

**Farming Without Harming**  
Understanding and Preventing Agricultural Runoff in the Tomebamba and  
Yanuncay Watersheds



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Subgerencia de Gestión Ambiental (ETAPA)

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### **Abstract**

Water degradation from agricultural runoff is a growing problem worldwide, and is visible in places such as Cuenca, Ecuador. While a local organization, ETAPA, has been successful in supplying Cuenca with clean drinking water, rising levels of agricultural runoff due to poor waste management have threatened ETAPA's ability to provide clean water. To address this issue, we supported ETAPA by developing an understanding of the different farm characteristics, agricultural land uses, and social relationships between the farmers and ETAPA in the Tomebamba and Yanuncay watersheds, later developing recommendations to improve them. To achieve this goal, we followed three main objectives:

1. Determining relevant farm characteristics and conditions
2. Understanding the farmers' perspectives
3. Investigating and disseminating potential recommendations to prevent agricultural runoff

Through our fieldwork, which included guided tours, observation programs, and interviews, we determined that for the successful adoption of recommended conservation practices, social tensions between ETAPA and the farmers should first be addressed. Additionally, for conservation practices to be utilized, they must be mindful of the available resources present on the farms.

### **Resumen**

La degradación del agua ocasionada por la escorrentía agrícola es un problema que está creciendo en el mundo, y es visible en lugares como Cuenca, Ecuador. Aunque la organización local, ETAPA, ha podido suplir a sus ciudadanos con agua potable, el incremento de la escorrentía agrícola ha amenazado la habilidad de ETAPA de proveer agua limpia. Para abordar este problema, nosotros apoyamos a ETAPA al desarrollar un entendimiento de las condiciones en cada propiedad, el uso del suelo, y las relaciones en las cuencas del Tomebamba y Yanuncay, y luego desarrollando recomendaciones para mejorarlas. Para cumplir con esta meta, nosotros seguimos tres objetivos principales:

1. Determinamos las características y condiciones más relevantes de las propiedades
2. Desarrollamos un entendimiento de las perspectivas de los propietarios
3. Investigamos y diseminamos recomendaciones potenciales para prevenir la escorrentía agrícola

A través de nuestro trabajo en el campo, incluyendo los recorridos guiados, programas de observación, y entrevistas, nosotros determinamos que para la adopción exitosa de las prácticas de conservación recomendadas, es necesario mejorar las relaciones que existen entre ETAPA y los propietarios. Adicionalmente, para que las prácticas de conservación sean utilizadas, se debe de tomar en cuenta los recursos disponibles.

## Acknowledgments

Our project would not have been possible without the continual support, collaboration and guidance of our sponsors—the employees from ETAPA EP, Subgerencia de Gestión Ambiental— our partner farmers, and our advisors, Professors Laureen Elgert and Gary Pollice.

Throughout our entire project, the ETAPA employees were invested in our work, patient, and accommodating, while also making sure to challenge us to explore the problem of agricultural runoff deeper. They were also helpful in our transition to Cuenca, making sure we were taking time for ourselves and enjoying the city, often giving us recommendations for places to go or foods to try. We would especially like to extend our gratitude to Juan Segarra and Geovanny Loja, the employees that specifically worked with us in the Tomebamba and Yanuncay watersheds. Juan and Geovanny not only shared their vast knowledge with us about the two watersheds and the status of Cuenca’s drinking water, but also made themselves readily available whenever our group needed help, clarification, or wanted feedback. Without their help, and the rest of the ETAPA employees, our project would not have been possible, and our stay in Cuenca would not have been as comfortable and memorable.

We would also like to thank farmers 1, 2, 3, and 4 for collaborating with us, and taking time out of their busy schedules to participate in our guided tours, observation programs, and interviews. Because of their collaboration, we were able to bring an important and new perspective to ETAPA, one that our project would have been incomplete without. We thoroughly appreciate their kindness, patience, and willingness to participate in our project.

Lastly, we would like to extend our deepest thanks to our two project advisors from Worcester Polytechnic Institute, Professors Laureen Elgert and Gary Pollice. Both of these individuals served as a huge support system for our team, both related and unrelated to our project. Throughout the duration of our work, they were encouraging, insightful, and accommodating, often squeezing in meetings with us to discuss concerns or confusions we had, always providing great and useful feedback that contributed to the betterment of our project. In addition, both Professor Elgert and Professor Pollice challenged us throughout the two terms, pushing our project to reach its full potential, allowing us to produce deliverables we were proud to give to our sponsors. Their guidance was both essential to the success of our project, as well as our transition to Cuenca.

## Agradecimientos

Nuestro proyecto no hubiese sido posible sin el soporte, colaboración, y directiva de nuestros patrocinadores, los empleados de ETAPA EP, Subgerencia de Gestión Ambiental, los propietarios, y nuestros asesores docentes, la Profesora Elgert y el Profesor Pollice.

Durante toda la trayectoria de nuestro proyecto, los empleados de ETAPA fueron dedicados, pacientes, y complacientes, y a su vez nos retaron para explorar más a fondo el problema de la escorrentía agrícola. Ellos fueron muy atentos durante nuestra transición a Cuenca, asegurándose de que nosotros tuviéramos tiempo y disfrutemos de la ciudad, de vez en cuando dándonos recomendaciones de lugares que podíamos visitar y comida que podíamos probar. En particular, nosotros quisiéramos extenderles nuestra gratitud a Juan Segarra y a Geovanny Loja, los empleados que trabajaron con nosotros en las cuencas del Tomebamba y el Yanuncay. Juan y Geovanny no solo compartieron sus conocimientos sobre ambas cuencas y el estado de la potabilidad del agua de Cuenca con nosotros, sino que también estuvieron muy atentos a lo que nuestro grupo necesitaba, como clarificaciones o retroalimentación sobre nuestro progreso. Sin su ayuda, y el resto de los empleados de ETAPA, nuestro proyecto no hubiese sido posible, y nuestra estadía en Cuenca no hubiese sido tan placentera y memorable.

También quisiéramos agradecer a los propietarios 1, 2, 3, y 4 por haber colaborado con nosotros y haber sacado tiempo de su horario tan atareado para participar en nuestros recorridos guiados, programas de observación, y entrevistas. Gracias a su colaboración, nosotros pudimos mostrarles a ETAPA una perspectiva nueva e importante, sin la cual nuestro proyecto estaría incompleto. Nosotros no olvidaremos su amabilidad, paciencia, y disposición de participar en nuestro proyecto.

Por último, nosotros quisiéramos extender nuestro profundo agradecimiento y aprecio a nuestros dos asesores docentes de Worcester Polytechnic Institute, la Profesora Laureen Elgert y el Profesor Gary Pollice. Ambos individuos sirvieron como un sistema de apoyo para nuestro equipo, dentro y fuera de nuestro proyecto. Durante la duración del proyecto, ellos nos dirigieron y fueron muy alentadores y complacientes, programando reuniones con nosotros para discutir nuestras confusiones y preocupaciones, siempre proveyéndonos con retroalimentación útil que contribuyó a la mejora de nuestro proyecto. Adicionalmente, ambos nos retaron durante ambos términos, impulsándonos a alcanzar nuestro máximo potencial, y produciendo entregables de los que estábamos orgullosos de presentarles a nuestros patrocinadores. Sus directivas fueron esenciales para el éxito de nuestro proyecto al igual que nuestra transición a Cuenca.

## **Executive Summary**

The lack of availability of clean drinking water is a prevalent issue throughout the world. In 2015, 844 million people lacked clean water, often depending on contaminated water sources for cooking, hygiene, and other daily uses. The consumption of this contaminated water can cause significant health complications, such as cholera, diarrhea, and typhoid. In addition to the threats posed on human health, insufficient access to clean water can have a variety of societal implications, relating to a region's economic and educational well-being (World Health Organization [WHO], 2017).

Many factors contribute to the unavailability of clean drinking water, with a large contribution stemming from wastewater pollution. While this wastewater often results from urban and industrial processes, a significant quantity originates from poor agricultural land use and waste management (Food and Agriculture Organization [FAO], n.d.). A region that largely struggles with this issue is the city of Cuenca, Ecuador, where improper waste management on local farms contributes significantly to agricultural runoff, causing the degradation of essential water sources. A local organization, ETAPA, is particularly concerned with two of Cuenca's watersheds, the Tomebamba and the Yanuncay, where agricultural production is most prevalent (Subgerencia de Gestión Ambiental, 2017). Due to the improper waste management and runoff in these watersheds, ETAPA projects a ~5% water deficit by the year 2030 (ETAPA, 2004). In order to address this issue, ETAPA seeks to take preventative measures to protect Cuenca's water sources.

### **The Process: A Guide to Understanding the Problem of Agricultural Runoff in Cuenca**

This project serves to support ETAPA's goal in preventing the contamination of the Tomebamba and Yanuncay rivers by first understanding the notable conditions, agricultural activities, and social relationships in the watersheds, later developing recommendations to improve them. To achieve this project's goal, we followed three guiding objectives: determining the farming characteristics and land uses along the rivers to identify sources of environmental harm; developing an understanding of the farmers' perspectives regarding their current practices, the corresponding environmental effects, as well as their relationships with ETAPA; and investigating and disseminating recommendations for both the farmers and ETAPA to utilize.

To achieve these objectives, our project worked in three phases: inspiration, ideation, and dissemination. These three phases molded our team's approach to build strong relationships with the project stakeholders and create solutions to accommodate their needs. In the inspiration phase, we utilized guided tours, observation programs, and interviews while working on four farms throughout the Tomebamba and Yanuncay watersheds to gain an understanding of the principal sources of agricultural runoff, as well as gain an insight into the farmers' lives and perspectives towards their practices, the environment, and ETAPA. In the ideation phase, we brainstormed and drafted several sets of recommendations to address our findings, deciding that encouraging social

## FARMING WITHOUT HARMING

change first would allow for the successful adoption of conservation practices in the future. In this phase, we also solicited feedback from ETAPA about the viability, desirability, and feasibility of our proposed recommendations, refining them accordingly. Finally, in the dissemination phase, we created and distributed a final report to ETAPA and a pamphlet to the farmers detailing our project findings and recommendations.

### **The Findings: An Insight Into the Contributors of Agricultural Runoff Into the Rivers**

After a careful analysis of the collected data from the inspiration phase of our project, we were able to understand the existing environmental concerns on the different farms, as well as understand the farmers' perspectives and their ability and willingness to adopt new practices. First, we determined that the farms' current waste management techniques pose threats to the environment; in the Tomebamba watershed, the main source of contamination stems from poor cow manure and fish waste management, while in the Yanuncay watershed, the main source is the mismanagement of cow manure. We also discovered that while the farmers in these watersheds are generally environmentally aware, there are some gaps in their understanding regarding the effects of contamination. For example, the farmers often lacked insight into the severity of agricultural runoff, disregarding the effect of contamination on wildlife and claiming that animals do not contribute to severe cases of eutrophication. Another finding is that farmers' ability and willingness may hinder the adoption of new practices, stemming from their lack of interest and available resources, as well as from their strained relationships with ETAPA. Finally, we concluded what ETAPA sees as successful recommendations to the issue of agricultural runoff: focusing on improving their relations with the farmers to facilitate the implementation of manure management strategies.

### **The Outcome: A Step in the Right Direction Towards Protecting Cuenca's Water Sources**

As our fieldwork highlighted that strained relationships between ETAPA and the farmers may negatively influence the farmers' adoption of suggested practices, we recommend that ETAPA first build stronger relations with the farmers, later advocating for the adoption of conservation practices to prevent agricultural runoff. Below are several strategies ETAPA can utilize to build stronger rapport between themselves and the farmers:

- **Modify the PCA to Prioritize the Farmers' Willingness:** We recommend that ETAPA change the way in which they identify their partner farmers by incorporating the farmers' willingness to work with ETAPA into the PCA identification and scoring system. With these proposed changes, farmers will be prioritized to work with ETAPA if they have a higher ranking in regards to their willingness. We also recommend that ETAPA collaborate with *any* farmer willing to work with them, regardless of their ranked priority via the PCA scoring system. By doing this, they will create a culture of partnership between the two groups, allowing for the future success of conservation in the watersheds.

## FARMING WITHOUT HARMING

- **Host Social and Cultural Events:** We suggest that ETAPA hold social and cultural events for the farmers, as a means of strengthening the relationships between the two groups. Below are two events that we recommend ETAPA organize:
  - **Luncheon:** We recommend that ETAPA invite farmers to a luncheon, in which ETAPA presents on Cuenca's future water deficit, their involvement in preventing the deficit, their future goals in terms of water protection, and how achieving these goals will benefit both the farmers and Cuenca. In holding this luncheon, the bond between ETAPA and the farmers will grow stronger, as the farmers will feel that ETAPA is calling in experts to aid in their preventive efforts.
  - **Annual Celebration:** We recommend that ETAPA hold an annual celebration to recognize the work of the farmers and their collaboration with ETAPA. At this event, we recommend that ETAPA provide a small token of appreciation to the farmers, as well as give a presentation explaining ETAPA's progress in the watersheds throughout the year, and how their feats would not have been possible without the farmers. This will make the farmers feel more like a part of the ETAPA team, rather than targeted outsiders, further improving the relationship between the two groups.
- **Organize an Exchange of Experiences:** We propose that ETAPA invite farmers from each watershed to a small, informal event in which they have the opportunity to talk to one another about different practices used on their farm, elaborating on the benefits and losses of each practice. The purpose of this is to allow the farmers to discuss and consider the potential implementation of environmentally friendly practices on their farms *without* the influence of ETAPA. This will be beneficial to ETAPA, as it takes the pressure off of them to be the ones proposing new practices, which will ease tensions. If this goes well, we recommend that ETAPA make this an annual, larger event where they invite farmers that utilize environmentally-friendly techniques to speak about their practices.
- **Collecting More Data on Relations:** We recommend that ETAPA representatives continue to collect information regarding their relationships with the farmers. It is necessary to deepen their knowledge on these relationships so that ETAPA can work to improve them, making the farmers a more integral part of their work. Themes to explore include what people generally think of ETAPA, what people think ETAPA's mission is, and what people think the ETAPA representatives do on a daily basis.

Once the relationships between ETAPA and the farmers improve, ETAPA can begin to introduce and promote new practices to avert agricultural contamination. We recommend that ETAPA hold workshops when suggesting these practices, explaining the benefits and limitations of each. Given that poor waste management is the main contributor of agricultural runoff on the farms, we propose several recommendations relating to manure management and utilization:

- **Expand Riparian Zones:** Given the inadequate size of the riparian zones on the farms, and their importance in the prevention of agricultural runoff, we recommend that the



## FARMING WITHOUT HARMING

farmers and ETAPA work jointly to expand the existing riparian zones. The main limitations of this recommendation are the cost of implementation, the reduction of available pasture, and the time commitment required for maintenance.

