia, Dylan Hoffman, Justin Shen
Worcester Polytechnic Institute

May 1st, 2024

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An Interactive Qualifying Project Report
submitted to the Faculty of
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by
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Report Submitted to:

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Abstract

Working with faculty and Master's students from the Agronomy Department at the University of Cuenca, our project aimed to understand farmers' lifestyles in the region of San Antonio de Gapal to identify a pertinent problem, and to propose strategies to resolve that problem. To do this, we interviewed 12 farmers in the region, observed their properties, and analyzed collected data to create strategies to mitigate these issues. Our key finding was that water collection and retention during droughts and excessive rain was a critical issue for farm productivity. Lastly, we conducted a participatory SWOT analysis to share our recommendations, which were to increase the number of barrels, investigate the use of fog nets for water collection, and reduce erosion with terraces among others.

Resumen[1]

Trabajando con profesores y estudiantes de maestría del Departamento de Agronomía de la Universidad de Cuenca, nuestro proyecto tuvo como objetivo comprender los estilos de vida de los agricultores en la región de San Antonio de Gapal para identificar un problema pertinente y proponer estrategias para resolverlo. Para hacer esto, entrevistamos a 12 agricultores de la región, observamos sus propiedades y analizamos los datos recopilados para crear estrategias para mitigar estos problemas. Nuestro hallazgo clave fue que la recolección y retención de agua durante las sequías y las lluvias excesivas era una cuestión crítica para la productividad agrícola. Por último, realizamos un análisis FODA participativo para compartir nuestras recomendaciones, las cuales fueron aumentar el número de barriles, investigar el uso de redes de niebla para recolección de agua y reducir la erosión con terrazas, entre otras.

[1] Translation by Google Translate in April 2024.

Acknowledgements

We would like to thank the following 12 agroproducers from the region of San Antonio de Gapal in Cuenca for taking the time to allow us to interview them. We learned a lot about farms, farming lifestyles in Cuenca, and agricultural processes used in Andean farming:

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Master's Students

Jose Luis Chimbo Llivipuma, Carmen Janneth Flores Chuñir
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Lastly, we are thankful for the opportunity to travel to the Cuenca project center. It was an incredible experience being able to work and live in Ecuador. We hope that our project will make a lasting, meaningful change in the lives of farmers in and around Cuenca.

Authorship

Section	Primary Author	Secondary Author	Primary Editor	Secondary Editor
Abstract	JS	DH	TB	JG
Executive Summary	JG	JS	TB	JS
Introduction	TB	DH	JS	JG
Background	TB	DH	JS	JG
2.1	DH	JG	TB	JS
2.2	JG	DH	JS	TB
2.2.1	DH	TB	DH	JG
2.3	JG	DH	JG	JS
2.3.1	TB	JG	JS	DH
2.4	JG	JS	TB	DH
2.5	TB	DH	JG	JS
2.6	TB	JG	JG	DH
2.7	JS	DH	JG	TB
2.8	TB	JS	DH	JG
2.9	DH	JS	JG	TB
Methodology	JS	JG	TB	DH
3.1	JG	TB	JG	TB
3.1.1	JS	JG	TB	DH
3.1.2	JG	JS	JG	DH
3.2	DH	JS	TB	DH
3.3	JS	JG	DH	JG
3.4	TB	JS	TB	DH
3.5	DH	JS	JG	TB
3.6	TB	JG	DH	JS
3.6.1	DH	TB	JG	JS
3.7	JS	DH	TB	JG
Findings	TB	JG	JG	TB
4.1	JS	TB	JG	DH
4.1.1	TB	JS	JG	JS

4.1.2	JS	TB	JG	DH
4.1.3	JG	JS	TB	JS
4.2	JS	TB	JS	DH
4.3	TB, JS	JG	DH	N/A
4.4	TB	JS	DH	JS
4.5	TB	DH	JG	JS
4.6	JG	JS	TB	DH
4.6.1	DH	JG	TB	JS
5	TB	DH	JG	JS
Appendix A	JS	JG	TB	DH
Appendix B	JS	TB	DH	JG
Appendix C	JG	DH	JS	TB
Appendix D	JS	JG	DH	TB
Appendix E	JS	JG	DH	TB

Meet the Team

Trevor Bush - ‘25 - Biotechnology and Biochemistry

Teaching at the Cape Cod Museum of Natural History has revealed to me the fundamental importance of relationships in the world. Nothing exists in isolation. As a natural products chemistry researcher, I am captivated by how organisms chemically interact to thrive. It has been insightful to observe how farms flourish through interconnectedness between farmers, plants, animals, land, and climate. They harness ecological systems guided by principles of nature rather than resorting to destructive practices.

Joshua Garcia - ‘25 - Aerospace Engineering

In my undergraduate studies, I find that experience is the greatest teacher for skills in any career path. I find that the world I live in is extremely connected through relationships. At school, I enjoy using my free time to participate in aerospace clubs, as I see them directly connecting to my future career. Becoming more versed in this project has allowed me to become more experienced in project-based learning throughout my career.

Dylan Hoffman - ‘25 - Data Science

Coming from the rural state of Wyoming, there are many different types of farms I get to see while driving around. I was interested in the type of work they do and even got to experience some of it while landscaping over my sophomore year summer. I wanted to get involved in this project to satisfy my curiosity of how farming was being done in other places outside the US.

Justin Shen - ‘25 - Aerospace Engineering and Physics

I have a passion for learning as much as I can about the world. This includes things I have never seen before, so getting the opportunity to analyze farming practices and tools by visiting a rural community in Cuenca was intriguing to me. It was exciting to learn about a lifestyle that was different from my own, and I am grateful to have had this opportunity as part of my undergraduate experience.

Table of Contents

List of Figures*

*Observations in Section 4 captured by T. Bush. J. Shen captured Figure 18.

List of Tables

Abbreviations, Acronyms, and Definitions

Acronym/Term	Meaning/Definition
FODA	**Fortalezas, Oportunidades, Debilidades, y Amenazas**[2]
IQP	**Interactive Qualifying Project**
Mg ha^{-1} yr^{-1}	**Megagrams per hectare each year**
SES	**Social-Ecological System**
SOM	**Soil Organic Matter**
Sra	**Señora**[3]
SWOT	**Strengths, Weaknesses, Opportunities, and Threats**
UCuenca	**University of Cuenca**
UPA	**Urban and Peri-urban Agriculture**
US	**United States**
WPI	**Worcester Polytechnic Institute**

[2] Translates to English (in order) as Strengths, Opportunities, Weaknesses, and Threats. Translation by J. Shen.
[3] Translates to English as the prefix "Mrs." Translation by J. Shen.

Executive Summary

Introduction and Background

After an investigation into the challenges faced by the agrarian community of San Antonio de Gapal in the city of Cuenca, Ecuador, clear threats have emerged with a forthcoming change in climate, such as prolonged droughts and excessive rain. Agriculture in Ecuador is troubled by land degradation, erosion, and changes in soil nutrient balance, all of which impact crop productivity. To address these issues, we worked with staff at the University of Cuenca, specifically in the Faculty of Agricultural Sciences, to identify and propose strategies to improve the livelihoods of farmers in this region. This project is a part of a larger diagnostic known as *"CICLA,"* which is directed by professors Dr. Pablo Geovanny Quichimbo Miguitama and Dr. Pablo Marcelo Borja Ramon from the Agronomy Department at the University of Cuenca.

The background of our project entailed researching the farming landscapes of the Andes mountains. This included the region's geography, the intrinsic farming challenges it brings, as well as the historical context of agricultural practices in Cuenca, such as those developed by the Inca and the Quechua indigenous communities. The influence of external factors on these practices were also of interest, such as foreign influences from the Green Revolution and economic instability due to political abandonment and its impact on the agricultural sector.

From our background research, it was evident that agricultural production is dependent on soil science and health. From review of prior studies conducted within the Andes, we presumed the possibility of maladaptive practices within the region of San Antonio de Gapal that were negatively affecting soil health and nutrient cycling. However, certain adaptive practices from indigenous influence may have persisted. We expected our investigation to uncover the current state of agricultural adaptivity.

After reviewing agricultural research in Cuenca, the demand for further development of water collection and retention systems was emphasized. Recognizing the importance of integrating local and scientific knowledge, there was a significant need for a holistic approach that combined anthropological elements with technical solutions. Using this approach, the project aimed to support the livelihoods of small farmers in San Antonio de Gapal while promoting sustainability.

Methods

We sought a comprehensive understanding of the economic and environmental aspects of the farmers' practices in San Antonio de Gapal to improve the livelihoods of those farmers. In pursuit of this goal, we developed six research objectives which allowed us to learn and analyze our findings and receive feedback and comments to evaluate our work. These are detailed below:

Objective 1: Obtain an understanding of farmers' lifestyles and the social, environmental, and economic aspects of their practices in the community of San Antonio de Gapal

Objective 2: Identify relevant and consistent practices and problems in the farmers' experience

Objective 3: Formulate strategies to alleviate a pertinent problem

Objective 4: Propose strategies to agroproducers for revision and feedback

Objective 5: Develop technical-scientific material

Objective 6: Disseminate materials, outcomes, and deliverables

We conducted 12 semi-structured interviews while taking observations from the farms we visited to gain an understanding of their daily practices in San Antonio de Gapal. These interviews provided insights into the economic and environmental aspects of their farming techniques. Consent was obtained from all participants, informing them of how we planned to use their information. All the information we collected was organized and analyzed to generate main themes. The performed analysis examined strengths, weaknesses, opportunities, and threats (a SWOT analysis) within their properties, allowing the project team to formulate targeted strategies in response to a pertinent problem the farmers had, which was later identified to be water collection and retention. We developed a poster and a scientific manuscript to share our findings with others. We also conducted a participatory SWOT analysis to receive feedback from the farmers on the strategies we proposed, supported by the UCuenca Agronomy Department faculty, ensuring our deliverables were practical, feasible, and clear.

Findings

Several key findings and insights emerged as a result of interviews and observations:

1) Farms are dependent and thrive on relationships, between both biotic and abiotic factors
2) Practices lead to ecological and economic resilience
3) Associations increase farming efficiency
4) Water accessibility during droughts is a farmer's greatest challenge
5) Augmenting water capacity for greater storage was the most significant solution

The first finding brought interconnected farming relationships to light: farms operate on a cycle where elements are reused and repurposed in different ways. The farmers' practices demonstrated ecological resilience, with a diverse array of crops and plants protecting farms from environmental disturbances. Economic resilience was achieved through the adaptive practices which leveraged ecological resilience and natural selection, which absolved the need for chemicals. Farming associations also facilitated a vibrant and connected community of agroproducers.

The most impactful finding we found was lack of access to water, particularly during prolonged periods of drought. The intensity of droughts threatens farm productivity, which can have devastating effects for the soil, plants, animals, and the farmers themselves.

Our final finding described the outcomes of the participatory SWOT analysis, where we conversed with farmers about proposed strategies. In these discussions, feasibility was the main factor considered for implementation.

Recommendations

We shared six recommendations to address water management challenges in San Antonio de Gapal:

Strategy 1: ***Increase the size and number of barrels (cisterns)***

Many of the farmers used containers to collect water as detailed in Finding 2. However, drought remained a consistent challenge. We recommended that farmers place more and larger barrels on their property to be able to hold more water. Increasing the number of barrels or cisterns provides additional storage for rainwater, mitigating the impact of droughts and ensuring a steadier water supply during dry spells (García-Ávila et al., 2023).

Strategy 2: ***Do not remove la hierba by the root, only cut it to maintain crop cover which fixes soil, nutrients, and humidity***

From discussions on nutrient cycling detailed in Section 4.1.1 and Section 4.1.2 we noted many of the farmers already employed this strategy. Thus, we concluded that adopting a practice of not removing *la hierba* by the root but instead cutting it to maintain crop cover helps to preserve soil structure, nutrients, and moisture levels, promoting water retention (Kocira et al., 2020).

Strategy 3: ***Use fertilizer from livestock and excess vegetables to increase SOM and increase water retention***

Based on our findings in the livestock section detailed in Section 4.1.1 and Section 4.1.2, we concluded that utilizing fertilizer from livestock and excess vegetables enriches SOM, enhancing its ability to retain water (Bhunia et al., 2021). Therefore, we recommend that farmers continue to use manure *(abono)* and *bokashi* to maintain humidity within the soil and to increase SOM content. Hopefully, these practices can be shared at association meetings, leading to an increased systemization of the practice.

Strategy 4: ***Employ terraces for decreased erosion susceptibility***

Erosion is an issue voiced by the agroproducers and is further discussed in Sections 4.1.1 and 4.2. As mentioned in our background, terraces were employed by the Incas and the Quechua people to prevent watershed sediment loss and to retain water (Posthumus, 2005). We recommended terraces be employed by the farmers to reduce sediment loss which otherwise might uproot crops and leave them susceptible to other disturbances such as wind.

Strategy 5: ***Use fog nets to harvest water from overnight condensation***

Droughts as discussed in Sections 4.1.1 and 4.1.2 threaten farming productivity. Upon reviewing literature, fog collectors were an effective method used locally within the Ecuadorian highlands to harvest water, increasing water security. A study conducted in the highland communities of Yaguachi and Galtie, which constantly struggle with water deficits, evaluated a three-dimensional fog-catcher for cost-effectiveness and to see if it met community water demands. The nets yielded at least 2.63 L/m^2 and a minimum of 0.65 L/m^2 per day. In a year, the fog catchers produced 26,577 m^3/year, satisfying crop water needs. The economic analysis also indicated the catcher was a valuable investment, as the benefit to cost ratio was 1.90 (Carrera-Villacrés et al., 2023). Even the Incas above the rain line developed their own fog-water techniques which funneled water into cisterns (Ismail & Go, 2021). Other studies conducted in the region evaluated different types of fog nets, which did not satisfy all water needs but significantly offset water deficits (Echeverría et al., 2020; Carrera-Vullacrés et al., 2017). Therefore, we recommended the use of fog nets to harvest water from overnight condensation. This water would drip into a container below (Qadir et al., 2021).

Strategy 6: ***Use a micro-irrigation system to maximize water conservation***

From our findings outlined in our discussion of drought in Section 4.1.1 and Section 4.2, we concluded that implementing a micro-irrigation system such as sprinkler irrigation and/or drip irrigation using water already held in containers would increase water retention (Üzen & Cetin, 2013). Such irrigation methods would ensure efficient water usage by delivering small quantities of water directly to the roots of plants, thus following a unifying principle of nature (see Figure 21), and maximizing water conservation efforts (Drip Irrigation Systems, 2023). In 2017, "the Ministry of Agriculture Livestock, Fishery and Fishing (MAGAP), began a project where farmers could submit funding to obtain financing for the installation of localized irrigation systems" (Paul Salazar, 2017).

Conclusion

After interviews and observations with 12 farmers, water collection and retention were the areas for greatest improvement to increase resilience against a forthcoming volatile climate, including prolonged droughts and excessive rain. The recommendations provided were to increase the number and size of barrels or to employ a cistern for rain collection. We also recommended to continue maintaining *hierba* and employing *abono* and *bokashi* from livestock and vegetable leftovers. Novel methods proposed to the agroproducers were the use of fog nets to collect dew throughout the night and to employ terraces to reduce erosion and increase water retention. Small studies are recommended to the Agronomy faculty at UCuenca to assess how much water agroproducers use in a given time, how much rain falls in the same period, and thus what dimensions and costs are required to design a fog net that satisfies water needs in periods of excessive drought. Terraces, having been employed since ancient times, were also discussed with agropoducers for incorporation into the hilly landscape in which they cultivate. Agroproducers may then empirically determine if water retention increases and soil loss decreases. Further research in agriculture within the community of San Antonio de Gapal would be to quantitatively evaluate rainfall and drought patterns specifically within the area, as well as sediment loss over time. This may inform more effective strategies given numerical data supported by the qualitative data provided in this study. Furthermore, we suggested collaboration with local researchers who have employed rain nets and cisterns in other regions of the Andes.

Resumen Ejecutivo[4]

Introducción y Antecedentes

Después de una investigación sobre los desafíos que enfrenta la comunidad agraria de San Antonio de Gapal en la ciudad de Cuenca, Ecuador, han surgido claras amenazas con un próximo cambio climático, como sequías prolongadas y lluvias excesivas. La agricultura en Ecuador se ve afectada por la degradación de la tierra, la erosión y los cambios en el equilibrio de nutrientes del suelo, todo lo cual afecta la productividad de los cultivos. Para abordar estos problemas, trabajamos con personal de la Universidad de Cuenca, específicamente en la Facultad de Ciencias Agrícolas, para identificar y proponer estrategias para mejorar los medios de vida de los agricultores en esta región. Este proyecto forma parte de un diagnóstico más amplio conocido como "CICLA", el cual está dirigido por los profesores Dr. Pablo Geovanny Quichimbo Miguitama y Dr. Pablo Marcelo Borja Ramón del Departamento de Agronomía de la Universidad de Cuenca.

El trasfondo de nuestro proyecto implicó la investigación de los paisajes agrícolas de las montañas de los Andes. Esto incluyó la geografía de la región, los desafíos agrícolas intrínsecos que trae consigo, así como el contexto histórico de las prácticas agrícolas en Cuenca, como las desarrolladas por las comunidades indígenas incas y quechuas. También fue de interés la influencia de factores externos en estas prácticas, como las influencias extranjeras de la Revolución Verde y la inestabilidad económica por el abandono político y su impacto en el sector agrícola.

A partir de nuestra investigación de antecedentes, fue evidente que la producción agrícola depende de la ciencia y la salud del suelo. A partir de una revisión de estudios previos realizados en los Andes, asumimos la posibilidad de prácticas desadaptativas dentro de la región de San Antonio de Gapal que estaban afectando negativamente la salud del suelo y el ciclo de nutrientes. Sin embargo, es posible que hayan persistido ciertas prácticas adaptativas de influencia indígena. Esperábamos que nuestra investigación descubriera el estado actual de la adaptabilidad agrícola.

Luego de revisar la investigación agrícola en Cuenca, se enfatizó la demanda de un mayor desarrollo de los sistemas de recolección y retención de agua. Al reconocer la importancia de integrar el conocimiento local y el científico, era importante adoptar un enfoque holístico que

[4] Translation by Google Translate in April 2024.

combinara elementos antropológicos con soluciones técnicas. Utilizando este enfoque, el proyecto tenía como objetivo apoyar los medios de vida de los pequeños agricultores en San Antonio de Gapal y al mismo tiempo promover la sostenibilidad.

Métodos

Buscamos una comprensión integral de los aspectos económicos y ambientales de las prácticas de los agricultores en San Antonio de Gapal para mejorar los medios de vida de esos agricultores. Para lograr este objetivo, desarrollamos seis objetivos de investigación que nos permitieron aprender y analizar nuestros hallazgos y recibir retroalimentación y comentarios para evaluar nuestro trabajo. Estos se detallan a continuación:

Objetivo 1: Obtener una comprensión de los estilos de vida de los agricultores y los factores sociales, aspectos ambientales, económicos y de sus prácticas en la comunidad de San Antonio de Gapal.

