School Gardens: Providing Improved Food Security and Nutrition for Students in Ecuador

Food security for students in ecuador via school gardens
An Interactive Qualifying Project
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

Ecuadorian school gardens as a method of improving nutrition

BY:
Will Burnham
Anne Davis
Pat Flaherty
Adrienne Whitney

DATE:
18 March 2021

SUBMITTED TO:

Desmion Dizney
Castle Foundation

Professor Laureen Elgert
Professor Fabienne Miller
Worcester Polytechnic Institute

Abstract

This project focuses on food security and malnutrition among students around Cuenca, Ecuador, and provides recommendations on how to alleviate these problems by providing guidelines for expanding and improving school gardens. After extensive research and interviews with subject matter experts, the project team formed six major recommendations to improve the diversity and nutrition of the plants in school gardens. These recommendations focus on growing native plants, producing a variety of different crop types, practicing water conservation, implementing composting methods, growing medicinal herbs, and maintaining a management system. These recommendations, if applied and sustained over time, are meant to help alleviate malnutrition and food insecurity for students in the region.

Executive Summary

Food insecurity and poverty are prevalent issues in communities throughout Ecuador. In 2018, poverty rates hovered around 43% in rural communities, nearly triple the rate in urban areas (Global Nutrition Report, 2020). For some Ecuadorian children, the only meal they can rely on during the day is the one provided by the food grown in their school's garden. However, for many schools, this meal may not provide adequate nutrients and vitamins for the students. This project is focused on providing the methods necessary to grow more and healthier crops in school gardens in and around the city of Cuenca, Ecuador. This project provides the methods to build a center of life and wellbeing that the school community can take pride in and will contribute to alleviating food insecurity among students. This plan aims to aid the diversity of available foods and overall nutrition that students receive from their school meals.

The team organized the next actionable items into three main objectives, shown in *Figure 1*.

Objective 1: Find potential crops through research and interviews, then determine what makes a plant relevant for use in a school garden.

Objective 2: Identify techniques and sustainable practices for gardens, develop criteria that will help determine what makes them relevant for a school garden.

Objective 3: Assess and compare various crops and sustainable practices with attention to criteria that make a plant or technique useful for school garden applications, such as cost and labor, to present in a gardening guide.

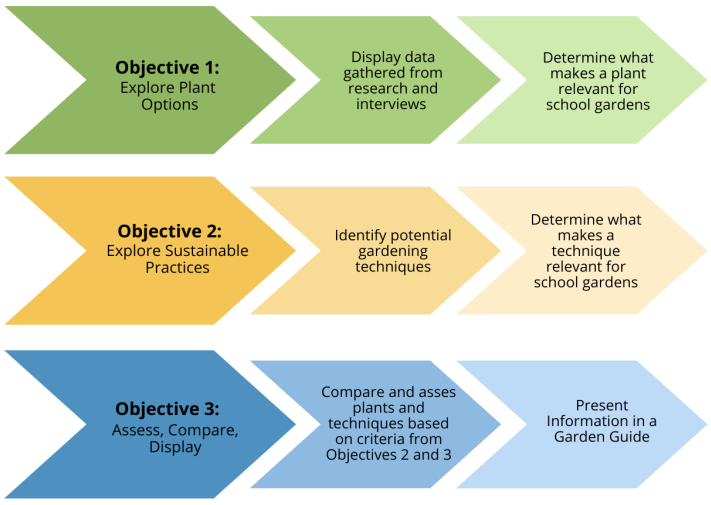

Figure 1: A visual summarization of the project objectives and the process to complete them

The main nutrients that should fuel a child's diet are protein, iron, calcium, and vitamins A and C (Bernstein, 2016). Nutrient rich foods are typically expensive, which is why most children in impoverished areas are not receiving a healthy amount. While children in some areas lack access to some nutrients, they may be over-consuming others. A lack of money in impoverished areas often leads to buying cheap foods that are loaded with carbohydrates and simple sugars that, when eaten in excess, can cause obesity. For this reason, the project is focusing on variety as well as quantity.

Without the proper crops in the garden, the conceptual and physical preparation will be futile. The key considerations and feasibility of potential crop options are shown in the figure below (*Figure 2*). The team has constructed several tables that analyze the nutritional benefits of potential crops, with an emphasis on crops that are native to Ecuador. Native plants often have cultural significance in Ecuador, and it is important to cater to the needs of these native plants when recommending methods of gardening.

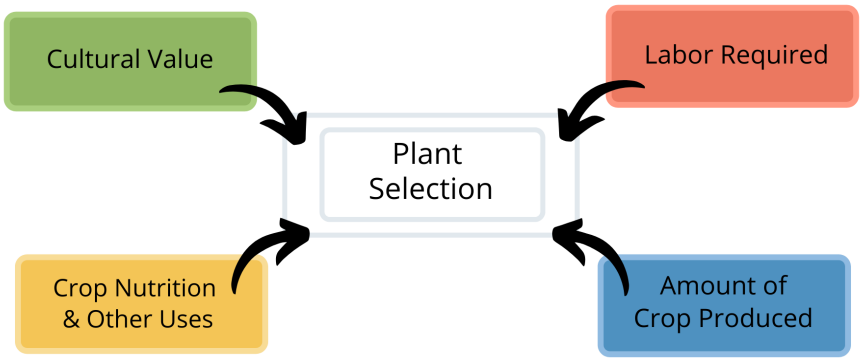

Figure 2: A visual summary of the considerations for plant selection in school garden applications

The four main types of foods considered for a garden are fruits, vegetables, grains, and herbs. Fruits are an under consumed food type in Ecuador, and reintroducing them will be a breath of fresh air for many school communities. Vegetables are the most commonly grown food type in school gardens, but often lack variety. Grains also provide ample amounts of protein and fiber, which are often not present in school aged children's diets. Lastly, medicinal herbs have a certain cultural significance that makes them very important to have in a school garden. *Figure 3* shows the different parts of the garden that will be discussed and how they interact. It also provides the framework of how the paper is set up to discuss each topic in detail.

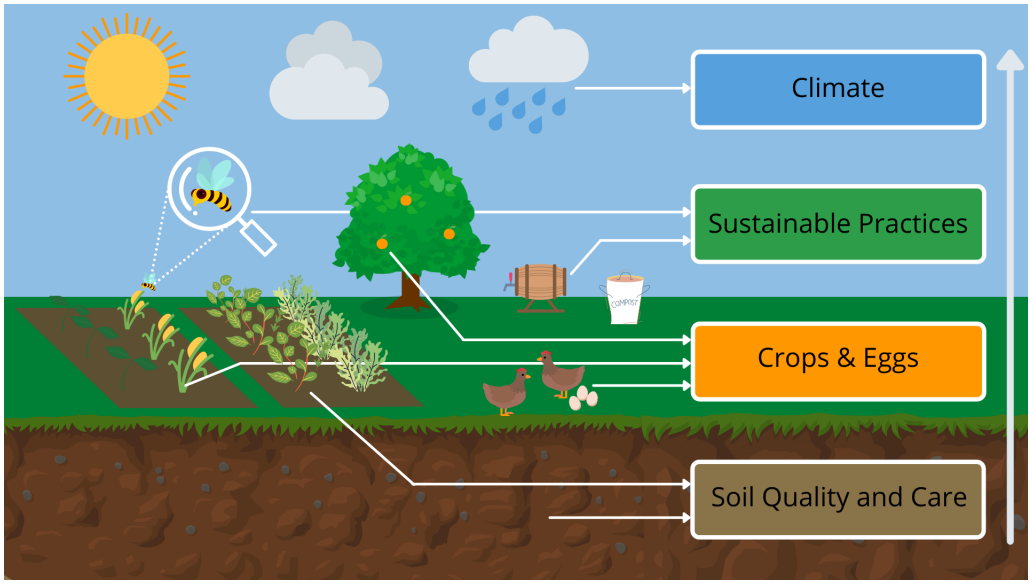

Figure 3: Diagram of each element involved in a successful garden

The first part of the garden that needs to be examined is the soil. This project will provide a method in which even small, rural schools can examine the soil and determine its overall health and quality. Much of the soil in this region is rich volcanic soil, which is loaded with organic material and other nutrients. However, it is still vital to establish the overall health of the soil, and not assume its condition. For most crops, the soil should be relatively loose in structure, contain ample amounts of organic material, and have helpful organisms, such as earthworms, living under the surface. If the available soil is unhealthy, it can be treated with organic matter, such as compost, to deliver the nutrients necessary to support a garden.

Garden sustainability is also key, and there are several methods by which schools can maintain the garden's health. The first of these methods is fertilization, which involves regularly integrating organic material into the soil bed in order to better provide nutrients for the crops. This primary method that this project has determined to be most efficient is composting. Vermiculture is the use of worms to speed up the decomposition process. Open bin composting integrates the use of wooden or fenced in bins, with the use of either three bins or one bin depending on the space available. Pit and piling composting is the use of either a pit or a pile to decompose the organic materials. Secondly, permaculture is a technique that can be helpful in using the natural layout of the garden to maximize efficiency. This can include the structure of plant rows, using cover crops, and minimizing soil tilling.

Having a consistent source of water is also a key item to address. This project has outlined several efficient methods of water conservation to provide water for crops as needed. Mulching with organic matter is an easy and effective way to retain more water. Xeriscaping is the technique of only growing native plants and grouping them by similar water requirements. Rainwater catchment systems are a way of collecting rainwater through a system of gutters attached to a roof of a building. The water can then find its way to a holding tank, and be used during dry spells. Drip irrigation is the last method discussed. This utilizes a network of pipes that run through the garden and directly water plants at the roots. This reduces the amount of evaporation during watering. All selected composting and water conservation methods are analyzed in the tables below (*Tables 1 and 2*).

Table 1: Comparison of selected composting techniques

Composting Method	Cost	Materials Needed	Space Required	Time	Labor Involved
Vermiculture	$$	✓✓	⌂ ⌂	☼ ☼	Ψ Ψ
Open Bin (One Bin)	$$$	✓✓✓	⌂ ⌂	☼ ☼ ☼	Ψ Ψ Ψ
Open Bin (Three Bins)	$$$	✓✓✓	⌂ ⌂ ⌂	☼ ☼	Ψ Ψ Ψ
Pit	$	✓	⌂	☼ ☼ ☼	Ψ Ψ
Piling	$	✓	⌂ ⌂ ⌂	☼ ☼ ☼	Ψ Ψ Ψ

Table 2: Comparison of selected water conservation techniques

Water Conservation Method	Cost	Materials Needed	Labor Required
Mulching with Organic Matter	$	✓	Ψ Ψ
Xeriscape	$	✓	Ψ
Rainwater Catchment System - New Tank	$$$	✓✓✓	Ψ Ψ Ψ
Rainwater Catchment System - Recycled Tank	$$	✓✓✓	Ψ Ψ Ψ
Drip Irrigation	$$$	✓✓	Ψ Ψ Ψ

The last topic to evaluate is garden management. This involves evaluating the feasibility of certain methods for organizing people's roles in caring for the garden. This includes electing a teacher or other faculty member as garden manager, seed saving, and forming a community program called a "minga" to keep the school community motivated to take care of the garden.

Lastly, there are several recommendations that the team has made for schools using the information in this report. These recommendations were then presented in a garden guide to help schools formulate ideas for their garden. The team's recommendations are as follows:

1. Prioritizing the use of native plants
2. Producing a variety of food types (fruits, vegetables, grains, eggs)
3. Practicing water conservation
4. Implementing a composting method
5. Including medicinal herbs in the garden
6. Maintaining a management system

The benefits of each of these recommendations are also shown in the three tables below. Each recommendation is evaluated across several different aspects involved with a successful garden and a higher crop yield.