- **Construct an Anaerobic Digester:** Many farms in the Tomebamba and Yanuncay watersheds can benefit from the installation and utilization of an anaerobic digester. These digesters reduce the harmful effects of the nutrients present in raw manure, converting the manure into a product capable of being used as an organic fertilizer. While free fertilizer and the reduction of contamination are clear benefits of digesters, there are some downsides, including the complexity of construction.
- **Build Compost Piles:** We recommend that each farmer construct an aerated windrow compost pile as a means to manage the waste produced on their properties. When constructing this pile, one should take into account its aeration, carbon-to-nitrogen content, moisture level, and temperature. Composting is advantageous, as it produces a fertilizer that improves soil health and has a lesser potential to degrade water quality, additionally saving money on fertilizer. However, it is limited by its cost of construction and significant maintenance demands.
- **Establish a Manure Share Program:** We recommend that the farmers and ETAPA work together to establish a manure share program in the watersheds. In this program, ETAPA will help coordinate, alongside farmer associations, a phone line used to facilitate the manure exchange. We recommend that ETAPA start this as a pilot program for select farmers, and, if successful, expand the program to include other individuals, such as gardeners and landscapers. While this program brings economic benefits to the farmers and directly prevents agricultural runoff, there are limitations, such as the logistics of organizing the program.

These proposed recommendations will allow for the gradual reduction of agricultural runoff into the Tomebamba and Yanuncay rivers, directly benefiting the community of Cuenca by preventing the impending water deficit. Being that these recommendations promote gradual change in the communities, we advise that both the farmers and ETAPA remain patient and understanding throughout the process, keeping in mind that they are working towards a common goal of bettering the city's water supply. Once stronger relationships between the two groups are established, ETAPA can proceed to recommend conservation practices and assist the farmers in their implementation.

## Resumen Ejecutivo

La falta de accesibilidad al agua potable es un problema prevalente en todo el mundo. En el 2015, 844 millones de personas no tenían acceso a agua potable, y muy a menudo dependían de fuentes de agua contaminadas para cocinar, bañarse, y otros usos diarios. El consumo de esta agua contaminada puede causar complicaciones a la salud de las personas, como el cólera, la diarrea, y la fiebre tifoidea. En adición a las amenazas a la salud de los seres humanos, un acceso insuficiente al agua potable puede tener varias implicaciones en la sociedad, todos relacionados al bienestar económico y educativo de una región (World Health Organization [WHO], 2017).

Muchos factores contribuyen a la inaccesibilidad del agua potable, uno de ellos siendo la contaminación de aguas residuales. Mientras que la mayoría de estas aguas residuales resultan de procesos urbanos e industriales, una cantidad significativa proviene del mal uso del suelo proveniente del sector agropecuario y el mal manejo de desechos (Food and Agriculture Organization [FAO], n.d.). Una región que tiene dificultades con este problema es la ciudad de Cuenca, Ecuador, donde el mal manejo de los desechos en las granjas locales tiene una contribución significativa a la escorrentía agrícola, causando una degradación a fuentes de aguas esenciales. Una organización local, ETAPA, está particularmente preocupada con dos de las cuencas hidrográficas de Cuenca, el Tomebamba y el Yanuncay, donde la producción agropecuaria es muy común. Debido al mal manejo de los desechos y la escorrentía en estas cuencas, ETAPA proyecta que para el año 2030 habrá un déficit de agua de ~5% del agua. Para abordar este problema, ETAPA busca tomar medidas preventivas para proteger las fuentes de agua de Cuenca.

### **El Proceso: Un guía para entender el problema de la escorrentía agrícola en Cuenca**

Este proyecto sirve para apoyar el objetivo de ETAPA en prevenir la contaminación de los ríos Tomebamba y Yanuncay al entender las características más relevantes, las actividades agropecuarias, y la relación social dentro de las cuencas, para luego desarrollar un conjunto de recomendaciones para mejorarlas. Para cumplir el objetivo de este proyecto, nosotros desarrollamos tres objetivos específicos: determinar las características relevantes y el uso del suelo en las cuencas hidrográficas para identificar la mayor fuente de daños ambientales, desarrollar un entendimiento de las perspectivas de los granjeros en cuanto a sus prácticas actuales, y sus efectos medioambientales correspondientes, al igual que su relación con ETAPA, e investigar y disseminar recomendaciones para que ambos, los granjeros y ETAPA, lo puedan utilizar.

Para cumplir con estos objetivos, nuestro proyecto trabajó en tres fases: inspiración, ideación e implementación. Estas fases formaron el acercamiento que nuestro equipo tuvo en fortalecer las relaciones entre los beneficiarios de este proyecto y en crear soluciones que acomoden sus necesidades. En fase de inspiración, nosotros utilizamos recorridos guiados, programas de

observación, y entrevistas mientras trabajábamos en las cuatro granjas a lo largo de las cuencas del Tomebamba y el Yanuncay para obtener un entendimiento de las fuentes principales de la escorrentía agrícola, al igual que tener una mejor percepción en las vidas de los granjeros y sus perspectivas en cuanto a sus prácticas agropecuarias, el medio ambiente, y ETAPA. En la fase de ideación, nosotros pensamos y redactamos un conjunto de recomendaciones para albergar nuestros hallazgos, decidiendo que alentando un cambio social primero permitiría una adopción exitosa de las prácticas de conservación en un futuro. Durante esta fase, nosotros también solicitamos retroalimentación de ETAPA en cuanto a la viabilidad, deseabilidad, y factibilidad de las recomendaciones propuestas, y luego refinándolas de manera apropiada. Finalmente, en la fase de diseminación, nosotros creamos y distribuimos un reporte final para ETAPA en el cual detallamos los hallazgos principales de nuestro proyecto y las recomendaciones. La intención de este reporte es para que ambos, ETAPA y los granjeros, lo utilicen en el futuro.

### **Los Hallazgos: Una Percepción en los Contribuyentes de la Escorrentía Agrícola a los Ríos**

Luego de un análisis crítico de los datos recolectados durante la fase de inspiración de nuestro proyecto, nosotros pudimos entender las preocupaciones medioambientales en las granjas diferentes, al igual que entender las perspectivas de los granjeros en cuanto a su habilidad y disposición en adoptar nuevas prácticas. Primero, nosotros determinamos que el manejo de desechos dentro de las granjas constituye una amenaza al medio ambiente; en la cuenca del Tomebamba, la fuente principal de contaminación radica de un mal manejo del estiércol de vacas y de peces. Nosotros también descubrimos que aunque las granjas son generalmente conscientes del medio ambiente, aún existen unas lagunas de conocimientos en cuanto a los efectos de la contaminación. Por ejemplo, a estos propietarios usualmente les faltaba una percepción en cuanto a la severidad de la escorrentía agrícola, ignorando los efectos de la contaminación en la vida silvestre y estableciendo que los animales no contribuyen a casos severos de la eutrofización. Otro de los hallazgos fue que la habilidad y disposición de los granjeros puede impedir la adopción de nuevas prácticas, radicando de una falta de interés y recursos, al igual que por las relaciones tensas que existen entre ellos y ETAPA. Esto afectó nuestras recomendaciones, ya que tuvimos que enfocarnos en sugerir prácticas de conservación que son rentables y que no requieran mucho tiempo, al igual que recomendaciones que alberguen las tensiones que existen entre ETAPA y los propietarios. Finalmente, nosotros concluimos que ETAPA considera recomendaciones exitosas en cuanto a la escorrentía agrícola, al igual de que ellos podrían aportar en cuanto a las recomendaciones propuestas. Esencialmente, ETAPA quiere enfocarse en mejorar sus relaciones con los propietarios para facilitar la implementación de estrategias de manejo y utilización de estiércol para prevenir la escorrentía.

### **El Resultado: Un Paso en la Dirección Correcta para la Protección de las Fuentes de Agua de Cuenca**

Nuestro trabajo en el campo destacó que las relaciones tensas entre ETAPA y los granjeros pueden influenciar negativamente la adopción de las prácticas de parte de los propietarios, por ello nosotros recomendamos que ETAPA primero se enfoque en fortalecer las relaciones con los propietarios, y luego abogue por la adopción de prácticas de conservación para prevenir la escorrentía agrícola. Debajo tenemos varias estrategias que ETAPA puede utilizar para mejorar las relaciones entre ellos y los propietarios:

- **Modificar el Sistema del PCA para Priorizar a los Propietarios:** Nosotros recomendamos que ETAPA cambie su método de identificar a los granjeros con los que van a trabajar. Aunque nosotros recomendamos que ETAPA continúe con su método actual, el PCA, para identificar las áreas de preocupación medioambiental en las cuencas del Tomebamba y el Yanuncay, nosotros también proponemos que ETAPA colaboren con los granjeros que estén dispuestos a trabajar con ellos, en vez de forzar relaciones con el fin de proteger al medio ambiente. Al hacer esto, se crearía una cultura de colaboración entre ambos grupos, permitiendo el éxito de la conservación de las cuencas.
- **Albergar Eventos Sociales y Culturales:** Nosotros recomendamos que ETAPA anfitrione eventos sociales y culturales para los granjeros, con el fin de fortalecer las relaciones entre ambos grupos. Aquí tenemos dos eventos que ETAPA podría organizar:
  - **Almuerzo:** Nosotros recomendamos que ETAPA organice e invite a los propietarios a un almuerzo, en el que ETAPA les de una presentación sobre el déficit de agua futuro, su participación en la prevención de este déficit, sus metas futuras en cuanto a la protección de los recursos hídricos, y cómo cumplir estas metas beneficiarían a todos. Al hacer este almuerzo, la relación entre ETAPA y los propietarios sería más fuerte, y los haría sentir como si ETAPA los están llamando como expertos para ayudarlos en sus esfuerzos preventivos.
  - **Celebración Anual:** Nosotros recomendamos que ETAPA albergue una celebración anual para reconocer el arduo trabajo de los granjeros y su colaboración con ETAPA. Durante este evento, nosotros recomendamos a que ETAPA le provea un pequeño regalo de aprecio a los granjeros, al igual que una presentación explicando el progreso de ETAPA en las cuencas a través del año, resaltando la importancia que tienen los granjeros en estas hazañas. Esto hará que los granjeros se sientan como parte del equipo de ETAPA, en vez de intrusos, mejorando la relación entre ambos grupos.
- **Organizar un Intercambio de Experiencias:** Nosotros proponemos que ETAPA invite a granjeros de cada cuenca a un evento pequeño e informal en la cual ellos tendrán la oportunidad de hablar entre ellos sobre las prácticas utilizadas dentro de sus granjas, elaborando los beneficios y limitaciones de estas. El propósito de esto es permitir que los granjeros discutan y consideren la implementación prácticas que son ecológicas en su propiedad sin la influencia de ETAPA. Esto será beneficioso para ETAPA ya que le

quitaría la presión a ETAPA de ser los que proponen prácticas nuevas, lo que aliviaría las tensiones. Si evento es exitoso, nosotros recomendamos a que ETAPA albergue este evento anualmente a una mayor escala, específicamente invitando a los granjeros que implementen técnicas ecológicas a hablar sobre sus prácticas.

- **Recolectar Más Información sobre las Relaciones:** Nosotros recomendamos que los representantes de ETAPA trabajen para recolectar más información en cuanto a sus relaciones con los propietarios. Es necesario obtener más información e incrementar el conocimiento en cuanto a estas relaciones para que ETAPA pueda mejorarlas, haciendo que los granjeros sean una parte integral del trabajo de ETAPA. Temas que podrían explorar incluyen lo que las personas generalmente piensan de ETAPA, lo que las personas piensan del propósito de ETAPA, y que las personas opinan que hacen los representantes de ETAPA a diario.

Una vez que las relaciones entre ETAPA y los propietarios mejoren, ETAPA puede empezar a introducir y promover nuevas prácticas para evitar la contaminación agrícola en las propiedades. Nosotros recomendamos que ETAPA albergue talleres para abordar estas prácticas, explicando los beneficios y limitaciones de ellas. Dado a que el mal manejo de estiércol en las propiedades contribuye a la mayoría de la escorrentía agrícola, proponemos algunas recomendaciones relacionadas al manejo y utilización de estiércol:

- **Expandir los Bosques de Ribera:** Dado el tamaño inadecuado de las zonas de ribera, además de su importancia en la prevención de la escorrentía agrícola, recomendamos que los granjeros y ETAPA trabajen juntos para expandir los bosques de ribera. Las limitaciones principales de esta recomendación son el costo de implementación, la reducción del área de pastoreo, y el tiempo requerido para mantenerlas.
- **Construir un Digestor Anaeróbico:** Muchas propiedades en las cuencas del Tomebamba y el Yanuncay se beneficiarían de la instalación y utilización de un digestor anaeróbico. Estos digestores reducen los efectos dañinos de los nutrientes del estiércol, convirtiéndolo en un producto capaz de ser usado como un fertilizante orgánico. Aunque el fertilizante gratis y la reducción de la contaminación son beneficios obvios de los digestores, hay algunos inconvenientes, como la complejidad de construirlos.
- **Construir Pilas de Compost:** Recomendamos que cada propietario construya una hozada aireada con el fin de manejar el estiércol producido en las propiedades. Para construir la pila y optimizar sus capacidades, se debe tomar en consideración su aireación, la proporción de carbono a nitrógeno, el nivel de humedad, y la temperatura. El compost es beneficioso porque produce un abono que mejora el suelo y que tiene un menor potencial para degradar la calidad del agua. Sin embargo, el compost tiene limitaciones como el costo de construcción y el mantenimiento que se le debe dar.
- **Establecer un Programa de “Manure Share,” o Compartir de Estiércol:** Nosotros recomendamos a que ETAPA y los granjeros trabajen juntos para establecer un programa de “Manure Share,” o compartir de estiércol, en las cuencas hidrográficas. En este

## FARMING WITHOUT HARMING

programa, ETAPA ayudaría a coordinar, con las asociaciones de los granjeros, una línea telefónica utilizada para facilitar el intercambio de estiércol. Nosotros recomendamos que ETAPA inicie esto como un programa piloto con algunos granjeros, y, si es exitoso, que expandan el programa para incluir a otras personas que necesiten el estiércol. Mientras que este programa no brinda beneficios económicos a los granjeros, al igual que previene la escorrentía agrícola directamente, hay limitaciones para el programa, como organizar la logística del programa.

Las recomendaciones propuestas permitirán la reducción gradual de la escorrentía agrícola en las cuencas del Tomebamba y el Yanuncay, beneficiando directamente la comunidad de Cuenca al prevenir el déficit de agua. Debido a la naturaleza gradual de estas recomendaciones, nosotros aconsejamos que ETAPA y los granjeros sean pacientes y comprensivos durante el proceso, tomando en cuenta que todos están trabajando para la meta que tienen en común de mejorar el suministro de agua de la ciudad. Una vez se hayan establecido mejores relaciones entre ambos grupos, ETAPA puede proceder en recomendar prácticas de conservaciones y asistir a los propietarios en su implementación.