Objetivo 2: Identificar prácticas y problemas relevantes y consistentes en el experiencia de los agricultores

Objetivo 3: Formular estrategias para paliar un problema pertinente

Objetivo 4: Proponer estrategias a los agroproductores para su revisión y retroalimentación

Objetivo 5: Desarrollar material técnico-científico

Objetivo 6: Difundir materiales, resultados y entregables

Realizamos 12 entrevistas semiestructuradas mientras tomamos observaciones de las fincas que visitamos para comprender sus prácticas diarias en San Antonio de Gapal. Estas entrevistas proporcionaron información sobre los aspectos económicos y ambientales de sus técnicas agrícolas. Se obtuvo el consentimiento de todos los participantes, informándoles de cómo planeamos utilizar su información. Toda la información que recopilamos fue organizada y analizada para generar temas principales. El análisis realizado examinó las fortalezas, debilidades, oportunidades y amenazas (un análisis FODA) dentro de sus propiedades, lo que permitió al equipo del proyecto formular estrategias específicas en respuesta a un problema pertinente que tenían los agricultores, que luego se identificó como la recolección y retención de agua. Desarrollamos un póster y un manuscrito científico para compartir nuestros hallazgos con otros. También realizamos un análisis FODA participativo para recibir comentarios de los agricultores sobre las estrategias que propusimos, con el apoyo de la facultad del departamento de Agronomía de la UCuenca, asegurando que nuestros resultados fueran prácticos, factibles y claros.

Resultados

Varios hallazgos e ideas clave surgieron como resultado de entrevistas y observaciones:

1) Las granjas dependen y prosperan de las relaciones entre factores bióticos y abióticos.
2) Las prácticas conducen a la resiliencia ecológica y económica
3) Las asociaciones aumentan la eficiencia agrícola
4) La accesibilidad al agua durante las sequías es el mayor desafío del agricultor
5) Aumentar la capacidad de agua para un mayor almacenamiento fue la solución más importante

El primer hallazgo sacó a la luz las relaciones agrícolas interconectadas: las granjas operan en un ciclo en el que los elementos se reutilizan y reutilizan de diferentes maneras. Las prácticas de los agricultores demostraron resiliencia ecológica, con una amplia gama de cultivos y plantas protegiendo las granjas de las perturbaciones ambientales. La resiliencia económica se logró mediante prácticas adaptativas que aprovecharon la resiliencia ecológica y la selección natural, que absolvieron la necesidad de productos químicos. Las asociaciones agrícolas también facilitaron una comunidad vibrante y conectada de productores agrícolas.

El hallazgo más impactante que encontramos fue la falta de acceso al agua, particularmente durante períodos prolongados de sequía. La intensidad de las sequías amenaza la productividad agrícola, lo que puede tener efectos devastadores para el suelo, las plantas, los animales y los propios agricultores.

Nuestro hallazgo final describió los resultados del análisis FODA participativo, donde conversamos con los agricultores sobre las estrategias propuestas. En estas discusiones, la viabilidad fue el principal factor considerado para la implementación.

Recomendaciones

Compartimos seis recomendaciones para abordar los desafíos de la gestión del agua en San Antonio de Gapal:

Estrategia 1: ***Incrementar el tamaño y número de barriles (cisternas)***

Muchos de los agricultores utilizaron contenedores para recolectar agua, como se detalla en el Hallazgo 2. Sin embargo, la sequía siguió siendo un desafío constante. Recomendamos que los agricultores coloquen más barriles y más grandes en sus propiedades para poder retener más agua. Aumentar el número de barriles o cisternas proporciona almacenamiento adicional para el agua de lluvia, mitigando el impacto de las sequías y asegurando un suministro de agua más estable durante los períodos secos (García-Ávila et al., 2023).

Estrategia 2: ***No quitar la hierba de raíz, solo cortarla para mantener el cultivo cubierta que fija el suelo, los nutrientes y la humedad***

De las discusiones sobre el ciclo de nutrientes detalladas en la Sección 4.1.1 y la Sección 4.1.2 notamos que muchos de los agricultores ya empleaban esta estrategia. Así, concluimos que adoptar la práctica de no quitar la hierba de raíz sino cortarla para mantener la cobertura del cultivo ayuda a preservar la estructura del suelo, los nutrientes y los niveles de humedad, promoviendo la retención de agua (Kocira et al., 2020).

Estrategia 3: ***Utilizar fertilizantes del ganado y exceso de hortalizas para aumentar la MOS y aumentar la retención de agua***

Con base en nuestros hallazgos en la sección de ganadería detallada en la Sección 4.1.1 y la Sección 4.1.2, llegamos a la conclusión de que la utilización de fertilizantes del ganado y el exceso de vegetales enriquece la MOS, mejorando su capacidad para retener agua (Bhunia et al., 2021). Por lo tanto, recomendamos que los agricultores continúen usando estiércol (abono) y bokashi para mantener la humedad dentro del suelo y aumentar el contenido de MOS. Con suerte, estas prácticas se pueden compartir en las reuniones de la asociación, lo que conducirá a una mayor sistematización de la práctica.

Estrategia 4: ***Emplear terrazas para reducir la susceptibilidad a la erosión***

La erosión es un tema expresado por los agroproductores y se analiza más detalladamente en las Secciones 4.1.1 y 4.2. Como se mencionó en nuestros antecedentes, los incas y los quechuas emplearon terrazas para evitar la pérdida de sedimentos de las cuencas y retener agua (Posthumus, 2005). Recomendamos que los agricultores empleen terrazas para reducir la pérdida de sedimentos que, de otro modo, podrían arrancar los cultivos y dejarlos susceptibles a otras perturbaciones como el viento.

Estrategia 5: ***Utilizar redes de niebla para recolectar agua de la condensación nocturna***

Las sequías, como se analiza en las Secciones 4.1.1 y 4.1.2, amenazan la productividad agrícola. Al revisar la literatura, los recolectores de niebla fueron un método eficaz utilizado localmente en las tierras altas del Ecuador para recolectar agua, aumentando la seguridad hídrica. Un estudio realizado en las comunidades montañosas de Yaguachi y Galtie, que luchan constantemente con déficits de agua, evaluó la rentabilidad de un captanieblas tridimensional y para ver si satisfacía las demandas de agua de la comunidad. Las redes produjeron al menos 2,63 L/m2 y un mínimo de 0,65 L/m2 por día. En un año, los captanieblas produjeron 26.577 m3/año, satisfaciendo las necesidades hídricas de los cultivos. El análisis económico también indicó que el receptor era una inversión valiosa, ya que la relación beneficio-costo fue de 1,90 (Carrera-Villacrés et al., 2023). Incluso los incas que se encontraban por encima de la línea de lluvia desarrollaron sus propias técnicas de agua de niebla que canalizaban el agua hacia cisternas (Ismail & Go, 2021). Otros estudios realizados en la región evaluaron diferentes tipos de redes de niebla, que no satisfacían todas las necesidades de agua pero compensaban significativamente los déficits hídricos (Echeverría et al., 2020; Carrera-Vullacrés et al., 2017). Por lo tanto, recomendamos el uso de redes de niebla para recolectar agua de la condensación nocturna. Esta agua gotearía en un recipiente debajo (Qadir et al., 2021).

Estrategia 6: ***Utilizar un sistema de microriego para maximizar la conservación del agua***

A partir de nuestros hallazgos descritos en nuestra discusión sobre la sequía en la Sección 4.1.1 y la Sección 4.2, llegamos a la conclusión de que implementar un sistema de microriego, como riego por aspersión y/o riego por goteo utilizando agua ya contenida en contenedores, aumentaría la retención de agua (Üzen & Cetin, 2013). Dichos métodos de riego garantizarían un uso eficiente del agua al entregar pequeñas cantidades de agua directamente a las raíces de las plantas, siguiendo así un principio unificador de la naturaleza (ver Figura 21) y maximizando los esfuerzos de conservación del agua (Drip Irrigation Systems, 2023). En 2017, "el Ministerio de Agricultura Ganadería, Pesca y Pesca (MAGAP), inició un proyecto donde los agricultores podrían presentar recursos para obtener financiamiento para la instalación de sistemas de riego localizado" (Paul Salazar, 2017).

Conclusión

Después de entrevistas y observaciones con 12 agricultores, la recolección y retención de agua fueron las áreas de mayor mejora para aumentar la resiliencia frente a un clima volátil que se avecina, incluidas sequías prolongadas y lluvias excesivas. Las recomendaciones dadas fueron aumentar el número y tamaño de los barriles o emplear una cisterna para recoger la lluvia. También recomendamos seguir manteniendo la hierba y empleando abono y bokashi de restos de ganado y vegetales. Los métodos novedosos propuestos a los agroproductores fueron el uso de redes de niebla para recolectar el rocío durante la noche y el empleo de terrazas para reducir la erosión y aumentar la retención de agua. Se recomiendan pequeños estudios a la facultad de Agronomía de la UCuenca para evaluar cuánta agua utilizan los agroproductores en un tiempo determinado, cuánta lluvia cae en el mismo periodo y, por tanto, qué dimensiones y costos se requieren para diseñar una red de niebla que satisfaga las necesidades hídricas en periodos. de sequía excesiva. También se discutió con los agroproductores las terrazas, que se han utilizado desde la antigüedad, para incorporarlas al paisaje montañoso en el que cultivan. Los agroproductores podrán entonces determinar empíricamente si la retención de agua aumenta y la pérdida de suelo disminuye. Una investigación adicional en agricultura dentro de la comunidad de San Antonio de Gapal sería evaluar cuantitativamente los patrones de lluvia y sequía específicamente dentro del área, así como la pérdida de sedimentos a lo largo del tiempo. Esto puede informar estrategias más efectivas dados los datos numéricos respaldados por los datos cualitativos proporcionados en este estudio. Además, sugerimos la colaboración con investigadores locales que han empleado redes de lluvia y cisternas en otras regiones de los Andes.

1. Introduction

Farmland in the Azuay province of Ecuador is largely composed of many small family farms (Cifras Agroproductivas, 2022). Prior studies argue that the land suffers from degradation in the form of erosion, negative nutrient balances, and loss of organic soil matter, all of which hurt crop productivity (Caulfield et al., 2020).

Our sponsoring organization is the Faculty of Agricultural Sciences (Agronomy School) of the University of Cuenca. Dr. Pablo Geovanny Quichimbo Miguitama, a soil science professor, agronomist, and director of the Department of Water Resources and Environmental Sciences at the University of Cuenca, led the faculty who worked with us (UCUENCA, 2024). The co-director of the project is Dr. Pablo Marcelo Borja Ramon, who is also a soil scientist. Our project was a small portion of *"CICLA,"* a larger diagnostic initiative they led, aimed at assisting farmers in the Azuay province.

The goal of our project was to propose strategies that enhance agricultural practices, which would improve the livelihoods of farmers in San Antonio de Gapal, a small community in Cuenca, Ecuador. To aid in the completion of our project, we developed six objectives, outlined as follows: Objective 1: Obtain an understanding of farmers' lifestyles and the social, environmental, and economic aspects of their practices in the community of San Antonio de Gapal; Objective 2: Identify relevant and consistent practices and problems in the farmers' experience; Objective 3: Formulate strategies to alleviate a pertinent problem; Objective 4: Propose strategies to agroproducers for revision and feedback; Objective 5: Develop technical-scientific material; Objective 6: Disseminate materials, outcomes, and deliverables.

After data collection, we ascertained the primary issues agroproducers experienced were water collection and retention, which are used to combat the effects of droughts and erosion caused by excessive rain, which are detrimental to crop productivity. Strategies recommended to mitigate these threats include increasing water storage capacity via the use of barrels and cisterns, fog nets, terracing, and micro-irrigation among others. The strategies were proposed to a subset of farmers to discuss the feasibility of implementing each strategy.

2. Background

The community of San Antonio de Gapal in Cuenca, Ecuador is composed of small farming families. Although farming has been a longstanding practice in this community and is central for the economy, agricultural issues persist, and current practices may not be appropriate when confronted with a changing climate. This provides an opportunity to investigate the strengths, weaknesses, opportunities, and threats that influence farming practices and livelihoods. After this, strategies can be proposed to facilitate an improvement upon existing practices and support the farmers' livelihoods. To begin, we investigated Andean farming by examining the mountainous geography, the challenges its landscape presents, and a brief history of how people historically met these challenges. Our team conducted a more thorough inquiry into how the geography and topography dictate the productivity of the land, and subsequently the intentional and unintentional changes to soil science and nutrient cycling over time within Cuenca's agriculture.

The next part of our literature review analyzes the history of agriculture practices, both before and after foreign influence. We discovered that generational farming practices were adaptive and upheld by the community, while historical external influences incentivized maladaptive practices. After discussing this history, we explored the current state of agriculture with respect to the economic instability in Ecuador because of political abandonment.

As our team approached collaborating with the local community, we included sections that considered current agricultural research and an approach towards harmonious solutions from foreign and internal perspectives. A collection of agricultural studies in Cuenca was referenced to understand a demand for agricultural investigation. In our discussion of improving and integrating more effective and sustainable practices, we considered the connection between local and scientific knowledge in soil science and agricultural practice improvement. This is because agricultural change which includes significant cultural and anthropological elements should consider both internal and external viewpoints. Lastly, the use of a SWOT analysis was reviewed to understand its implications within our project.

2.1 Overview of Andean Farming in Southern Ecuador

Ecuador is divided into 24 provinces. The Azuay province, which is on the southern side of the country, is divided into 15 cantons. The largest of the Azuay cantons is Cuenca (see Figure 1), and it is in the northern region of the province. As of 2022, the land used for agriculture in Azuay is measured at 531,552 hectares (ha). Forests and mountainous areas are the main types of land used in agriculture. Within these types of land, the top five cultivars in Azuay are dry soft corn, dry rough corn, dry beans, cacao, and potatoes (Cifras Agroproductivas, 2022). Considering about 43,000 peasant farms out of nearly a total of 100,000 farms in the Azuay province contain about 0-1 ha of land, much of the farming landscape is composed of small family farms rather than large, centralized farming land (Fonte et al., 2012).

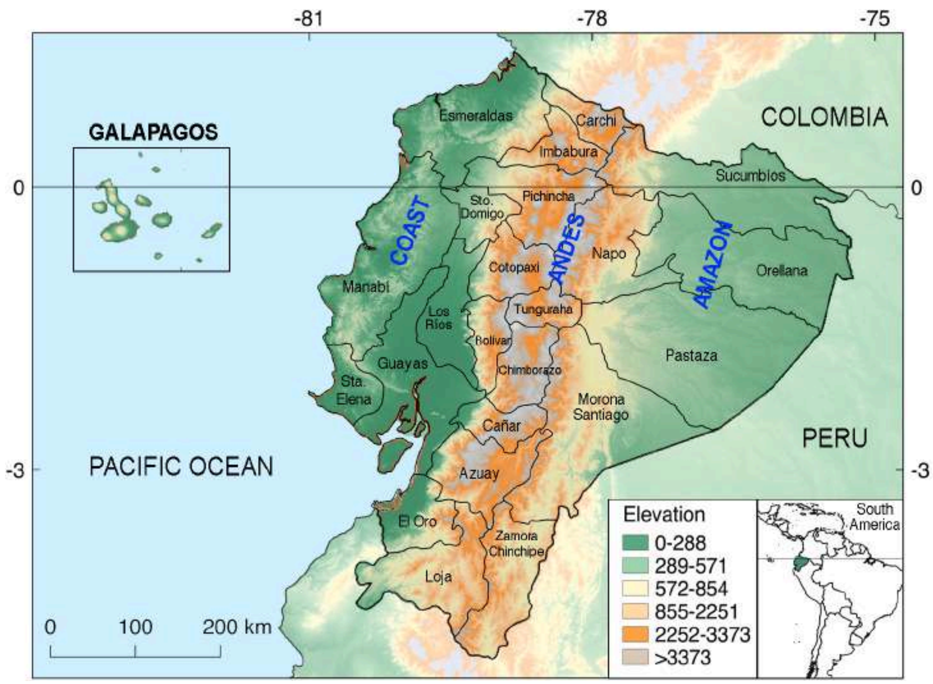
Figure 1. ***Map of Ecuadorian Cantons in the Azuay Province***[5]

Note. A map of the Ecuadorian cantons. They are the equivalent of US states. From "File: Cantones de Azuay.png", by D. C. S., 2011, (https://commons.wikimedia.org/wiki/File:Cantones_de_Azuay.png).

[5] The original image title is *Cantones de Azuay*, which translates to English as *Cantons of Azuay*. Translation by J. Shen.

Farming in the Andes Mountain range varies greatly from farming in non-mountainous regions. The mountainous region roughly splits the country in half (see Figure 2). The steep slopes from these mountains, which inherently increases the susceptibility to erosion, in the Azuay region demand effective water management and soil conservation techniques. The terrain requires specialized agricultural practices to optimize the use of the limited land apt for growing crops (Guarderas et al., 2022).

Figure 2. ***Elevation Map of Ecuador***[6]



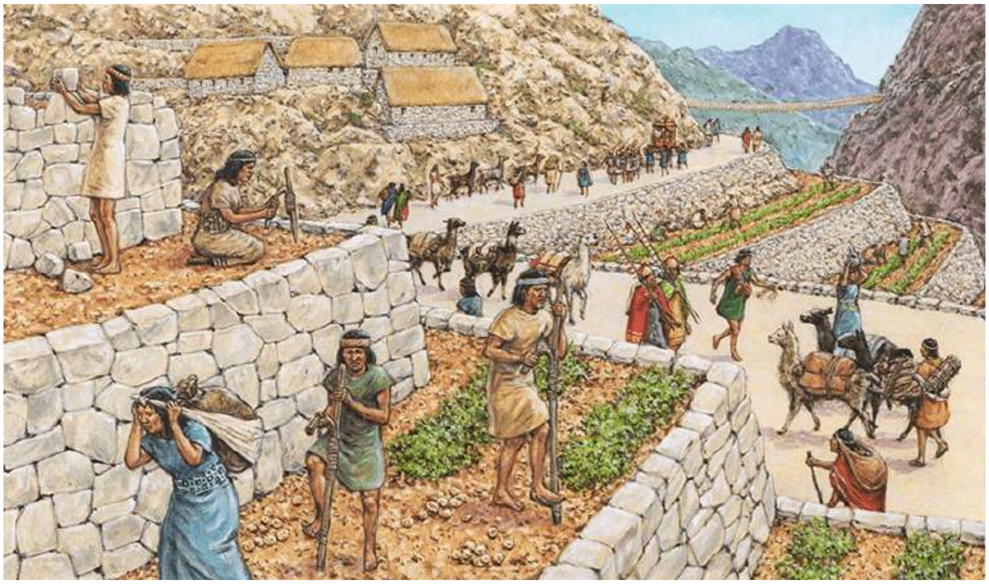
Note. A topographical map of Ecuador. From "Leptospirosis", by M. Calvopiña et al., 2022, (https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0010430), Copyright 2022 by Calvopiña et al.

Ancient civilizations such as the Incas dealt with these demands efficiently. They developed sophisticated terracing systems, irrigation canals, and cisterns, which are storage tanks for water to cultivate crops on steep slopes. A terrace is sloping land that descends into a number of level flat areas resembling a series of steps. Terraces provide heat retention for plants, as well as efficient water conservation (Rodríguez et al., 2022). These ancient techniques were born out

[6] The numerical values describing elevation in the bottom-right hand corner of the figure have units of meters.

of necessity and demonstrated remarkable resilience and efficiency in navigating the challenges of the Andean landscape (Graber, 2011; see Figure 3).

Figure 3. ***Illustration of Incan Farming***



Note. Copyright 2023 Adam Hook. (2009). *Inca Farming.* [*Acrylic*]. Eastbourne, United Kingdom.