Table 3: Overall recommendations and their contributions to improved nutrition

Recommendation	Essential Nutrients	Crop Production	Native Plants
Prioritizing Native Plants	✓	✓	✓
Including Medicinal Herbs	✓	✓	✓
Producing a Variety of Food Types	✓	✓	✓
Practicing Water Conservation	X	✓	✓
Implementing a Composting Method	X	✓	✓
Maintaining a Management System	X	✓	X

Table 4: Overall recommendations and their contributions to agricultural sustainability

Recommendation	Pollinators	Soil Quality	Pest Control	Water Conservation
Prioritizing Native Plants	✓	X	X	✓
Including Medicinal Herbs	✓	X	✓	X
Producing a Variety of Food Types	✓	✓	X	✓
Practicing Water Conservation	X	✓	X	✓
Implementing a Composting Method	X	✓	X	✓
Maintaining a Management System	X	✓	✓	✓

Table 5: Overall recommendations and their contributions to garden management

Recommendation	Community Engagement	Decision Making	Motivation
Prioritizing Native Plants	✓	✓	✓
Including Medicinal Herbs	✓	X	✓
Producing a Variety of Food Types	✓	✓	✓
Practicing Water Conservation	✓	X	✓
Implementing a Composting Method	✓	X	✓
Maintaining a Management System	✓	✓	✓

These recommendations are highlighted in an easily digestible reference manual that includes our findings and recommendations. The analysis has been included in this reference manual in a manner that is easy to understand. With these recommendations and manual, the team aims to educate schools in Cuenca on the different avenues in growing a successful garden. Through this education and garden building, the team hopes to contribute to the alleviation of food insecurity for children throughout the region, and bring to their schools a center of science, culture, and life.

Abstracto

Este proyecto se centra en la seguridad alimentaria y la desnutrición entre los estudiantes en la región de Cuenca, Ecuador, y proporciona recomendaciones sobre el aliviamiento de estos problemas proporcionando directrices para ampliar y mejorar los huertos escolares. Después de extensas investigaciones y entrevistas con expertos en la materia, el equipo del proyecto formuló seis recomendaciones principales para mejorar la diversidad y nutrición de las plantas en un jardín escolar. Estas recomendaciones tienen por objeto ayudar a aliviar la malnutrición y la inseguridad alimentaria que se pueden encontrar en la región. Estas recomendaciones se centran en el cultivo de plantas nativas, la producción de una variedad de diferentes tiempos de cultivo, la práctica de la conservación del agua, la implementación de un método de compostaje, incluyendo hierbas medicinales en el jardín, y el mantenimiento de un sistema de gestión para el jardín.

Informe Ejecutivo

La inseguridad alimentaria y la pobreza son cuestiones prevalentes en las comunidades de todo el Ecuador. En 2018, las tasas nacionales de pobreza rondan el 43% en las comunidades rurales, casi el triple de la tasa urbana (Global Nutrition Report, 2020). Para algunos niños ecuatorianos, la comida más grande que pueden esperar durante el día es la que proporcionan los alimentos cultivados en el huerto de su escuela. Sin embargo, para muchas escuelas, esta comida podría incluir solo papas y repollo, ya que muchos huertos no tienen los medios o métodos adecuados para crecer más que esos cultivos simples. Este proyecto se centra en proporcionar los métodos necesarios para cultivar más y más saludables cultivos en los huertos escolares de Cuenca, Ecuador y sus alrededores.A través de esto, el equipo del proyecto espera aliviar la inseguridad alimentaria entre los estudiantes y proporcionar los métodos para construir un centro de vida y bienestar en el que la comunidad escolar pueda enorgullecerse.

A continuación, el equipo organizó los siguientes elementos procesables en tres objetivos principales:

Objetivo 1: Encontrar cultivos potenciales a través de investigaciones y entrevistas, luego determinar qué hace que una planta sea relevante para su uso en un huerto escolar

Objetivo 2: Identificar técnicas y prácticas sostenibles para huertos, y desarrollar criterios que ayuden a determinar qué los hace relevantes para un huerto escolar

Objetivo 3: Detallar las alternativas viables en una guía de jardinería escolar

Figura 1: Una resumen visual de los objetivos del proyecto y el proceso para completarlos

Los principales nutrientes que deben alimentar la dieta de un niño son las proteínas, el hierro, el calcio y las vitaminas A y C (Bernstein, 2016). Los alimentos ricos en nutrientes suelen ser relativamente caros, por lo que la mayoría de los niños de las zonas empobrecidas no reciben una cantidad saludable. Mientras que los niños en algunas áreas carecen de acceso a algunos nutrientes, pueden consumir demasiado otros. La falta de dinero en las zonas empobrecidas a menudo conduce a la compra de alimentos baratos que están cargados de carbohidratos y azúcares simples que, cuando se consumen en exceso, pueden causar obesidad. Por esta razón, el proyecto se centra en la variedad y la cantidad.

Sin los cultivos adecuados en el huerto, la preparación conceptual y física será inútil. Las consideraciones clave y la viabilidad de las posibles opciones de cultivo para la selección de plantas se muestran en la siguiente figura (Figura 2). El equipo ha construido varias tablas que analizan los beneficios nutricionales de los cultivos potenciales, con énfasis en los cultivos nativos de Ecuador. Las plantas nativas a menudo tienen importancia cultural para las comunidades de todo el país, y es importante satisfacer las necesidades de estas plantas nativas al recomendar métodos de jardinería.

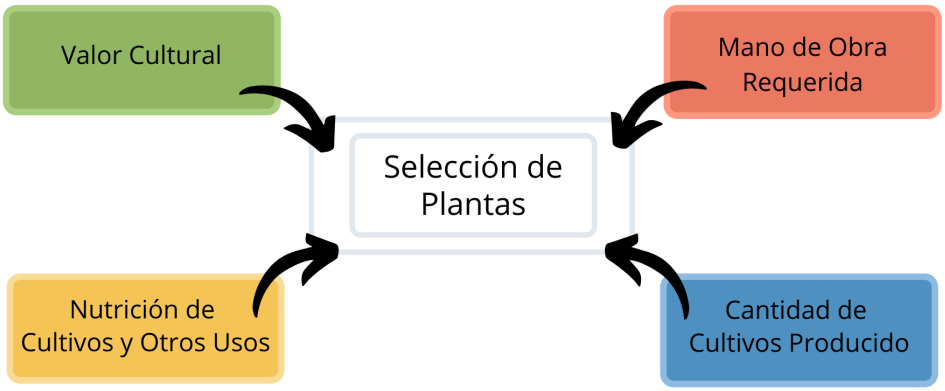

Figura 2: Un resumen visual de las consideraciones para la selección de plantas en aplicaciones de huerto escolar

Los cuatro tipos principales de alimentos considerados para un huerto son frutas, verduras, granos y hierbas. Las frutas son un tipo de alimento subconsumido en Ecuador, y reintroducirlas será un soplo de aire fresco para muchas comunidades escolares. Las verduras son el tipo de alimento más comúnmente cultivado en los jardines escolares, pero a menudo carecen de variedad. Los granos también proporcionan cantidades amplias de proteína y fibra, que faltan entre las dietas actuales de los niños en edad escolar. Por último, las hierbas medicinales tienen un cierto significado cultural que las hace muy importantes para tener en un huerto escolar. La Figura 3 a continuación muestra las diferentes partes del jardín que se discutirán y cómo interactúan.

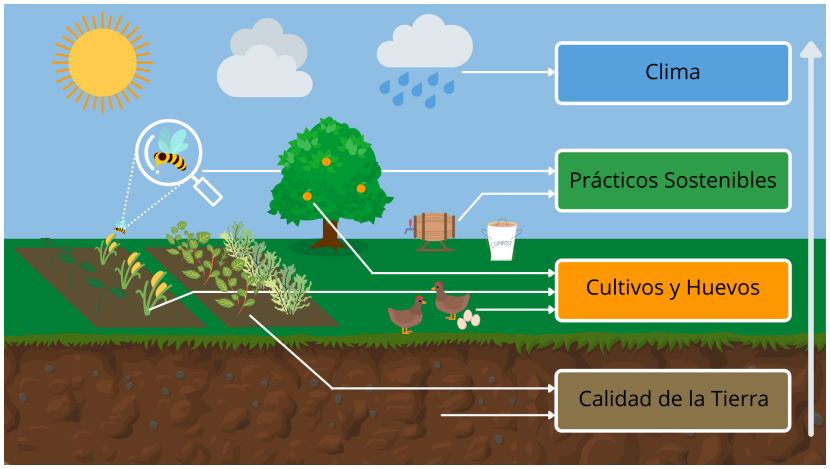

Figura 3: Diagrama de cada elemento involucrado en un huerto exitoso

La primera parte del jardín que necesita ser examinada es la tierra. Este proyecto proporcionará un método en el que incluso las pequeñas escuelas rurales pueden examinar la tierra y determinar su salud y calidad en general. Gran parte de la tierra en esta región es rica, tierra volcánica y cargada de material orgánico y otros nutrientes. Sin embargo, sigue siendo vital para la salud del huerto para establecer la salud general de la tierra, y no asumir que es saludable. Para la mayoría de los cultivos, la tierra debe estar relativamente suelta en estructura, contener cantidades amplias de materiales orgánicos, y tener organismos útiles, como lombrices de tierra, que viven bajo la superficie. Si la tierra disponible resulta ser malsano, puede tratarse con materia orgánica, como el abono, para entregar los nutrientes necesarios para apoyar un huerto.

La sostenibilidad del huerto también es clave, y hay varios métodos por los cuales las escuelas pueden mantener la salud de un huerto. El primero de estos métodos es la fertilización, que implica integrar regularmente material orgánico en el lecho de la tierra para proporcionar mejor nutrientes para los cultivos. Este método primario que este proyecto ha determinado ser más eficiente es el compostaje. La vermicultura es el uso de gusanos para acelerar el proceso de descomposición. El compostaje de gavetas abiertas integra el uso de gavetas de madera o valladas, con el uso de tres gavetas o un gaveta dependiendo del espacio disponible. El compostaje de foso y pilote es el uso de un foso o un montón para descomponer los materiales orgánicos. En segundo lugar, la permacultura es una técnica que puede ser útil en el uso de la disposición natural del huerto para maximizar la eficiencia. Esto puede incluir la estructura de las hileras de plantas, el uso de cultivos de cobertura y la minimización de la labranza de la tierra.

Tener una fuente constante de agua es también un elemento clave a tratar. Este proyecto ha esbozado varios métodos eficientes de conservación del agua y los ha utilizado para mantener cada cultivo hidratado según sea necesario. El mantillo con materia orgánica es una manera fácil y eficaz de retener más agua. Xeriscaping es la técnica de cultivar solamente plantas nativas y agruparlas por requisitos de agua similares. Los sistemas de captación de agua de lluvia son una forma de recoger el agua de lluvia a través de un sistema de canaletas adosado a un techo de un edificio. El agua recolectada entonces puede usarse para cualquier propósito del huerto. El riego por goteo es el último método discutido y es una red de tuberías que corren a través del huerto y directamente las plantas de agua en su sistema de raíces. Esto reduce la cantidad de evaporación

que ocurre al regar. Todos los métodos seleccionados de compostaje y conservación del agua se analizan en las siguientes tablas (*Tabla 1* y *Tabla 2*).