## **Authorship Page**

### **Jack Grubbs**

Jack researched and wrote about our project site, Cuenca Ecuador. He was also one of the primary editors, spending many hours rereading our report, checking for grammatical errors, sentence structure, and punctuation. Jack further contributed through his strong writing skills, often reworking sections until they effectively explained the purpose behind them.

### **Hong Chon Ng Fang**

Hong served as the primary translator between English and Spanish during our project and the production of our report. He also played an important role in the writing and research of certain topics, including the manure share program. On top of this, Hong spent a lot of time reading reports we received from ETAPA to supplement our paper in regard to the project site, and ETAPA's previous work.

### **Adam Peternell**

Adam contributed to the report through his research and writing of the technical and social solutions to agricultural contamination. He also worked on editing the report, focusing on the structure and flow of sections. More specifically, Adam helped clarify any points he felt would be confusing to readers, often questioning the purpose and intent behind different sections or sentences.

### **Olivia Verdone**

Olivia contributed to the report through her research and writing, regarding the environmental and health implications of agricultural contamination, as well as different case studies in which organizations worked to reduce agricultural runoff. Similar to Jack, she was another primary editor focusing on grammatical errors, sentence structure, and punctuation. Olivia was especially helpful in her organizational skills in terms of the paper's overall narrative.

## Table of Contents

Abstract	iii
Resumen	iii
Acknowledgments	iv
Agradecimientos	v
Executive Summary	vi
The Process: A Guide to Understanding the Problem of Agricultural Runoff in Cuenca	vi
The Findings: An Insight Into the Contributors of Agricultural Runoff Into the Rivers	vii
The Outcome: A Step in the Right Direction Towards Protecting Cuenca’s Water Sources	vii
Resumen Ejecutivo	x
El Proceso: Un guía para entender el problema de la escorrentía agrícola en Cuenca	x
Los Hallazgos: Una Percepción en los Contribuyentes de la Escorrentía Agrícola a los Ríos	xi
El Resultado: Un Paso en la Dirección Correcta para la Protección de las Fuentes de Agua de Cuenca	xii
Authorship Page	xv
Table of Contents	xvi
List of Figures	xviii
List of Tables	xix
Glossary	xx
Chapter 1: The Problem	1
Chapter 2: The Foundation	2
2.1 Agricultural Runoff and Its Implications	2
2.2 Prevention of Agricultural Runoff	3
2.3 Manure Management Strategies	3
2.4 The Importance of Collaboration and Understanding Farmers’ Perspectives	5
2.5 Land Use in the Tomebamba and Yanuncay Watersheds in Cuenca, Ecuador	6
Chapter 3: The Process	9
3.1 Inspiration	9
3.2 Ideation	9
3.3 Dissemination	10
Chapter 4: The Findings	11
	xvi



## FARMING WITHOUT HARMING

4.1 Current Waste Management Techniques Pose Environmental Threats	11
4.2 Farmers are Environmentally Aware, Though Some Gaps in Understanding Exist	12
4.3 The Farmers' Ability and Willingness may Hinder the Adoption of New Practices	12
4.3.1 There is a lack of interest and available resources on the farms	13
4.3.2 There are strained relations between ETAPA and the farmers	13
4.4 ETAPA Seeks to Implement Manure Management Strategies as Well as Improve Their Relationships with the Farmers	15
4.5 Conclusion	16
Chapter 5: The Outcome	17
5.1 Building stronger relationships	17
5.2 Implementing new Practices	19
5.3 Conclusion	21
References	22
Appendices	28
Appendix A. Gantt Chart	28
Appendix B. Guided Tour Interview Guide	29
Appendix C. Principal Sources of Contamination on Each Farm	32
Appendix D. Semi-structured Interview Guide and Responses	39
Appendix E. Themes and Questions to Investigate in the Future with the Farmers	55

## List of Figures

Figure 1. Map of watersheds in Cuenca	6
Figure 2. Supply and demand of water research done by ETAPA	7
Figure 3. Farmer 1: Break in fence that allows cows to drink from the Tomebamba River	32
Figure 4. Farmer 1: Water tanks used to raise trout lack adequate filtration systems, allowing wastewater from the tanks to flow into the Tomebamba River	33
Figure 5. Farmer 2: Man-made channel where manure is shoveled and hosed into after the milking process; this channel leads into natural channels (shown in Figure 6) which eventually flow into the Tomebamba River	34
Figure 6. Farmer 2: Natural channel that carries the wastewater from the man-made channel (shown in Figure 5) to the Tomebamba River	35
Figure 7. Farmer 3: Man-made channels that run through the pasture and carry the produced wastewater into the Yanuncay River	36
Figure 8 Farmer 4: The spraying of cow manure after the milking process which produces wastewater that eventually flows into channels (shown in Figure 9) that enter the Yanuncay River	37
Figure 9. Farmer 4: The produced wastewater from the hosing process (shown in Figure 8) running into channels that lead into the Yanuncay River	38
Figure 10. Cows drinking from river	41
Figure 11. Compost Pile	41
Figure 12. Irrigation system	41
Figure 13. Manure storage facility	42
Figure 14. Mixed fertilizer, chemical fertilizer, and chicken fertilizer	42
Figure 15. Traditional farm (left) and semi-technological farm (right)	43
Figure 16. Eutrophic river	43

## **List of Tables**

Table 1. Summary of Important Farm Characteristics	8
Table 2. Gantt Chart Outlining the Time Frame of our Methods	28
Table 3. Farm Characteristics Determined from Guided Tours Part 1	29
Table 4. Farm Characteristics Determined from Guided Tours Part 2	30
Table 5. Farm Characteristics Determined from Guided Tours Part 3	31

## Glossary

**Anaerobic digesters:** airtight chambers for biogas production (Wilkie, 2017).

**Cyanobacteria:** bacteria that participates in photosynthesis, also known as blue-green algae (Vermont Department of Health, 2017).

**Dysentery:** type of gastroenteritis where blood is present in diarrhea (Buff, 2017, Jul 27).

**E.coli (escherichia coli):** large and broad group of bacteria found in foods and both intestines of animals and human beings (Oram, 2014).

**Eutrophication:** the enrichment of nutrients in water bodies which produces cyanobacteria (EEA, 2017).

**Feasibility:** What is technically and organizationally possible (IDEO, 2011).

**Fecal coliform:** bacteria found in fecal matter of warm-blooded animals (Centers for Disease Control and Prevention, 2017).

**Forage Crops:** Crops that are cultivated primarily for animal feed (FAO, 1994)

**Gastroenteritis:** stomach flu (United States National Library of Medicine, 2017, Nov 06).

**Hemoglobin:** a protein inside of red blood cells that uses iron to transport oxygen from the lungs to parts of the body (Davis, 2017, Nov 8).

**Hepatitis:** group of diseases that negatively affect the liver (Web MD, 2017).

**Hypoxic:** oxygen deprived (Boudreau, et al., 2011).

**Human-centered design (HCD):** a process aimed at hearing the voices of one's constituents, creating innovative solutions to meet their needs, and delivering solutions with financial sustainability in mind (IDEO, 2011).

**Irrigation:** watering of land or crops to promote growth (Centers for Disease Control and Prevention, 2016).

**Mineralization:** the decomposition or oxidation of the chemical compounds in organic matter releasing the nutrients contained in those compounds into soluble inorganic forms that may be plant-accessible (White, 2005).

**Nonpoint source pollution (runoff):** caused by melted snow or rainfall moving through and across the ground; the moving water picks up pollutants and carries them to bodies of water (US EPA, 2015).

**Páramo:** A high treeless plateau in tropical South America with rocky soil and poor vegetation (WordReference, 2018).

**Photoautotrophs:** Species who need sunlight to make energy (EEA, 2017).

**Soil erosion:** the process by which topsoil is worn away (Ontario Ministry of Agriculture, Food, and Rural Affairs, 2016).

**Typhoid fever:** contracted through consumption of contaminated food or water and causes high fever, constipation or diarrhea, and headaches (Mayo Clinic, 2015, Jul 11).

**Viability:** What can be financially possible (IDEO, 2011).

## **Chapter 1: The Problem**

### **Water Degradation and Agricultural Runoff**

The United Nations General Assembly acknowledges access to safe water as a basic human right (United Nations [UN], 2010). Access to safe water promotes widespread prosperity on both social and economic fronts, which in turn can lower health care expenditures, increase school attendance, reduce poverty levels, and allow more people to remain productive contributors to the economy. However, insufficient access to safe water can have implications other than those affecting a region's educational and economic opportunities; it can also lead to serious health complications, such as cholera, diarrhea, and typhoid. A 2015 study found that, worldwide, 844 million people lacked access to clean water, which in many cases was not a problem of physical availability, but rather one of available water becoming unusable due to inadequate wastewater management (WHO, 2017). Though this wastewater often originates from urban and industrial processes, a large contribution stems from poor agricultural land use (FAO, n.d.).

The city of Cuenca, Ecuador also struggles with poor agricultural land use, causing the degradation of essential water sources from runoff. While the municipality— along with the help of a local organization, the Empresa Pública Municipal de Telecomunicaciones, Agua Potable, Alcantarillado y Saneamiento, Subgerencia de Gestión Ambiental (ETAPA) — has thus far been successful in providing clean water to its residents, they project a ~5% water deficit by the year 2030 due to the harmful effects of runoff (ETAPA, 2004). This is especially concerning to ETAPA in two of the city's watersheds, the Tomebamba and Yanuncay, where agricultural production is most prevalent. To respond to this issue, ETAPA seeks to prevent agricultural runoff into the rivers by addressing poor waste management.

We supported ETAPA's goal of preventing the contamination of the Tomebamba and Yanuncay rivers by understanding the notable conditions, agricultural activities, and social relationships in the watersheds, later developing recommendations to improve them. To accomplish this goal, we followed three main objectives. First, we determined different farm characteristics and land uses along the rivers to identify sources of environmental harm. Second, we developed an understanding of the farmers' perspectives regarding their current practices, the corresponding environmental effects, as well as their relationships with ETAPA. Lastly, we investigated and disseminated recommendations for both the farmers and ETAPA to utilize. This plan worked to understand the problem of agricultural runoff so that ETAPA, the farmers, subsequent Interdisciplinary Qualifying Project groups, and other organizations have the resources to move forward in executing a plan to reduce runoff into the Tomebamba and Yanuncay watersheds.

## **Chapter 2: The Foundation**

### **Agricultural Runoff and its Presence in Cuenca**

In this chapter, we begin with the causes of agricultural runoff, as well as its harmful effects. Next, we discuss several runoff prevention methods and manure management strategies. After, we consider the importance of understanding farmers' perspectives regarding conservation practices, as well as collaborating with farmers when suggesting new practices. Finally, we explore how ETAPA and the city of Cuenca work to protect water quality, specifically through the use of the technical assistance program, Manejo Integrado de Cuencas Hidrográficas para la Protección de Agua (MICPA), or the Integrated Management of the Watersheds for the Protection of Water.

#### **2.1 Agricultural Runoff and Its Implications**

Agricultural runoff is a form of nonpoint source pollution, when rain, snowmelt, or water from irrigation travels across farm fields, carrying pollutants, such as herbicides, fertilizers, and other wastes, into bodies of water (US EPA, 2015; United States National Library of Medicine, 2017). Factors that can contribute to agricultural runoff are overgrazing, animal waste accumulation, excess application of chemicals and fertilizers, and over-irrigation. Often, agricultural runoff results in the oversupply of nitrogen and phosphorus to bodies of water, which destroys wildlife habitats and water sources by encouraging eutrophication (Executive Office of Energy and Environmental Affairs [EEA], 2017).

Eutrophication causes accelerated weed and cyanobacterial, or blue-green algae, growth (Boudreau, Costa, Hall, Hunt, McDaniel, Ramroop, Teng, 2011). This excess growth drastically reduces the water's available oxygen content for other species, often causing a large number of fish kills, for example. In addition, these plants block sunlight from penetrating the water's surface, causing photoautotrophs to die. When left unresolved, excessive algae growth ultimately leads to dead zones, or hypoxic regions that cannot sustain animal life (EEA, 2017; Boudreau, et al., 2011).

Besides the environmental effects of agricultural runoff, there are serious health complications that can result from the consumption of agriculturally contaminated water, as it typically contains high quantities of nitrogen and phosphorus. Upon consuming nitrogen, the iron in hemoglobin oxidizes, converting into a compound unable to distribute sufficient amounts of oxygen to the body; when excess phosphorus is consumed, it can affect the way the body utilizes other minerals, as well as potentially cause diarrhea and the hardening of organs (Rehman, 2001; Sheldon, 2017). Agriculturally contaminated water can also contain fecal coliform and E.coli, which when consumed, can lead to typhoid fever, hepatitis, gastroenteritis, dysentery, and kidney failure (EEA, 2017; Centers for Disease Control and Prevention, 2017; Oram, 2014).

### **2.2 Prevention of Agricultural Runoff**

Many prevention methods exist to minimize the environmental and health complications of agricultural runoff. Two commonly used techniques are correcting excess fertilizer use and implementing riparian zones.

Often, farms apply excessive amounts of fertilizer to the point in which forage crops are unable to absorb all of the fertilizer's nutrients. Eventually, these excess nutrients leach into nearby water sources, contributing to agricultural runoff. The most reliable way to prevent runoff from inappropriate fertilizer use is to determine the nutrient levels in the fertilizer used, as well as the appropriate amounts needed for forage crop growth, and then correcting for them. Farmers can use either commercial or organic fertilizers. Commercial fertilizers are easier to manage, as farmers can buy them with varying compositions of nitrogen, phosphorus, potassium, and micronutrients that correspond to the desired forage crops' needs. On the other hand, using organic fertilizer, such as manure, makes obtaining the correct levels of nutrients more complicated, as farmers need to address factors such as the type of livestock, livestock feed, and manure storage system used on their farms (Baldi, Toselli, Marcolini, Quartieri, Cirillo, Innocenti, Marangoni, 2010; US EPA, 2005).

In addition to correcting excess fertilizer use, growing riparian zones is another effective way to prevent agricultural contamination. Riparian zones are large strips of vegetation that slow the velocity of contaminated water to a point where large suspended particles can settle and be absorbed, consequently reducing the number of pollutants able to enter bordering water sources (Sanders, 2016). Additionally, the plant roots in these strips absorb nutrients and contain bacteria that use the runoff's excess nitrogen as an energy source, therefore reducing the water's nitrate concentration. The most important factor in creating an effective riparian zone is its width, as greater widths yield greater efficiencies. The trade off, though, is how much land can be given up to grow adequate riparian zones while still allowing farmers enough room to yield their desired products (Hawes & Smith, 2005).

### **2.3 Manure Management Strategies**

Another way to prevent agricultural runoff is through proper manure management as it repurposes excess manure, directly preventing its capability to contaminate the environment. Common manure management strategies include using livestock waste as fertilizer, constructing a compost pile or anaerobic digester, and establishing a manure share program.