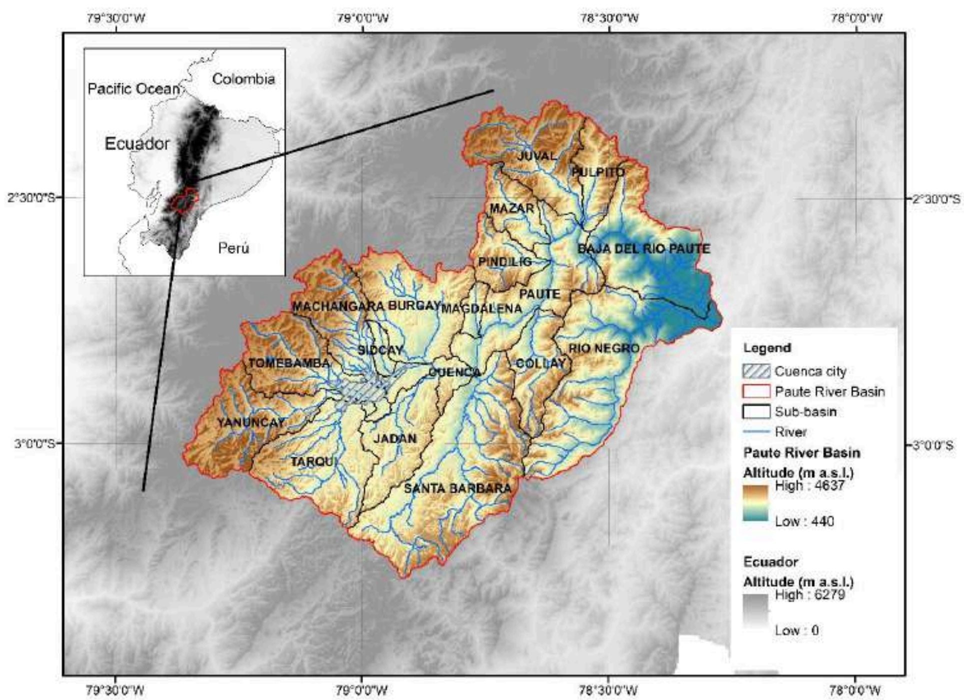
The farming demographic in the Ecuadorian Andes today mostly consists of small-scale farming within local communities that have continued the use of terracing systems. Currently, many farmers have limited access to agricultural inputs, which include organic amendments, fertilizers, pesticides, and irrigation (Fonte et al., 2012). Most people in the Andes mountains make use of several benefits that terraces provide. However, knowledge of Incan practices has diminished over time due to external influences, changes in land use, and shifts in agricultural needs and preferences (Graber, 2011).

Family farms may utilize agricultural practices and tools they developed themselves, which may lead to a lack of systemized techniques among farmers within the region. Therefore, learning practices from farmers may aid in developing material to share with small farms who use less efficacious techniques.

2.2 The Geography and Topography of the Paute River Basin Dictates Agricultural Production

There are many factors that influence agricultural production. Due to the topography of Ecuador (see Figure 4), the climate varies in relation to several factors, including altitude, the orientation of mountain ranges, proximity to the Pacific Ocean, ocean currents, and winds. Among these factors, altitude has the most significant impact on climate. "Thanks to the climatic conditions, Ecuador has developed agricultural activities that allow it to obtain products according to market demands; the most representative within the country's economy is the cultivation of bananas, cocoa, African Palm, coffee, and sugarcane, among others" (Mihai et al., 2023). Given these aforementioned factors, the impact that climate has had on Ecuadorian farming is evident.

Figure 4. ***Topological Map of the Paute River Basin***



Note. A topological map of the Paute River Basin. From "Paute River Basin (Ecuador)", by R. Celleri, 2024, Copyright 2024 by Basin Info.

The elevation of the Paute River Basin ranges from 2,600 to 3,600 meters above sea level (see Figure 2), which produces drastically different microclimate conditions. Three classifications exist within these elevations. The ground is within 2,600 and 2,900 meters above sea level location in the south. The medium floor is between 2,900 and 3,200 meters, and the higher floor is between 3,200 and 3,600 meters above sea level in the north. The canton of Cuenca rests within the ground floor where there is self-consumption cultivation, vegetables, and natural grass. On the ground floor, there are numerous rivers, with clay soils, rich chemical fertility, and reduced risk of frost, which are all conducive for crops. The soils within the medium altitude are finer and contain less chemical fertility. This altitude also has lower temperatures and more frost which can kill crops. Therefore, farmers limit this area to livestock. The highest altitudes have limestone rock with low clay content. Most of this area is restricted to cold tolerant herbaceous plants such as alfalfa and is primarily for domestic use. Farmers are also more inclined to cultivate in the outskirts of cities such as Cuenca. This allows for greater access to agricultural inputs and for accessibility to markets (Consejo de Gestión, 2006).

2.2.1 The Paute River Basin

The Paute River Basin, a large basin where Cuenca is located (see Figure 4), is nestled within the Andes in the south of Ecuador. It contains the provinces Azuay, Cañar, and Morona Santiago. Towards the west of the basin are numerous tributaries at higher elevations that flow east towards the Amazon. The basin has a land coverage of about 5200 square kilometers with a population of about 620,000 inhabitants. The upper mountain ranges are covered in native vegetation, while the population and crops are centered in the middle of the basin. The temperature of the basin averages 14°C and precipitation gradually increases from the mountainous west to the Amazonian east (Consejo de Gestión, 2006).

The Paute River Basin tributary system is essential to its residents because it “supplies downstream areas with drinking water and water for agricultural production, livestock and fish farming” (Rolando Celleri et al., 2024). Thus, the people of Cuenca have developed a strong dependence on this basin.

2.3 Soil Science and Nutrient Cycling in Cuenca's Agriculture

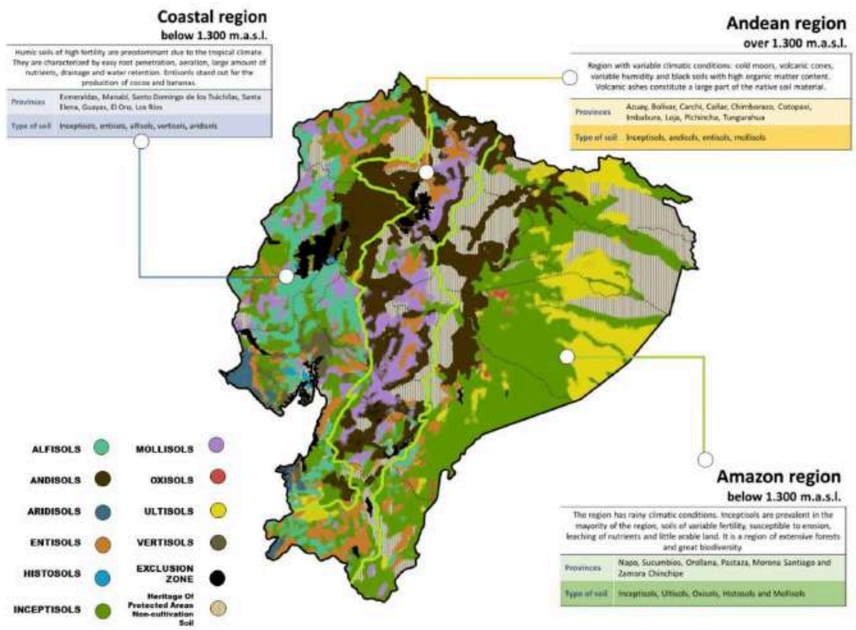
In agriculture, soil is central. Everything the farm produces is dependent on soil health and its management, and thus must be upheld. Soil vitality, the potential yield of soil, is a key aspect for farmers to understand how to provide essential nutrients, maintain proper drainage, and to create a conducive environment for plant growth, ultimately increasing productivity (*Soil Health Principles and Practices*, 2020; Huera-Lucero et al., 2020). Thus, soil conservation in Ecuador is crucial for food production and environmental preservation (Dehn, 1995).

Nutrient cycling is a process that recycles organic and inorganic matter; it describes a constant flow of aforementioned essential nutrients and elements to and from animals, plants and the soil. "Animals and plants consume nutrients found in the soil, and these nutrients are then released back into the environment via death and decomposition" (*Nutrient Cycling – Crandall Park Trees*, 2024). By understanding and managing these cycles effectively, farmers can enhance soil fertility, sustain crop productivity, and promote long-term environmental sustainability in uneven landscapes.

Nutrient cycling is used for all agricultural processes and is a key factor in the ability to grow crops. At higher altitudes, this process differs significantly from those in lower altitudes. "Some of the reasons for this include changing climatic conditions, precipitation patterns, vegetation, and parent rock type. The key nutrients, carbon (C), nitrogen (N), phosphorus (P), and potassium (K) of soils at higher altitude differ significantly from those that are present on plains" (Packialakshmi et al., 2020). These are different in that carbon concentration increases while the availability of soil nutrients like potassium and phosphorus would be decreasing with elevation.

Soil composition differs all over the world depending on the surrounding environment. Categorizing each type of soil that is cultivated is important information because the choice of crop depends on the soil type for better crop yield. The Ecuadorian soil composition ranges from tropical in the Amazon Rainforest, to mountainous in the Andes Mountains (Huera-Lucero et al., 2020). There are three prominent soils in the Andean region of Ecuador (see Figure 5), which include andisols, mollisols and entisols. Andisol, one of the more common soils in the mountainous region of Ecuador, is a soil composed of volcanic ash and highly packed with minerals. Andisol has properties equipped for growing crops due to its high phosphate and moisture retention capacity. Which allows the soil to be proficient at growing potatoes and cereals. Mollisol soil type is also found commonly in the Andean region and is a rich soil in organic materials making it excel at growing cocoa, soft corn, hard corn, sugarcane, beans, fruit trees, and potatoes, and other crops. Entisol soil type is found in the Andean region of Ecuador: it provides no nutrients and is shallow and sandy soil not optimal for growing crops (Mihai et al., 2023).

Figure 5. ***Soil Types in Ecuador***



Note. A geographic map of Ecuador depicting soil types throughout the country. From "The Panoramic View", by R. Mihai, et al., 2023, *Toxics* 2023, *11*(2), 123.

Soil organic matter (SOM) is also a critical component in maintaining soil health. SOM increases biological activity and biodiversity and is essential for regulating soil processes such as nutrient cycling, plant growth, soil aggregation, and water storage (Caulfield et al., 2020). "A close second, however, is the loss of soil organic matter which decreases aggregate stability, weakens soil structure, and negatively impacts soil water availability to crops" (Karlen & Rice, 2015). The decrease in SOM directly impacts the ability of crop's health and productivity and increases the change in soil structure and makes erosion more prevalent.

2.3.1 Intentional and Unintentional Soil Changes from Ancient and Traditional Anthropogenic Influence

In ancient agricultural communities, soil change was deliberately managed and developed through iterative means. This was dependent on reducing constraints for production, changing the landscape to satisfy crop needs, as well as preventing and reversing hazards. The ultimate goal of this soil change was to “increase the probability of successful crop production, improve soil productivity, maintain yield stability, and achieve sustainability” (Sandor & Homburg, 2017, p.198). In semiarid environments, such as the Andes, water supply is especially critical. Other soil management practices that are important for crop productivity “include erosion control, physical stability, nutrient supply, and microclimate conditions, such as temperature and wind” (Sandor & Homburg, 2017, p.199). Deliberate soil management is also important for climate and hydrologic extremes, as well as excessive salt and sodium. Management practices that have come up more recently can also be incited by human-induced degradation processes that accelerate erosion and salinization.

Soil degradation in Ecuador has also occurred through unintentional means. These means usually have a negative impact on agricultural productivity. Soil degradation results from mismanagement of land resources. Because soil degradation and the complex nature of soil, climate, and other environmental changes can threaten crop productivity, this most likely leads to the iterative development of sustainable management practices (Noni & Trujillo, 1986, p. 552). “Currently, [these] problems are most severe in mountainous, tropical latitude areas of Central and South America where natural or environmentally induced soil degradation (e.g. landslides) is prevalent, and in Africa, which unlike Asia, has not been able to capitalize on benefits associated with the traditional ‘green revolution’” (Karlen & Rice, 2015, p. 12,491). Unfortunately, this green revolution caused many more problems despite original intentions, which led to maladaptive practices worldwide.

2.4 Generational Farming Practices are Adaptive and Upheld by the Community

Farming is a human-centered practice that involves many people and their communities; it has long been rooted in sharing knowledge across generations. These internal influences affect the types of processes and tools farmers use. They may implement local practices used in the community. For example, in an interview we conducted with Mr. Bishop Mumford, a 5th generation farmer from Griffin, Indiana, had many practices informed by his neighbors and other local practices. If there is a history of using a certain crop, farming communities may be likely to pass down generational practices used to sustain that crop, as was the case for soybean and corn for Mr. Mumford (B. Mumford, personal communication, February 23, 2024).

A traditional practice developed in the Ecuadorian Andes mountains is the Chakra, which is a “traditional agroforestry system [which contributes] to climate change adaptation and biodiversity conservation in Ecuador’s Amazonian communities” (Torres et al., 2015, p.1973). The Chakra is a sustainable system of practices that was established by using the harsh conditions of the mountainous regions for their benefit. Using a diverse strategy of using intra and inter specific crops to maximize their efficiency and effectiveness against the environmental demands. This Chakra is based on an “Andean belief system in which all elements are an integral part of each of the beings living on the ‘Pacha Mama’ (Mother Earth), Chakras are living places where nature and communities have lived in harmony for centuries” (FAO, 2024).

A group of indigenous peoples, the Quechua, located in the Ecuadorian Andean region who created their livelihood from understanding a sustainable system of the region. “The Chakra sites in Ecuador have thrived thanks to collective action by Indigenous Peoples, ensuring sustainable management of natural resources and food sovereignty over the centuries” (*Globally Important Agricultural Heritage Systems*, 2024).

Indigenous Ecuadorian communities manage their land differently than settlers. Indigenous communities rely heavily on forest ecosystems for their livelihood and manage land for multiple uses. Indigenous communities also strive to cultivate different products that reach a production level with respect to “stability cycles and requirements of all the elements that are part of a ‘Chakra’, that is: soil, water, crops, livestock breeding and families” (FAO, 2024). In contrast, settlers tend to manage their land through intensification (higher use of inputs), and extensification (growth of agricultural area via deforestation), and usually have less crop diversity (Sellers & Bilsborrow, 2019).

2.5 Historical External Influences Incentivized Maladaptive Practices

Intensification was a trend in areas that were highly dependent on agricultural presence. Since the 1960s, there has been a negative large worldwide agricultural shift referred to as the green revolution, as briefly discussed in Section 2.3.1. Many of the practices stemming from this revolution contribute greatly to threats to agricultural production. Among these threats is land degradation, which is caused by erosion, SOM depletion, and negative nutrient balances (Vanek et al., 2016; Vanek & Drinkwater, 2013). However, during this time, productivity of main agricultural crops increased up to four to five times at the expense of the soil's health. The revolution relied on fossil energy for fertilizers, pesticides, and irrigation. As a result, over time, these technologies have led to a decline in yields (Ameen & Raza, 2018). Additionally, this use of fossil fuels has led to overproduction and loss of both biodiversity and soil fertility. Other practices leading to erosion and land degradation include over-tilling, excessive nitrogen fertilization, and saline irrigation water. Chemical fertilizer reliance to compensate for bioactive soil shortages has also masked the problem of erosion. The dependence on fossil fuel fertilizers for production maximization is directly linked to climate change (Toledo et al., 2023). Thus, systemized sustainable management practices are necessary for resource management and improvement.

Since the early 1970s, there has been a steady increase in the intensification of the land, land overuse, and an increase in productivity which has led to land degradation (Blackmore et al., 2021). This is correlated with an increase in labor and an arrival of immigrants in Ecuador (Gray, 2009). Additionally, this intensification can be a result of capital intensification and the need for increased yield (Meena et al., 2023). Labor may include more frequent weeding and shorter fallow periods to allow the land to regenerate but may also include chemical inputs to increase agricultural yields, such as pesticides, fungicides, herbicides, and fertilizers. "Other forms of intensification also exist, including … increasing irrigation, multiple cropping, and changing crops to higher value, more labor-intensive crops" (Sellers & Bilsborrow, 2019, p.348). In discussions about standard farming practices with Mr. Mumford, he stressed that there was "one rule: no weeds" (B. Mumford, personal communication, February 23, 2024). They remove crops, and use valuable resources intended for other produce. In the interest of increasing productivity and reducing threats to the land, farmers often adopt these practices, allocating more resources to the land and crop production leads to greater yields.

Aside from the natural mountainous landscape which can increase watershed, the agricultural land can become prone to erosion by the lack of vegetation cover, intense tillage, increased aeration from plowing, soil compaction from heavy traffic, and biocides that reduce biological activity and thus plant growth (Meena et al., 2023). With a lack of sustainable soil management and an increase in land degradation, farmers are unable to replace the nutrients contained within the harvested crops. Ultimately, soils are reported to have overall deficits in nutrient balances of nitrogen, phosphorus, and potassium because of current farming systems. In a study conducted in the Ecuadorian Andes, specifically in the rural indigenous community of Naubug, Flores Parish, in the province of Chimborazo, SOM levels under croplands were 15% lower than local forest land. It was later concluded that land use conversion and unsustainable soil management were the driver of this disparity (Caulfield et al., 2020).

Although multiple tributaries exist in the Paute River basin that flow from the mountains to the Amazon, there was a systemic inequality regarding water accessibility. In 2001, only 20% of UPAs (Urban and Peri-urban Agriculture) of the 11 cantons within the river basin had irrigation systems (Consejo de Gestión, 2006, p.30). However, "irrigation efficiency is low due to a lack of technical development. The majority of these irrigation systems were built more than 50 years ago," (Rolando Celleri et al., 2024, para. 2) and they have not been updated since. This inequality limited agricultural productivity in certain regions, which negatively affected the influx of new small farm owners that came with agrarian reform in the 1950s. This provoked the farmers to augment their land, damaging native vegetation which was responsible for climate and weather regulation. This began the process of natural resource and environmental quality deterioration. In the late 1900s, a detrimental combination of water flow reduction and soil erosion acceleration occurred. In the 2000s, approximately 40,000 hectares of forest had been lost and roughly 135,000 hectares of soil had deteriorated from erosion (Consejo de Gestión, 2006, p.31). Farmers also used the land for short term and extractivist activities, such as deforestation, which prioritized producing and selling product over replenishing resources, which does not restore land (Acosta, 2013; Veltmeyer & Ezquerro-Cañete, 2023). This is in complete contrast to the Quechua lifestyle and belief - the idea of sustained nature and community as mentioned in Section 2.4. As discussed in Section 2.1, this eventually led to a lack of income for small to medium landowners, with an average poverty index of 73.5 in the 11 cantons, and a force that pushed male workforce to find other jobs or migrate with their families (Consejo de Gestión, 2006, p.32).

Considering agriculture is central to Ecuador's economy as well as for the livelihoods of small-scale farmers, the lack of its productivity is worrisome for the country's future. The country could become reliant on tourism, a dump for waste treatment, a forest reserve, or a source for exploitation of raw materials and biodiversity (Consejo de Gestión, 2006). This would lead to future job opportunities, a decrease in the income of its citizens, and would decrease the competitiveness of the country's market and role in the world.

One study in the central part of the Cuenca intermontane basin, located between 2,300 and 3,300 meters above sea level recorded watershed sediment losses in rural landscapes ranging from 0.26 to 151 Mg ha^{-1} yr^{-1} with an overall soil loss of 22 Mg ha^{-1} yr^{-1}. This study shows that "sediment yield decreases exponentially with an increasing vegetation cover, and a decreasing percentage of the catchment underlain by argillaceous rocks" (Molina et al., 2008, p.9). Additionally, the data from the study indicated that "a small (10 to 25%) increase in the contact vegetation cover can lead to a significant (60%) decrease in sediment yield" (Molina et al., 2008, p.10). An additional study in the local Río Chimbo watershed found erosion losses averaging 27 Mg ha^{-1} yr^{-1}, with estimates as high as 150 Mg ha^{-1} yr^{-1} (Henry et al., 2013).