Tabla 1: Comparación de técnicas seleccionadas de compostaje seleccionadas

Método de Compostaje	Costo	Materiales Necesarios	Espacio Requerido	Tiempo	Mano de Obra
Vermicultura	$$	✓✓	⌂ ⌂	☼ ☼	ψ ψ
Compostador Abierto (Un Compostador)	$$$	✓✓✓	⌂ ⌂	☼ ☼ ☼	ψ ψ ψ
Compostador Abierto (Tres Compostadors)	$$$	✓✓✓	⌂ ⌂ ⌂	☼ ☼	ψ ψ ψ
Pozo	$	✓	⌂	☼ ☼ ☼	ψ ψ
Amontonar	$	✓	⌂ ⌂ ⌂	☼ ☼ ☼	ψ ψ ψ

Tabla 2: Comparación de técnicas seleccionadas de conservación del agua

Método de Conservación del Agua	Costo	Materiales Necesarios	Mano de Obra
Cubrir con Mantillo Orgánico	$	✓	ψ ψ
Xeriscape	$	✓	ψ
Sistema de Captación de Agua de Lluvia - Tanque Nuevo	$$$	✓✓✓	ψ ψ ψ
Sistema de Captación de Agua de Lluvia - Tanque Reciclado	$$	✓✓✓	ψ ψ ψ
Riego por Goteo	$$$	✓✓	ψ ψ ψ

El último tema a evaluar es la gestión del huerto. Esto implica evaluar la viabilidad de ciertos métodos para organizar los roles de las personas en el cuidado del huerto. Los métodos involucrados incluyen la elección de un maestro u otro miembro de la facultad como gerente de huerto, ahorro de semillas, y la formación de un programa comunitario llamado "minga" para mantener a la comunidad escolar motivada para cuidar el huerto.

Por último, hay varias recomendaciones que el equipo ha hecho para las escuelas utilizando la información de este informe. Estas recomendaciones fueron presentadas en una guía de huerto para ayudar a las escuelas a formular ideas para su huerto. Las recomendaciones del equipo son las siguientes:

1. Priorizar el uso de plantas nativas
2. Producir una variedad de tipos de alimentos (frutas, verduras, granos, huevos)
3. Practicar la conservación del agua
4. Implementar un método de compostaje
5. Incluir hierbas medicinales en el huerto
6. Mantener un sistema de gestión

Los beneficios de cada una de estas recomendaciones también se muestran en las tres tablas siguientes. Cada recomendación se evalúa en varios aspectos diferentes involucrados con un huerto exitoso y un mayor rendimiento de los cultivos.

Tabla 3: Recomendaciones generales y sus contribuciones a la mejora de la nutrición

Recomendación	Nutrientes Esenciales	Producción de Cultivos	Plantas Nativas
Priorizar las Plantas Nativas	✓	✓	✓
Incluir Hierbas Medicinales	✓	✓	✓
Producir una Variedad de Tipos de Alimentos	✓	✓	✓
La Práctica de la Conservación del Agua	X	✓	✓
La Implementación de un Método de Compostaje	X	✓	✓
Mantener un Sistema de Gestión	X	✓	X

Tabla 4: Recomendaciones generales y sus contribuciones a la mejora de la agricultura sostenible

Recomendación	Polinizadors	Calidad de la Tierra	Control de Plagas	Conservación del Agua
Priorizar las Plantas Nativas	✓	X	X	✓
Incluir Hierbas Medicinales	✓	X	✓	X
Producir una Variedad de Tipos de Alimentos	✓	✓	X	✓
La Práctica de la Conservación del Agua	X	✓	X	✓
La Implementación de un Método de Compostaje	X	✓	X	✓
Mantener un Sistema de Gestión	X	✓	✓	✓

Tabla 5: Recomendaciones generales y sus contribuciones a la mejora de la gestión del huerto

Recomendación	Participación Comunitaria	El Proceso Decisorio	La Motivación
Priorizar las Plantas Nativas	✓	✓	✓
Incluir Hierbas Medicinales	✓	X	✓
Producir una Variedad de Tipos de Alimentos	✓	✓	✓
La Práctica de la Conservación del Agua	✓	X	✓
La Implementación de un Método de Compostaje	✓	X	✓
Mantener un Sistema de Gestión	✓	✓	✓

Estas recomendaciones se destacarán en un manual de referencia fácilmente digerible que incluye nuestras conclusiones y recomendaciones. Los análisis se incluirán en este manual de referencia de una manera que sea fácil de entender y de la que se pueda llegar a una conclusión. Con estas recomendaciones y manual el equipo pretende educar a las escuelas de Cuenca sobre

las diferentes vías para el crecimiento de un huerto exitoso. A través de esta educación y construcción de huertos, el equipo espera contribuir al alivio de la inseguridad alimentaria para los niños de toda la región, y llevar a sus escuelas un centro de ciencia, cultura y vida.

Table of Contents

List of Figures

List of Tables

Authorship

Section	Author(s)	Editor(s)
1. Introduction	Will Burnham	All
2. Landscape of Alternatives	All	All
2.1 Purpose of School Gardens	Adrienne Whitney	Will Burnham
2.2 Nutritional Considerations	Pat Flaherty	Anne Davis
2.3 Soil Quality and Care	Pat Flaherty, Adrienne Whitney	Pat Flaherty, Adrienne Whitney
2.4 Food Options	Adrienne Whitney, Pat Flaherty, Will Burnham	Anne Davis, Adrienne Whitney
2.5 Sustainable Practices	Pat Flaherty, Adrienne Whitney	Adrienne Whitney
2.6 Climate	Pat Flaherty, Will Burnham	Adrienne Whitney
2.7 Garden Management	Will Burnham	Pat Flaherty
2.8 Conclusion	Anne Davis	Will Burnham
3. Methods	Will Burnham, Adrienne Whitney	Pat Flaherty
3.1 Objective 1	Adrienne Whitney	Anne Davis
3.2 Objective 2	Adrienne Whitney, Will Burnham	Pat Flaherty
3.3 Objective 3	Will Burnham	Adrienne Whitney
3.5 Ethical Implications	Adrienne Whitney	Will Burnham
4. Application Within School Garden Environment	All	All
5. Recommendations	Anne Davis, Will Burnham, Adrienne Whitney	All
6. Conclusion	Will Burnham	Adrienne Whitney
References	All	All
Appendices	All	All

1. Introduction

Food insecurity and poverty are serious social concerns throughout Ecuador. Nearly half of Ecuador's population lives in poverty, and individuals in both urban and rural areas experience negative effects associated with these issues. In 2018, national poverty rates hovered around 43% in rural communities, nearly triple the rate in urban areas (Global Nutrition Report, 2020). Many households, especially in rural areas, make their living through agriculture, which limits opportunities for career growth, and access to higher levels of education. However, rural schools still wield a strong influence in the lives of their students and the communities they serve.

In addition to education, schools in Ecuador often provide students with a stable primary source of food (G. Palacios, personal communication, February 22, 2021). This is a critical element of a child's wellbeing, as there is a clearly defined link between poverty, education level, and health (Bertoli & Marchetta, 2014). Students who live in poverty are less likely to perform well in school, and more likely to live their entire lives in poverty (McCarty, 2013). To help combat this issue, some schools choose to host a garden. This allows students to gain access to a healthier variety and quantity of food than they might be exposed to at home. The increase in quantity and variety is critical to improving the diet and overall health of students (Sherman, 2005). Additionally, these gardens can provide an avenue for students to explore educational topics in science and botany.

This project focuses on schools in rural communities surrounding Cuenca, Ecuador. These communities are affected by poverty and food insecurity. Schools across the region commonly utilize gardens as a solution to provide critical meals to students. However, these gardens are often limited to a few basic plantings. Our project team worked to create a school garden guide that can be applied to schools throughout this area. This garden guide is a tool to assist the diversity of available foods and overall nutrition that students receive from their school meals. This work has been done with the help of the Castle Foundation, a non-profit organization whose aim is to impact future generations and create opportunity through education, health, and well-being. Many of the organization's projects aim to establish easily implementable programs in schools for the purpose of benefiting local children and communities, which is where the vision for this school garden project originated. The background research explores the most vital factors in creating a school garden for rural communities around Cuenca.

2. Landscape of Alternatives

There are a myriad of factors and techniques to consider when gardening. But before diving into all the gardening possibilities, the paper will discuss the different purposes of school gardens. Then nutrition is addressed, followed by the aspects of gardening, from the ground up. This is done to better understand both gardening in general and also in Ecuador specifically. Lastly, garden management will cover the human aspect of maintaining a garden effectively.

2.1 Purpose of School Gardens

School gardens are becoming commonplace around the world (Seaman, 2021). They are an incredibly low cost method of producing healthy food at the school grounds, and can provide students hands-on learning opportunities outside of the traditional classroom. While gardening may be a fun activity for students in the U.S., it is often a necessity for students in areas where access to food is not always stable, such as in the rural areas surrounding Cuenca, Ecuador. In addition to providing basic science and botany education, school gardens are vital to improving student nutrition through increased access to fruits, vegetables, and other crops (Smith et al., 2017).

2.1.1 Alleviating Food Insecurity

A lack of food security is the underlying issue for hunger and malnutrition in students throughout Ecuador. The Food and Agriculture Organization of the United Nations (FAO) has defined food security as the state when all people in a community have economic, social, and physical access to sufficient, nutritious, and safe foods which meet the dietary requirements for individuals to lead a healthy lifestyle (Mohammadpour et al., 2019). Often the largest limiting factor for students in impoverished areas is lack of access to a steady source of nutritional food. The United Nations

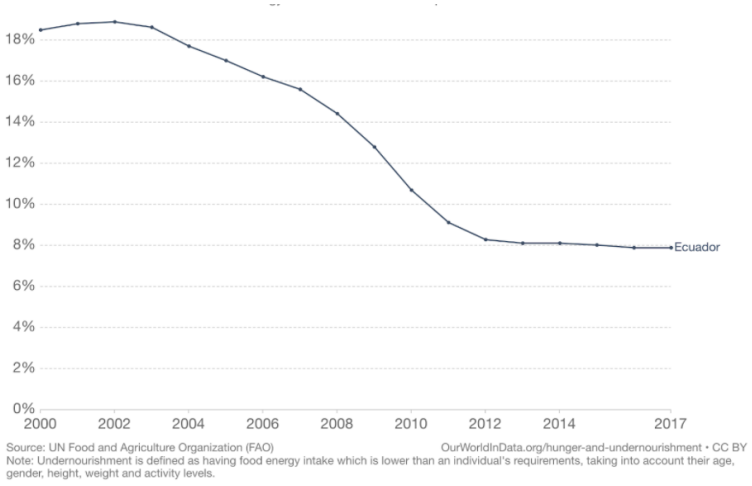

Figure 1: Percent of population classified as undernourished in Ecuador [Percent of population undernourished in Ecuador].

currently classifies eight percent of Ecuadorians as undernourished, meaning they have food-energy intake lower than healthy amount (*Figure 1*). Rural environments in Ecuador are especially vulnerable to stunting due to malnutrition, and as of 2014 nearly one third of children under five in rural areas were experiencing stunting (Global Nutrition Report, 2020). However, in 2017, over 98% of school-aged children in Ecuador attended primary school, demonstrating the potential for school gardens to reach many students, and have a widespread impact on alleviating food insecurity (World Bank, 2017).