Often, farmers manage livestock manure by applying it to fields as organic fertilizer. This process is advantageous, as it is free and can reduce the amount of soil runoff and erosion (Baldi, et al., 2010). However, it is difficult to effectively utilize manure without causing environmental harm, as one must take into account many factors, such as controlling the ratio of nutrients for the desired forage crop. Another factor that must be taken into account is choosing the appropriate

## FARMING WITHOUT HARMING

application method, determined by the animal wastes' consistency. Lastly, one must determine the appropriate timing of manure application to maximize forage crop yield. For example, in temperate climate zones, applying manure several months before planting seeds permits the mineralization of nutrients, making them readily available for plant uptake (Food and Agriculture Organization of the United Nations, 1984).

Another common manure management strategy is composting, which works by combining organic matter, such as livestock manure and vegetable wastes, together in a pile (Department of Animal Science, n.d.). Commonly used forms of composting include aerated windrows, aerated static piles, and in-vessel composting. Aerated windrow composting involves creating windrows, or long piles, of organic waste that need to be turned periodically to aerate the pile. Aerated static pile composting involves forming a large pile of organic waste that is aerated by a system of underground pipes. In-vessel composting utilizes a drum, typically made of concrete, to deposit and mix organic wastes. Much like in aerated windrow composting, in-vessel composting requires the periodic turning of the pile to ensure sufficient aeration (US EPA, 2016). In all of these composting methods, microorganisms grow and convert the wastes into a fertilizer that is much safer to spread on fields than raw manure (Department of Animal Science, n.d.). Benefits to composting include a reduction in the volume of waste present on farms, as well as a product that not only promotes soil health, but is less likely to degrade local water sources (Gamroth, 2012; Hill, 1975). Unfortunately, though, composting is more costly and time consuming than other alternatives, as it requires resources other than manure to be functional (Gamroth, 2012).

A similar manure management strategy to composting is constructing and utilizing an anaerobic digester, as it creates fertilizer from animal waste that is safe to spread on fields. An anaerobic digester is an airtight tank that stores a mixture of animal waste and water, resulting in the breakdown of harmful pollutants, while also producing nutrients that are readily available for plant uptake (Manure Management Technology Development Team, 2007). There are many different types of anaerobic digesters, each with their own benefits and limitations in regard to size, cost, and technical complexity (Extension, 2012, Apr 2). A common type of digester implemented on farms is a polyethylene tube digester, as it is cheap and easy to build (Luer, 2010).

Lastly, establishing a manure share program is another effective way to manage excess manure. These programs connect livestock owners who have excess manure to those in need of fertilizer, such as other farmers, gardeners, and landscapers. A benefit to these programs is that farmers can make a profit from selling their excess manure, while also reducing the chances of agricultural runoff on their properties. However, they can be time consuming, as it is often difficult to coordinate the manure exchange. An institution that has seen great success in its manure share program is the University of Illinois. Much of their success can be attributed to their user-friendly online platform, which allows both individuals seeking manure and individuals who have excess



manure to make listings. In these listings, people indicate their location and the type of manure they have, or are looking for, allowing for an easier exchange (National Hog Farmer, 2012).

### **2.4 The Importance of Collaboration and Understanding Farmers' Perspectives**

When attempting to implement conservation practices, like the ones previously mentioned, government organizations often undervalue the importance of understanding farmers' perspectives and collaborating with farmers to create mutualistic relationships and plans. Instead, many governments organizations practice top-down management, where those who do not comply with environmental legislation receive penalties. This often creates strained relations between the organizations and the people, hindering the adoption of suggested practices and the compliance with environmental regulations (Vanclay, Lawrence, 1994). Recent studies have investigated these strained relationships and have found that to more successfully recommend conservation practices, government organizations should take into consideration what motivates farmers to adopt new practices. Additionally, these studies emphasized the importance of collaborating with farmers when suggesting conservation practices and creating restoration plans (Judit, Navarro, Labianca, 2016).

One study in Malaysia determined that a major factor affecting a farmer's willingness to adopt conservation practices involves finances. Out of six primary motivators, "[receiving] payment for conservation" was ranked lowest in influencing the farmers to adopt environmentally-friendly practices, as this suggested to the farmers that the government undermined their financial self-sufficiency (Ryan, Erikson, Young, 2003). Although the "receiving payment" incentive did not greatly motivate farmers, another study indicated that the decision to adopt conservation practices was largely dependent on production benefits or losses (Lankester, Valentine, 2012). For example, farmers with higher levels of production were less likely to adopt new practices that seemed time- and land-restrictive, as they felt their production would decrease (Defrancesco, Gatto, Runge, Trestini, 2008).

An additional factor that influences the adoption of conservation practices is the farmers' knowledge of the practice, as well as their awareness of the necessity to implement new practices due to the current environmental state. For instance, farmers in Malaysia were more likely to partake in conservation management after becoming aware of and understanding the benefits and limitations of different conservation practices (Abdulkarim, Yacob, Abdullahi, Radam, 2017). This finding is also seen in the Gulf of Mexico, where suggested strategies were not adopted due to poor public awareness of the severity of the growing dead zone (Babcock & Kling, 2008).

Aside from different motivators, studies also illustrate that collaborating with the farmers is essential in the adoption and implementation of new practices. For instance, one place that has seen great success in its restoration efforts is the Baltic Sea, where an organization, known as the Baltic Compass, worked to understand the farmers' perspectives towards agricultural pollution

## FARMING WITHOUT HARMING

and conservation practices (Baltic Compass, n.d.). From their collaboration with the farmers and the recommendation of new practices, the Baltic Sea has since seen a 20% and 17% decrease in phosphorus and nitrogen inputs, respectively (McCrackin, Svävback, n.d.). Their work also demonstrated that to successfully recommend new practices, they must be presented to the farmers as outcome based procedures, instead of a rigid, outlined measures, and that using positive language increased the farmers' willingness to adopt new practices (Baltic Compass, n.d.). Similarly, the work of the KwaZulu-Natal Department of Agriculture and Environment in South Africa emphasized the importance of collaborating with the farmers when recommending new practices, as their efforts proved ineffective due to their top-down approach. Their project, LandCare, was created to make better use of the land in the area and to slow soil degradation using conservation agriculture. However, the representatives of this program presented themselves as the technical experts, there to teach the farmers about better practices to use on their farms, instead of making the farmers feel like a part of their team, working towards a common goal. Consequently, little improvements were made. Their work demonstrates that without working alongside farmers to make change, conservation practices are unlikely to become adopted (Sterve, 2010).

### 2.5 Land Use in the Tomebamba and Yanuncay Watersheds in Cuenca, Ecuador

Cuenca, Ecuador, the capital of the Azuay Province, is situated in the Andes Mountains. Four main rivers run through the city—the Tomebamba, the Yanuncay, the Machángara, and the Tarqui—all which compose Cuenca's watersheds, as seen in Figure 1 (MacLeod, Knapp, & Pozo Vélez, 2017). Due to a rise in runoff from agricultural land use in these watersheds, ETAPA projects that by the year 2030 there will be a ~5% water deficit, as seen in Figure 2 (ETAPA, 2004). The Tomebamba and Yanuncay watersheds are specifically concerning as this is where agricultural land use is most prevalent.

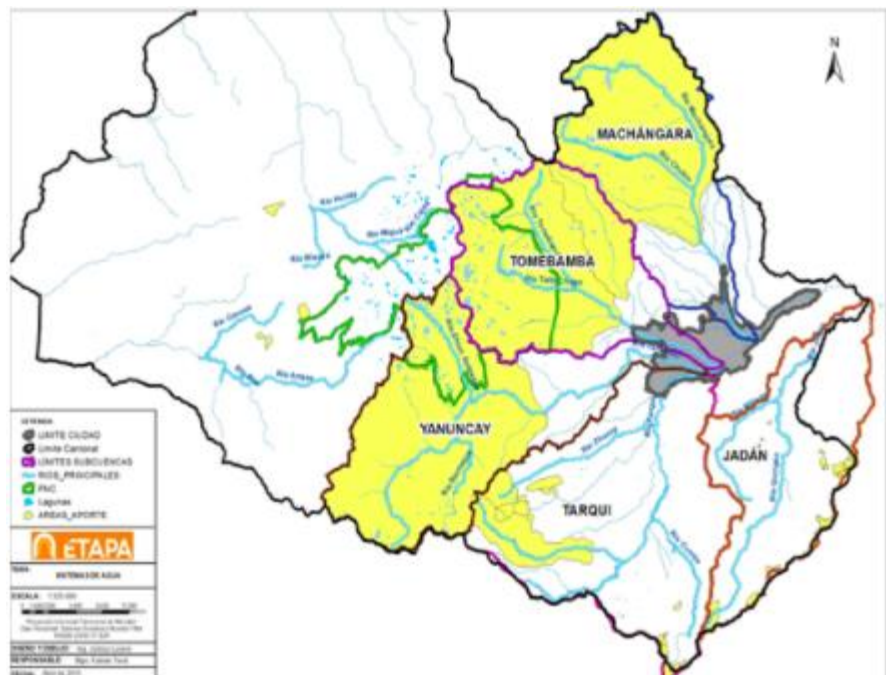


Figure 1. Map of watersheds in Cuenca (ETAPA EP, 2017c)

Along the Tomebamba River, cattle ranching and fish farming are prominent, while along the Yanuncay River, cattle ranching is the primary activity (Subgerencia de Gestión Ambiental,

2017). To address the growing concern in these watersheds, ETAPA is becoming increasingly proactive in its preventative efforts against contamination.

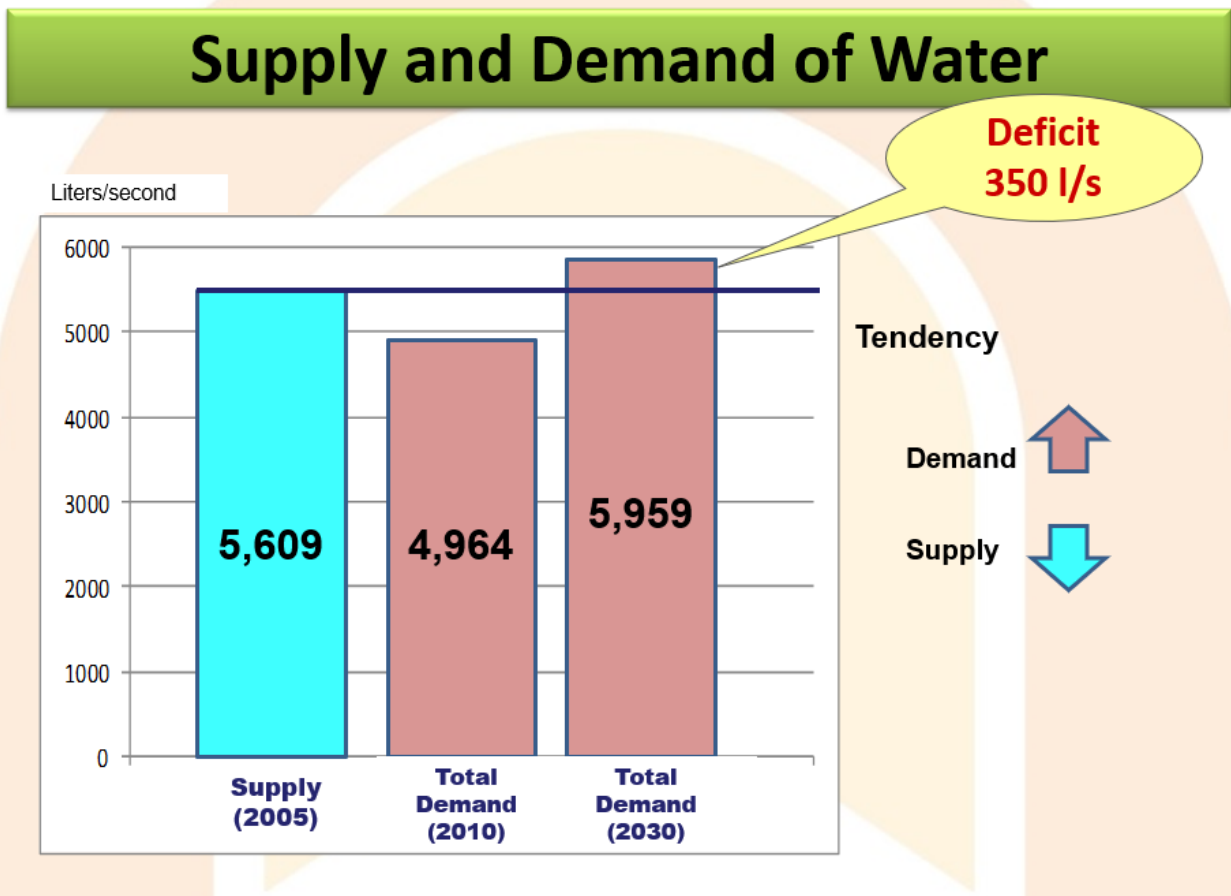


Figure 2. Supply and demand of water (ETAPA, 2004)

ETAPA has invested in many resources throughout the years to expand and improve their water distribution and management system to respond to the projected deficit (ETAPA EP, 2017b). For example, they have established a technical assistance program, known as MICPA, which aims to protect watersheds around the city through the promotion of eco-friendly farm practices. MICPA uses the Manual de Planificación para la Conservación de Áreas (PCA), or the Planning Manual for the Conservation of Areas, to evaluate and score regions based on a set of criteria that describes the environmental value of the land, ultimately identifying the areas in need of greatest intervention.

In accordance with the PCA, MICPA has identified several properties along the Tomebamba and Yanuncay watersheds that have risen environmental concern due to their extensive cattle ranching and fish farming; along the Tomebamba River, they are working with Farmer 1 and Farmer 2, while along the Yanuncay River, they are working with Farmer 3 and Farmer 4 (the real names of the farmers were not used to maintain their confidentiality). Table 1 below highlights important

## FARMING WITHOUT HARMING

characteristics of these farms. For a more detailed table of farm characteristics, please see Appendix B.