Aside from the loss of essential soil nutrients, soil degradation leads to a loss of soil biological activity and the structure offered by such activity. These are critical in soil water capture and retention, soil erosion, nutrient cycling, root penetration, and overall productivity of agricultural lands. The addition of fertilizer can mitigate some of these issues, however, this serves more as a quick mask rather than the slower regenerative rehabilitation of soil health and productivity that is needed (Caulfield et al., 2020).

Another contributing factor to negative nutrient balances is the inaccessibility to agricultural inputs such as food and water for rural small-scale Andean farmers. These farmers have low financial resources to invest in these inputs and the remote location of Cuenca's region is a barrier in obtaining such resources. "Although overall inputs are low, there appears to be great variability in the spatial allocation of the available nutrient and organic matter inputs" (Caulfield et al., 2020, p.1651). Farmers are reported to provide more inputs closer to the farmers' homestead as compared to outer fields due to limited labor. Thus, farmland closer to homesteads may be more biologically active and sustained, however the further from the homestead the more degraded the land may be even within the small-scale of the farmers in Cuenca. Therefore, defects in SOM and nutrients may be partly attributed to the distribution of inputs from farmers, and labor limitations, not necessarily due to constrained resources (Caulfield et al., 2020). This suggests alternative *in situ* methods and ways of managing farmland are required for addressing negative nutrient balances rather than increasing inputs overall.

2.6 Political Abandonment Prompts Economic Instability in the Agricultural Sector

In regards to Government support, and the instability of being able to staffing the Ministry of Agriculture is leading to permanent unpredictable fluctuations in the economy which is negatively affecting the agricultural sector (Jumbo, 2023). “In Ecuador the countryside has usually been abandoned by the State” (Moreano-Logroño & Mancheno-Herrera, 2020, p.413). The third minister since the year 2020 and a new manager has been appointed. This increases the difficulty for long-term programs to succeed. Additionally, “this has led to limited productivity resulting in lost investments, low crop yields and low participation rates” (Moreano-Logroño & Mancheno-Herrera, 2020, p.413). Jumbo (2023) suggests that the result is a deficiency in the development of competitive production in peasant family agriculture. Farming families are left behind in new technologies, agricultural education, and financial support. This is especially important because agriculture provides most of the food for Ecuador and is the main driver of Ecuador’s economy. Thus, there is an unmet need for agricultural practice and tool reform in Andean farming (*The World Bank In Ecuador*, 2024).

Government can do work to shelter the agricultural sector. In the early months of 2024, the economy slowed due to “increase in insecurity caused by organized crime, disruptions in oil production, climate-related events, and political uncertainty” (*The World Bank In Ecuador*, 2024).

The country has an enormous growth potential which can be used to generate jobs and cut poverty. However, there needs to be political consensus to decrease the inhibitors of job creation and increase private investment and export diversification. These barriers include market intervention, limited competition, limited trade integration, and rigid labor regulations (*The World Bank In Ecuador*, 2024). Most of the planting is for domestic consumption with no objective to market agricultural products and “there is no intention to design, produce and sell products that have the attribute, in terms of price, innovation, environmental sustainability” (Moreano-Logroño & Mancheno-Herrera, 2020, p.427). In addition, the public sector can reduce its dependence on the oil sector and switch to leverage the agricultural sector (*The World Bank In Ecuador*, 2024).

2.7 Development of Farming Research in Ecuador

In the years prior to 2006, there have been numerous studies conducted on the socio-economic dynamics of the upper Paute River Basin, where Cuenca resides. These studies aimed to understand the “dynamics and discuss political alternatives and local support actions to improve the living conditions of peasant families, and the management of natural resources in the basin” (Consejo de Gestión, 2006, p.9). The overall goal of this initiative was to achieve an improvement in the living conditions of the population, relaunch the economy of small producers, improve the regional economy, achieve a harmonious relationship with nature, and see an optimal allocation of financial resources (Consejo de Gestión, 2006). There was also the hope to produce information that would aid in the development of political and intervention proposals. Much of this work lays the foundation and vision for the objectives of this project. Given that the farmers of Cuenca are unable to generate income, it is therefore impossible to buy modern tools and purchase survival necessities such as food, water, and shelter. This is the most likely cause of mass immigration to other countries: a difficulty in the acquisition of living necessities (Moreano-Logroño & Mancheno-Herrera, 2020).

An undergraduate thesis written by a member of our sponsor team, Dr. Pablo Quichimbo, a soil science professor at UCuenca (see Appendix A), provides detail on “the Tabacay River micro-basin, which is located within the province of Cañar” in Ecuador (Quichimbo, 2008, p.59).[7] The basin spans an area of about 66 square kilometers, which the Guapán and Bayas parishes share. Its elevation ranges from about 2500 to 3700 meters above sea level, with steep terrain slopes. “The topography corresponds to a mountainous terrain since the slopes mostly exceed 12% inclination, with slopes greater than 45% predominating” (Quichimbo, 2008, p.68).

[7] Information taken from the source with citation (Quichimbo, 2008) comes from an English translation of the original thesis.

Unfortunately, this land is considered to be “marginal,” indicating it is unfit for farming and provides minimal agricultural value.

PROMAS, a unit affiliated with UCuenca under their Faculty of Engineering, carried out a survey in the early 2000s and identified that 71% of households argue that there is water and soil contamination. Contamination and other related problems such as excrement disposal have varying severity depending on exact location (Vinueza et al., 2021).

2.8 Synergy Between Local and Scientific Knowledge for Soil Conservation and Agricultural Practice Improvement

To restore and protect soils and improve agricultural practices, it is crucial to incorporate both local and scientific knowledge (Mora et al., 2020). There is always the risk that co-management with full participation of locals can become a form of co-optation of local knowledge. Just as biodiversity is essential for a thriving ecosystem, so is cultural diversity, which is needed to solve problems in society. This avoids the risk of approaching a globalized monoculture, a culture “where only a single type of knowledge and science is genuinely recognized as such” (Mazzocchi, 2018, p.20). By integrating the distinct system of scientific knowledge and local knowledge, the scientification may result in a sterilization of the native, thus leading to a sterilization of diversity (Suarez & Gwozdz, 2023).

Thus, it is incredibly important to construct a system where recognition, accommodation, and valuation of possibly conflicting interpretations of reality and knowledge criteria is important. Proper integration would spur a genuine ecology of knowledge, an amalgamation of multiple interactions with nature, time, and space. Thus, allowing for the “possibility to relate to each other, mutually learn, and discover or develop changed meanings” (Mazzocchi, 2018, p.29). The knowledge is legitimate in their context, “separately but in parallel,” would interact and enrich each other, triggering cross-cultural hybridization (Marotta, 2020). Ultimately, something new can be learned from knowledge obtained by communicating with different groups.

There are many methods people can use to communicate with other groups of people. Surveys, for example, are a powerful tool for gathering information from a variety of groups, and can provide valuable insights into behaviors, opinions, attitudes, and preferences. For example, research on perceptions of soil fertility indicators in southern Ecuador by Andean farmers were collected via surveys since 2018 (Jiménez et al., 2024). This was used to revalue and enhance local knowledge. The conclusions of this study highlighted complementarity and few discordances between indigenous and scientific knowledge. Additionally, they found it essential to understand and propose alternatives for the management and conservation of soil fertility that respond to the technical, social, cultural, economic, and soil-climatic conditions of the area (Mora et al., 2020).

These reports validate the use of surveys and interviews to understand the farming techniques and tools Andean farmers use. This method allows for the incorporation of local knowledge with scientific knowledge to develop systemic sustainable farming, soil health, and nutrient cycling, in the Cuenca farming region.

2.9 SWOT Analysis

A SWOT analysis is a useful template by which one can identify the strengths, weaknesses, opportunities, and threats. These subcategories can be matched up to internal and external factors, where strengths and weaknesses are internal, and opportunities and threats are external. Each factor has its own importance in making justified decisions. Some of its uses entail allowing "organizations (businesses, public administration or associations) to quickly identify both its internal factors linked to internal functioning and external factors that depend on the environment in which it is evolving. The SWOT analysis is used as a decision-making tool and to facilitate the development of strategic plans" (50MINUTES, 2015). For these reasons SWOT is an important tool for business decisions, as well as any strategic decision within an organization; In this project, we used it to analyze the information from the farmers to synthesize a strategy to alleviate a problem of choice.

3. Methodology

The goal of our project was to propose strategies that enhance agricultural practices, which would improve the livelihoods of farmers in the community of San Antonio de Gapal. To achieve this goal, the team developed six research objectives which are shown below, each to be completed with various research methods and specific expected outcomes (see Table 1).

Objective 1: Obtain an understanding of farmers' lifestyles and the social, environmental, and economic aspects of their practices in the community of San Antonio de Gapal

Objective 2: Identify relevant and consistent practices and problems in the farmers' experience

Objective 3: Formulate strategies to alleviate a pertinent problem

Objective 4: Propose strategies to agroproducers for revision and feedback

Objective 5: Develop technical-scientific material

Objective 6: Disseminate materials, outcomes, and deliverables

Table 1. Methods Used for Objectives

A description of our methods and expected outcomes for each of our six objectives.

Objective	Method	Outcomes
1	Semi-Structured Interviews	Understand life history, farmer lifestyles, practices, and challenges
	Observations	Understand farming practices, and relationships between different elements on the farm
2	Analysis of Interviews and Observations	Determine strengths, weaknesses, opportunities, and threats to identify pertinent issues the farmers face
3		Develop several strategies to propose to the farmers
4	Participatory SWOT Analysis	Propose our developed strategies and receive comments and feedback
5	Technical-scientific material	Develop and prepare a scientific manuscript to share the findings of our project
6	Open House and Local Scientific Journal	Disseminating deliverables to the public

3.1 Objective 1: Obtain an understanding of farmers' lifestyles and the social, environmental, and economic aspects of their practices in the community of San Antonio de Gapal

For this objective, an understanding of those farming in San Antonio de Gapal was developed. We learned directly from these farmers via semi-structured interviews we prepared (see Appendix C). We kept the same interview questions with each of the different 12 farmers to maintain consistency in general ideas generated.

The types of questions we asked sought to guide each of the interviewees in a certain direction for ease of conversion into data. Several qualitative and quantitative questions were asked to achieve this, such as what age they began to farm and what the most important factors in the types of processes and tools the farmers used. By aggregating both types of data, a more comprehensive understanding of the farmers' lives and practices was realized.

Each of our data collection methods contain information respective to five dimensions of SESs, which are listed below (see Table 2). An SES is an interconnected relationship between a society and the nature it is embedded in (Sheona Shackleton et al., 2021). Farms are examples of SESs, an amalgamation of society and nature, so they are of particular interest for this project.

Table 2. Five Dimensions of Social-Ecological Systems (SES)

A tabular representation of the five dimensions of SESs.

Dimension	Definition
Social-ecological	How people interact with nature, values, stewardship, and resources
Institutional	How a system interacts with the government, management and other regulating influences.
Social-relational	How a community collaborates and learns together. Power dynamics.
Contextual	The background information of a community, including history, culture, political systems, knowledge systems, and socio-economic systems.
Individual	An individual's experience of agency, identity, belonging, behavior, and perceptions

Note. Adapted from (Sheona Shackleton et al., 2021)

3.1.1 Semi-Structured Interviews

Unlike a standard interview, which has a fixed set of questions, semi-structured interviews are more open, which allows new ideas to be brought up during the interview informed by the participant. Semi-structured interviews allow for collection of qualitative data regarding farmer perspectives, experiences, attitudes, motivations, and beliefs, as well as the factors that influence such perspectives (Sheona Shackleton et al., 2021). Interviews took place on the farms, which allowed for observations as detailed in Section 3.1.2. The interviews addressed the life history of the farmers, in addition to the economic and environmental factors that influence their use of current agricultural processes. A limitation of this method is bias, which can subconsciously push opinions in a certain direction, distorting responses and interpretations.

All interviews were voice-recorded using a smartphone. The recordings were saved and transcribed using the encrypted transcription service MyGoodTape (Zetland, (n.d.)). The recordings were reviewed manually for accuracy and all transcriptions were saved in a Google Drive folder.

3.1.2 Participant Observation

The team made observations as we explored the farmers' properties and learned how they utilized their land and conducted their practices. This method provided insights that other research methods would be unable to provide. This has been especially helpful for us to see what crops each farm possesses. The Master's students we worked with graciously took notes during the interviews to support our comprehension. We also took photos that illustrate farming scenes after obtaining permission through a signed participation form (see Section 3.7). A limitation of observations is the effect of our perceptual bias, including prejudices which affected what we decided to capture.

3.2 Objective 2: Identify relevant and consistent problems in the farmers' experience

After data collection, the team analyzed both the observations and interviews. This was so that we could create a list of the strengths, weaknesses, opportunities, and threats to prepare to create our SWOT analysis. SWOT analysis is widely regarded as one of the best methods by which to create strategies in the business world. This is because the SWOT analysis helps analyze the ins and outs of a company or organization before reworking or adding new products or techniques into a business (Benzaghta et al., 2021).

Our application and use of a SWOT analysis was to determine the strengths of different techniques in use, as well as to determine points of improvement. A SWOT analysis can be summarized as an outline (see Table 3) of the following four types of strategies:

1) Successes: Strengths and Opportunities
2) Survival: Weakness and Threats
3) Adaptations: Opportunities and Weakness
4) Reactions: Threats and Strengths

Table 3. Diagram of a SWOT Matrix

	Strengths	**Weaknesses**
Opportunities	Taking advantage of opportunities	Introducing new opportunities by reducing weaknesses
Threats	Avoiding threats	Avoiding threats by minimizing weaknesses

After identifying these elements, we were able to create our analysis using the many aspects of data we collected. The analysis performed followed the template above. When performing this analysis, there are several things to keep in mind to avoid generalizations. The goal of identifying why something is a strength or a weakness was of utmost importance. For example, why would working with a specific crop cause issues? Why is this crop adjacent to this one?

A SWOT analysis is often a preferred method of research because it considers and organizes multiple perspectives and provides a visual representation of how all aspects of a particular decision relate to each other.

3.3 Objective 3: Formulate strategies to alleviate a chosen problem

Once a particular problem of interest was identified, we formulated targeted strategies to recommend. This was accomplished by using the SWOT elements previously mentioned in Objective 2.

Evaluation of Potential Economic and Labor Impacts

Certain strategies may have varying effects on the economic elements and labor of the farmers. Farmers may not want to endanger their livelihoods by embracing new practices. Some of the strategies may be feasible for some farmers but not for others. This is dependent on the geography of their land, available resources, etc. Strategies that are more labor-intensive or expensive may be a barrier for farmers. It is possible that current processes are more efficient and cost-effective, but changing processes may decrease profits and increase the duration and strain of labor. It is therefore important to ask the farmers to confirm their economic and labor concerns. This is to determine if the proposed methods are economically and physically feasible and if the farmers are willing to adopt new practices in such respects.

Evaluation of Potential Environmental Impacts

As farmers are introduced to proposed strategies, they may wonder if these practices support their soils and crops, as well as if they will drive success. Farmers know their property through generational and daily empirical observation. Along with scientific research, their input would confirm if such practices support their properties.

3.4 Objective 4: Propose strategies to agroproducers for revision and feedback

Shortly after creating strategies, we met with some of the farmers we interviewed to propose these strategies. In our participatory SWOT analysis, we shared results from our SWOT matrix and proposed diverse strategies. This was to get the comments and feedback from the people who these tactics would have the most impact for. A limitation of this participatory SWOT analysis was that only a subset of the community came to this event, which does not reveal the collective perspective of the whole community.

3.5 Objective 5: Develop a technical-scientific manuscript

With support from agronomy Master's students and faculty at UCuenca, we wrote a scientific manuscript summarizing our work throughout the project. This manuscript was used as part of a larger project, referred to as *"CICLA"* by our sponsors as mentioned in the introduction. The paper our team wrote described our methods, experiences, observations and conclusions, and was exported to a local scientific journal named *"La Granja"* on behalf of the university. The manuscript format allows researchers and other students to access and further this knowledge in the future.

3.6 Objective 6: Dissemination of outcomes and deliverables

To get an overview of our work, we shared what we learned with those we worked with by creating and presenting a poster at an open house at UCuenca. We also created a manuscript based on the entire project we did as part of the *"CICLA"* project as discussed in Objective 5.

3.6.1 UCuenca Agronomy Open House

During our project, we created and presented a poster at an open house at the Yanuncay campus of UCuenca, celebrating the 45th anniversary of the Agronomy Department. We presented to both UCuenca students, students from other schools, and faculty. We also briefly touched on the *"CICLA"* project we are a part of. We were able to present successfully with the support and cooperation of the Master's students and our sponsors who assisted us with the local language.

The poster (see Appendix D) consisted of our findings at the time, and we explained our interview process, collected data, SWOT analysis, and interview findings. For example, we shared some of our observational photographs, and our relationship flow diagram (see Section 4.1). It addressed the economic and environmental impacts of the practices used by the farmers.

3.7 Informed Consent and Ethical Management of Data

Our project team obtained consent from all farmers who chose to participate in the study. We ensured that all participants read, signed, and dated the form of participation (see Appendix B), which included information about the purpose of this project and how the collected data was used. This was to ensure that all participants remain comfortable knowing that the information that was shared was up to their own discretion. Interview participants were given the option to remain anonymous. If a participant chose to remain anonymous, any personal identifying information (including but not limited to names, place of residence, and family members) we gathered from them were removed from all transcripts, analyses and official reports. This included appendices and public reports, including the final IQP report.

4. Findings, Discussions, Recommendations

Visiting Farms in San Antonio de Gapal: March 26, 2024 - March 27, 2024

Entering from the northeast, the sun glared down from above as the bus carried us further along the windy road within the small, verdant community. Towards the north, houses, sheds, and crop fields lie nestled along the hillside facing the sun. These properties continue to the south among the bumpy landscape. As we viewed the huertas,[8] we were taken aback and perplexed. "Weeds" covered the ground, encompassing every crop. After interviewing Mr. Bishop Mumford, a generational farmer from Griffin, Indiana, we believed "weeds" would be one of the greatest threats to crop production, as they compete for resources that would otherwise go to cash crops. Upon conversing with the farmers in San Antonio de Gapal, "weed" did not appear in their vocabulary. Weeds indicate something out of place, and these grasses were not. Instead, this green coverage was referred to as "la hierba," a word that translates to grass or herbs. These grasses captured the humidity close to the ground, essential nutrients were fixed and shared in soil rich in SOM and held the soil firm in place along the slope. As we walked further throughout la huerta, lettuce and onions were grown thickly together, corn and beans intertwined, and birds flew down to eat the pests that would otherwise consume these vulnerable crops. It became clear produce did not thrive alone, without the company of an interspecific diversity. The effect of pesticides, herbicides, fungicides, and excessive tilling were nowhere to be seen. The presence of intensification, extensification, and extractivism had no home in this land. Although our team did not expect the complex systems employed by the Incas or Quechua, it appeared that some of the Chakra practices were certainly used. The model of an innate ecosystem, a harmonious relationship with nature, and, in the great words of Janine Benyus that came to mind, "a part, not apart, of the genius that surrounds us" (Benyus, 2002, p. 10), persisted.

[8] Translates to English as a "land of greater extension than the orchard, in which vegetables, legumes and fruit trees are cultivated." Definition from la Real Academia Española.