2.1.2 Education

School gardens can do much more than help supplement diets, one additional benefit is education. School gardens have been used for experiential teaching, where both students' learning and nutrition can benefit (Duncan et al., 2016). Garden-based learning can bring many benefits, including improved eating habits and food literacy, greater interest in learning, community building, and a positive attitude toward the environment (Smith et al., 2017). Ideally this education and experience in the garden gives students an opportunity to bring something home to their family by learning gardening techniques and methods. School gardens have also been shown to increase the ties between schools and communities by expanding gathering places, which can create further interest in the garden (Seaman, 2021).

2.2 Nutritional Considerations

There are numerous nutritional concerns arising from the lack of food security. This includes protein-calorie malnutrition, a lack of dietary fiber, and vitamin-A deficiency (Hackett et al., 2007). These nutritional issues occur in both the cities and rural areas of Ecuador, despite a significant income inequality between these two areas (*Ecuador | World Food Programme*, n.d.). This inequality has a direct negative effect on rural areas, meaning people cannot buy the more expensive and healthier foods that are nutrient rich (A. Loja, personal communication, February 24, 2021). This lack of purchasing power also causes excessive consumption of carbohydrates and simple sugars by people in rural areas, as these are present in foods that are less expensive to buy. This excess can often lead to obesity, despite being malnourished (G. Palacios, personal communication, February 22, 2021). There is also little intake of fruit in spite of natural fruits being fairly common to the region.

To combat malnutrition, children should have daily access to nutrient dense foods and consume foods with low nutrient density in moderation (S. Cloran, personal communication, February 11, 2021). According to Dra. Palacios, a nutrition expert at the University of Cuenca, protein and fiber are two main nutrients that many students in the Cuenca region are regularly under consuming (G. Palacios, personal communication, February 22, 2021). These nutritional deficiencies were addressed by exploring the nutritional benefits from certain vegetables, fruits, grains, herbs, and eggs. Native crops were emphasized as they are known to survive the climate, additionally, they are underutilized for their nutritional benefits, despite their availability (A. Loja, personal communication, February 24, 2021). The following infographic serves a visual representation and structure for the rest of the background, beginning with the soil, and ending with climate.

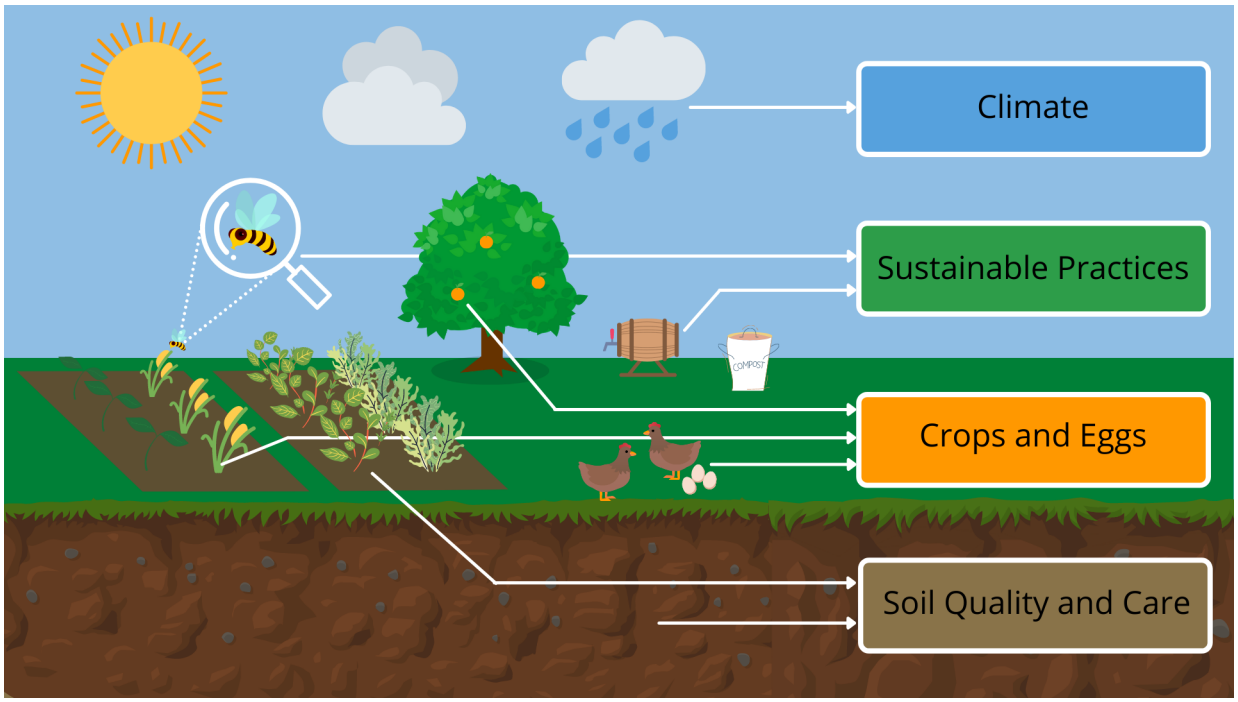

Figure 2: Diagram of the different elements involved in a successful garden

2.3 Soil Quality and Care

As illustrated in *Figure 2*, there are many elements that play a role in a successful garden. These will be examined throughout the paper. Beginning at the bottom of the infographic (*Figure 2*) and moving up, the first building block to a healthy garden is the soil. Plants need soil with particular characteristics. Soil within the Paute River Basin is characterized as rich, dark soil that

is highly organic (Buytaert et al., 2005). The soil in this region is made up of significant amounts of decomposed volcanic material and organic matter (Buytaert et al., 2005; *Histosols*, n.d.). These two elements lead to high water retention and indicate that the soil is enriched with iron and aluminum (Espinosa et al., 2018). *Figure 3* shows an example of soil texture in the target area and successful crop growth. Although the soil may look healthy, there are a few things to check for before committing to planting.

Figure 3: Potatoes and soil at a school garden outside of Cuenca, Ecuador

There are three aspects of the soil that should be tested: the chemical, physical, and biological properties. The first of these, chemical, may be difficult to measure in rural or urban Ecuador as it requires a pH testing kit. Many schools may not have the resources needed to acquire one. Instead, both the physical and biological aspects can be tested relatively easily. Physical structure of the soil refers to the texture and composition. For example, soil can have a composition similar to clay, or sand, or somewhere in between. Clay-like soil is very nutrient rich, but does not drain water well, and is therefore prone to pooling during heavy rainfall (Espinosa et al., 2018). Sandy soil is able to drain water quickly, but does not have many nutrients. The ideal soil is somewhere in between these two, where the soil molds together well, but comes apart partially in soft chunks and grains. This soil is best for water retention and drainage, while still containing nutrients (Seaman, 2021). The composition can be evaluated using a squeeze test, which is essentially squeezing a sample of soil and observing if it reflects the previously mentioned structure. The third aspect is the presence of insects and bugs that are helpful for the growth of the garden, such as earthworms. The presence of earthworms indicates that the soil contains an adequate amount of organic material.

Soil health can also determine the type of garden bed that should be used. If the soil is healthy, the garden bed can be the soil in the ground. If the soil is not healthy, a raised bed can be used by bringing in soil from another location or treating the existing soil with organic material. A raised bed should ideally have a frame that allows at least 6 inches of soil above the ground (Cabannes & Cecilia, 2018). This frame can be made out of wood, but schools can also use

recycled materials to save on cost. The flowchart in *Figure 4* shows the thought process behind choosing which type of garden to build.

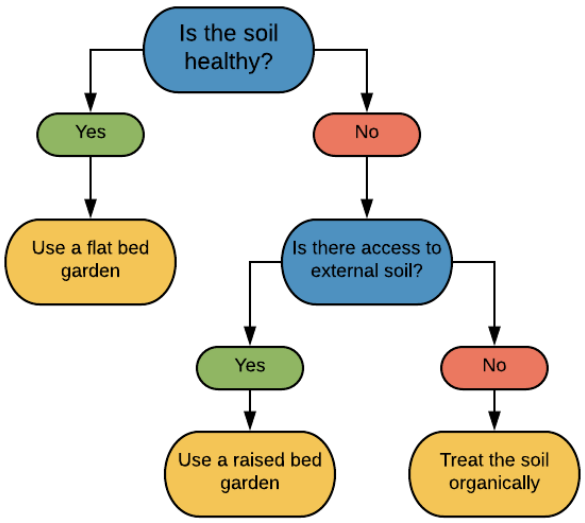

Figure 4: Decision tree for soil care and garden bed construction

No matter the type of garden bed that is being used, fertilization is an essential part of keeping soil healthy. It is a way of providing vital nutrients to the plants. However, these nutrients are depleted the more plants that are grown in an area (Prasad, 1999). The nutrients found in the soil naturally need to be replenished regularly in order for a garden area to thrive (*Sustainable Green Alternatives to Fertilizers Could Boost Food, Energy Security*, n.d.). Replenishing can be done by composting organic matter like dead plants or leftover food scraps.

Composting is the breakdown of this matter into natural fertilizer that helps the soil retain moisture, prevent plant diseases, and become enriched with nutrients (US EPA, 2013). There are numerous types of composting methods that strive to achieve these results. No matter the method utilized, there are five main considerations that need to be kept in mind when composting. The particle size of the materials being composted should be reduced to increase the overall surface area that microorganisms can feed upon. This speeds up the decomposition process (US EPA, 2015). Having smaller particle sizes also improves the homogeneity of the pile. This idea of homogeneity also plays into the concept of the balance of nutrients. This balance of nutrients is performed by adding different materials to the compost pile. These materials are generally sorted into green and brown categories. Green organic matter would be material that is high in nitrogen (US EPA, 2015). Examples of this would be manure, grass clippings, or food scraps. Brown organic materials generally have higher amounts of carbon and less nitrogen. Main examples of

this category would be sticks or dried leaves. Microorganisms also need moisture to survive. Water's movement is also the way that the nutrients are moved within the pile. Oxygen is also crucial to success. Regularly turning a compost pile or adding a bulking agent, such as wood chips, allows for air flow within the pile and the process of decomposition to occur at a faster rate (US EPA, 2015). These four components are all used to control the fifth. The temperature of the pile affects the efficiency of the microorganisms. If the temperature is not high enough weeds and rot can occur, while a higher temperature prevents these from happening.

Vermiculture is a type of composting that uses red worms to help decompose the organic material (Bement, 2014). There is little work or setup involved besides a container that has two compartments. To start, one side should be prepared with bedding material, such as shredded paper or dead leaves, and burying food waste beneath this bedding to reduce the chances for flies. When this side is ready to be used as soil after several months, the same initial setup can be applied to the second compartment and the worms will migrate leaving the soil ready for use and free of worms (US EPA, 2015). Open bin is another common composting practice. This practice involves a cylindrical enclosure with an open top. The enclosure can be made using either mesh or wooden materials, so long as the sides have some access to air. This open design enables the user to have easy access to the pile to turn or to harvest (Bement, 2014). Another benefit of this option is the number of bins that can be set up. A one bin system requires less space, but is less effective for composting. A three bin system allows for easy transfers of piles as well as piles within several stages of decomposition (Bement, 2014). Pit composting is another simple option. All that is needed is to dig several holes, or pits, and then bury the organic waste. The materials gradually break down over several months and then create an excellent location to grow plants. The biggest downside to this method is that once a location is picked it cannot be changed easily. Lastly, piling is another inexpensive method that simply is creating a large pile of mixed organic materials. This method is simple and effective, but requires a decent amount of space (US EPA, 2013).