*Table 1. Summary of Important Farm Characteristics*

		Tomebamba		Yanuncay	
Owner		Farmer 1	Farmer 2	Farmer 3	Farmer 4
Farm Type		Traditional (cattle ranch & fish farm)	Semi- technological (cattle ranch)	Traditional (cattle ranch)	Semi-technological (cattle ranch)
Total Land (ha)		40	130	27	70
Grazing Land (ha)		12	30	11	12
Number of Workers		2 full time 4 part time	3 full time	2 full time	2 full time
Livestock		Cows Trout	Cows	Cows	Cows
Fertilizer	Chemical	Chemical of Unknown Type (Unknown amount and application rate)	Yaramila, (3 quintales used per ha, applied 3 times per year)	Mixture of Yaramila, Fertiforage, and 184060 Fosforo (4 sacks used per ha, applied 3 times per year)	Fertiforraje, SAM (Unknown amount and application rate)
	Other Organic	Gallinaza (20,000 bags used on total farmland, applied every 3 years)  Manure from trout spread (Unknown amount/applicatio n rate)	None	None	Calcium carbonate (Unknown amount and application rate)  Molasses (Unknown amount and application rate)
Cow Manure Management		Excrement accumulated during milking is spread on fields if workers are available	Defecate and excrement is left in piles	Defecate in current grazing zone, excrement is spread on fields using a hose	Defecate in current grazing zone, excrement is spread on fields using a rake

## **Chapter 3: The Process**

### **A Guide to Understanding the Problem of Agricultural Runoff in Cuenca**

To support ETAPA's goal of preventing the contamination of the Tomebamba and Yanuncay rivers, our team utilized a human-centered design approach to create viable, feasible, and desirable recommendations to avert agricultural runoff. Human-centered design approaches work in three phases— inspiration, ideation, and implementation —to build strong relationships with the project stakeholders and create solutions that accommodate their needs. During the inspiration phase, a design team aims to understand both the problem and the lives of the stakeholders. In the ideation phase, the team analyzes the information collected from the inspiration phase and brainstorms potential solutions to the main issues identified. Finally, during the implementation phase, the team prototypes and modifies their proposed solutions, eventually allowing for their utilization in the stakeholders' communities (Innovation, Design Engineering Organization, n.d.). Our team followed this approach, however, given the fast-paced nature of our seven weeks of fieldwork, we did not work to implement solutions, but rather to disseminate refined recommendations that ETAPA and the farmers could work towards implementing in the future.

#### **3.1 Inspiration**

The inspiration phase of our project focused on gaining an understanding of the environmental threats presented by our partner farms along the Tomebamba and Yanuncay rivers, as well as gaining an understanding of the farmers' lives and perspectives. Through the use of guided tours, observation programs, interviews, and many conversations, our team identified the principal sources of agricultural runoff on each farm, as well as gained insight into the farmers' environmental awareness, willingness to adopt new practices, and their relationships with ETAPA (please refer to Appendix A for a detailed schedule of the utilization of our methods). Our team prioritized ethics while collecting our data, asking permission from the stakeholders to use the gathered information in our report.

#### **3.2 Ideation**

After analyzing the collected information from the inspiration phase, our team brainstormed recommendations that would best accommodate both ETAPA and the farmers' needs, all the while lessening agricultural pollution. From this initial brainstorm, we determined that our recommendations would have to encourage social change first, in order to see any adoption of conservation practices in the future. Therefore, we drafted potential recommendations, placing a large focus on building relationships between ETAPA and the farmers, while also providing alternative waste management strategies. We additionally held weekly meetings, soliciting feedback from ETAPA about our recommendations so we could refine them accordingly. A limitation of our work during this phase was that, due to a lack of time, we were unable to refine our preliminary set of recommendations according to the farmers' feedback, as meetings with

## FARMING WITHOUT HARMING

them continually fell through. However, we did work closely with ETAPA and our project advisors to be inclusive of the farmers' needs and desires that we identified during the inspiration phase of our project.

### **3.3 Dissemination**

Once we refined the recommendations according to the stakeholders' needs, we created a final report that outlined the collected data from each farm, as well as a detailed list of our recommendations. We distributed this report to ETAPA at a weekly meeting for their use in working to prevent agricultural runoff in the Tomebamba and Yanuncay watersheds. We also disseminated this information to the farmers by creating and distributing a pamphlet that outlined our project's motivation, findings, and recommendations.

## **Chapter 4: The Findings**

### **An Insight Into the Contributors of Agricultural Runoff in Cuenca**

Executing the process previously described, we gathered information about the Tomebamba and Yanuncay watersheds to better understand the problem of agricultural runoff. After a careful analysis of the collected data, we were able to understand the existing environmental concerns on the different farms, as well as understand the farmers' perspectives and their ability and willingness to adopt new practices. This guided us in creating viable, feasible, and desirable recommendations.

#### **4.1 Current Waste Management Techniques Pose Environmental Threats**

Before being able to provide recommendations, it was paramount to explore the conditions of the different farms to better understand and identify the environmental concerns in the watersheds. Without having understood the practices used on each farm, especially those that pose environmental threats, it would have been difficult to form appropriate recommendations.

From the use of guided tours and observation programs, our team identified the principal sources of contamination in each watershed (which can be seen in Appendix C). Along the Tomebamba, the main sources of contamination are poor cow manure and fish waste management. On Farmer 1's farm, there are two main sources of contamination: a break in the fence surrounding her pasture and an ineffective filtration system on her fish farm. Fences are often built surrounding pastures to prevent cattle from contaminating the water; however, upon construction on Farmer 1's farm, a small section was left open so the cows could enter and drink from the river. This open area is concerning, as it is likely that the cattle will defecate or transmit diseases into the river, both causing serious environmental effects. Her fish farm also contributes to the contamination of the river, as there is poor management of fish food and waste. Oftentimes, too much food is given to the fish, allowing the excess to settle to the bottom of the tank, along with the fish's waste. From there, a filtration system takes in this contaminated water as a means of treatment before entering the Tomebamba; unfortunately, though, this filter is unable to purify the water completely, allowing this excess organic matter to enter and contaminate the river (Segarra, J. personal communication, Jan 17, 2018). In the case of Farmer 2's farm, the cow manure is mishandled during the milking process, as the excrements are shoveled into a drainage channel that eventually leads to the river. Afterwards, the milking area is hosed down, carrying the residual manure to the drainage channel, thereby directly contaminating the river.

Along the Yanuncay River, the main source of contamination is the mismanagement of cow manure. On Farmer 3's farm, during the milking process, the cattle gather in a specific area of pasture, resulting in the accumulation of manure. Afterwards, the manure is hosed down and dispersed around the area, allowing the produced wastewater to flow into small channels that feed

## FARMING WITHOUT HARMING

into the river. Moreover, the cattle can defecate directly into these small channels, also leading to river contamination. Similarly, on Farmer 4's farm, cow manure accumulates during the milking process, however it is then hosed into concrete tanks for storage. The wastewater produced is later used on the farm as an organic fertilizer, though a portion of it flows into channels that lead to the river.

### **4.2 Farmers are Environmentally Aware, Though Some Gaps in Understanding Exist**

Understanding the farmers' environmental awareness was vital in creating viable recommendations to prevent agricultural runoff. From our semi-structured interviews, we discovered that while the farmers are environmentally conscious, this conscience does not stem from the desire to protect local wildlife habitats, but instead to protect drinking water for human consumption. We also determined that while the farmers have a good grasp on environmental topics, important gaps in understanding exist regarding how severely agricultural runoff can affect a region.

When carrying out the photo-elicitation activity as part of our semi-structured interview, the farmers' responses demonstrated general knowledge of the environmental consequences of cattle ranching. For instance, when shown a photo of cows drinking from a river, the farmers immediately acknowledged how this farming practice would lead to a contaminated river, threatening the water's potability. Farmer 3 pointed out that the cow feces can transfer harmful bacteria to the river, while Farmer 4 mentioned how the cows can transmit tuberculosis into the water when drinking from a water source. Although the farmers demonstrated awareness that cattle can contaminate drinking water, none of them mentioned that contaminated water can also destroy local ecosystems. This indicated to our team that while the farmers are aware of the implications of contaminated water, this awareness is mainly based on the consequences to human life, rather than to wildlife. We were also clued in to their lack of understanding when the farmers were shown a photo of a eutrophicated river and the majority of them did not believe that agricultural runoff was the main contributor to the intense algae growth. Farmer 2, in particular, said "este río tiene que estar cerca de una ciudad," or "this river has to be close a city." When asked why he thought this, he said that while animals can contaminate a river, they cannot contaminate it to this severity, and that human waste and trash had to be responsible for such contamination. This portrayed that the land users along the watersheds are aware that poor farming practices can cause environmental complications, yet they are unaware of how serious these issues can become. Please see Appendix D for more detailed responses from each farmer.

### **4.3 The Farmers' Ability and Willingness may Hinder the Adoption of New Practices**

Understanding the farmers' ability to adopt new practices based on their available resources was crucial in formulating viable recommendations, as a farm's limitations in money, time, and labor can affect the recommendations' effectiveness. In addition, understanding the farmers' willingness



## FARMING WITHOUT HARMING

to adopt suggested alternatives—in terms of their interest in investing on their farms, as well as their relationships with ETAPA— was of great importance.

### **4.3.1 There is a lack of interest and available resources on the farms**

Various activities, such as conversations with the farmers and our resource flow worksheet, informed us that there is a lack of resources on the farms, which may hinder the adoption of new practices. For instance, Farmer 2 used a compost pile in the past due to its production of high quality fertilizer. He also used to make his own food for the cattle, as it was a healthier option than pre-made food. However, he had to stop both of these practices due to financial limitations. By the same token, Farmer 1 has mentioned her lack of free time, due to the upkeep of her ranch, fish farm, and restaurant; for example, she could only meet with us for ten or twenty minutes at a time to do an interview, as she was so preoccupied with her daily tasks. Additionally, Farmer 3 mentioned his lack of time, labor, and money when discussing new practices.

Our conversations and interviews with the farmers also allowed us to determine that regardless of available funds, some farmers have little interest in investing more time and money into their farms. For example, Farmer 1 and Farmer 2 currently want to sell their land, as cattle ranching is not a major source of their incomes and drains a lot of their resources. This indicated to our group that they are unlikely to dedicate themselves to something that is not financially beneficial, stressing to us the importance of forming cost-effective recommendations. Given the general lack of resources on the farms, as well as the general disinterest in investing on the farms, any recommendations made will have to consider the monetary and workforce availability.

### **4.3.2 There are strained relations between ETAPA and the farmers**

Other than identifying the farmers' disinterests and lack of available resources, our group worked to understand the relationships between land users and ETAPA. Through observing ETAPA-farmer interactions and engaging the farmers in a dialogue about ETAPA, we concluded that while land users respect the organization for its hard work around Cuenca, they still distrust ETAPA and their objectives.

We believe this distrust largely stems from a misunderstanding of ETAPA's mission, as we were able to conclude that many of the farmers along the watersheds have a misinformed and negative perception of what ETAPA does. This distrust was visibly apparent during our impromptu visit on a farm in the Tomebamba watershed, as seen in Box 1, when the farmers physically demonstrated the tension between them and ETAPA through avoiding any eye contact with us or the ETAPA representative. However, we noticed that this behavior changed upon explaining ETAPA's motives in working in the area; once the farmers discovered that ETAPA's intentions stem from a more pure and whole-hearted place, their attitude changed entirely. This stressed to us that

## FARMING WITHOUT HARMING

relationships between the two groups are uneasy, in part because of a misunderstanding of the true nature of ETAPA's motives.

### **Box 1**

An ETAPA representative brought our team onto a small farm on the Tomebamba River, explaining to our group how these types of farms contribute less to the river's contamination than our partner farms. As we were speaking, the landowners heard our voices and came out of their house to speak to us. During our introductions with the farmers, the ETAPA representative explained that we are students from a university in the United States, completing a project about water quality in the watersheds, and that he was showing us several people's properties along the Tomebamba River. Throughout these introductions, the farmers never once made eye contact with the us, or the ETAPA representative, instead looking in a different direction.

After conversing for a brief time, a question arose regarding ETAPA's interest on the farm. The farmers stated that they heard ETAPA was working to buy the land away from the people in the area. To this claim, the representative explained that their goal is not to take away people's property, but instead to help implement conservation practices, such as expanding riparian zones along the river, to protect Cuenca's drinking water. Upon clarifying the organization's mission in these farms, the farmers' attitudes changed completely, one of them finally looking at the ETAPA representative, smiling, and saying, "Pues, eso cambia la situación," or "Well, that changes things."

This strained relationship became further emphasized when we engaged the farmers in a dialogue about ETAPA, asking them what people in the area think of the organization. The farmers responded to this question with a wide variety of reactions, but ultimately gave unclear responses that avoided the question at hand. For example, Farmer 1 avoided giving much detail about her, or other farmers' opinions, appearing uncomfortable and unfocused throughout the entire interview, demonstrating her general discomfort in speaking with us, as seen in Box 2a. Additionally, Farmer 4 ignored the question altogether, answering with multiple unrelated responses about what ETAPA does, even after multiple clarifications from our team, as described in Box 2b. It also appeared as though he was nervous throughout the interview, looking

constantly towards the door, leading us to believe he felt pressured to answer in a certain way, especially being in the ETAPA building for the interview. Given that these responses were often ambiguous and avoidant of the question, it became apparent that the farmers were treading lightly so as to not incriminate themselves, further demonstrating their tense relationships with ETAPA. Also, it is possible that their responses remained indirect and brief to appease ETAPA and prevent future complications, as the farmers knew we were working alongside ETAPA.

### **Box 2a**

During an interview with Farmer 1, we asked her a question regarding what people in the Tomebamba watershed think of ETAPA. She immediately sighed and put her face in her hands, saying, “No tengo nada en contra de ellos,” or “I don’t have anything against them” with a slight chuckle. We then asked the question again, emphasizing that we were curious of what other people in the area think of ETAPA, to which she replied by saying she had no idea what others thought of ETAPA because she does not have time to talk to other people. In general, throughout the interview, Farmer 1 was frequently turning away from us and asking us how many questions we had left.

### **Box 2b**

During an interview in the ETAPA office with Farmer 4, we asked him about what people in the Yanuncay watershed generally think of ETAPA. To this question, he first responded by saying that ETAPA helps the farmers with production on their farms. We then clarified the question again, restating that it was about the people’s opinions and perspectives of ETAPA. To this reframed question, he said that ETAPA helps to manage the soil and land on their properties. Throughout the entire interview, Farmer 4 continuously looked at the door of the office room.

Aside from our interactions with the farmers, we noted additional ETAPA-farmer tensions upon learning about how ETAPA identifies farms with which to work along the watershed. In their identification method, or the PCA, ETAPA uses a scoring system to target farms of environmental concern so that they can subsequently begin interventions on these farms. Given that this system solely selects partner farms based on environmental factors, disregarding the willingness of farmers to work with ETAPA, we determined that this method is not very effective in promoting the alliance between ETAPA and the farmers, likely contributing to strained relationships.

### **4.4 ETAPA Seeks to Implement Manure Management Strategies as Well as Improve Their Relationships with the Farmers**

From our meetings and conversations with ETAPA, we were able to determine what they see as successful recommendations, as well as what they are able to contribute to the implementation of each recommendation. From our first meeting with ETAPA, it became apparent to us that they wanted a manure management strategy to be implemented on the farms to prevent runoff, as poor waste management systems were the main sources of environmental contamination. In later conversations about the recommendations, we discovered that ETAPA does not have the funds to supply farmers with resources or incentives to implement conservation practices. This may make the adoption and implementation of new practices a bit more difficult, as the farmers are also strained for resources, only reinforcing the need for cost- and time-effective solutions. Finally, after hearing our initial findings regarding the tense relationships between ETAPA and the farmers, ETAPA became interested in further investigating and improving these relations to facilitate the implementation of new practices and the compliance with environmental regulations.