Figure 6. ***Entering the Community of San Antonio de Gapal***

Photo Credit: T. Bush, San Antonio de Gapal, Cuenca, Ecuador, 03/27/2024.

Several methods were used to collect data for this project. These methods included semi-structured interviews and observational photography conducted on the properties of the 12 farmers in San Antonio de Gapal. We also engaged in an open house at UCuenca, and a participatory SWOT analysis with farmers to discuss results and next steps.

From the interviews and observations, several findings became clear. These farms were built upon relationships between biotic factors, such as plants, animals, and humans, and abiotic factors, such as the climate and structure of the land. In connection with this finding, the farmers' practices established resiliency and independence. Lastly, the most important takeaway from our data is that lack of water accessibility during periods of drought is an opportunity for improvement. This is especially true for predicted volatile climate conditions in the future in the Andean region.

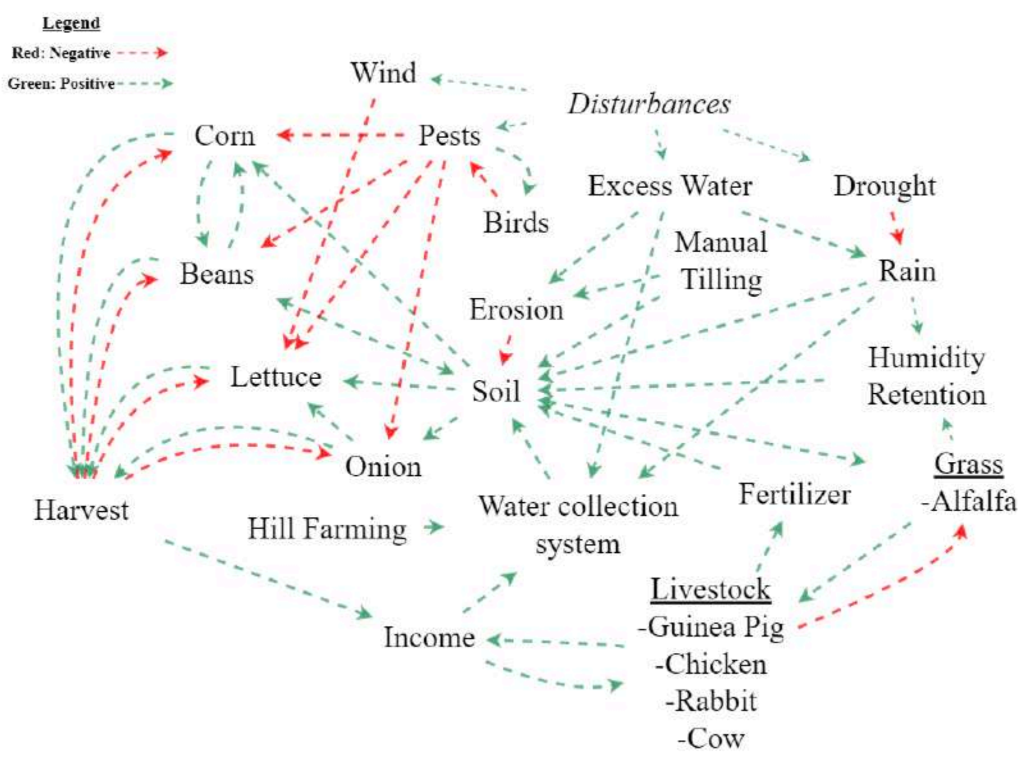
The first section of our findings was supported by the results from the interviews and observations. These are discussed regarding limitations, implications, and recommendations towards the ultimate goal of proposing strategies to alleviate the pertinent issue of water accessibility and retention. The second section of our findings was supported by further evidence, provided from the participatory SWOT analysis.

4.1 Farms are dependent and thrive on relationships

During our observations, we learned about the importance of maximizing the utility of all resources present on farms, including nutrients and farm life as a whole. All elements on these properties were interdependent, many of which fulfill multiple purposes. Finally, we discovered that the cyclical nature of relationships on the farm function in an entirely natural manner, where few external inputs are needed.

To visualize the interrelated nature of these systems, we developed a diagram as a part of a dynamic systems model (see Figure 7) using Insight Maker, a simulation and modeling software.

Figure 7. ***Sustainable Farm Flow Diagram Observation***



Note. (Fortmann-Roe, 2014)

An important takeaway from this flow diagram is that soil is a central component of the ecosystem. Crops depend entirely on the soil's health to grow. While soil is almost entirely responsible for farming productivity, it also has a complete dependence on external factors, such as water, in the form of humidity and rain.

4.1.1 Agricultural practices facilitate ecological resilience

When touring each farming property, we observed that the farmers manage a great variety of crops and plants. These properties had mostly vegetables, such as lettuce, onion, soybean, corn, beans, carrots, broccoli, cauliflower, avocado, and tomatoes, but some also had fruits, such as raspberries. All these crops are susceptible to external disturbances, such as wind, drought, and excessive rain. However, an interspecific diversity of plants increases a farm's capability to withstand dangers that hinder the farm's productivity, because there is reduced dependence on fewer resources. This is the concept of ecological resilience, which is "the capacity of an ecosystem to absorb repeated disturbances or shocks and adapt to change without fundamentally switching to an alternative stable state," (Holling, 1973). Thus, farms thrive on biodiversity as a measure of ecological protection.

Drought

To combat drought, farmers strategically placed plants to retain humidity. Instead of constantly watering dry soil, farmers relied upon the existing *hierba*. The *hierba* consists of varying grasses and alfalfa and is close to the ground (see Figure 8). As a powerful neighbor, the grasses hold a layer of humidity in place above the soil, as well as fix nutrients that increase water retaining SOM in the soil. The *hierba* and beans keep the soil hydrated as observed in Figures 9a-b. These crops cover the hills on the three properties owned by Sra. Rosa Pillacela, Sra. Ana Rojas, and Sra. Rosalina Rojas (see Figure 8; Figures 9a-b). Each discussed how the *hierba* was essential for maintaining humidity around the soil, as well as fixing the soil in place and sharing nutrients. This *hierba*, once fed to the guinea pig, becomes fertilizer which provides another source of humidity. When Sra. Pillacela was asked about using less water to maintain humidity, she mentioned that "es importante para usar toda la tierra. Es, sí, usar toda la tierra para muchas diferentes cosas. Para dar comida al cuy, para el pastoreo de los pollos también, para quedar humedad, para proteger el suelo, sí" (Sra. Pillacela, 03/27/2024).[9]

[9] Translates to English as "It is important to use all the land. It is, yes, using all of the land for many different things. To feed the guinea pig, to graze the chickens as well, to keep humidity, to protect the soil, yes." Translation by Google Translate in April 2024.

Figure 8. ***Alfalfa, Corn, and Tomatoes Landscape***

Note. Photo of Sra. Rosa Pillacela's Property, with permission, 03/27/2024.

Figures 9a-b. ***Hierba and Bean Plants Maintain Humidity for Corn***

Note. a) Photo of Sra. Ana Rojas' Property, 03/27/2024.

b) Photo of Sra. Rosalina Rojas' property, 03/27/2024. Both with permission.

Excessive Rain

Another threat expressed by agroproducers is when excessive rain during rainy seasons leads to an increase in erosion. As mentioned previously, agroproducers' crops are grown on hills at the base of mountains. When rain falls, watershed carries the soil, which can cause landslides and the uprooting of crops. As shown in Figure 8; Figures 9a-b, cover crops densely pack the fields grown on the hillside. The roots of these cover crops act like a sponge, absorbing excess water which helps prevent erosion if excessive rain is present. The roots of grass and alfalfa plants prevent erosion along the hillside. Although terraces, as discussed in Section 2.1 are not common in this area, these densely packed cover crops create a natural barrier that reduces the impact of heavy rain on the land.

Wind

On certain days, wind can be quite intense, and certain crops are more susceptible than others to this force. Many farmers strategically placed wind resistant crops near vulnerable ones. Vulnerable crops include lettuce, peppers, and coles. In a section of farmland on the property Sra. Ana Farfán, she carefully placed onion and cole in a grid (see Figure 10). Examples of cole crops include broccoli, cabbage, and cauliflower. In each cardinal direction of a single cole was an onion plant with its stalks slightly above the cole. Sra. Farfán revealed to us that her plants were arranged this way "para proteger del viento" (Sra. Farfán, 03/27/2024).[10] This placement of the onion perturbed the wind from all directions, protecting the cole.

[10] Translates to English as "To protect against the wind." Translation by J. Shen.

Figure 10. ***Onion and Lettuce Relationship***

Note. Photo of Sra. Ana Farfán's property, with permission, 03/27/2024.

Pests

To manage pests, farmers did not apply insecticide or remove them manually. In a section of Sra. Ana Farfán's property, a variety of lettuces and cabbage, with *hierba* scattered in between, were growing robustly. As shown in Figure 11, there was minimal damage, such as holes in the leaves. Upon observation, we asked Sra. Farfán to explain how there was minimal pest damage and how pests were controlled: "no necesitamos insecticidas, tenemos a los pájaros" (Sra. Farfán, 03/27/2024).[11] Birds easily feed on the insects that would devour crops.

[11] Translates to English as "We do not need insecticides, we have the birds." Translation by J. Shen.

Figure 11. ***Mitigated Pest Damage on Lettuce and Cabbage Varieties***

Note. Photo of Sra. Ana Farfán's property, with permission, 03/27/2024.

Pests were also mitigated through interspecific plant relationships. Onion and garlic were often planted together with other crops, such as carrots, which in addition to reducing wind disturbance, repelled insects (see Figures 10 and 12). While visiting Sra. Rosa Chicaiza's vegetable garden, she discussed how the onion wards off pests from her carrots: "la cebolla mantiene las plagas alejadas de las zanahorias" (Sra. Chicaiza, 03/27/2024; see Figure 11).[12] Pest control also reduced disease presence, as produce consumption from insects can introduce pathogens.

[12] Translates to English as "The onion keeps pests away from the carrots." Translation by Google Translate in April 2024.

Figure 12. ***Onion and Carrot Relationship***

Note. Photo of Sra. Rosa Chicaiza's Property, with permission, 03/27/2024.

Disease

Plant disease on farms can have devastating impacts on crop yields and subsequently the livelihoods of farmers. To combat this, many farms use synthetic fungicides to support their plants as discussed in Section 2.5. However, agroproducers in San Antonio de Gapal do not need to give disease attention due to the long-term effects of natural selection. Over many centuries, natural selection has been used to cultivate a selective breeding process that created a natural-born, disease-resistant crop. The farmers use seeds in an iterative process where "nosotros traemos las semillas y ya, y sembramos. Y lo que dé resultado seguimos sembrando, y lo que no, no" (Sra. Chicaiza, 03/27/2024).[13] This approach not only eliminates the need for synthetic fertilizers and pesticides, but also removes the need to purchase seeds in the first place. By repeatedly trying different seeds to see what works, they can selectively breed those most resistant to disease. By going through this process, farmers create intraspecific variation within a species of a plant, which is "based on genetical heritable variation among populations or individuals" (*Intraspecific Variation*, (n.d.)). With intraspecific variation, a given plant species is

[13] Translates to English as "We bring the seeds and that's it, and we sow. And what works we continue to sow, and what doesn't, we don't." Translation by Google Translate in April 2024.

less vulnerable by exhibiting a larger spectrum of traits, which decreases the likelihood of one epidemic wiping out all members of a crop population.

Nutrient Cycling

Relationships are also harnessed to fix and share nutrients within the soil, and enrich the land with SOM. As mentioned previously, alfalfa (see Figure 8) fixes nitrogen in the soil for local plants to use. Corn exchanges nutrients as well as providing structure and protection to bean plants (see Figure 13). As mentioned earlier, onion plants also shield lettuce from wind (see Figure 10).

Figure 13. ***Structural Support Between Corn and Bean Plants***

Note. Photo of Sra. Rosalina Rojas' property, with permission, 03/27/2024.

The large number of multifunctional crops significantly boost a farm's ecological resilience by enhancing sustainability and adaptability. These crops are responsible for food production, soil enrichment, physical protection, and reducing the need for external inputs, such as chemical fertilizers. Through this approach, multifunctional crops contribute to a more resilient and robust agricultural system.

4.1.2 Agricultural practices lead to economic resilience

Ecological resilience discusses a system's resistance to outside environmental disruptions. Closely related to this concept is economic resilience, which is an ecosystem's durability when challenged by economic disturbance. Farms employ several techniques that foster an environment independent of the external economy. Self-sufficiency also allows farms to create and access valuable resources internally. Forms of economic resilience are demonstrated using natural fertilizer, crop rotation, and use of livestock.

When we walked with Sra. Ana Farfán through her garden, she described the independence her property offers, pointing to plants for their role in sustaining her family. **"**Siempre hacemos con una ensalada. Digo, no, me voy a cogerme una lechuga, le rallo una zanahoria y ya tengo la ensalada. Ya, entonces, es así. O de pronto un … un brócoli, una coliflor, le pongo queso, una ensalada y ya tengo yo una sopa, lo que sea, una crema. No necesito viajar lejos. Ya tengo la comida aquí" (Sra. Farfán, 03/27/2024).[14]

Crop Rotation

Crop rotation is a practice which entails "growing different types of crops in the same land in sequential growing seasons" (Crop Rotation, 2022). Crop rotation can help soil in several ways, one of which is replenishing nutrients. If there exists a crop with a high nitrogen demand, it can be replaced after some period of time to replenish the now nitrogen-depleted soil. When we asked Sra. Rosalina Rojas about soil practices, she mentioned that they rotate crops "entre maíz y hortalizas" (Sra. R. Rojas, 03/27/2024).[15] Several other farmers also follow this practice, including Sra. Ana Farfán, and Sra. Rosa Pillacela. In other properties, such as that of Sra. Rosa Chicaiza, crop rotation is not necessarily employed, as multiple crops can be grown together to support soil health. She stated that "si siembro solo maíz … no me va a dar. Entonces, cómo sembramos las tres cosas o cuatro cosas juntas, entonces eso nos ayuda a mejorar el suelo" (Sra.

[14] Translates to English as: "We always make it with a salad. I say, no, I'm going to get lettuce, grate a carrot and I've got the salad. So, that's the way it is. Or maybe a … a broccoli, a cauliflower, I put cheese, a salad and I have a soup, whatever, a cream. I don't need to travel far. I've got the food here." Translation by Google Translate in April 2024.
[15] From interview notes taken by Master's students during interviews. Translates to English as "between corn and vegetables." Translation by Google Translate in April 2024.

Chicaiza, 03/27/2024).[16] When Sra. Blanca Dután was asked, "Por ejemplo, usted nos mencionaba que siembra hortalizas. ¿Dentro de esas hortalizas usted siembra lo mismo siempre o cambia de … sí, entonces eso se le conoce como rotación de cultivos," she responded, "ah, bien, sí. Ajá. Tal vez también realiza la fertilización, colocación de abonos, tanto pueden ser los de los animales … Sí" (Sra. Dután, 03/26/2024).[17] Thus, crop rotation was employed as well as rotation of livestock fertilizer as well. The property of Sra. Rosalina Rojas (see Figure 14) illustrates how a field is split between alfalfa and corn, which is then swapped in the subsequent season.

Figure 14. ***Corn and Alfalfa Rotation***

Note. Photo of Sra. Rosalina Rojas's property, with permission, 03/27/2024.

Non-Chemical Fertilizer

A surprising discovery for our team was the lack of chemicals used on these properties. Cuencan farmers do not rely on chemicals because they can harm soil and animal health. Sra. Rosa Chicaiza shared "las químicas pueden ser peligrosos para los animales. Claro, por eso …

[16] Translates to English as: "if I sow just corn … it won't give me. So how we plant the three things or four things together, then that helps us improve the soil." Translation by Google Translate in April 2024.
[17] Translates to English as: "For example, you mentioned that you sow vegetables. Within those vegetables you always sow the same thing or change … yes, then that's known as crop rotation," she responded "oh, well, yes. Aha. Maybe it also performs fertilization, placement of fertilizers, so much can be those of animals … yes" Translation by Google Translate in April 2024.

yo no compro nada" (Sra. Chicaiza, 03/27/2024).[18] Many farmers, including Sra. Chicaiza herself, also value the natural state of their farm, which works together with the nearby surroundings to maintain the health of all biotic factors present on these agricultural estates.

The agroproducers we met had unique ways to control pests with the type of fertilizers they used. For example, on some of the farms they used lime and ash to prevent pests from killing their plants. Sra. Rosalina Rojas shared that "Con eso ya viene a descomponerse rápido y también le quita la mal olor que tiene, entonces ya no la sienta la mosca" (Sra. R. Rojas, 03/27/2024).[19] She also mixed in milk and eggshells to boost calcium content, which is essential for cole and spinach development. Her compost can be seen maturing under tarps as shown in Figure 15.

Figure 15. ***Natural Fertilizer***

Note. Photo of Sra. Rosalina Rojas's property, with permission, 03/27/2024.

Other farmers employ a blend of *bokashi*, a fermented compost, as a potent natural fertilizer. Agroproducer Sra. Marilu Matute shares, "hacemos el abono ese del *bokashi* porque ese es el bueno ese es el bueno y más rápido de preparar el abono también sí, pero más nos

[18] Translates to English as: "Chemicals can be dangerous to animals. Of course, that's why … I don't buy anything." Translation by Google Translate in April 2024.
[19] Translates to English as: "With that, it decomposes quickly and also removes the bad smell it has, so the fly no longer notices it." Translation by Google Translate in April 2024.

usemos por el *bokashi* y esto del estiércol con cal o ceniza es lo que más es más rápido el proceso porque mientras más rápido se hace mejor" (Sra. Matute, 03/27/2024).[20] When Sra. Rosa Pillacela was asked about her type of fertilization, she concurred with the use of *bokashi*. "Eh, sí, lo que es de los *bokashi*, que es para el abono para el huerto, y digamos, el té, el té de estiércol, que consiste en la basura de la vaca. Ya es la alfalfa picada, un galón de leche, una panela, odeno o melaza que decimos. Un galón de leche. Sí, eso se le pone para hacer el, diríamos, el té, para ponerlo en los huertos, sí. Sí, se le deja quince días de ahí, bien tapado" (Sra. Pillacela, 03/27/2024).[21]

This use of naturally obtained resources to sustain the farms as opposed to buying harmful chemicals further demonstrates economic resilience, as well as another aspect of pest control which was discussed previously in Section 4.1.1.

Uses of Livestock

As mentioned in Section 4.1.1, these farms grew multiple crops, such as beans, broccoli, and avocado. While this crop diversification allows farms to lose a few crops without losing their production completely, this also provides farms many means for income. This diversification applies to animals as well. On most (if not all) of the farms we visited, there were both guinea pigs (see Figure 16) and chickens (see Figure 17), each of which provide additional contributions to the farm in different ways. As shown in Figure 18, the farmers' chickens provide another source of food in the form of eggs. Guinea pigs are also used for food, as marketable products, and their excrement functions as fertilizer, which facilitates the growth of other crops (Sra. Chicaiza, 03/27/2024). Sra. Inés Rojas mentioned that it "es el abono del cuy. Ahí en las plantas se ponen" (Sra. I. Rojas, 03/26/2024).[22] This exemplifies the cyclical nature of these farms' operations.

[20] Translates to English as: "We make the *bokashi* fertilizer because that's the good one, that's the good one and the faster to prepare the fertilizer too, yes, but the more we use the *bokashi* and this manure with lime or ash is what the faster, the faster the process is because the faster it is done the better." Translation by Google Translate in April 2024.