Another technique to keep the soil healthy is crop rotation, the idea that what some crops take away from the soil, other crops can give back. This system is used to ensure that the soil stays healthy between planting and harvesting. This involves planting one crop in a given section of the garden, and then planting a different crop there the following season (Coulson et al.,

2018). Selection of crops is very specific to a school's particular conditions, as such, crops should be chosen on a case by case basis to best support the school's environment and needs.

Another concept in garden planning which is an aspect of local culture is la chakra andina. Also known as swollen gardens, chakras are a type of polyculture agrarian systems used throughout Ecuadorian Amazonia and are composed of a mix of forest and complementary crops (Coq-Huelva et al., 2017). A traditional chakra is an agroforestry system which involves a high number of timber and fruit trees, which are an essential component as they help contribute to shade management in the garden. The garden's trees also aid in capturing inorganic nutrients from deeper soil layers, introducing them back into the vegetation cycle and enriching superficial soil layers. Additionally, the presence of trees in the chakra prevents erosion and reduces loss of the thin and fertile upper soil layer. Chakras foster a high biodiversity of plants and animals, and this diversity of biotic mass helps conserve the fertility of the garden's soil (Coq-Huelva et al., 2017). One key element of the chakra andina is the coexistence of small-scale livestock rearing, particularly poultry farming (Coq-Huelva et al., 2017). Poultry keeping has strong biological rationality in chakras because plant matter not consumed by humans can be fed to the poultry. This aspect of the chakra also supports one of the proposed concepts for the project's garden guide: introducing chickens to the garden. Chicken manure is also another sustainable method of fertilization. Including chicken manure within a compost pile is beneficial as it contains nitrogen, phosphorus, and potassium, which all promote plant health and growth (Stonebrook, 2011; *Using Chicken Manure Safely in Home Gardens and Landscapes*, n.d.).

Another popular method of garden sustainability is permaculture (E. Lawrence, personal communication, March 3, 2021). This is a gardening technique that uses natural elements to construct the garden and keep it healthy. One consideration of permaculture is planting the garden so that the caretaker never has to step foot on the growing soil in order to water or treat the plants while they grow. It is also important to dig up the soil as little as possible. Tilling can expose the lower layers of soil to sunlight and heat, which can decrease the moisture and organic content of the soil's root layers (E. Lawrence, personal communication, March 3, 2021). Lastly, cover crops such as beans and peas are useful for keeping the soil in place and are easy to use as compost. Cover crops also have the additional benefits of improving water penetration into the soil and habitats for native pollinators (Driver, 2014). Close attention to soil health allows for a more open selection of crops and herbs.

2.4 Food Options

2.4.1 Crops

Vegetables are a key part of maintaining a healthy and balanced diet. They provide many nutrients that can help lower blood pressure, reduce the risk of certain diseases (*Vegetables and Fruits*, 2012). Protein promotes muscle, bone, and skin growth (Zelman, 2019). Fiber is known to help maintain a healthy weight and lower chances of heart disease as well as lowering cholesterol and supporting the immune system (Bhargava, n.d.). Minerals are a key factor to the growth and development of the body. Vitamins play various roles, vitamin A supports cell function while vitamin C is an antioxidant that promotes healing and helps the body absorb iron (Brennan, 2020). The B vitamins are essential for the metabolism, digestion, and wound healing. All of these minerals, vitamins, and nutrients, work together to keep the body healthy.

Table 1 below shows a variety of vegetables that are well suited for surviving in the Andean climate, while also being good sources of various nutrients. The table also outlines whether or not the plant is native to Ecuador, and general food uses.

Table 1: Table outlining the nutrient information of potential vegetable options

Vegetable	Native	Protein	Fiber	Calcium	Iron	Potassium	Vitamins	Other Nutrients	Food Uses
Broccoli	N	Y	N	Y	Y	Y	A,C,D,E,K	phosphorus, zinc	raw, roast, steam, stir-fry
Black Beans	Y	Y	Y	Y	Y	Y	A,C	magnesium	soak
Cabbage	N	N	Y	Y	Y	Y	C,K,B-6	magnesium	boil, raw
Carrots	N	N	Y	Y	Y	Y	A,C,K		boil, roast, steam, stir-fry
Choclo	Y	Y	Y	N	N	N	C		boil, steam, roast
Kale	N	Y	Y	Y	N	Y	A,C,K,B-6	copper, manganese, phosphorus, zinc	raw, roast, steam, stir-fry
Lentils	N	Y	Y	Y	Y	Y	N		boil
Peas	N	Y	N	Y	Y	N	A,B,C,E	zinc	boil, saute
Potatoes	Y	N	Y	N	N	Y	N	magnesium	bake, fry, roast

*Table mainly generated from: (Albert, 2009; Brennan, 2020; Zelman, 2019)

Vegetables are not the only important food group to consider when trying to improve a diet. Having a regular and balanced intake of fruit is also critical for achieving this (*Vegetables and Fruits*, 2012). There are many fruits that can grow in the Andean climate. These fruits are able to provide nutrients that cannot be obtained from consuming vegetables or eggs. Naturally occurring sugars are healthy in moderation and when accompanied by foods containing

important nutrients. Naturally occurring sugars can often make foods more palatable for kids. (*Sugar 101*, n.d.). *Table 2* below provides a nutrient profile of several potential fruits that are suited to living in the climate.

Table 2: Table outlining the nutrient information of potential fruit options

Fruit	Native	Protein	Fiber	Calcium	Iron	Potassium	Vitamins	Other Nutrients	Food Uses
Babaco	Y	Y	Y	Y	Y	Y	A,C	magnesium	cooked, juice, raw
Banana Passionfruit	Y	Y	Y	Y	Y	Y	A,C		juice, raw
Uvilla	Y	N	Y	Y	N	N	C		jam, jelly, raw
Naranjilla	Y	N	Y	N	N	Y	A,C,K,B-6	niacin	cooked, jam, jelly, juice, raw
Strawberry	N	N	Y	N	N	Y	C	manganese, healthy cholesterol	jam, jelly, raw
Tree Tomato	Y	Y	N	Y	Y	Y	A,B,C	copper, zinc	jam, jelly, salsa

*Table mainly generated from: (Bhargava, n.d.; Boeckmann, n.d.; England, 2020)

While fruits and vegetables are both two major components of a healthy diet, it is also important to mix in a regular intake of whole grains (Krans, 2020). Whole grains are often rich in protein, fiber, antioxidants, and trace minerals. With a greater inclusion of whole grains in a diet there is a reduced risk of obesity, type 2 diabetes, and heart disease (Zelman, 2011). *Table 3* below is focused on grains indigenous to Ecuador and the Andes mountains.

Table 3: Table illustrating potential grain options and their nutrition data

Grain	Native	Protein	Fiber	Calcium	Iron	Potassium	Vitamins	Other Nutrients	Food Uses
Amaranth	Y	Y	Y	Y	Y	N	C	amino acids, magnesium, manganese, phosphorus, selenium	baking, boil, dried, soup
Kaniwa	Y	Y	Y	Y	Y	N	A,C	amino acids, magnesium, zinc	baking, dried, soup
Quinoa	Y	Y	Y	Y	N	N	B-1	magnesium, manganese, phosphorus	baking, soup

*Table mainly generated from: (Carroll, n.d.; Repo-Carrasco-Valencia & Vidaurre-Ruiz, 2019; Smith, n.d.)

Medicinal herbs are another important crop to include when growing gardens around Cuenca, as herbs have a great cultural importance due to their various uses. Rather than an over-the-counter pain reliever or other commercially produced medicine, many herbs are used to help naturally soothe minor aches and ailments (A. Loja, personal communication, February 24, 2021). Some such uses of medicinal herbs include reducing symptoms of arthritis, inflammation,

minor infections, migraines, and respiratory ailments like the common cold (Garalli et al., n.d.). The most common way these herbs are used is in herbal teas, which are often consumed with edible flowers as well (Pujol, 2011). The use of medicinal herbs in Ecuador is even more critical as in many areas there is poor access to manufactured supplements, and some herbs like chamomile can provide essential vitamins and minerals (A. Loja, personal communication, February 24, 2021). Many of the popular herbs include chamomile, rue, and marigolds (A. Loja, personal communication, February 24, 2021). While chamomile and rue are not native to Ecuador, they both provide medicinal uses such as aiding with digestion and soothing coughs and rashes. Marigolds are another key native plant to include in school gardens as the oil from the plant's leaves can be used to help reduce minor skin inflammations and heal small wounds. Agriculturally, marigolds are resilient and succeed under a wide range of growing conditions, and can tolerate dry and hot weather with ease. As a medicinal herb, the leaves of rue plants can be used to treat insect bites and reduce the severity of stomach cramps. Leaves can be harvested in moderation from mature plants continuously throughout the year, and although not native to Ecuador, this plant is hardy and drought resistant making it an easy plant to care for in a school garden. Mugwort and lemon balm are both non-natives, but they both are popular for medicinal uses. Mugwort is often used to help with arthritis and lemon balm is often used in teas to alleviate sleep disorders (A. Loja, personal communication, February 24, 2021). Mugwort is an especially beneficial option as it requires little water and would survive the dry season well. Lemon balm grows densely, making it a good choice for container gardening, but gardeners should be wary of planting lemon balm in the ground as it grows rapidly and can overtake a garden space (*Lemon Balm, 19.3 Oz (2-Pack), Live Plants – Bonnie Plants*, n.d.).

2.4.2 Chickens

Adding egg-laying chickens to the garden area could also help schools offer a wider variety of food for student meals. Chickens are space-efficient and cheap to feed. The eggs they produce are an inexpensive but highly nutritious food. Eggs contain a variety of minerals that aid in creating a healthy diet (Guoxun Chen et al., 2018). In a study conducted on individuals in the Cotopaxi Province, in Ecuador, it was found that eggs can have a very positive impact on growth at younger ages and have the potential to provide important nutrients to communities who do not have access to a wide variety of other foods (Iannotti et al., 2017). Adding egg-laying chickens

to the garden of a school could provide a source of protein which would otherwise be difficult to obtain. Eggs and crops are great sources of nutrition, but the garden will be even more successful if sustainable practices are implemented.

2.5 Sustainable Practices

Sustainable practices are methods of using the resources that are available naturally, to take care of the garden. They help promote water conservation, attracting pollinators, and managing pests. Sustainable practices reduce the inputs into the garden, and therefore help lower costs, making them more feasible for rural schools.

2.5.1 Water Conservation

There are several important practices which can be used to make sure a garden's production can be sustained. Water conservation is an important aspect to consider, as some schools in the area surrounding Cuenca experience water shortages, and the sloped environment at some schools presents an issue to relying on rainwater alone. Especially in the wet seasons, water runoff occurs, but one method of reducing runoff is to use thick layers of dead plant materials to soak up and retain water (Stonebrook, 2011). This essentially involves applying any unused or inedible plant matter from the garden to improve rainwater retention. In the event that the garden does not produce a significant amount of unused organic matter, rural schools can collect and use grass clippings as a slightly less-effective substitute.

Xeriscaping is a water-saving technique that is focused on only growing native plants that need minimal water. The logic behind this is that the climate will provide all that the native plants will need to survive (Rutledge et al., 2011). It also includes the idea of grouping plants with similar water needs near each other so as no plant is being under or over watered due to its proximity to a plant with different water requirements (Beaulieu, 2019). Even when utilizing the xeriscaping tactic a garden might still have additional water requirements beyond the natural climate.