### **4.5 Conclusion**

After working closely with the farmers and ETAPA, our group decided that effective recommendations to the problem of agricultural runoff along the Tomebamba and Yanuncay watersheds are those that target waste management in a cost- and time-effective manner. Our group also determined that ETAPA building closer relations with the farmers must be addressed first, as greater trust built between the two groups will likely increase their cooperation with one another, as well as the likelihood of farmers adopting conservation practices.

## Chapter 5: The Outcome

### A Step in the Right Direction Towards Protecting Cuenca's Water Sources

In visiting the Tomebamba and Yanuncay watersheds, we observed common impacts that the different farms have on the environment. Through guided tours, observation programs, and semi-structured interviews, it became apparent that poor waste management on each farm contributes to the problem of agricultural runoff. This issue, along with limitations in environmental awareness and resources, may be addressed through various conservation- and management-based recommendations given to both ETAPA and the farmers. However, tense relationships between these two groups makes recommending new practices a complicated task. For this reason, we recommend that ETAPA first build stronger relationships with the farmers, and then advocate for the adoption of new practices.

#### 5.1 Building stronger relationships

Our fieldwork highlighted strained relations between the farmers and ETAPA that may negatively influence the farmers' adoption of recommended practices, as well as their compliance with environmental regulations. Therefore, we recommend that the ETAPA representatives along each watershed work to build rapport between themselves and the farmers. To do this, we propose several ideas that together will strengthen the relationships between ETAPA and the farmers:

- **Modify the PCA to Prioritize the Farmers' Willingness:** We recommend that ETAPA modify the way in which they identify their partner farmers. While their current method of identification, the PCA, targets those who contribute most significantly to agricultural runoff, it disregards the willingness of farmers to work with ETAPA. Instead, we propose that ETAPA still use the PCA to identify target areas, but also incorporate the farmers' willingness to work with ETAPA into the PCA identification and scoring system. With these proposed changes, farmers will be prioritized to work with ETAPA if they have a higher ranking in regards to their willingness. We also recommend that ETAPA collaborate with *any* farmer willing to work with them, regardless of their ranked priority via the PCA scoring system. These changes will gradually create a culture of teamwork and partnership between the farmers and ETAPA, in which farmers are more willing to work alongside the organization. The farmers will also realize ETAPA is not targeting landowners they see as problematic, but instead is looking to work with agricultural experts in the region to protect local water sources.
- **Host Social and Cultural Events:** We recommend that ETAPA hold social and cultural events for the farmers, as a means of strengthening the relationships between the two groups. Below are two events that we recommend ETAPA organize:
  - **Luncheon:** We recommend that ETAPA invite all of the farmers to a luncheon. At this luncheon, there should be a presentation that explains the future water deficit, what ETAPA has done to prevent the deficit, what their future goals are in terms of

## FARMING WITHOUT HARMING

water protection, and how achieving these goals will benefit both the people of Cuenca and the farmers. This must be done carefully so that the farmers do not feel blamed for the deficit, but instead feel that ETAPA is calling in experts to aid in their preventative efforts.

- **Annual Celebration:** We suggest that ETAPA hold an annual lunch or dinner party to celebrate the work of the farmers and their collaboration with ETAPA. At this party, there should be a small token of appreciation, in the form of an ETAPA keychain or water bottle, that is given to the farmers. The ETAPA representatives should also prepare a speech or presentation that explains the strides ETAPA has made in the previous year, and how these feats would not have been achievable without the farmers. This will make the farmers feel more like a part of the ETAPA team, rather than targeted outsiders, and it will also make their work seem valued by ETAPA, instead of scrutinized for aspects ETAPA view as environmentally-irresponsible.
- **Organize an Exchange of Experiences:** We propose that ETAPA also organize a small, informal event in which farmers from each watershed have the opportunity to talk to one another in a relaxed setting about the different practices they use on their farm, and why they use them in terms of benefits and losses. The idea behind this event is to engage the farmers in a dialogue about different farming practices, and to get them thinking about how implementing or utilizing different practices could benefit them and the environment. We also recommend that, José Velez, a well-respected farmer in Cuenca known for environmentally-friendly techniques, attend this event, so that he can encourage a discussion about more-environmentally friendly practices. This takes the pressure off of ETAPA to be the ones recommending conservation practices, which will ease tensions and aid in building stronger relationships. If the first event goes well, we recommend that ETAPA make it a larger, annual event, where they call in farmers they notice using beneficial practices, and have them set up stations where the farmers can teach others about their practices. Again, this will take the harsh light off of ETAPA to always be the ones recommending new practices, and it will also help build relations in that it is an event where both parties will be and can socialize.
- **Collect More Data on Relations:** We advise that the ETAPA representatives work to collect more in-depth information on the relationships they share with the farmers. Given that the fast-paced nature of our project only allowed us enough time to collect information from four farmers in two of the watersheds, it is necessary that ETAPA further explore these relations, making sure to include more farmers in their studies, as well as farmers from the other two watersheds. Themes to explore include what people generally think of ETAPA, what people think ETAPA's purpose is, and what people think the ETAPA representatives do on a daily basis. We have provided a list of additional themes and questions in Appendix E aimed at probing the farmers' perceptions of ETAPA.

### 5.2 Implementing new Practices

Once the relationships between ETAPA and the farmers improve, ETAPA can begin to introduce and promote new practices to avert agricultural contamination. When advocating for the adoption of these new practices, we suggest that ETAPA hold workshops in each watershed to explain the benefits and limitations of each practice on the farms, while also emphasizing how the practice would contribute to the betterment of Cuenca's drinking water.

Given that poor waste management on the farms is the main contributor to agricultural runoff, we propose several recommendations relating to manure management, taking into account the limited resources present on each farm, as well as ETAPA's limited resources:

- **Expand Riparian Zones:** Given the lack of adequate sizing of riparian zones on the farms and their importance in the prevention of agricultural runoff, our team recommends that the farmers, in conjunction with ETAPA, expand the existing riparian zones on the farms. Limitations to this recommendation include the lengthy periods of time it takes to grow the riparian zones, the reduction of pasture for the farmers, and the costs associated with the maintenance of the riparian zones.
- **Construct an Anaerobic Digester:** Many of the farms in the Tomebamba and Yanuncay watersheds can benefit from the installation and utilization of an anaerobic digester. Due to the harmful nature of the nutrients present in raw animal waste, these farms risk contaminating the rivers that border their land, especially when the animal waste is allowed to run directly into the rivers. The implementation of an anaerobic digester would reduce the levels of harmful nutrients present in raw manure, while also promoting the production of safer nutrients that are readily available for plant uptake (Manure Management Technology Development Team 2007). The farmers can facilitate the process of breaking down harmful contaminants by adding materials with high organic carbon content, such as dead leaves and tree bark, collected from the forests on their farmland (Blowes, Merkle, Ptacek, Robertson, 1994). Once this process is complete, the product can be used as organic fertilizer. While free fertilizer and the reduction of contamination are clear benefits of digesters, there are some downsides, including construction location. For example, in order to facilitate the movement of animal waste into the digester, it should be constructed near the point of animal waste accumulation (e.g. the milking area for dairy cows). At the same time, it should be located higher than the pasture to achieve the pressure required to spread the manure without having to buy and install a pump. However, if the point of animal waste accumulation is not located above the pasture, the choice needs to be made between one of the two locations. An additional drawback is the complexity and cost of building an anaerobic digester, as the tank must be completely airtight (Luer, 2010).
- **Build Compost Piles:** Our team recommends that each farmer construct an aerated windrow compost pile as a means to manage the waste produced on their properties. To construct this pile and optimize the composting process, the windrow must be sufficiently

## FARMING WITHOUT HARMING

aerated, have an appropriate nutrient ratio of carbon to nitrogen, have an adequate moisture content, and it also must be maintained at a specific temperature (Gamroth, 2012; Hill, 1975; Vermont Agency of Natural Resources, n.d.). Ensuring sufficient aeration is crucial, as the microbial bacteria that aid in decomposition require oxygen to function. To allow for adequate aeration, the windrows should be approximately three feet wide and ten feet tall, and should be frequently turned, potentially using a pitchfork or shovel, to release trapped gases and allow more air into the pile (Hill, 1975). Maintaining an appropriate carbon to nitrogen ratio (25-30 parts of carbon to one part of nitrogen) is also important in optimizing a compost pile, as carbon and nitrogen are both nutrients required by the microbial bacteria to function. If this ratio is too high, the decomposition rate will decrease, making the composting process take longer; if the ratio is too low, a bad odor will form, as ammonia is released into the environment. To monitor nutrient levels, one can simply use their senses, noticing a slowed decomposition rate or a strange smell (Gamroth, 2012; Vermont Agency of Natural Resources, n.d.). In addition, maintaining a moisture content of about 60% is essential in maximizing the composting process. This is because lower moisture levels inhibit the activity of microbial bacteria, whereas higher levels create anaerobic conditions, as the added moisture takes away space from oxygen in the windrows (Vermont Agency of Natural Resources, n.d.). To measure the moisture content, the farmers can squeeze some of the compost in their hands; at the appropriate levels, the compost should feel damp, but no water should drip out (Hill, 1975). Finally, to achieve the maximum composting rate, the temperature of the windrows must be maintained between 43 and 65°C, as this is when the microbial bacteria is most active, and can be monitored using a temperature probe (Hill, 1975; Vermont Agency of Natural Resources, n.d.). If the temperature is measured below 43°C, the pile must be turned; if the temperature is measured above 65°C, water can be added (Vermont Agency of Natural Resources, n.d.). We also recommend that farmers construct a hood made of plastic tarp over the windrows to protect the compost from getting wet and leading to runoff (Hill, 1975). Composting is quite advantageous as it has a lower potential than raw manure to degrade water quality, it improves soil health when used as a fertilizer, and it can also save costs on fertilizer. However, great limitations of this recommendation are the initial costs of construction and the demand of time and attention it requires (Gamroth, 2012; Hill, 1975).

- **Establish a Manure Share Program:** Our team recommends that the farmers and ETAPA work together to establish a manure share program. As part of this program, ETAPA will coordinate with the farming associations along each watershed to create a phone line that those who both have and need manure can call to arrange a manure exchange. The farming association will then coordinate the exchange of manure, using one of their trucks to make the pick-up and delivery. Instead of working to implement this system on a large scale, our team recommends running a pilot test of this program and monitoring its success. If the program is successful, ETAPA and the associations can open



## FARMING WITHOUT HARMING

it up to other individuals in need of manure, such as other farmers, gardeners, and landscapers. While a manure share program brings economic benefits to the farmers and aids in the prevention of agricultural runoff, there are limitations, such as the logistics of coordinating the program and the willingness of the farmers to partake in the program.

### **5.3 Conclusion**

The aforementioned recommendations allow for the gradual reduction of agricultural runoff into the Tomebamba and Yanuncay rivers, which will directly benefit the community of Cuenca by preventing the impending water deficit. By utilizing the recommendations aimed at building better relationships with the farmers, ETAPA will be able to work effectively with the farmers toward their goal. However, being that these recommendations encourage gradual change, it is important for both parties to remain patient and understanding throughout the process, keeping in mind that they are working towards a common goal of protecting their city's drinking water. Once ETAPA establishes stronger relationships with the farmers, they can proceed to recommend and assist the farmers in the implementation of the previously mentioned conservation practices, which directly work to reduce runoff into the rivers.

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## Appendices

### Appendix A. Gantt Chart

*Table 2. Gantt Chart Outlining the Time Frame of our Methods*

Timeline	Week 1 (Jan. 8-12)	Week 2 (Jan.15-19)	Week 3 (Jan.22-26)	Week 4 (Jan.29-Feb. 2)	Week 5 (Feb.5-9)	Week 6 (Feb.12-16)	Week 7 (Feb.19-23)	Week 8 (Feb.26-Mar.2)
<b>Guided Tours</b>								
<b>Observation Programs</b>								
<b>Semi-structured Interviews</b>								
<b>Interview with Student Working on Anaerobic Bacteria Thesis</b>								
<b>Formation of Recommendations</b>								
<b>Final Conclusions, and Dissemination of Final Report</b>								
<b>Meetings with ETAPA</b>								
<b>Analysis of Collected Information</b>								



**Appendix B. Guided Tour Interview Guide**

**Questions Asked During the Guided Tours:**

1. How large is your farm?
2. Who else works on your farm besides yourself?
3. What is produced on your farm? (Crops, milk, etc.)
4. What kinds of plants, animals, and crops are on your farm?
5. How many animals are on your farm?
6. What kind of fertilizer do you use?
7. How frequently do you apply the fertilizer to your fields?
8. How much fertilizer do you use each time you apply it?
9. What do you do with the waste produced by the animals on your farm?
10. What do you feed the animals on your farm? How often and in what quantities do you feed them?

*Table 3. Farm Characteristics Determined from Guided Tours Part 1*

	Owner	Milking Method	Total Land (ha)	Grazing Land (ha)	Products
Tomebamba	Farmer 1	Traditional	40	12	Milk Cheese Trout Restaurant
	Farmer 2	Semi- technological	130	30	Milk Restaurant
Yanuncay	Farmer 3	Traditional	27	11	Milk
	Farmer 4	Semi- technological	70	12	Milk Cheese

# FARMING WITHOUT HARMING

*Table 4. Farm Characteristics Determined from Guided Tours Part 2*

	Owner	Fertilizer			# of Workers
		Chemical	Cow Manure Management	Other Organic	
Tomebamba	Farmer 1	Chemical of unknown type (Unknown amount and application rate)	Excrement accumulated during milking is spread if workers are available	Gallinaza (20,000 bags used on total farmland, applied every 3 years)  Manure from trout spread (Unknown amount/ application rate)	2 full time 4 part time
	Farmer 2	Yaramila (3 quintales used per ha, applied 3 times a year)	Defecate and excrement is left in piles	None	3 full time
Yanuncay	Farmer 3	Mixture of Yaramila, Fertiforage, and 184060 Fosforo (4 sacks used per ha, applied 3 times per year)	Defecate in current grazing zone, excrement is spread on fields using a hose	None	2 full time
	Farmer 4	Mixture of Fertiforraje and SAM (Unknown amount and application rate)	Defecate in current grazing zone, excrement is spread on fields using a rake	Calcium carbonate (Unknown amount and application rate)  Molasses (Unknown amount and application rate)	2 full time

# FARMING WITHOUT HARMING

*Table 5. Farm Characteristics Determined from Guided Tours Part 3*

	Owner	Total # Dairy Cows	Producing Cows	Total Milk Produced Daily (L)	Daily Feed
Tomebamba	Farmer 1	60	30	300	Mixture of corn flour, soy flour, and wheat (20-30L sacks per cow)  Alimento (2-3kg per cow)
	Farmer 2	60	30	450	Bio Alimentar (Unknown amounts per cow)  Mineral salts (Unknown amounts per cow)
Yanuncay	Farmer 3	40	17	60-70	Mixture of molasses, corn, beans, and wheat (1-2kg per cow)  Minerals (100g per cow)
	Farmer 4	34	25	250	Protein of unknown type (11.3kg per cow)  Scoop of minerals (per cow)

**Appendix C. Principal Sources of Contamination on Each Farm**



*Figure 3. Farmer 1: Break in the fence that allows cows to drink from the Tomebamba River and contaminate it*



*Figure 4.* Farmer 1: Water tanks used to raise trout lack adequate filtration systems, allowing wastewater from the tanks to flow into the Tomebamba River



*Figure 5. Farmer 2: Man-made channel where manure is shoveled and hosed into after the milking process; this channel leads into natural channels (shown in Figure 6) which eventually flow into the Tomebamba River*



*Figure 6. Farmer 2: Natural channel that carries the wastewater from the man-made channel (shown in Figure 5) to the Tomebamba River*



*Figure 7. Farmer 3: Man-made channels that run through the pasture and carry the produced wastewater into the Yanuncay River*





*Figure 8. Farmer 4: The spraying of cow manure after the milking process which produces wastewater that eventually flows into channels (shown in Figure 9) that enter the Yanuncay River*



*Figure 9.* Farmer 4: The produced wastewater from the hosing process (shown in Figure 8) running into channels that lead into the Yanuncay River

### Appendix D. Semi-structured Interview Guide and Responses

#### ETAPA Relations Interview Question

To start the interview, we would like to ask you if you know what other people in the watershed think about ETAPA? Do you agree with them and their opinions of ETAPA?