[21] Translates to English as: "Eh, yes, what's from the *bokashi*, which is for the compost for the orchard, and let's say, the tea, the dung tea, which consists of the cow's garbage. It's already chopped alfalfa, a gallon of milk, panela, odeno or molasses as we say. A gallon of milk. Yes, that's put on to make the, we would say, tea, to put it in the orchards, yes. Yes, he is left for fifteen days there, well covered." Translation by Google Translate in April 2024.

[22] Translates to English as "is the fertilizer for the guinea pig. There they put it on the plants." Translation by Google Translate in April 2024.

Figure 16. ***Guinea Pig Livestock***

Note. Photo of Sra. Rosa Chicaiza's Property, with permission, 03/27/2024.

Figure 17. ***Chicken Livestock***

Note. Photo of Sra. Ana Farfán's property, with permission, 03/27/2024.

Figure 18. ***Chicken Eggs***

Note. Photo of Sra. Rosa Pillacela's property, with permission, 03/27/2024.

Sra. Ana Farfán also shared that other agroproducers and herself rely on livestock produce during economic disturbance, such as the COVID-19 pandemic. "Entonces, la pandemia en el campo casi no se sintió mucho, por lo que. Igual como decía la compañera, uno se mataba una gallina, se comía un cuy, se comía. Había el grano. Se hacía un locro de porotos. Había choclo. Se hacía una ensaladita de choclo. O sea, era así. O sea, nosotros como que no teníamos mucho" (Sra. Farfán, 03/27/2024).[23] Thus, by leveraging their livestock in multiple ways, these farmers are insulated from market fluctuations and other economic disturbances.

Land Structure Reduces Labor Needs

The unique structure of cultivating on a hill reduces labor for farmers. Firstly, seeds can be easily dispersed to cover more area. We asked Sra. Ana Farfán about the location of the corn, and why it was on hills instead of flat ground. She stated that "O sea, no sé cómo es eso del proceso de las semillas, de lo que es el poroto, el maíz, pero eso en colina se da más que en

[23] Translates to English as "So, the pandemic in the field hardly felt much. Just as your colleague said, you killed a chicken, you ate a guinea pig, you ate it. There was the grain. A lot of beans were eaten. There was corn. A corn salad was made. I mean, that's how it was. I mean, we kind of didn't have much." Translation by Google Translate in April 2024.

plano" (Sra. Farfán, 03/27/2024).[24] Secondly, the hill structure reduces labor needed to evenly disperse water. As rain falls, or when water is added from containers, it is absorbed by the *hierba* as it flows down the hill.

Through the farmers' practices, the arable land used for farming is resilient to disturbances caused by a constantly evolving economy. Resilience from natural disturbances and relationships allows the farmers to be completely independent from the external community. From our interviews and observations, the farmers do not spend money on outside resources, instead using self-reliance to allow farms to run naturally. This independence is born from the ability to create and harvest sustainably due to centuries of farming developments.

4.1.3 Associations increase farming efficacy

The majority of the agroproducers we interviewed mentioned their varying involvement with associations. These associations can be used to share the information between farmers, allowing for a robust system of communication where strategies and techniques can be shared. These associations are already being used for this as mentioned by Sra. Rosalina Rojas, who said: "Y ahí formamos la asociación, formamos la asociación de agroecología. Bueno, hemos recibido varias capacitaciones, varias capacitaciones hemos recibido para nosotros, cómo saber, cómo hacer. Cómo manejar el terreno" (Sra. R. Rojas, 03/27/2024).[25]

Associations can be highly effective in systemizing practices by fostering collaboration and problem-solving among members. With regards to solving problems in a group as a part of their association, Sra. Rosa Pillacela stated that: "Bueno, en nuestra asociación, bueno, sí hay unión. ¿Para qué decir? Sí, sí somos unidas, ¿no? Por ejemplo, tratamos de dar una idea y de hacer realidad. ¿Es una asociación de mujeres? Sí. Somos hombres y mujeres" (Sra. Pillacela, 03/27/2024).[26] The essence of an association lies in its ability to unite individuals with a common purpose. Through shared goals and mutual support, associations can transform ideas and practices into tangible realities. This collaborative spirit transcends boundaries, as illustrated by

[24] Translates to English as "I mean, I don't know what the seed process is like, what the bean is, the corn, but that happens more in the hill than in the flat." Translation by Google Translate in April 2024.
[25] Translates to English as "And there we formed the association, we formed the agroecology association. Well, we have received several trainings, several trainings we have received for ourselves, how to know, how to do. How to handle the terrain." Translation by Google Translate in April 2024.
[26] Translates to English as "Well, in our association, well, there is union. What's the point? Yes, we are united, right? For example, we try to give an idea and make it a reality. Is it a women's association? Yes. We are men and women." Translation by Google Translate in April 2024.

the inclusion of both men and women in the example provided. By leveraging diverse perspectives and harnessing collective efforts, associations become powerful engines for innovation and progress.

The diversity of these associations is present as demonstrated by the experiences the agroproducers shared. For example, Sra. Dorila Nieves described her personal connection to one of these associations: “siempre hemos estado y, por lo que yo pertenezco a la asociación, una. Y también pertenezco a una red de productores, de donde, que el mercado que yo vendo la carne,” (Sra. Nieves)[27]. It became clear that these associations were designed for more than just simply planting and cultivating crops. Diversity flourishes within these associations, reflecting the myriad of interconnected communities and industries across the country. Whether it be a local cooperative, a regional network, or a national federation, these associations serve as vital hubs for collaboration, knowledge exchange, and market access, embodying the diverse and dynamic essence of Ecuador's social and economic ecosystem.

Although not included in the diagram shown in Figure 7, another important external element to the success of the farms in San Antonio de Gapal is the “Asociación de emprendedores,” which is a farming association that brings farm owners together (Sra. Pillacela, 03/27/2024).[28]

4.2 Water accessibility during droughts is the greatest challenge

Water Collection

The most significant technique we observed on the farms were water collection systems. The importance of water on arable land and the problems that water shortages cause for the well-being of farms are further discussed in Section 4.3. Collecting rainwater reduces a farm’s reliance on external water sources, and the need to purchase water. Several of the farmers have methods of directing rainwater into storage containers like tanks, barrels, and buckets to save water from rainfall (see Figures 19a-c).

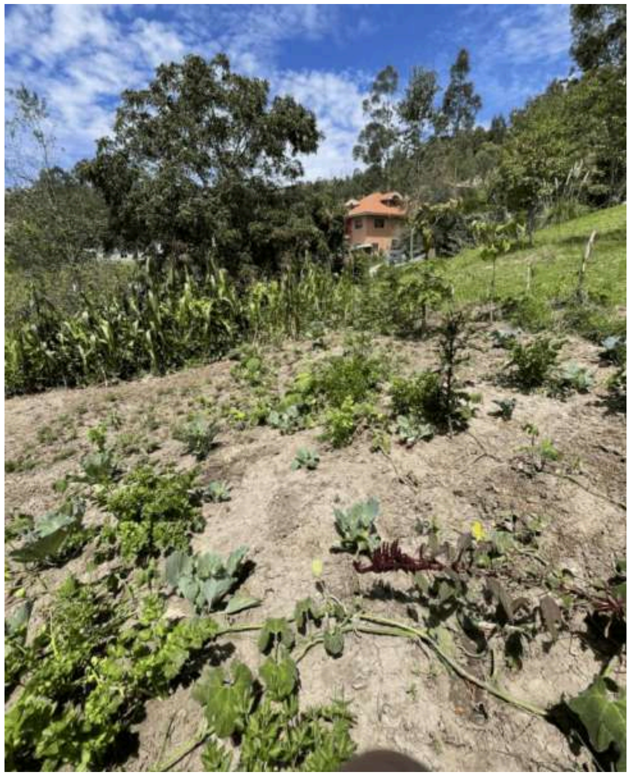
[27]Translates to English as “We have always been there and, as far as I belong to the association, one. And I also belong to a network of producers, from where, the market where I sell the meat.” Translation by Google Translate in April 2024.
[28] From interview notes taken by Master’s students during interviews. Translates to English as “Entrepreneurs Association.” Translation by Google Translate in April 2024.

Figures 19a-c. ***Water Collection Systems***

Note. a) Hole to collect excess rain. Photo of Sra. Rosa Pillacela's property, 03/27/2024. b) Using pipes to direct rainwater from roof to container. Photo of Sra. Ana Farfán's property, 03/27/2024. c) Various containers to collect and store rainwater. Photo of Sra. Ana Farfán's property, 03/27/2024. All photos taken with permission.

Although practices have been fine-tuned over hundreds of years to be dependable, efficacious, and environmentally and ecologically efficient, farmers continue to face a consistent threat. According to our interviews, water collection and retention was the most important and significant challenge for all 12 farmers. A few properties did not utilize grass and alfalfa, and the soil on those farms was dried out from the sun (Sra. R. Rojas, 03/27/2024; see Figure 20).

Figure 20. ***Dry Soil***



Note. Photo of Sra. Rosalina Rojas' property, with permission, 03/27/2024.

Water is a pressing issue because it represents life for nearly every aspect of agricultural farming, ranging from plants and animals to people and soil. It is widely known that plants need water to grow, and many other dependencies stem from this relationship, such as the animals which rely on the plants for food.

In the context of abiotic factors, although farmers may buy water in rare circumstances, many farmers employed water collection systems, such as the use of large holes or wells in the ground (see Figure 19a), simple pipe systems to direct rainfall from roofs to tanks (see Figure 19b), or barrels and other containers (Figure 19c). Sra. Ana Farfán also mentioned that the hilly nature of the land was important for the spread of seeds, or even water dispersion among the crops such as those shown in Figure 8.

Many of the farmers we interviewed said that they just "Esperar que llueva. Sí" (Sra. Matute, 03/27/2024)[29] when asked about cultivating without rain. Sra. Ana Molina also mentioned that "Hay que esperar la voluntad de nuestro Padre Dios si él no … toda es la

[29] Translates to English as "Wait for it to rain. Yes." Translation by J. Shen.

voluntad de lo que tenemos, sembramos, los animalitos, la salud de uno, es todo" (Sra. Molina, 03/26/2024).[30] With regards to rain, Sra. María Chapa explains that "no tenemos la hierba ya. Entonces aquí nosotros dependemos bastante, bastante es de la lluvia, porque aquí no tenemos riego ni nada de eso" (Sra. Chapa, 03/26/2024).[31]

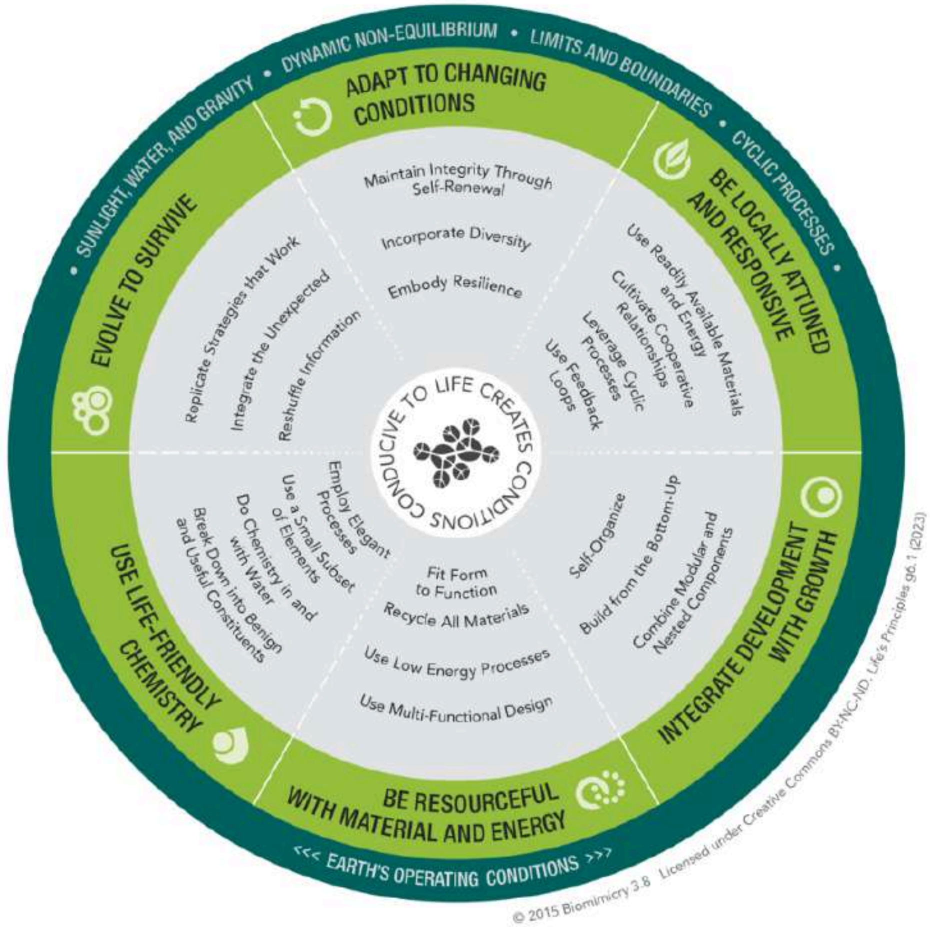
4.3 Discussion of Relationships in Farming

Farming practices were grounded in relationships which facilitated ecological and economic resilience. However, water harvest and retention appeared to be the primary areas for improvement to combat prolonged droughts and excessive rain. Their practices are long standing, and as discussed in Section 2.4, reflect similarities to the indigenous practices of the Chakra, which became efficacious to meet the demands of the economy and the environmental and ecological infrastructure. This is contrary to industrial farming methods in the US, where most common American practices use chemicals to aid with pest control, the growth of weeds, and disease (US EPA, 2013). Evidence of lost Chakra practice was apparent, as these properties seemed separated rather than organized in large systemized ancient indigenous communities.

The model of their farms seemed to follow a highly efficient system, modeling the unifying principles of nature (see Figure 21). These unifying principles ultimately describe conditions conducive to life. The way properties leverage nature's principles are shown in Table 4. By following these principles, these farms can reduce costs and labor, increase productivity, prevent nutrient disruption, and protect the health of local environments.

[30] Translates to English as "we must wait for the will of our Father God if he does not ... everything is the will of what we have, we sow, the little animals, one's health, that's all." Translation by Google Translate in April 2024.
[31] Translates to English as "Eh, sometimes because of the environment. We here depend on what the rain is more than anything. Sometimes when it is planted, so if it doesn't rain, we don't have the grass anymore. So here we depend a lot, a lot of it depends on the rain, because here we don't have irrigation or anything like that." Translation by Google Translate in April 2024.

Figure 21. ***Nature's Unifying Principles***



Note. Design Lens Life's Principles. From "Biomimicry 3.8",
by NC-ND, et al., 2015, g6.1 2023.

Table 4. How Properties in San Antonio de Gapal Leverage Nature's Principles

Principle		Example
1	Nature uses only the energy it needs and relies on freely available energy	Soil fertilizer from guinea pigs and alfalfa are abundant on many properties, which provide sustenance to the soil and guinea pigs respectively. The sun provides thermal energy which decreases frost at lower altitudes. SOM maintained in the soil is a source of chemical energy for crops.
2	Nature recycles all materials	Although many properties were constructed from plastic and metal infrastructure, most of what was grown, if not sold, was reworked into the property. This includes *abono*, *bokashi*, and *hierba*.
3	Nature is resilient to disturbances	See Sections 4.1.1 and 4.1.2
4	Nature tends to optimize rather than maximize	Production levels respect the "stability cycles and requirements of all the elements that are part of a 'Chakra', that is: soil, water, crops, livestock breeding and families" (FAO, 2024). Agroproducers do not plant more than they can sustain and only use locally available inputs.
5	Nature provides mutual benefits	Relationships between plants and animals provide mutual nutritional and structural benefits.
6	Nature runs on information	Plants can exchange nutrients if needed. Agroproducers communicate challenges with each other.
7	Nature uses chemistry and materials that are safe for all living beings	Properties do not rely upon synthetic pesticides, herbicides, fungicides, and fertilizers.
8	Nature builds using abundant resources, incorporating rare resources only sparingly	Agroproducers do not heavily depend on external inputs such as chemicals and purchased water. Instead they use fertilizer from livestock, leverage relationships, and collect rainwater.
9	Nature is locally attuned and responsive	Plants are adjusted to the altitude and climate of this region, which reduces labor and costs to support these plants. Agroproducers adjust practices depending on disturbance.
10	Nature uses shape to determine functionality	Hill structure allows for even water dispersal from rain instead of the need for a built-in irrigation system and also allows for greater seed dispersal.

Note. Adapted from (*Nature's Unifying Patterns*, n.d.).

Drought

Drought was one of the primary challenges we addressed with the farmers, considering its significant impact on the land. The farmers dealt with droughts by using grass and other naturally growing *hierba* to retain humidity within their fields. Keeping the soil healthy promotes the soil's ability to retain water. While these methods have proven effective in the past, the increasing intensity of droughts in the future may render them insufficient in safeguarding crops from the effects of droughts (Campozano et al., 2020). An analysis of droughts done in another study on the Ecuadorian Andes "shows that they will be more frequent and prolonged in the highlands (Andes) and the middle part of the basin. In the future, wet periods will be less frequent but of greater duration and intensity on the Ecuadorian coast" (Ilbay-Yupa et al., 2021). There is a "critical need for integrated climate adaptation strategies in Ecuador, focusing on mitigating risks to health, agriculture, and ecosystems" (Portalanza et al., 2024). As a result, we developed strategies for farmers to combat prolonged droughts caused by the changing climate.

Excessive Rain

As referenced in Section 4.1.1, our observations took place on hillsides susceptible to erosive effects from excessive rainfall. The threat of erosion from rainy seasons posed a risk of landslides, which can lead to crop destruction. To mitigate this risk, farmers densely packed their fields with different types of crops (see Figure 8). Nature was left to manage these fields, permitting natural root systemization (Alexey Matyunin, 2022). Extensive root systems acted like sponges, soaking up excess water and stabilizing the soil. We believed that farmers would need to adapt to the changing climate with the increase of excess rain during future rainy seasons (Campozano et al., 2020). Therefore, excessive rain was a focus for recommendations.

Pests

Pests can decrease farming productivity by consuming crops (Dangles et al., 2009). According to the Food and Agricultural Organization of the United Nations, 40% of crop loss may be attributed to insect pests (FAO, 2019). This form of biological control is a more effective method than chemical insecticides and can reduce ecosystem disruption (Cevallos et al., 2021). Ecuador's strong biodiversity can increase the services of biocontrol and pollination, leading to more coverage of pest diversity (Dangles et al., 2009). This cannot be said for other tropical countries where pesticides may remain on plants or enter waterways, leading to environmental health damage and risks to surrounding communities. Although the products causing environmental and health damage have been banned, there are remnants in soil and water that pose a potential risk to the well-being of surrounding communities (Mollocana-Lara & Gonzales, 2020).

Disease

Traditional farming practices in San Antonio de Gapal utilize selective breeding and natural selection as a method to develop disease immunity in their plants. The iterative nature of this process creates a robust intraspecific variation within plant species, leading to enhancing crop resilience against diseases. This approach promotes sustainable agriculture and ensures consistent crop production despite the presence of fungal disease. The success of natural selection depends on variation within the population. Future studies could examine the differences in cultivation methods that facilitate an intraspecific diversity, overall strengthening the crop.