One method of storing rainwater is to use a gutter system from the roof of a building to direct rainwater into a large container, an example of which is shown in *Figure 5* (E. Lawrence, personal communication, March 3, 2021). By using the roof as a catchment tool, a school can bypass the expense of constructing or buying a new catchment system. Rainwater collection was

also recommended for use in school gardens by Gerardina Juela from CETAP-LUCY in Cuenca, as the organization has used rainwater collection for years to water their garden (G. Juela, personal communication, March 2, 2021). However, this technique requires a tank that can hold large amounts of water, which is often expensive if a recycled alternative cannot be found.

Figure 5: An example of a rainwater catchment system utilizing a roof and gutter system

A method of water conservation which can help reduce the amount of water wasted during application is drip irrigation. In drip irrigation systems, water is applied directly to a plant's roots, reducing the evaporation which occurs when spray watering systems such as sprinklers are used. Allowing the system to only run for a select amount of time during cooler parts of the day such as the morning further aids in reducing water loss. When properly installed, drip irrigation may help gardeners save up to 50% more water than conventional watering systems (*10 Ways Farmers Are Saving Water*, 2014). However, there are many pipes, stakes, and other parts needed to establish and maintain a successful drip irrigation system. There are numerous setup mistakes which gardeners may experience, such as not correctly installing a filter or pressure reducer, using overly long lengths of mainline pipe, and poking too many holes in the irrigation pipes (Bauer & Wilson, n.d.). Without a proper filter or pressure reducer, regular maintenance inspections are necessary to maintain system effectiveness so that the small holes in each pipe do not get clogged. Similarly, pipe placement could be disrupted by movement in the garden and require gardeners to manually move them back into place (Bauer & Wilson, n.d.).

2.5.2 Attracting Pollinators

Attracting pollinators and fostering a supportive ecosystem is a vital element for maintaining the diversity of the garden and ensuring all crops produce fruit. Although not all plants require assistance during pollination as some are able to self-pollinate and some rely on wind to transport their pollen, pollination through insects and other pollinators is key to the success of dioecious crops such as cabbage. Pollination is especially important for these kinds of plants as the female plant will not produce fruit unless pollen from the male plant is received (Westerfield, 2000). Some plants like broccoli, kale, carrots, and strawberries are cross-pollinators which benefit from insect pollination, although if necessary they may self-pollinate with lesser degrees of success (Westerfield, 2000). In the case of many crops which are able to self-pollinate, like strawberries, the more heavily pollinated a particular plant is, the larger and better tasting the fruit it can produce ("Strawberry Pollination Guide," 2015). Other plants, such as the babaco tree, can produce fruit without insect pollination, but pollination is necessary in order for viable seeds to be formed (*Vasconcellea x Heilbornii - V.M.Badillo*, n.d.).

In the Cuenca area the main pollinators which contribute to garden success are butterflies, hummingbirds, and bees. In general, butterflies are attracted to crown-shaped flowers, hummingbirds to tubular flowers, and bees to plants with high amounts of both pollen and nectar. Planting crops and herbs which produce flowers in varying colors and types helps encourage a variety of pollinators to interact with gardens. An especially effective method of pollinator attraction is to grow plants native to the area (G. Juela, personal communication, March 2, 2021). As an area's pollinators have evolved over centuries alongside the native flora, native plants are often more effective in attracting pollinators than non-native plants ("Pollination and Bee Plants," 2007). It may also be beneficial to pollinators if a shallow dish of water is placed in the garden during hot or dry weather, as even insects can get dehydrated and suffer during intense heat or drought (*How to Make a Bee Friendly Garden*, 2021).

2.5.3 Pest Management

Next, pest management is an important factor in protecting the health of the garden. If provided unblocked access to a garden, birds and ground-dwelling animals like rodents may damage plants and consume the produce before it can be harvested. One prominent example is the white fly. According to Gerardina Juela of CETAP LUCY, the white fly has been a constant

nuisance for her school's garden (G. Juela, personal communication, March 2, 2021). In order to prevent damage, it is important to put in place either physical or chemical deterrents. Physical deterrents include fences or netting that can prevent rodents from getting into the garden, as well as scarecrows to keep birds away. Chemical deterrents such as pesticides can sometimes work, however many schools do not have access to such resources. Therefore, it will be more effective to use plants as deterrents by taking advantage of the odor properties of certain plants. Some potential plants of this nature include rue, mugwort, and marigolds, which grow in the Ecuadorian countryside and may be available to many schools (G. Juela, personal communication, March 2, 2021). Using these plants as natural deterrents will also promote pollinator interaction, whereas using physical barriers might act as a pollinator deterrent ("Pollination and Bee Plants," 2007).

2.6 Climate

Climate plays a major role in the types of plants which can be grown. Many plants have specific water, light, and temperature needs which must be met for them to provide the greatest yield. Ecuador is known as one of the most environmentally diverse nations in the world. Cuenca is situated in the Paute River Basin within the Southern Andes of Ecuador with elevations between 8,000 and 13,000 feet (*Paute River Basin (Ecuador) - BASIN INFO – Web Based River Basin Information System*, n.d.). This affects the overall climate as well as growing conditions for gardens. Due to the higher elevation, schools outside of Cuenca may experience cooler temperatures and less significant seasonal changes than in the city (Mora et al., 2014). There are two main dry seasons that occur from June to September and from December to January, while peak rain occurs during the Equinoxes (MacLeod, n.d.). The Paute River Basin experiences around 30 inches of rainfall annually (*CUENCA Climate: Average Temperature, Weather by Month, CUENCA Weather Averages - Climate-Data.Org*, n.d.). It is vital to the health of the garden to ensure that plants are not over or underwatered. These two distinct seasons provide another reason for practicing a method of water conservation. Implementing a garden management structure is another way of being sure the garden is cared for properly.

2.7 Garden Management

Garden management is the way by which a garden is organized and taken care of, it is essential to the success and sustainability of a garden. An undertaking as large as a school garden requires a team of individuals to take care of it. The major players in hosting a garden include teachers, students, community members, and parents. With all these members, there is an importance in keeping them engaged and motivated to take care of the garden.

The creation of a garden management team is done through forming a committee. This can be composed of teachers, parents, and members of the community. Engaging as many people as possible helps keep the project alive in case individual members lose motivation (Seaman, 2021). One technique is to have a garden management committee to help pick a garden manager based on their interest and ability. The garden manager's responsibility is to assign tasks and make sure the garden is being properly maintained. A garden manager will instruct faculty, community members, and students on topics like watering, planting, and harvesting schedules (E. Lawrence, personal communication, March 3, 2021). A schedule is an important piece in managing a garden. A garden is a series of cycles, and the garden manager is responsible for maintaining a schedule that controls these cycles, largely as the climate and seasons dictate. Additional garden tasks will include things like weeding and maintaining compost.

All of this upkeep can be very reliant on the traditional Ecuadorian work party known as a minga. A minga is an opportunity to bring the community together and work on something to benefit everyone (RealWorld Media, 2015). The minga can also be important for establishing new gardens for schools as it is an opportunity for a lot of work to be done in a short amount of time.

Another tool for creating engagement is the tradition of seed saving. This is the practice of saving the plant's reproductive material after the harvest, to be used for planting in the following season. Not only does seed saving cut costs because you are producing your own seeds, it can also lead to biodiversity and has deep cultural roots in mayan based agroecosystems (Gliessman, 2015). Seed saving allows for members of the community to plant their seeds that have been passed down from previous generations, and allow for preservation of their cultural roots, and utilize the same plantings as their ancestors.

Along with encouraging engagement, motivating people to participate in the garden will help with sustaining the garden in the long term. Younger students can be motivated by being

given responsibility in the garden. This can often be asking them to keep an eye on a plant which encourages them to come back and check on the garden. For motivating those who are not directly part of the school, and further creating the feeling of a minga, parents and community members can be rewarded with a portion of the harvest if they are key contributors to the garden (E. Lawrence, personal communication, March 3, 2021). Garden management is an important piece to creating a productive and sustainable garden.

2.8 Summary of Considerations

In summary, the three main points that need to be considered when starting a school garden are nutrition, agriculture, and management. Nutritional considerations refer to the types of plants grown in the garden and the different nutrients that they will provide. Agriculture refers to climate and soil conditions. Lastly, management refers to the hierarchy of caretakers that will be involved in the garden's upkeep. The team took several steps in order to address each of these considerations.

3. Methodology

This section examines this project's main objectives, as well as the steps taken to complete each. The three main objectives, as described in *Figure 6*, were as follows:

Objective 1: Find potential crops through research and interviews, then determine what makes a plant relevant for use in a school garden.

Objective 2: Identify techniques and sustainable practices for gardens, develop criteria that will help determine what makes them relevant for a school garden.

Objective 3: Assess and compare various crops and sustainable practices with attention to criteria that make a plant or technique useful for school garden applications, such as cost and labor, to present in a gardening guide.

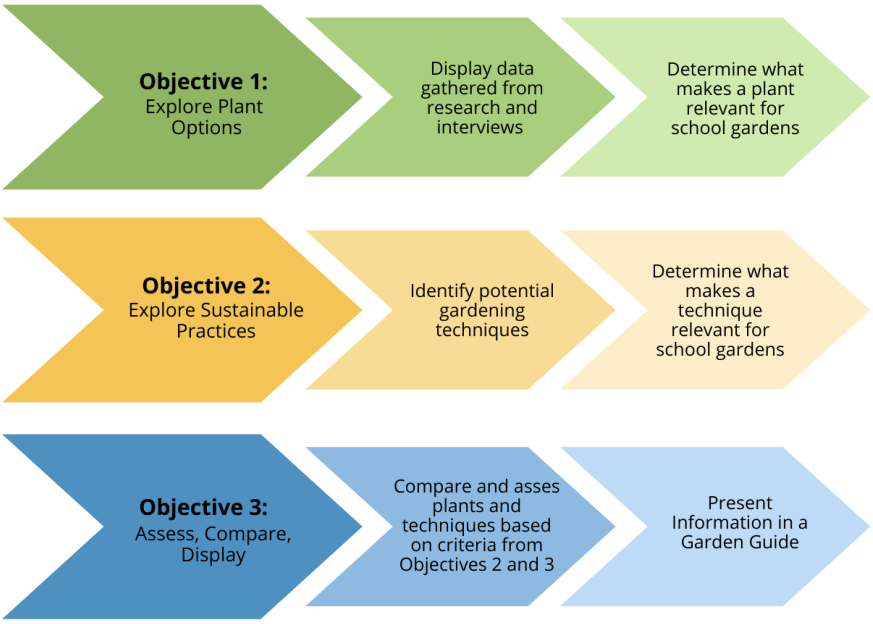

Figure 6: A visual summarization of the project objectives and the process to complete them

3.1 Objective 1: Plants For Nutrient Deficiencies

Through our background research, we discovered several key nutrient deficiencies in students in rural Ecuador. With continued research and interviews, we found and recommended crops that can help alleviate these deficiencies. These crops were then tabulated along with their planting requirements. Next, we determined what makes a crop or plant relevant or useful for a

school garden. With these new selection criteria, the information was further refined into tables based on the type of crop being examined.

3.2 Objective 2: Sustainable Practices

Many schools do not have perfect garden conditions and have a limited budget, creating a need for affordable sustainable practices. In order to assess potential sustainable practices and techniques, the team conducted several interviews with the locals of Cuenca, Ecuador. These interviewees included garden professionals and teachers of schools where school gardens are present. The team also interviewed professionals local to the Worcester, Massachusetts area to attain general recommendations on the science and growing techniques involved in gardening. A list of interviewees, their qualifications, and general topics of discussion are detailed in *Table 4* below.