#### Free List Prompts

Another activity we would like you to do is what we call a Free List. The Free List consists of having you make a list of words in accordance with some prompts we will give you.

- Please list important qualities of a farm that is:
  - Successful
  - Efficient
  - Organized
  - Eco-friendly/ environmentally aware
  - Profitable
- Please list the most important qualities of your farm.
- Please list what you wish you could change about your farm.
- Please list what you would not change about your farm.

#### Resource Flow Prompts

We would like to conduct a resource flow activity as part of this interview. The purpose of this activity is to understand what is important on your farm from a financial perspective. You do not have to give us costs or amounts, we only want to know what is important and what is not, as long as you are comfortable sharing this information with us.

- Please list everything that brings money into the farm.
- Please list everything that takes money out of the farm.
- Please rank the assets coming in and going out in terms of what is most important to you.
- What one item on this list is something the farm would not be able to function correctly without?
- If you had enough money, what would you do differently on your property?

#### Photo-Elicitation Prompts and Pictures

Another activity we would like you to participate in is a photo-elicitation. This activity consists of showing you pictures and having you describe them, giving us your opinions about them. We know that you are an expert and we do not know much about these topics, so we would like to use your answers to learn more about them.

*Photo 1:* The cows are drinking from the river because there are no fences that prevent the cows from entering the river.

1. What do you think about this picture?
2. What are the advantages and disadvantages of the cows drinking from the river?

## FARMING WITHOUT HARMING

3. If they say nothing: Do you think there are negative effects when the cows defecate in the river when they drink water?
4. Do cows carry diseases that can go into the river when they drink from it? What diseases do they carry?

*Photo 2:* This is a picture of a compost pile. Composting is a method to use cow manure to reduce waste in the pasture and make fertilizer for the farm.

1. What do you think about this picture?
2. Do you think this would work in your farm? Why?
3. What are the advantages and disadvantages of this system?

*Photo 3:* This picture shows an irrigation system inside a property.

1. What do you think about this picture?
2. What are the advantages and disadvantages of this system?
3. Do you use in your farm?

*Photo 4:* This picture shows a manure storage facility for cow manure. It is a way to reduce the amount of waste on the pasture.

1. What do you think about this picture?
2. What are the advantages and disadvantages of this system?
3. Do you have enough space in your farm to build this facility?

*Photo 5:* This picture shows pictures of different types of fertilizers. The first picture is cow manure, the second one is a chemical fertilizer, and the last one is gallinaza.

1. What do you think about this picture?
2. Which one would you use over the other one? In which case would you use chemical fertilizer? Organic fertilizer?
3. Which is your preferred fertilizer? Why?
4. Which is the most economical?
5. Which is the best for the pasture? For the soil? For the wellbeing of your farm?

*Photo 6.* The picture to the right shows a traditional farm whereas the one to the right shows a semi-technological farm.

1. What do you think about this picture?
2. What are the advantages and disadvantages of the traditional farm?
3. What are the advantages and disadvantages of the semi-technological farm?

*Photo 7.* From our investigations, we discovered that algae growth is an effect of agricultural runoff.

1. What do you think is happening in the picture?

## FARMING WITHOUT HARMING

2. What do you think caused this situation?
3. What is the seriousness or gravity of this situation?
4. How do you think this situation affects aquatic life? Human life?



*Figure 10. Cows drinking from river (Swan, n.d)*



*Figure 11. Compost pile (Gifford, n.d.)*



*Figure 12. Irrigation system (Southwest Irrigation, n.d.)*

## FARMING WITHOUT HARMING



*Figure 13. Manure storage system (Rutgers, 2018)*



*Figure 14. Mixed fertilizer, chemical fertilizer, and gallinaza (Salmanova, 2017; Intagri, n.d.; Getty Images, 2012)*

## FARMING WITHOUT HARMING



*Figure 15. Traditional farm (left) and semi-technological farm (right) (Department of Dairy Science, n.d.; The Organic Farmer, 2015)*



*Figure 16. Eutrophic river caused from agricultural runoff (Chadwick, 2012)*

### **Interview with Farmer 1:**

**Farmer 1 = Farmer, ME = Team Member**

### **ETAPA Relations Interview Question:**

**ME:** To start the interview, we would like to ask you if you know what other people in the watershed think about ETAPA? Do you agree with them and their opinions of ETAPA?

**Farmer 1:** I have nothing against them.

We were not able to complete the semi-structured interview with Farmer 1 due to her busy schedule.

## FARMING WITHOUT HARMING

We were not able to complete the semi-structured interview activities such as the Free List, Resource Flow, and Photo-elicitation with Farmer 1 due to her busy schedule.

### Interview with Farmer 2

**Farmer 2 = Farmer, ME = Team Member**

#### **ETAPA Relations Interview Question:**

**ME:** To start the interview, we would like to ask you if you know what other people in the watershed think about ETAPA? Do you agree with them and their opinions of ETAPA?

**Farmer 2:** ETAPA is very respected, the farmers understand that they are also drinking the water need to try to be environmentally aware.

#### **Free List:**

**ME:** Thank you. Another activity we would like you to do is what we call a Free List. The Free List consists of having you make a list of words in accordance with some prompts we will give you. Please list important qualities of a farm that is successful.

**Farmer 2:** The property needs to have technology and a cold tank to store the milk.

**ME:** Please list the characteristics of a farm that is efficient.

**Farmer 2:** The pasture needs to be good, and there needs to be someone with technical knowledge on how to manage the pasture and the cattle.

**ME:** Please list the characteristics of a farm that is respectful of the environment.

**Farmer 2:** The farmers need to be conscious, they cannot contaminate the water. ETAPA should host meetings and try to make people more conscious of the water problem. Constructions are also bad for the environment, so people need to be careful.

**ME:** Please list the characteristics of a farm that is profitable.

**Farmer 2:** Well, you need to be able to live off of it. People need to be enthusiastic about their work, and should try to make the farm as technological as possible to optimize the milking process. Currently, the price of the milk in Cuenca is not good, it is fifty cents, which is more expensive than the rest of Ecuador. The government does not give us anything, and after the dollarization process the country is becoming very expensive.

**ME:** Please list the most important characteristic of your farm.

**Farmer 2:** My farm is semi-technological, and it has benefits as well as its disadvantages. The milking process uses machines, making the cows less prone to diseases, there is more food for cows, it is possible to breed any types of cows, and there is hygiene. Milk is pure, cows can adapt pretty well. If it were a traditional farm, the milk production would be lower, milk is not as pure, and the cow utters can be dirty, leading to a contaminated milk. The disadvantages to this system is the maintenance cost and the profit margin is not that high.

**ME:** Thank you.

#### **Resource Flow:**



## FARMING WITHOUT HARMING

**ME:** We would like to conduct a resource flow activity as part of this interview. The purpose of this activity is to understand what is important on your farm from a financial perspective. You do not have to give us costs or amounts, we only want to know what is important and what is not, as long as you are comfortable sharing this information with us. Please list everything that brings money into the farm.

**Farmer 2:** The milk.

**ME:** Please list everything that takes money out of the farm.

**Farmer 2:** Fertilizers and critical seasons. Whenever it is the rainy season, pasture does not grow well, causing a decrease in the milk production.

**ME:** If you had enough funds, what would you do differently on your property?

**Farmer 2:** I would do some tourism-related activity to gain more money. It would be more fun and I would try to establish my fish farm.

**ME:** Thank you.

### **Photo-elicitation:**

**ME:** Another activity we would like you to participate in is a photo-elicitation. This activity consists of showing you pictures and having you describe them, giving us your opinions about them. We know that you are an expert and we do not know much about these topics, so we would like to use your answers to learn more about them. (We show them the first picture). The cows are drinking from the river because there are no fences that prevent the cows from entering the river. What do you think about this picture?

**Farmer 2:** The brown cows are pretty, we do not have many in Ecuador, but we do have some. Was the picture taken in the US?

**ME:** We do not know.

**Farmer 2:** The cows can contaminate the water, not from drinking in it, but just from defecating and peeing in it. The cows in my farms do not do this.

**ME:** Do cows carry diseases that can go into the river when they drink from it? What diseases do they carry?

**Farmer 2:** Cows have many diseases, which is why I vaccinate them.

**ME:** Thank you. (We show them the second picture) This is a picture of compost. Compost is a method to use cow manure to reduce waste in the pasture and make fertilizer for the farm. What do you think about this picture?

**Farmer 2:** Is it really good.

**ME:** Do you think this would work in your farm? Why?

**Farmer 2:** It could work on my farm, but I do not have a compost pile and it requires a lot of money.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 2:** The advantages is that it decomposes, can reduce contamination, and the resulting fertilizer is of really good quality. The disadvantages to this is that I would lose money and will need people to work.

## FARMING WITHOUT HARMING

**ME:** Thank you. (We show them the third picture). This picture shows an irrigation system inside a property. What do you think about this picture?

**Farmer 2:** I do not have an irrigation system on my farm because the soil is very humid, but it could be useful about thirty minutes away from my farm, where the soil is dryer.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 2:** The disadvantages on the irrigation is that when the soil is too wet the cows can get diseases and get sick, when makes them weaker and tired, and do not give as much milk. Also, the pasture grows less with a ton of water. The farm is the only irrigation my farm needs. I benefit from it since I don't have to pay for workers or spend money on it.

**ME:** Thank you. (We show them the fourth picture). This picture shows a manure storage facility for cow manure. It is a way to reduce the amount of waste in the pasture. What do you think about this picture?

**Farmer 2:** I have a manure storage place on my farm. I will dry the cow manure in the storage center, where it decomposes, and then I take advantage of it when it is time to need to apply fertilizer to the grass.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 2:** The advantages of this is that I save money on fertilizers and it does not take too much time to maintain. The disadvantage is that it is expensive to build and maintain.

**ME:** Thank you. (We show them the fifth picture). This picture shows pictures of different types of fertilizers. The first picture is cow manure, the second one is a chemical fertilizer, and the last one is gallinaza. What do you think about this picture?

**Farmer 2:** The cow manure fertilizer is too expensive, that's why I don't use it on my farm. I mostly use chemical fertilizer, because it is easy to spread on the field, less workers are needed, it is slightly cheaper than cow manure and gallinaza, and the benefit for the soil is the same or no less than the others. The ground is very acidic here and so is chicken manure so I would not recommend this to anyone. It is also very expensive. I use Yaramila because it has nitrogen and is the most complete.

**ME:** Thank you. (We show them the sixth picture) The picture to the right shows a traditional farm whereas the one to the left shows a semi-technological farm. What do you think about this picture?

**Farmer 2:** The technological farm is always better.

**ME:** What are the advantages and disadvantages of the traditional farm? What semi-technological farm?

**Farmer 2:** In the semi-technological farm, cows produce more milk and the milk is of better quality, however the health of the cows in both farms is the same.

**ME:** Thank you. (We show them the seventh picture). From our investigations, we discovered that algae growth is an effect of agricultural runoff. What do you think is happening in the picture?

**Farmer 2:** I do not think it is because of animal waste, that is impossible. The river must be by a city and is probably caused by human contamination.

## FARMING WITHOUT HARMING

**ME:** What do you think caused this situation?

**Farmer 2:** Like I said, the situation must have been caused by humans and the rivers must be by a city. This does not happen here.

**ME:** What is the seriousness or gravity of this situation?

**Farmer 2:** I think that this is a very sad situation because animals and humans can now not drink from the river and aquatic life cannot survive.

**ME:** Thank you very much for your time.

### Interview with Farmer 3

**Farmer 3 = Farmer, ME = Team Member**

#### **ETAPA Relations Interview Question:**

**ME:** To start the interview, we would like to ask you if you know what other people in the watershed think about ETAPA? Do you agree with them and their opinions of ETAPA?

**Farmer 3:** ETAPA is concerned with the protection of the environment. They have helped us, farmers, by helping us increase production and apply practices that are better for the environment.

#### **Free-List:**

**ME:** Thank you. Another activity we would like you to do is what we call a Free List. The Free List consists of having you make a list of words in accordance with some prompts we will give you. Please list important qualities of a farm that is successful.

**Farmer 3:** The farmer must be conscious of all the activities that happen in the farm, whoever works in it should love his job, and they need to protect the environment. With regards to my farm, whoever works in it should love his job, there needs to be good planning of what happens in the farm, coordination between the whoever is working there and myself, proper management of the property, a good irrigation system, to have good pasture, good fertilizers and proper fertilizing techniques, control of the cattle in terms of health, hygiene, and reproduction, hygiene during the milking process, careful application of fertilizers to avoid contaminating the environment, conservation of the native forests

**ME:** Please list the characteristics of a farm that is efficient.

**Farmer 3:** In terms of production it depends on the type of economic activity that will be done on the plot of land, whether it is agricultural or cattle ranching, depends on the location it is in, the type of soil, and also the accessibility and Management of water sources and other resources.

**ME:** Please list the characteristics of a farm that is respectful of the environment.

**Farmer 3:** They need to adopt practices that are favorable to the environment, owner and workers need to inform oneself of other practices and the effects they have on the environment, and it needs to protect the rivers and forests.

**ME:** Please list the characteristics of a farm that is profitable.

**Farmer 3:** They need to have an adequate terrain, it must be easy to irrigate and apply fertilizer the land, it must be close to a water source, and it must have favorable soil.

## FARMING WITHOUT HARMING

**ME:** Please list the most important characteristic of your farm.

**Farmer 3:** The location of the property, must be able to sustain economic activity, the quality of the terrain, and the availability of water.