Nutrient Cycling

The farmers of Cuenca are intercropping and companion planting to enhance nutrient cycling, soil enrichment, and crop protection. These techniques contribute to a more resilient and sustainable agricultural system by optimizing resource utilization and reducing dependency on external inputs like chemical fertilizers. We recommended that farmers follow a holistic approach that integrates the following techniques into their existing farming practices. Instead of uprooting the *hierba*, farmers should focus on cutting it to maintain crop cover, which plays a crucial role in fixing soil, retaining nutrients, and preserving humidity levels. This method not only helps in crop management but also supports the overall health of the soil and crops. Additionally, utilizing fertilizer derived from livestock and excess vegetables can significantly enhance SOM and improve water retention capacity. By incorporating these practices, agroproducers can create a more sustainable and resilient agricultural system that benefits both their crops and the environment.

Crop Rotation

Crop rotation is a vital agricultural practice that involves alternating between different crops in the same field between seasons, in the pursuit of better soil health. Not varying crops throughout a property can often cause problems, because "growing the same crop in the same place year after year fosters the buildup of disease pathogens and pests in the soil; rotation tends to break their cycles. Crops do not require the same nutrients, so rotating them helps in fertility management" (*Crop Rotation*, n.d.). This observation emphasizes the importance of crop rotation in sustainable agriculture. Many of the farmers we interviewed explained their use of crop rotation and its effective use in nutrient cycling, so the team did not make recommendations on this topic.

Non-Chemical Farming

In Cuenca many of the practices done by the farmers are sustainable and practical. For example, using lime and ash to deter flies from the crops as detailed in Section 4.1.2 is an easy and practical solution, because limes and ash can both be obtained without the need to spend money. Birds and certain crops repel insects, and many natural fertilizers are employed as well. This is quite different than in the US; most common American practices use chemical pesticides to aid with pest control, the growth of weeds, and disease (US EPA, 2013). For these reasons, strategies were not recommended regarding the use of chemicals in farming.

Uses of Livestock

As discussed in Section 4.1.2, livestock diversification underpins farming resilience and sustainability. By having a variety of animals, farmers can maintain income and food supply even if one type of livestock is negatively affected in some way. All byproducts of the animals living in these areas, such as cows, chickens, and guinea pigs are used optimally, where they are allocated for selling, farm maintenance, or sources of food. Therefore, the team did not make recommendations on the use of livestock.

Associations

Associations in Cuenca help share information and expertise, and distribute recommendations to enhance their practices and farming productivity. Other information pertinent to the growth and development of Cuencan agriculture can also be shared throughout the region. By actively participating in these associations, farmers can access a wealth of knowledge on various strategies and techniques for cultivation, pest management, soil health, and more. Sra. Rosalina Rojas' testimony in Section 4.1.3 underscores the collaborative nature of these associations, emphasizing their role in uniting members towards common goals. Farmers can capitalize on this collaborative spirit to address shared challenges and create innovative solutions collectively. Moreover, the diversity of these associations, as evidenced by the involvement of farmers in networks beyond traditional farming, highlights the versatility and inclusivity of these platforms. By engaging with associations, farmers can tap into a vast network of support, exchange ideas, and access resources essential for thriving in Ecuador's dynamic agricultural landscape.

Limitations

The interviews and observations limited our results methodologically. Only 12 farmers in the community of San Antonio de Gapal were interviewed, which is a considerably small sample size compared to the numerous properties in the region. Other agroproducers not interviewed may have deviated in practices, which might alternatively affect ecosystem and soil health, and our study would be unrepresentative of the region. Additionally, all but one of the 12 farmers were women, which may have introduced gender bias. Although some agroproducers such as Sra. Rosalina Rojas spoke on behalf of their husbands, others fully administrated their farms. This gender difference may affect decisions and perspectives on the properties, and thus be unrepresentative of the larger farming population.

4.4 Strategy Recommendations

Strategy 1: *Increase the size and number of water containers (barrels or cisterns)*

Many of the farmers used containers to collect water as detailed in Figures 19a-c. However, drought remained a consistent challenge. We recommend that farmers increase the number of barrels and cisterns for additional rainwater storage, mitigating the impact of droughts and ensuring a steadier water supply during dry spells (García-Ávila et al., 2023). Many versions of a self-made barrel or cistern system are employed on properties throughout the world. Samples as shown in Figures 22 and 23 utilize a series of barrels connected by a tube. The system also contains a converter, valve plug, house outlets, adaptors, and a connector (Besore, 2019). Figure 24 provides a more detailed cistern schematic (Conservation District Snohamash, 2018). Another method that could be implemented is a large geomembrane pod (see Figure 25) that can harvest and store rainwater (*Estanques de geomembrana | Geosai*, n.d.). This larger cistern could then be accessed to distribute water to other crops.

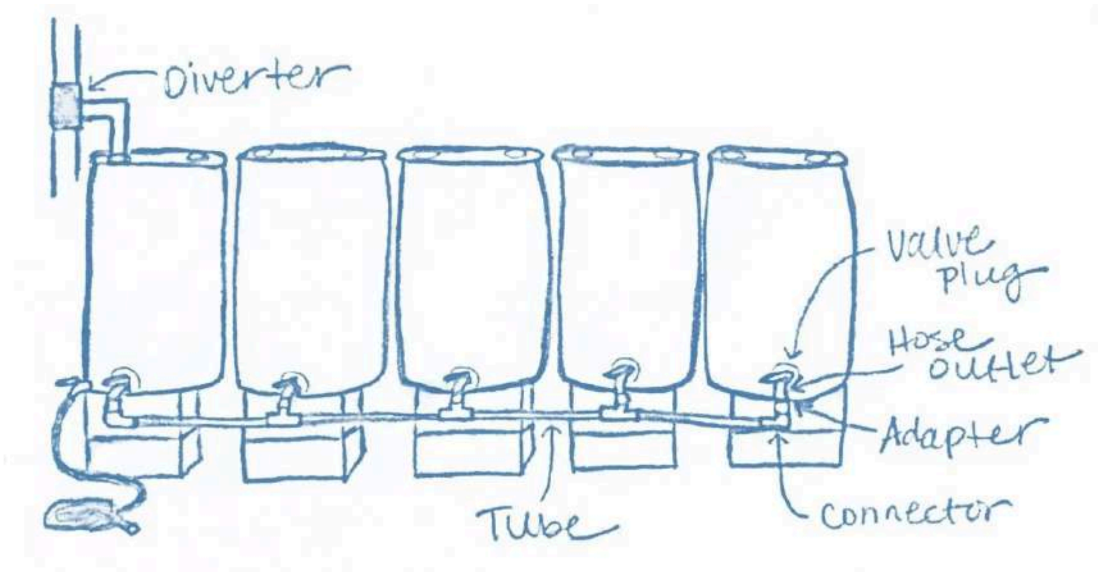
Steps:

1) Execute cost analysis of materials.
2) Execute a small study to see which cistern or barrel system most effectively harvests and stores water that is easiest to access for water distribution.
3) Identify a way where a farm can obtain more barrels. This may be through fundraising, a non-profit organization, or through government aid from MAGAP.

Figure 22. *Rain Barrels*

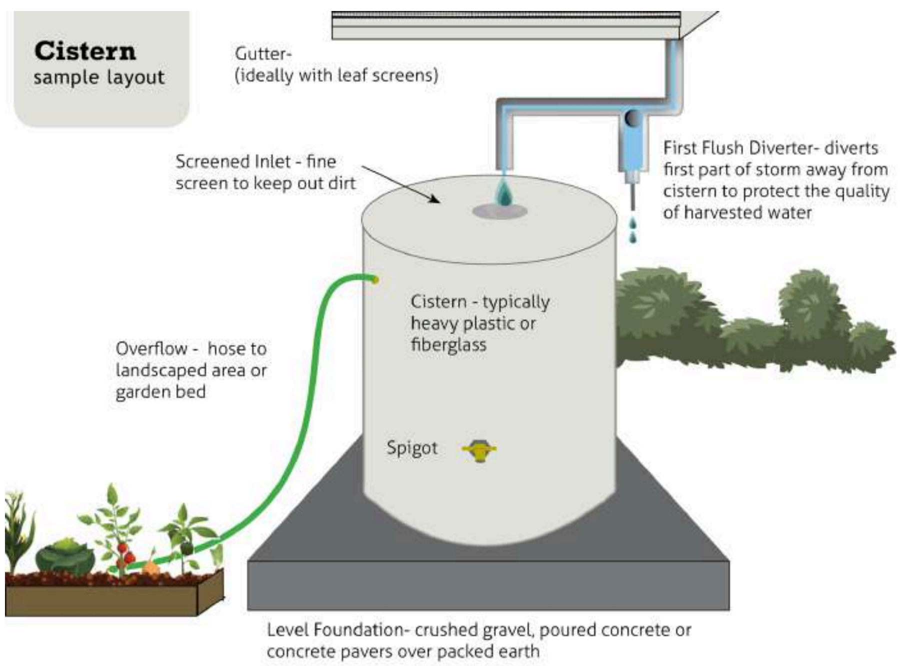
Note. (Besore, 2019)

Figure 23. ***Schematic of Rain Barrels***



Note. (Besore, 2019)

Figure 24. ***Cistern Schematic***



Note. (Conservation District Snohamash, 2018)

Figure 25. ***Geomembrane Pod***

Note. (*Estanques de geomembrana | Geosai*, n.d.)

Strategy 2: *Do not remove la hierba by the root, only cut it to maintain crop cover which fixes soil, nutrients, and humidity*

From the discussion on nutrient cycling in Section 4.1.1 and Section 4.1.2, we noted that many of the farmers already practiced this strategy. We also ascertained that not removing *la hierba* by the root but cutting it instead to maintain crop cover helps to preserve soil structure, nutrients, and moisture levels, promoting water retention (Kocira et al., 2020).

Steps:

1) Cut the *hierba* and alfalfa plants above the soil line, saving the remains.
2) Feed the plants to the livestock.

Strategy 3: *Use fertilizer from livestock and excess vegetables to increase SOM and increase water retention*

Based on our findings in our discussions of livestock in Section 4.1.1 and Section 4.1.2, we concluded that utilizing fertilizer from livestock and excess vegetables enriches SOM, enhancing its ability to retain water (Bhunia et al., 2021). Therefore, we recommend that farmers continue to use manure *(abono)* and *bokashi* to maintain humidity within the soil and to increase the soil's SOM content. We hope that these practices can be shared at association meetings, leading to an increased systemization of the practice.

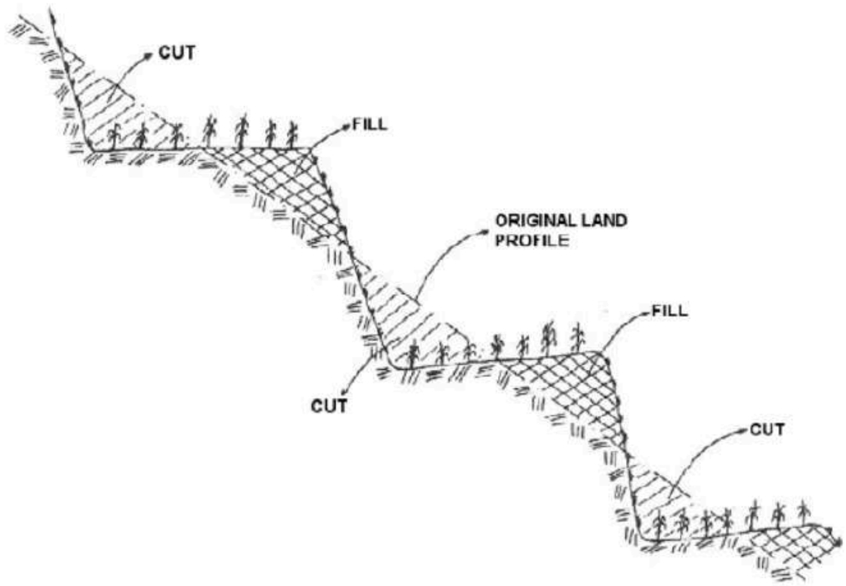
Steps:

1) Use leftover vegetable and plant scraps to create feed for livestock.
2) Collect manure *(abono)* from livestock.
3) Compost this manure along with extra plant scraps for *bokashi*.
4) Let the manure and *bokashi* mature for two weeks or until needed.
5) Share the practice with other agroproducers at association meetings.

Strategy 4: *Employ terraces for decreased erosion susceptibility*

Erosion is an issue voiced by the agroproducers and is further discussed in Sections 4.1.1 and 4.2. As mentioned in our background, terraces were employed by the Incas and the Quechua people to prevent watershed sediment loss and to retain water (Posthumus, 2005). It is one of the oldest ways of saving these resources. In a study conducted in Paraná, terracing reduces sediment loss by 50% (IAPAR, 1984). In another study at the Saint John River Valley in northwestern New Brunswick, Canada, terracing and grassed waterways decreased soil loss from an average of 20 tonnes per hectare, to less than one tonne per hectare. Runoff was also reduced by 25% (Chow et. al., 1999). Terrace science researchers Luuk Dorren and Freddy Rey discuss in their article how to construct and maintain a terrace depending on slope percentage and soil type (Dorren & Rey, 2004). A common terrace type that agroproducers could employ is a bench terrace (see Figure 26). With this knowledge, we recommend that farmers employ bench terraces to reduce sediment loss which otherwise might uproot crops and leave them susceptible to other disturbances such as wind.

Figure 26. ***Bench Terrace Schematic***



Note. (FAO, 2000)

Steps:

1) Agroproducers attempt small-scale terracing on their properties to empirically assess water retention.
2) The UCuenca Agronomy Department may quantitatively assess sediment losses.
3) If sediment losses are significantly reduced, the practice may be systemized across the community.

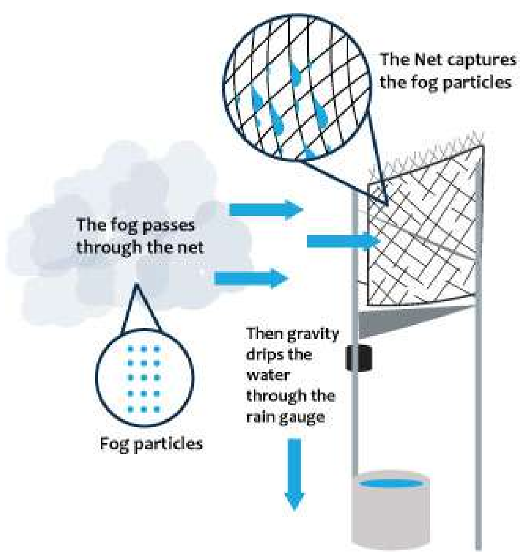
Strategy 5: *Use fog nets to harvest water from overnight condensation*

Drought as discussed in Sections 4.1.1 and 4.1.2 threatens farming productivity. Upon reviewing literature, fog collectors were an effective method used locally within the Ecuadorian highlands to harvest water, increasing water security. A diagram of a simple fog net mechanism is illustrated in Figure 27. A study conducted in the highland Andean communities of Yaguachi and Galtie, which constantly struggle with water deficits, evaluated a three-dimensional fog-catcher (see Figure 28) for cost-effectiveness and to see if it met community water demands. The nets yielded at least 2.63 L/m^2 and a minimum of 0.65 L/m^2 per day. In a year, the fog catchers produced 26,577 m^3/year, which was enough to satisfy crop needs. The economic analysis also indicated the catcher was a valuable investment, as the benefit to cost ratio was 1.90 (Carrera-Villacrés et al., 2023). Even the Incas above the rain line developed their own fog-water techniques which funneled water into cisterns (Ismail & Go, 2021). Other studies conducted in the region evaluated different types of fog nets, which did not satisfy all water needs but significantly offset water deficits (Echeverría et al., 2020; Carrera-Vullacrés et al., 2017). Therefore, we recommend the use of fog nets to harvest overnight condensation. This water would drip into a container below (Qadir et al., 2021).

Steps:

1) Determine the amount of water agroproducers use per year.
2) Determine quantitative changes between dry and rainy seasons.
3) Determine the amount of rain the community of San Antonio de Gapal receives
4) The UCuenca Agronomy Department can contact Carrera-Villacrés to understand how to potentially implement a fog catcher tower and to determine the amount of water collected per year.
5) Conduct a cost analysis and determine if fog catchers would be feasible for agroproducer implementation.

Figure 27. *Simplified Fog Net Diagram*



Note. (Khalil et al., 2021)

Figure 28. ***Fog Net Tower***

Note. "(**A**): Module's raising procedure after the clean-up of a giant reed cortex, where vertical elements with clamps assembled with rings of steel tubes; (**B**): assembling of diagonal reeds and joining procedure; (**C**): embedment of the base module to ground; (**D**): 'Urku Yaku' structure once finished and installed" (Carrera-Villacrés et al., 2023).

Strategy 6: *Use a micro-irrigation system to maximize water conservation*

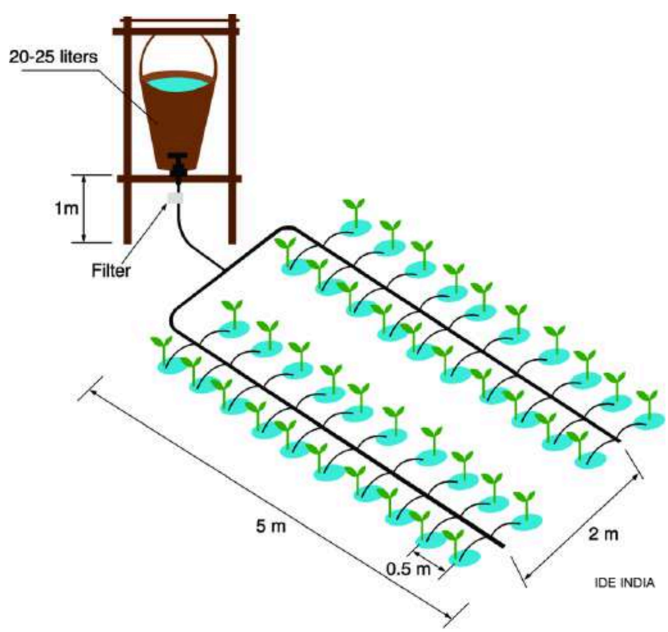
From our findings outlined in our discussion of drought in Section 4.1.1 and Section 4.2, we concluded that implementing a micro-irrigation system such as sprinkler or drip irrigation using already stored water would increase water retention (Üzen & Cetin, 2013). Such irrigation methods would ensure efficient water usage by delivering small quantities of water directly to the roots of plants, optimizing water usage, thus following a unifying principle of nature, and maximizing water conservation efforts (Drip Irrigation Systems, 2023). In 2017, "the Ministry of

Agriculture Livestock, Fishery and Fishing (MAGAP), began a project where farmers could submit funding to obtain financing for the installation of localized irrigation systems" (Paul Salazar, 2017). An example of a simple drip irrigation method is illustrated in Figure 29. Therefore, we recommend the UCuenca Agronomy Department and the agroproducers collaborate to implement such a technology.

Steps:

1) The UCuenca Agronomy Department can contact MAGAP to discuss micro-irrigation implementation and success.
2) A small-scale study could be conducted to know how much water is conserved over time.
3) Another study may be conducted to understand feasibility and cost of implementation
a) Containers at the bottom of the hill may need an electrically powered pump
4) The Agronomy Department could then collaborate with farms for implementation

Figure 29. *Drip Irrigation*



Note. "A simple bucket kit for irrigating a small vegetable garden plot of approximately 20 square meters." (Palada et al., 2011)

4.5 Participatory SWOT analysis partitioned recommendations for feasibility

We met with farmers from San Antonio de Gapal to conduct a participatory SWOT analysis (see Figure 30). At this event, we proposed to the farmers six strategies using the information we gathered from our interviews and observations and received their feedback.

Figure 30. ***Participatory SWOT Analysis***

Photo Credit: By Cpa. Diana Angelica Machuca Machuca, 04/09/2024.