Table 4: Table of interviewees for Objectives 2 and 3 and their respective qualifications

Interviewee	Qualifications	Relevant Appendix
Elisabeth Barreto	Leader and engineer for Fundación El Arenal, a non-government organization that provides socio-educational services for children and teens in Cuenca	Appendix H
Rocio Illescas, from CETAP-LUCY	Program Coordinator for CETAP-LUCY, an organization that works in Cuenca to improve food security and justice through gardening	Appendix I
Gerardina Juela from CETAP-LUCY	A leader at CETAP-LUCY; has spent years working with agro-ecological projects in the Cuenca area	Appendix I
Eliza Lawrence from the REC	School Garden Program Manager for the REC, an organization which helps implement and improve both community and school gardens throughout the city of Worcester	Appendix J
Elisabeth Stoddard	The co-director of the WPI Center for Sustainable Food Systems	Appendix K
Ana Loja	Faculty member at the University of Cuenca with extensive experience regarding agriculture in rural households and food availability in the Cuenca area	Appendix E
Dr. Gicela Monserrate Palacios Santana	Former director of Nutrition and Dietetics at the University of Cuenca; has a Master's Degree in Nutrition and Dietetics	Appendix G
Shavaun Cloran	Registered Dietitian for Chartwells at Worcester Polytechnic Institute	Appendix F

Interviews were performed via Zoom, as this method facilitates conversation with interviewees through face-to-face communication. Depending on the preference of the interviewee, interviews were performed in English or Spanish accordingly.

3.3 Objective 3: Detail Feasible Options

It is important to compare and assess the options from objectives 2 and 3. The plants were compared with the following criteria: nutritional value, space needed, water requirements, and time to yield. The sustainable practices we evaluated by cost, material needed, space requirements, time, and labor. The criteria for plants and sustainable practices were found to be the most critical factors. The final step in the project is making a detailed guide outlining different avenues that schools can take to implement a garden. The team has made several suggestions on the different types of gardens to build and crops to plant based on potential scenarios of different schools. These guides will be distributed online primarily, and then in hard copy form when schools reopen in the area.

3.4 Ethical Implications

This study has been approved by the Worcester Polytechnic Institute Institutional Review Board (IRB) for the Rights of Human Participants in Research and Training Programs. All subject-matter experts or other knowledgeable individuals interviewed have been asked for consent to use their name when citing the information provided, and all requests to remain anonymous have been honored. All interviewees were over the age of 18 and participation in this study was completely voluntary. This study presented very minimal risk to the participants.

4. Application Within the School Garden Environment

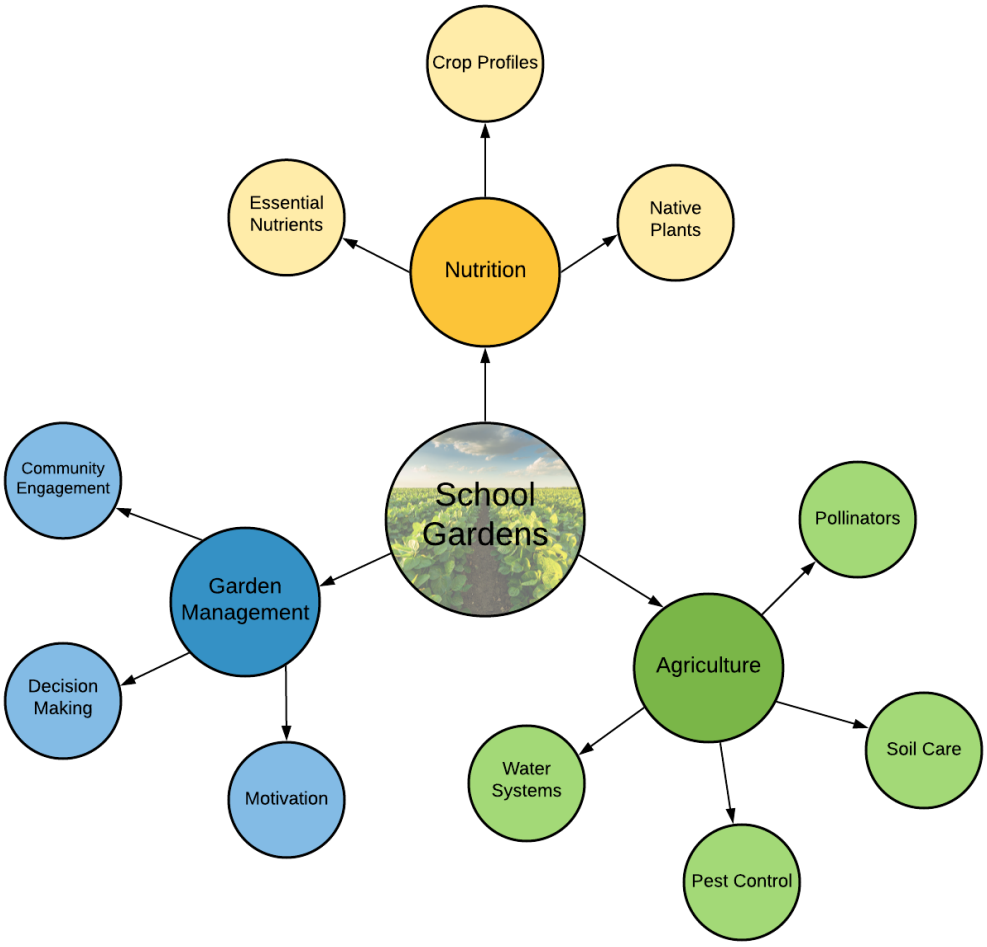

Figure 7: A concept map illustrating the relationship between each aspect of data collection

Figure 7 above shows the general applications that each subsection of background information can have on a school garden. The first of these subsections is nutrition, which includes the types of crops grown in the garden. The team's first objective was to determine the relevance of each crop using the data that had been gathered through research. The best method to complete this objective was to consolidate the data into tables. These tables display a series of categories with information relevant to their feasibility, from space requirements to pollinator attractivity. Many of the crops that were prioritized in these tables were recommended to the project team by interviewees that live in Ecuador and better understand the value of different plants in both culinary and cultural applications.

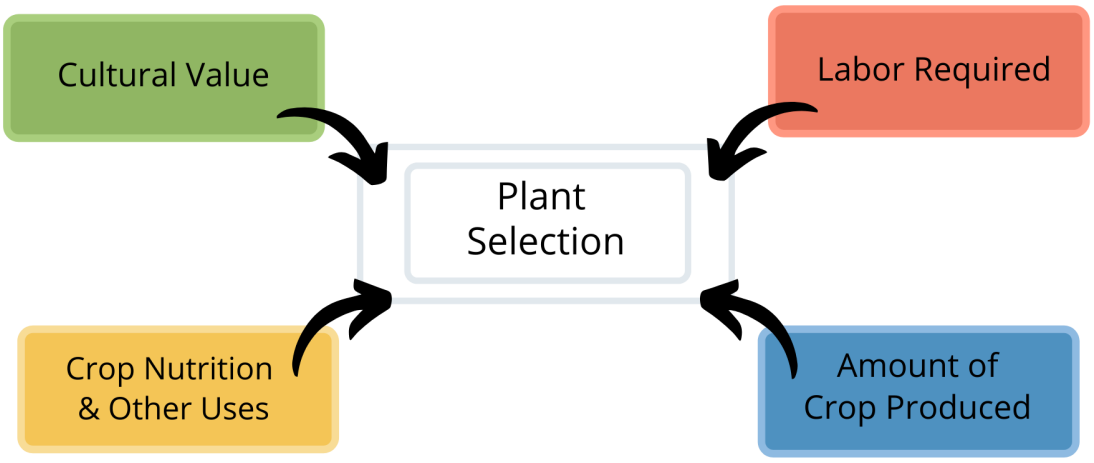

Figure 8: A visual summary of the considerations for plant selection in school garden applications

When selecting crops to grow in a school garden, there are four major aspects which should be brought into consideration as detailed in *Figure 8*. One of the most important considerations when choosing crops for an Andean school garden is the cultural significance, or lack thereof, of each plant being selected. Ensuring that cultural practices live on and are continued by future generations is essential. Given their long history of use in Ecuadorian medicine, growing and using medicinal plants is one such key practice. Utilizing native plants is another aspect of cultural importance, as they bring an appreciation to the natural Ecuadorian flora, fauna, and landscape. Invasive plants are a global issue, and prioritizing native plants in school gardens can both help preserve the area's culture as well as support the natural ecosystem.

Also, as many school gardens may be limited in the amount of time and labor which can be spent on the garden, the level of difficulty for plants and the required labor to grow them should be discussed during plant selection. A very fragile and easily trampled crop sensitive to small environmental changes may be a poor choice for use in a school garden, while a hardier, more resilient plant may better stand the test of time.

Next, the nutrition and other uses of each potential crop should be examined. In Andean gardening, there are certain crops which act as essential staples and are a cornerstone for any Ecuadorian garden. Three primary examples of these crops are, potatoes, cabbage, and black beans, and in Ecuador these foods are eaten regularly and in relatively high quantities. In addition to being relatively hardy and growing well in the area's conditions, potatoes and black beans are nutrient dense and can help students consume their daily caloric needs, which is an area of high concern for rural Ecuadorians. In contrast, some potential crops are often consumed

in smaller quantities, like fruits such as the cape gooseberry and babaco. Although not at the core of Ecuadorian diets, fruits can be especially valuable as they introduce variety into students' diets and help make the concept of trying new foods more attractive.

However, the amount of food produced by each potential crop should still be taken into account. With limited garden space at many schools, growing crops with low yield or large space requirements may be a poor choice. The primary goal for school gardens in the Cuenca region is to produce enough food to help sufficiently feed students, therefore time and space intensive crops should be kept in moderation. Choosing to include plants which can both thrive and produce food effectively in small spaces may help schools with limited space still grow a significant amount of food.