### **Resource Flow:**

**ME:** We would like to conduct a resource flow activity as part of this interview. The purpose of this activity is to understand what is important on your farm from a financial perspective. You do not have to give us costs or amounts, we only want to know what is important and what is not, as long as you are comfortable sharing this information with us. Please list everything that brings money into the farm.

**Farmer 3:** Selling milk and, occasionally, selling cattle.

**ME:** Please list everything that takes money out of the farm.

**Farmer 3:** Employee salary, buying of special cattle food, fertilizer, gas, expenses in irrigation system, medical care for the cattle.

**ME:** Please rank the assets coming in and going out in terms of what is most important to you.

**Farmer 3:** In terms of things that bring money into the farm, the first thing would be the selling of milk and then the selling of cattle. In terms of what takes money out of the farm, I would say employee salary, buying of special cattle food, fertilizer, medical care for the cattle, expenses in irrigation system, and gas.

**ME:** What one item on this list is something the farm would not be able to function correctly without?

**Farmer 3:** I can't say. I think that all of them are important. It is a cycle.

**ME:** If you had enough funds, what would you do differently on your property?

**Farmer 3:** I would make it more technological; fertilizer would be more constant, you could use a parcel of land to grow crops and improve the type of cattle in the farm.

**ME:** Thank you.

### **Photo-elicitation:**

**ME:** Another activity we would like you to participate in is a photo-elicitation. This activity consists of showing you pictures and having you describe them, giving us your opinions about them. We know that you are an expert and we do not know much about these topics, so we would like to use your answers to learn more about them. (We show them the first picture). The cows are drinking from the river because there are no fences that prevent the cows from entering the river. What do you think about this picture?

**Farmer 3:** The cattle is contaminating the river.

**ME:** What are the advantages and disadvantages of the cows drinking from the river?

**Farmer 3:** The advantage is that they have direct access to water and the disadvantage is the contamination of water sources.

**ME:** Do cows carry diseases that can go into the river when they drink from it? What diseases do they carry?

## FARMING WITHOUT HARMING

**Farmer 3:** They have multiple diseases. One of the diseases they carry is coli-bacilli, which is contained in manure.

**ME:** Thank you. (We show them the second picture). This is a picture of compost. Compost is a method to use cow manure to reduce waste in the pasture and make fertilizer for the farm. What do you think about this picture?

**Farmer 3:** Compost and vermiculture could be beneficial for his farm.

**ME:** Do you think this would work in your farm? Why?

**Farmer 3:** It could work in my farm, but it requires too much attention from workers and time

**ME:** What are the advantages and disadvantages of this system?

**Farmer 3:** The advantage to this is that I would be using organic fertilizer, and the disadvantage would be that it requires too much time and labor.

**ME:** Thank you. (We show them the third picture). This picture shows an irrigation system inside a property. What do you think about this picture?

**Farmer 3:** The most important irrigation method is irrigation by sprinklers, which is the one I use. The difference of the picture and the one I use is that it is an irrigation system that uses mist. The sprinkling system is best since it reduces the amount of water used.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 3:** Like I said, it reduces the amount of water use.

**ME:** Do you use in your farm?

**Farmer 3:** Yes.

**ME:** Thank you. (We show them the fourth picture). This picture shows a manure storage facility for cow manure. It is a way to reduce the amount of waste in the pasture. What do you think about this picture?

**Farmer 3:** I disagree with the manure storage warehouse idea in a traditional farm. However, it would be very beneficial to have it in the semi-technological farms. It would be a good way to benefit from cow manure, since you can use it to make compost and other organic fertilizers.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 3:** The advantage of this system is that you can store cow manure and use it to make organic fertilizer. There are no disadvantages.

**ME:** Do you have enough space in your farm to build this facility?

**Farmer 3:** I do not have a place in the farm for the warehouse.

**ME:** Thank you. (Show them fifth picture). This picture shows pictures of different types of fertilizers. The first picture is cow manure, the second one is a chemical fertilizer, and the last one is gallinaza. What do you think about this picture?

**Farmer 3:** The three fertilizers would be good to apply to the pasture. Gallinaza is the most expensive one and contaminates the environment pretty badly. Since there is small organic material in this type of fertilizer that takes a long time to decompose, it is not good because it can be carried into the river when it rains. If cattle consume the remains, it could make the cattle sick. Chemical fertilizer is the easiest to manage, pasture assimilates this fertilizer quicker, will not affect the production of milk. However, you must be careful and not use it in excess. Ecupasto is a

## FARMING WITHOUT HARMING

mix of chemical and organic fertilizer. Advantages and disadvantages are pretty similar to chemical fertilizers.

**ME:** Which one would you use over the other one?

**Farmer 3:** In order of preference, I would use chemical, the mix, and the chicken manure. If cow manure was there, I would use that first and then use the other ones in the same order I gave.

**ME:** Which is your preferred fertilizer? Why?

**Farmer 3:** My favorite one is cow manure, because it is the best for the environment and cheap.

**ME:** Which is the most economical?

**Farmer 3:** Cow manure.

**ME:** Which is the best for the pasture? For the soil? For the wellbeing of your farm?

**Farmer 3:** For the pasture the best would be organic, then chemical, then mixed. For the soil it would be mixed, and, in theory, organic fertilizers with minerals. Chemical fertilizers kill microorganisms in the soil that decompose the cow manure naturally. The best one would be the organic fertilizer, but it needs to be treated. It provides more nutrients to the soil and the pasture.

**ME:** Thank you. (We show them the sixth picture). The picture to the right shows a traditional farm whereas the one to the right shows a semi-technological farm. What do you think about this picture?

**Farmer 3:** The semi-technological farm is better, there is better hygiene, management, and production.

**ME:** What are the advantages and disadvantages of the traditional farm?

**Farmer 3:** The advantages are the optimization of production and the direct use of cow manure on grass. The disadvantage is that it is not completely hygienic.

**ME:** What are the advantages and disadvantages of a semi-technological farm?

**Farmer 3:** The advantages are better hygiene, production, and it is easier to manage. It is hard for me to add more technology to my farm due to lack of resources and the location of the farm. The disadvantage is the contamination due to pee and poo.

**ME:** Thank you. (We show them the seventh picture). From our investigations, we discovered that algae growth is an effect of agricultural runoff. What do you think is happening in the picture?

**Farmer 3:** At first, I thought it was contaminated, due to bad management from the farms along the river.

**ME:** What do you think caused this situation?

**Farmer 3:** Bad management from the farms around the river.

**ME:** What is the seriousness or gravity of this situation?

**Farmer 3:** It is a grave situation because of the contamination of the river from the farms.

**ME:** How do you think this situation affects aquatic life? Human life?

**Farmer 3:** Aquatic life is not possible if it is that contaminated; there are rivers in worse state due to petroleum (gasoline). Contamination affects aquatic life, which in turn cause secondary effects. This contamination harms the ecosystem, animal, and humans. If water is too contaminated, it can spread diseases to humans.

## FARMING WITHOUT HARMING

**ME:** Thank you for your time.

### Interview 4

**Farmer 4 = Farmer, ME = Team Member**

#### **ETAPA Relations Interview Question:**

**ME:** To start the interview, we would like to ask you if you know what other people in the watershed think about ETAPA? Do you agree with them and their opinions of ETAPA?

**Farmer 4:** ETAPA helps us, farmers, manage the land/soil.

#### **Free-List:**

**ME:** Thank you. Another activity we would like you to do is what we call a Free List. The Free List consists of having you make a list of words in accordance with some prompts we will give you. Please list important qualities of a farm that is successful.

**Farmer 4:** A successful farm has a good price for the milk it produces, a good riparian zone, there is good management of the farm, the property's pasture is good, and it discards animals that are sick, and medicate the cows to prevent diseases.

**ME:** Please list important qualities of a farm that is efficient.

**Farmer 4:** It has a good milk production, the owner must be at the farm, it needs to have water, punctual milking times, hygiene of the personnel, and have the necessary tools to deal with random and specific cases.

**ME:** Please list important qualities of a farm that is respectful of the environment.

**Farmer 4:** It needs to conserve the páramo and take care of the soil so it does not deteriorate.

**ME:** Please list important qualities of a farm that is profitable.

**Farmer 4:** The farm needs to have a food production and needs to have a controlled procreation period.

**ME:** Please list the most important qualities of your farm.

**Farmer 4:** My farm has good cattle ranching practices, it takes care of the páramo and the protected areas, it uses less water, and takes good care of the animals.

#### **Resource Flow:**

**ME:** We would like to conduct a resource flow activity as part of this interview. The purpose of this activity is to understand what is important on your farm from a financial perspective. You do not have to give us costs or amounts, we only want to know what is important and what is not, as long as you are comfortable sharing this information with us. Please list everything that brings money into the farm.

**Farmer 4:** Selling milk, occasionally selling cattle, taking care of the cattle of other farmers, and two other properties I have.

**ME:** Please list everything that takes money out of the farm.

## FARMING WITHOUT HARMING

**Farmer 4:** Food for cattle, melaza, minerals and vitamins, fertilizers, medicine, and the insemination tubes.

**ME:** Please rank the assets coming in and going out in terms of what is most important to you.

**Farmer 4:** In terms of things that bring money into the farm, selling milk, selling cattle, caring for other farms animals. In terms of what takes money out of the farm, I would say food for cows, melaza, minerals and vitamins, fertilizers, medicine, and the insemination tubes.

**ME:** What one item on this list is something the farm would not be able to function correctly without?

**Farmer 4:** The production of milk, because it is what brings income into the farm. The income allows me to invest in other things that can help me improve production.

**ME:** If you had enough funds, what would you do differently on your property?

**Farmer 4:** I would buy more eco-friendly fertilizers to avoid contaminating the environment and I would also invest in more insemination tubes to increase production.

**ME:** Thank you.

### **Photo-elicitation:**

**ME:** Another activity we would like you to participate in is a photo-elicitation. This activity consists of showing you pictures and having you describe them, giving us your opinions about them. We know that you are an expert and we do not know much about these topics, so we would like to use your answers to learn more about them. (We show them the first picture). The cows are drinking from the river because there are no fences that prevent the cows from entering the river. What do you think about this picture?

**Farmer 4:** The cows are contaminating the water and also the animal can be harmed.

**ME:** What are the advantages and disadvantages of the cows drinking from the river?

**Farmer 4:** There are no advantages. The disadvantage is that it contaminates the river.

**ME:** Do cows carry diseases that can go into the river when they drink from it? What diseases do they carry?

**Farmer 4:** If they do have diseases, the only way to contract the disease is by having direct contact with the animal. One of the diseases they have is tuberculosis.

**ME:** Thank you. (We show them the second picture). This is a picture of compost. Compost is a method to use cow manure to reduce waste in the pasture and make fertilizer for the farm. What do you think about this picture?

**Farmer 4:** I have a tank used to produce biol. I used to do compost, but now I am going to do vermicomposting.

**ME:** Do you think this would work in your farm? Why?

**Farmer 4:** No, because they require a lot of water and a lot of time.

**ME:** What are the advantages and disadvantages of the system?

**Farmer 4:** The advantage of using compost is having better grass, there are no disadvantages.

**ME:** Thank you. (We show them the third picture). This picture shows an irrigation system inside a property. What do you think about this picture?



## FARMING WITHOUT HARMING

**Farmer 4:** It is an advanced irrigation system.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 4:** The advantage is that it saves money, there are no disadvantages.

**ME:** Do you use it in your farm?

**Farmer 4:** Yes.

**ME:** Thank you. (We show them the fourth picture). This picture shows a manure storage facility for cow manure. It is a way to reduce the amount of waste in the pasture. What do you think about this picture?

**Farmer 4:** I think that it is good for a big property.

**ME:** What are the advantages and disadvantages of this system?

**Farmer 4:** The advantage is that it prevents contamination and the disadvantage is that it is expensive to build.

**ME:** Do you have enough space in your farm to build this facility?

**Farmer 4:** Yes, I have a place, but I do not have enough money.

**ME:** Thank you. (Show them fifth picture). This picture shows pictures of different types of fertilizers. The first picture is cow manure, the second one is a chemical fertilizer, and the last one is gallinaza. What do you think about this picture?

**Farmer 4:** It depends on the price, but I would go for the ecopasto (mixed) because it is the most feasible.

**ME:** Which one would you use over the other one?

**Farmer 4:** It would depend on the cost, but I would go for mixed, chemical, then gallinaza. If organic cow manure was an option, I would use that one over the other ones and then follow that list.

**ME:** Which is your preferred fertilizer? Why?

**Farmer 4:** Cow manure, because it is better for the environment.

**ME:** Which is the cheapest?

**Farmer 4:** Cow manure.

**ME:** Which is the best for the pasture? For the soil? For the well-being of your farm?

**Farmer 4:** For the grass gallinaza, but it contaminates too much. For the soil, cow manure. For the well-being of the property, cow manure.

**ME:** Thank you. (We show them the sixth picture). The picture to the right shows a traditional farm whereas the one to the left shows a semi-technological farm. What do you think about this picture?

**Farmer 4:** Before, I used to do it manually, with a bucket of water, and soap. But now I have a semi-technological farm.

**ME:** What are the advantages and disadvantages of the traditional farm?

**Farmer 4:** There are no advantages and the disadvantage is that it is time consuming.

**ME:** What are the advantages and disadvantages of a semi-technological farm?

## FARMING WITHOUT HARMING

**Farmer 4:** The advantages are that it does not take that much time and there is a bigger production. The disadvantage is that if there is no knowledge to use the appropriate technology it won't function and if you do not have the technological tools the farm will not function.

**ME:** Thank you. (We show them the seventh picture). From our investigations, we discovered that algae growth is an effect of agricultural runoff. What do you think is happening in the picture?

**Farmer 4:** The river is contaminated, there are no riparian zones, and there is a house by the river

**ME:** What do you think caused this situation?

**Farmer 4:** Bad management of natural resources.

**ME:** What is the seriousness or gravity of this situation?

**Farmer 3:** There will not be water, it is a grave situation.

**ME:** How do you think this situation affects aquatic life? Human life?

**Farmer 4:** There will not be aquatic life due to the high level of contamination and people cannot shower or utilize the water for other purposes.

**ME:** Thank you very much for your time and help!

**Appendix E. Themes and Questions to Investigate in the Future with the Farmers**

**Theme 1: Opinions about ETAPA**

1. What do people think about ETAPA? Do you agree?
2. What interactions have you had with ETAPA?
3. In general, do you have good or bad experiences with ETAPA? Could you explain this?
4. What is something that ETAPA does right? How do you think they can improve?
5. Would you like to collaborate with ETAPA in a project to protect the environment and Cuenca's water supply? Why?
6. Do you think ETAPA protects the interests of the farmers?

**Theme 2: Understanding ETAPA's Objectives**

1. In your opinion, what is ETAPA's mission? Do you support this mission?
2. What do you think ETAPA's representatives do daily?

**Theme 1: ETAPA's Involvement in the Community**

1. Do you know the name of the ETAPA representative that works in this watershed?
2. Do you see ETAPA as an organization that collaborates with the people of the community?