Table 5. Feedback on Proposed Strategies

<table>
<tr><th colspan="2">Proposed Strategies</th><th>Feedback</th></tr>
<tr><td>Strategy 1</td><td>Increase the size and number of barrels (cisterns)</td><td>Accepted</td></tr>
<tr><td>Strategy 2</td><td>Do not remove la hierba by the root, only cut to maintain crop cover which fixes soil, nutrients, and humidity</td><td rowspan="2">Already Employed</td></tr>
<tr><td>Strategy 3</td><td>Use fertilizer from livestock and excess vegetables to increase SOM and increase water retention</td></tr>
<tr><td>Strategy 4</td><td>Employ terraces for increased water capture and decreases erosion susceptibility</td><td rowspan="2">Hesitant</td></tr>
<tr><td>Strategy 5</td><td>Use fog nets to harvest water from overnight condensation</td></tr>
<tr><td>Strategy 6</td><td>Use a micro-irrigation system to maximize water conservation</td><td>Not Feasible</td></tr>
</table>

The strategies were developed with the intention of subverting effects of climate change, such as droughts and erosion. This discussion with farmers allowed us to think from their perspective, and pinpoint which strategies were feasible and those which the agroproducers were hesitant about. Strategy 1 (see Table 5) was by far the most well-received by the farmers. Farmers stated that Strategy 6 cost too much: "no hay dinero. No hay dinero, claro" (Sra. Farfán, 04/09/2024)[32]. For this reason, it was viewed as an impractical use of money for water conservation. Two of the strategies we proposed to the farmers were already being done on their properties which includes Strategies 2 and 3. These strategies resembled Chakra practices which have been passed down through generational farming from the Incas and Quechua. We also suggested Strategy 4 as a strategy to subvert erosion and allow for better water retention for crops growing on hills. They were hesitant to apply terrace farming due a lack of familiarity. Strategy 5 was a way to collect water, different from what farmers have done in the past. The creation of a fog net during prolonged drought seasons would allow farmers to collect dew overnight as another source of water. The farmers seemed hesitant about the amount of water that could be collected from this strategy:"¿tienen alguna idea de cuánta agua se puede capturar con estas trampas?" (Sra. Chicaiza, 04/09/2024).[33] Overall, the feedback received was a necessary next step to differentiating our ideas from those of the farmers and their perspectives on the resources they are willing to allocate to new strategies.

4.6 Discussion of Evaluated Recommendations

Not all recommendations were met with the same response; some strategies were favored, while others were less realistic. Farmers have already implemented some of our proposed strategies, but some proposals were met with hesitation.

However, farmers were in resounding agreement that upscaling the number of barrels and/or tanks for water storage was practical, and this was a simple recommendation to make (García-Ávila et al., 2023). We also recommended that farmers systemize sustainable strategies that they have already employed, so all farmers can reap the benefits of such practices, such as greater outputs. The farmers were hesitant to implement two specific strategies (see Table 5), and

[32] Translates to English as "There is no money. There is no money, of course." Translation by Google Translate in April 2024.
[33] Translates to English as "do you have any idea how much water can be captured with these traps?" Translation by Google Translate in April 2024.

we proposed distinct recommendations for each of them. For using fog nets to collect overnight dew, we recommended conducting a study to figure out how much water the agroproducers use per year, along with how much water they need. Another study could be conducted to determine the amount of water the fog nets would need to capture to be a worthwhile investment for the farmers. We do not believe that a study is necessary for terrace farming, as there are many past sources that examine areas worldwide and in Ecuador, which detail the importance of this method. The indigenous practices created by the Incan and Quechua peoples have proven to be sustainable for generations. Finally, the farmers believed that micro-irrigation was too expensive, making it impractical.

4.6.1 Limitations of participatory SWOT analysis

Our recommendations are limited by a small sample size. With data from only 12 interviews, which consisted of 11 females and one male, and a participatory SWOT analysis which featured only six female farmers and no male farmers, there was only a small spectrum of perspectives and feedback we could obtain. A larger group of people to learn from would provide a wider range of perspectives regarding the feasibility of our proposed strategies. Overall, the recommendations we made were enhanced by considering their perspectives.

5. Conclusion

Ecuador has an extensive history of longstanding indigenous agricultural practices that are harmonious with nature and meet the demands of the challenging landscape and climate. However, foreign influences, changes in land use, and shifts in agricultural needs and preferences have led to a loss of this efficacious knowledge. This has led to land degradation, and disruption in nutrient cycles, which places a tremendous strain upon the productive strength of agroproducers. This prompted our assessment, as part of a smaller diagnostic called *"CICLA,"* based on researching the local areas in and around Cuenca. In our assessment, we performed an analysis of the strengths, weaknesses, opportunities, and threats experienced on their properties.

After interviews and observations with 12 farmers, water collection and retention were the areas for greatest improvement to increase resilience against a forthcoming volatile climate, including prolonged droughts and excessive rain. The recommendations provided were to increase the number and size of barrels or to employ a cistern for rain collection. We also recommended to continue maintaining *hierba* and employing *abono* and *bokashi* from livestock and vegetable leftovers. Novel methods proposed to the agroproducers were the use of fog nets to collect dew throughout the night and to employ terraces to reduce erosion and increase water retention. Small studies are recommended to the Agronomy faculty at UCuenca to assess how much water agroproducers use in a given time, how much rain falls in the same period, and thus what dimensions and costs are required to design a fog net that satisfies water needs in periods of excessive drought. Terraces, having been employed since ancient times, were also discussed with agropoducers for incorporation into the hilly landscape in which they cultivate. Agroproducers may then empirically determine if water retention increases and soil loss decreases. Further research in agriculture within the community of San Antonio de Gapal would be to quantitatively evaluate rainfall and drought patterns specifically within the area, as well as sediment loss over time. This may inform more effective strategies given numerical data supported by the qualitative data provided in this study. Furthermore, we suggested collaboration with local researchers who have employed rain nets and cisterns in other regions of the Andes.

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Appendix A. Sponsor Description

Our project's sponsor is the Faculty of Agricultural Sciences (Agronomy School) of UCuenca. This Faculty is located at the Yanuncay Campus of UCuenca. Dr. Pablo Geovanny Quichimbo Miguitama, a soil science professor, agronomist, and director of the Department of Water Resources and Environmental Sciences at the University of Cuenca, led the faculty who worked with us (UCUENCA, 2024). The co-director of the project is Dr. Pablo Marcelo Borja Ramon, who is also a soil scientist. Also involved with the project were Cpa. Diana Angelica Machuca Machuca, Ing. Oscar Fabian Vintimilla Yanza, and Ing. Giomara Michelle Cherrez Cherrez, and Dr. Raul Alejandro Vanegas Cabrera. The university is a non-profit public institution funded by the state of Ecuador according to the United Nations Institute for Training and Research, (UNITAR, 2023). The different resources that the organization uses include the university's faculty, equipment, and funding.

This department works to investigate water resources and environmental sciences in the Cuenca region. The students and faculty within the department function as an interdisciplinary academic unit. They advance scientific and technological knowledge about water and its relationship to natural and artificial systems from a sustainability perspective (UCUENCA, 2024).

The sponsor's organization is UCuenca with 54 departments and facilities. The university is government-funded - the organization is ultimately within its control. Thus, our sponsor organization is the Faculty of Agricultural Sciences (UCUENCA, 2024). Because the university is publicly funded, not only does this project contribute to research publications of UCuenca's Agricultural Sciences Department but it also gives back to the community. Dr. Pablo Quichimbo's active involvement in the agricultural science community promotes the credibility of this project and indicates a dedicated effort to execute the project's logistics, utilizing his expertise and contributions in the field. The sponsor seeks the improvement of the community that follows their core values and mission statement (Yarzábal et al., 2017). UCuenca's mission is to train professionals and scientists committed to improving the quality of life, in the context of interculturalism in harmony with nature. Additionally, UCuenca hopes to use its resources to respond to human challenges of the times on "academic quality, creativity, and innovation, and to fulfill its commitment to the construction of an equitable, supportive, and efficient regional, national, and international society" (UNITAR, 2023). By bolstering and increasing the efficiency and sustainability of Cuenca's agricultural tools and practices pertaining to nutrient cycling and strengthening the training of Andean farmers, quality of life will increase with the rise of healthier and more abundant crops. Interculturalism will include collaboration between the project team from WPI and UCuenca. This project will also work in harmony with nature as the aim of the project is rooted in sustainability. Academic quality, creativity, and innovation are all needed for this project to be successful and to construct an equitable and supportive society.

Appendix B. Form of Participation[34]

Form of Participation

We are four students from Worcester Polytechnic Institute (WPI), a university in the United States. We are studying the lifestyles of Cuenca's farmers in the community of San Antonio de Gapal in Cuenca, and their farming practices to identify problems that they encounter in their daily lives. If you would like to participate in our study, we will audio record you as you answer questions regarding these topics:

Your perspectives on agriculture
Agricultural practices
Social, economic, and environmental implications of agriculture in your life
Agricultural challenges and the future

The purpose of the audio recording is to generate a transcript that can be referenced. During our interview, we will collect identifying information, opinions, and written observations of the surroundings. You may withdraw from the interview at any time and a response to each question is not required. Even if you do not want to be recorded, we would still appreciate your time to answer questions. Your responses will be used to develop scientific manuscripts and a pamphlet to socialize proposed strategies to alleviate a pertinent issue. Thus, your responses will NOT be confidential.

The information collected in this study will be used collaboratively between the University of Cuenca and Worcester Polytechnic Institute.

By signing this form, you fully agree to participate in our study.

Name of Producer (print): ____

Signature: ____

Date: ____

[34] A Spanish translation of the Form of Participation used in practice is provided on the next page. Translation by Google Translate in March 2024.

Forma de Participación

Somos cuatro estudiantes del Instituto Politécnico de Worcester (WPI), una universidad en los Estados Unidos. Estamos estudiando los estilos de vida de los agricultores en la comunidad San Antonio de Gapal en Cuenca, y sus prácticas agrícolas para identificar los problemas que encuentran en su vida cotidiana. Si desea participar en nuestro estudio, lo grabaremos en audio mientras responde preguntas sobre estos temas:

Sus perspectivas sobre la agricultura
Prácticas agrícolas
Implicaciones sociales, económicas y ambientales de la agricultura en su vida
Desafíos agrícolas y futuro

El propósito de la grabación de audio es generar una transcripción a la que se pueda hacer referencia. Durante nuestra entrevista, recopilaremos información de identificación, opiniones y observaciones escritas de los alrededores. Puede retirarse de la entrevista en cualquier momento y no se requiere una respuesta a cada pregunta. Incluso si no desea ser grabado, le agradeceríamos que nos diera tiempo para responder a sus preguntas. Sus respuestas se utilizarán para desarrollar manuscritos científicos y un folleto para socializar las estrategias propuestas para aliviar un problema pertinente. Por lo tanto, sus respuestas NO serán confidenciales.

Nos gustaría tomar fotos de la tierra que se usen, para recopilar datos físicos y visuales.

La información recogida en este estudio será utilizada en colaboración entre la Universidad de Cuenca y el Instituto Politécnico de Worcester.

Al firmar este formulario, usted acepta participar plenamente en nuestro estudio.

Nombre de Productor (imprimir): ____

Firmar: ____

Fecha: ____

Appendix C. Semi-Structured Interview Questions[35]

English Translation

1) From what age did you start working in agriculture?
2) What motivates you to continue in agriculture?
3) Could you tell us a little about yourself and your property?
4) Your property is your own:
   - ☐ Leased
   - ☐ To the match
     - i) When did you assume responsibility for the property?
5) What are the agricultural practices associated with the soil used by you?
   - ☐ Tillage
   - ☐ Fertilization
   - ☐ Crop rotation
   - ☐ Others: ___________
     - i) What tools do you use when tilling the soil?
6) How has the environment changed in the development of your agricultural practices?
7) How has economics influenced the practices and tools you use?
8) Have you reached out to other farmers, and if so, how has the farming community influenced the processes and tools you use?
9) What are the most important factors in the types of processes and tools you use?
10) What is your future vision for agriculture on your property?
    - a) What types of tools and techniques might change with the development of agriculture?
11) What are the challenges you have when managing your property? What are the most important aspects?
12) When you hear about sustainable agricultural practices, what comes to mind?
13) What advice would you give to someone interested in starting out in agriculture?

[35] A Spanish translation of the Semi-Structured Interview Questions used in practice is provided on the next page. Translation by Google Translate in March 2024.

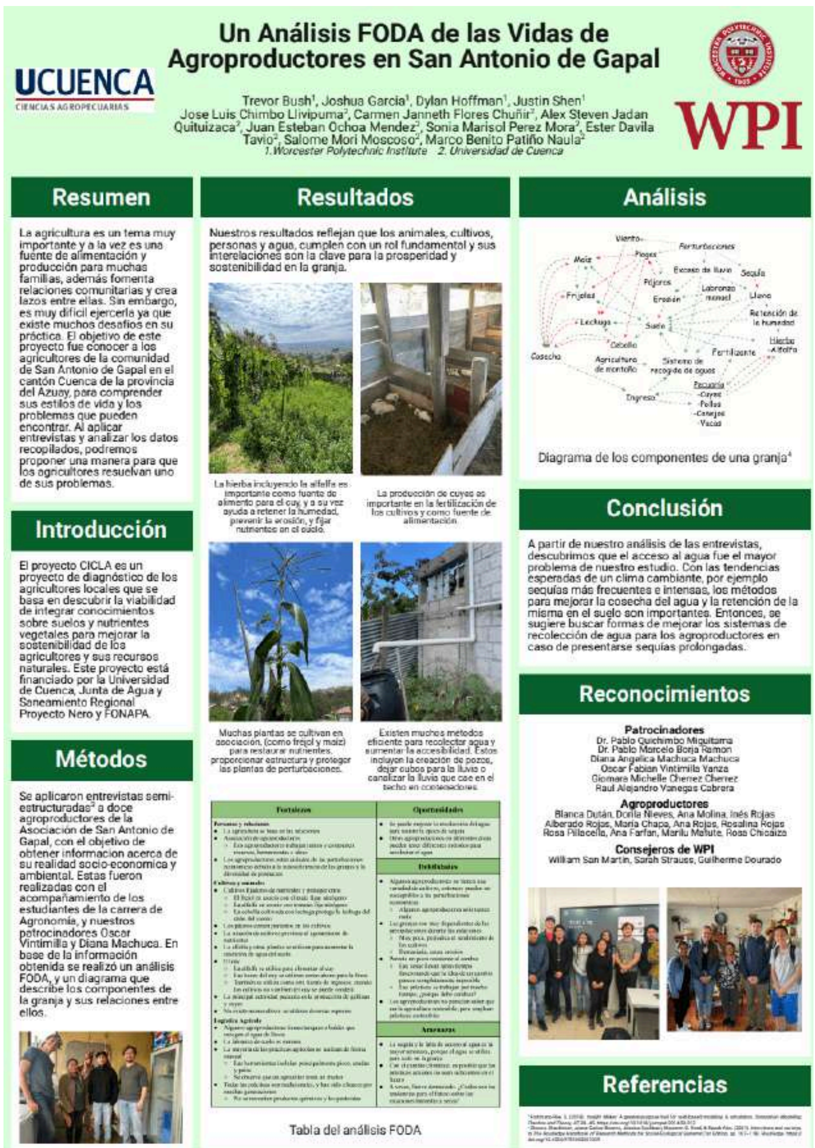
Spanish Translation

1) ¿Desde qué edad Usted inició en el trabajo de la agricultura?
2) ¿Qué le motiva a Usted a continuar en la agricultura?
3) ¿Podría contarnos un poco sobre usted y su propiedad?
4) Su propiedad es propia:
   - ☐ Arrendada
   - ☐ Al partido
     i) ¿Cuándo asumió la responsabilidad de la propiedad?
5) ¿Cuáles son las prácticas agrícolas asociadas al suelo utilizadas por usted?
   - ☐ Labranza
   - ☐ Fertilización
   - ☐ Rotación de cultivos
   - ☐ Otros: ___________
     i) ¿Qué herramientas emplea en la labranza del suelo?
6) ¿Cómo ha cambiado el entorno en el desarrollo de sus prácticas agrícolas?
7) ¿Cómo ha influido la economía en las prácticas y herramientas que utiliza?
8) ¿Se ha comunicado con otros agricultores, y de ser así, cómo ha influido la comunidad agrícola en los procesos y herramientas que utiliza?
9) ¿Cuáles son los factores más importantes en los tipos de procesos y herramientas que utiliza?
10) ¿Cual es su visión a futuro de la agricultura, en su propiedad?
    a) ¿Qué tipos de herramientas y técnicas podrían cambiar con el desarrollo de la agricultura?
11) ¿Cuáles son los desafíos que usted tiene al administrar su propiedad? ¿Cuáles son los aspectos más importantes?
12) Cuando usted escucha sobre prácticas agrícolas sostenibles, ¿qué se le viene a la mente?
13) ¿Qué consejos le daría a alguien interesada/o en empezar en la agricultura?

Appendix D. Poster: "Un Análisis FODA de las Vidas de Agroproductores en San Antonio de Gapal"[36]

This is a poster we created for an Open House at UCuenca celebrating the 45th anniversary of the agronomy career. We presented this poster with the support of agronomy Master's students at UCuenca on April 9th during our project term.

Figure 31. ***Poster for Agronomy Open House at UCuenca***



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[36] Translates to English as "A SWOT Analysis of Farmers' Lives in San Antonio de Gapal." Translation by J. Shen.

Appendix E. Gantt Chart

A Gantt chart shows the chronology of a project's timeline, and what project components are of focus at what time. According to our Gantt chart (see Table 4), we started by reviewing literature our sponsor sent us. This was to familiarize ourselves with the context of our project.

Table 6. Gantt Chart

The Gantt chart provided to us by our sponsor, Dr. Pablo Quichimbo. Translated to English. This chart was followed throughout the project term, week by week.

	ACTIVIDAD	SEMANA							
		1	2	3	4	5	6	7	7
		11-15 Mar	18-22 Mar	25-29 Mar	1-5 Abr	8-12 Abr	15-19 Abr	22-26 Abr	29-30 Abr
1	***Diagnóstico de productores***								
1.1.	Literature review, survey design and identification of farmers (GAPAL Producers Association, cooperators with the NERO project: 12 producers). Supervision: Oscar Vintimilla, Michelle Chérrez, Pablo Borja and Pablo Quichimbo	■							
1.2.	Carry out the surveys (first week: selection of accompanying students (minimum 1 national student per foreign student). Pablo Borja, Raúl Vanegas, Diana Machuca and Pablo Quichimbo		■	■					
1.3.	Analysis of data. Supervision: Pablo Borja and Pablo Quichimbo				■				
1.4.	Design of a solution for a problem (the problem will be identified based on a workshop through a SWOT with the producers). Supervision: Diana Machuca, Raúl Vanegas and Michelle Chérrez.					■	■		
1.5.	Socialization of the proposal for a solution to a producer problem (Supervision: all)							■	
2	***Edición de material técnico-científico*** (Supervisión: todos)		■	■	■	■	■	■	■

Once this literature review preparation was finished, Ing. Oscar Vintimilla, a member of our sponsor team, arranged our interviews for us by sending us farmer names, contact information, and their availability for an interview. Once our farmers were identified, we met with them and conducted the semi-structured interviews we created (see Appendix C). The following week, we performed our data analysis of looking through our interview information and putting our information through our SWOT analysis. After analyzing data for two weeks, we facilitated a participatory SWOT analysis with some of the farmers that we had interviewed during the sixth week of the project term. The last two weeks entailed the drafting, writing, and revision of a technical-scientific manuscript.