Table 5: Agricultural information for potential garden crops

Crop Name	**Native to Ecuador?**	**Space Needs**	**Water Needs**	**Soil Needs**	**Time to Yield**	**Sunlight Needs**	**Pollinator Attractivity**
Amaranth (*Amaranthus*)	Yes	Need good air circulation, plant 10-18 inches apart	No more than 1 inch of water per week	Overly Rich soil may hinder growth, use average soil	90-120 days	Partial Shade	Known to attract both bees and butterflies when in full bloom
Babaco (*Vasconcellea × heilbornii*)	Yes	Grows into a small tree of about 6 feet in height	Water sparingly after planting, soil should be allowed to dry partially between watering	Well-drained soil enriched with organic matter	2 years to maturity, followed by 8 years of producing 30-60 fruit per growing season	Partial shade to full sun	No key pollinator attracting qualities
Banana Passionfruit (*Pasiflora*)	Yes	Requires support, such as a trellis (~2m)	Regular water during growing season only	Well draining, but can grow in any soil type	2 years to maturity, followed by year round, continuous fruit production	Full sun	Beautiful red-pink flowers attractive to hummingbirds

Table 5 continued in Appendix C

Table 6: Agricultural information for potential medicinal herbs

Herb Name	Native to Ecuador?	Primary Benefits	Space Needs	Water Needs	Soil Needs	Time to Yield	Sunlight Needs	Pollinator Attractivity
Aloe Vera (*Asphodelaceae Liliaceae*)	No	Anti-inflammatory properties, can help soothe burns and digestive issues	Should space plants out so that each has at least 2 square feet of surrounding space	Soil must dry completely between water, may need to be potted	Cannot tolerate standing water, well drained	2 years to full size. Leaves can then be harvested in moderation anytime during the growing season	Prefers full sun but can tolerate partial shade	Rarely flowers, no key pollinator attracting qualities
Amaranth (*Amaranthus*)	Yes	Used to treat diarrhea and swelling	Need good air circulation, plant 10-18 inches apart	1 inch of water per week	Does not thrive in overly rich soil	90-120 days	Partial Shade	Flowers attract bees and butterflies
Borage (*Borago officinalis*)	No	Can act as a diuretic, decongestant, and cough soothing agent	Grows to be 1-3 feet tall and 6-18 inches wide. Space plants out 2 feet	Water seeds regularly, once established allow the soil to dry out completely between waterings	Can thrive in very poor soils. Given the choice, the plant prefers moist but well-drained soil with a pH level between 6.0 and 7.0	60 days to maturity. Leaves and flowers can then be harvested in moderation anytime during the growing season	Full sun to partial shade	Flowers known to attract bees and other pollinators

Table 6 continued in Appendix D

In order to compare all of the crops more effectively, the project group separated them by type. In *Table 7* below, the chosen vegetables are being compared based on their nutritional value, space and water needs, as well as the time they take to grow and produce a harvest. Each category is ranked out of three, with three being the highest and one the lowest. These rankings are only relevant to a given crop type.

Table 7: Table displaying analysis of selected vegetable options

Vegetable	Nutritional Value	Space Needed	Water Required	Time to Yield
Black Beans	✓✓✓	⌂ ⌂	💧	☼ ☼ ☼
Broccoli	✓✓✓	⌂ ⌂ ⌂	💧 💧 💧	☼ ☼ ☼
Cabbage	✓✓	⌂ ⌂ ⌂	💧 💧 💧	☼ ☼ ☼
Carrots	✓✓	⌂	💧 💧	☼
Kale	✓✓✓	⌂ ⌂	💧 💧 💧	☼ ☼
Lentils	✓✓	⌂	💧 💧	☼ ☼
Peas	✓✓	⌂ ⌂	💧 💧 💧	☼ ☼
Potatoes	✓	⌂ ⌂	💧 💧	☼ ☼ ☼

*Table collated from: (Albert, 2009; Bhargava, n.d.; Zelman, 2019)

Increased nutrition is obviously a crucial component of the project, but a school must be equipped to grow the plants in order for this goal to be successful. All of these growing conditions must be considered carefully. The variety is also important, as to consume different types of nutrients and vitamins. Shown below is the comparison of all the previously identified fruits suitable to growing in Andean Ecuador (*Table 8*). This table has the same ranking system and categories as *Table 7.*

Table 8: Table displaying analysis of selected fruit options

Fruit	Nutritional Value	Space Needed	Water Required	Time to Yield
Babaco	✓✓✓	⌂ ⌂	💧	☼ ☼ ☼
Banana Passionfruit	✓✓✓	⌂ ⌂ ⌂	💧 💧	☼ ☼ ☼
Naranjilla	✓✓	⌂ ⌂ ⌂	💧 💧	☼ ☼ ☼
Strawberry	✓	⌂	💧 💧 💧	☼ ☼
Tree Tomato	✓✓✓	⌂ ⌂ ⌂	💧 💧	☼ ☼ ☼
Uvilla	✓✓	⌂ ⌂	💧 💧	☼

*Table collated from: (Boeckmann, n.d.; Tilley, 2020; J. F. Morton, 1982)

Grains are another type of crop to consider when rounding out a healthy diet. *Table 9* explores the three options that were decided upon and compares them against the same criteria and ranking system as the previous two tables (*Table 7 and 8*).

Table 9: Table displaying analysis of selected grain options

Grain	Nutritional Value	Space Needed	Water Required	Time to Yield
Amaranth	✓✓✓	⌂	💧	☼☼
Kaniwa	✓✓✓	⌂⌂	💧💧	☼☼☼
Quinoa	✓✓	⌂⌂⌂	💧💧💧	☼☼

*Table collated from: (England, 2020; Repo-Carrasco-Valencia & Vidaurre-Ruiz, 2019)

Lastly, medicinal herbs are a large part of Cuencan culture and can have many positive impacts on a garden. In *Table 10* numerous herbs are ranked on the categories of space and water required and the time until they can be harvested. Many of these herbs have additional uses and benefits, but these are the considerations that need to be accounted for when growing them.

Table 10: Table displaying analysis of selected medicinal herb options

Herb	Space Needed	Water Required	Time to Yield
Aloe Vera	⌂⌂⌂	💧💧💧	☼☼☼
Amaranth	⌂⌂	💧	☼☼☼
Borage	⌂⌂	💧💧	☼
Broadleaf Plaintain	⌂	💧💧	☼☼
Chamomile	⌂⌂	💧💧💧	☼
Common Nettle	⌂	💧💧💧	☼☼
Donkey Ear	⌂⌂⌂	💧	☼
Escancel	⌂⌂⌂	💧💧	☼☼
Fennel	⌂⌂	💧💧💧	☼
Iresine	⌂⌂⌂	💧	☼☼
Lemon Balm	⌂	💧💧	☼☼
Lemon Verbena	⌂⌂⌂	💧💧💧	☼
Lemongrass	⌂⌂⌂	💧💧💧	☼☼
Marigolds	⌂⌂	💧💧💧	☼
Mugwort	⌂⌂⌂	💧💧	☼☼
Pansies	⌂	💧	☼
Parsley	⌂⌂⌂	💧💧	☼☼
Pata con Panga	⌂⌂	💧💧	☼☼
Rue	⌂⌂⌂	💧💧	☼
Spearmint	⌂	💧💧💧	☼

*Table collated from: (Carroll, n.d.; *Donkey Ear Plant Care: All About Growing Kalanchoe Gastonis-Bonnieri*, n.d.; England, 2020)

Composting is an essential process that should be a part of a successful school garden. Shown in the table below (*Table 11)* is a direct comparison of all the different composting

methods that were discussed in the background section. The table goes through all necessary components to consider before committing to one composting method. The values below are based upon cost, materials, space, time, and labor in relative terms to the other methods that are being discussed. The ranking is out of three icons with three requiring the most and one being the least. For schools with fewer resources focusing on methods that are lower cost and easier to maintain options might be preferred.

Table 11: Comparison of selected composting techniques

Composting Method	Cost	Materials Needed	Space Required	Time	Labor Involved
Vermiculture	$$	✓✓	⌂ ⌂	☼ ☼	Ψ Ψ
Open Bin (One Bin)	$$$	✓✓✓	⌂ ⌂	☼ ☼ ☼	Ψ Ψ Ψ
Open Bin (Three Bins)	$$$	✓✓✓	⌂ ⌂ ⌂	☼ ☼	Ψ Ψ Ψ
Pit	$	✓	⌂	☼ ☼ ☼	Ψ Ψ
Piling	$	✓	⌂ ⌂ ⌂	☼ ☼ ☼	Ψ Ψ Ψ

*Table collated from: (Bement, 2014; US EPA, 2015; Driver, 2014)

Providing the correct amount of water to each plant throughout their growing cycles will be key to providing the best nutrients possible for the students. A major part of this is knowing different water conservation methods and much they cost, and materials and labor needed to perform them. Displayed in *Table 12* below is a comparative analysis of all the water conservation methods previously discussed and selected.

Table 12: Comparison of selected water conservation methods

Water Conservation Method	Cost	Materials Needed	Labor Required
Mulching with Organic Matter	$	✓	Ψ Ψ
Xeriscape	$	✓	Ψ
Rainwater Catchment System - New Tank	$$$	✓✓✓	Ψ Ψ Ψ
Rainwater Catchment System - Recycled Tank	$$	✓✓✓	Ψ Ψ Ψ
Drip Irrigation	$$$	✓✓	Ψ Ψ Ψ

*Table collated from: (Bauer & Wilson, n.d.; Beaulieu, 2019; Rutledge et al., 2011)

Another component to a long-lasting and successful garden is pollination, there are several methods attracting pollinators to a garden. Pollinators in the area have evolved and adapted according to the native plants, and therefore will be most familiar with those native plants. *Table 6* also includes data on what types of plants are native to the region, and whether or

not they attract pollinators. Pollinators are important to the growth and production yield of a garden and taking extra steps to attract them to the garden should be taken when possible.

A garden is not something that takes care of itself. There is considerable maintenance, such as watering, weeding, and other tasks that need to be taken care of. A garden is in need of careful management to make sure it is taken care of. When creating a garden the project team that a school creates a garden planning committee. Unfortunately, many of these rural schools lack the resources and personnel to create an entire committee dedicated to the garden. For this reason, it is encouraged that an individual garden manager is chosen. Because of issues like teacher turnover, it is important to try to pick a teacher or member of the community that is passionate about the project and willing to dedicate some time to the project. If the given school does have a larger faculty, it can be helpful to pick someone like a principal or leader to choose a garden manager as they come and go.

To engage the community the team encourages traditional methods like seed saving. According to our background research, seed saving allows the community to preserve their history and past generation making the garden much more meaningful.

Motivation is not something that is often necessary in Ecuador. Many of these rural communities host 'mingas.' This is a sort of work party that is formed out of an obligation to each other. Everyone in the community will band together for the betterment of the community. Something like a school garden would be a great opportunity for this type of collaboration.

5. Recommendations

Listed below are the final recommendations of the project team. There is endless knowledge about agriculture and gardening, but the recommendations narrow this knowledge down to six critical points that should be emphasized the most for a successful school garden.

1. Prioritizing the use of native plants
2. Including medicinal herbs in the garden
3. Producing a variety of food types (fruits, vegetables, grains, eggs)
4. Practicing water conservation
5. Implementing a composting method
6. Maintaining a management system

The table below (*Table 13*) evaluates all of the final recommendations that the project team supports. It analyzes them across the three main nutrition criteria and simply displays whether or not they help support them, even if only indirectly.

Table 13: Overall recommendations and their contributions to nutrition

Recommendation	Essential Nutrients	Crop Production	Native Plants
Prioritizing Native Plants	✓	✓	✓
Including Medicinal Herbs	✓	✓	✓
Producing a Variety of Food Types	✓	✓	✓
Practicing Water Conservation	X	✓	✓
Implementing a Composting Method	X	✓	✓
Maintaining a Management System	X	✓	X

Improved nutrition for students is the most crucial aspect of the project. With these recommendations nutrition is supported through the increased yield and effectiveness of the garden. Analyzed below (*Table 14*) are the main recommendations evaluated against the four main concepts that support agriculture.

Table 14: Overall recommendations and their contributions to agricultural sustainability

Recommendation	Pollinators	Soil Quality	Pest Control	Water Conservation
Prioritizing Native Plants	✓	X	X	✓
Including Medicinal Herbs	✓	X	✓	X
Producing a Variety of Food Types	✓	✓	X	✓
Practicing Water Conservation	X	✓	X	✓
Implementing a Composting Method	X	✓	X	✓
Maintaining a Management System	X	✓	✓	✓

With a school garden comes many responsibilities and lots of work to be done. This is where the garden management is essential to prevent individual burnout and provide a structure for garden maintenance and care. In *Table 15* below are the project team's recommendations and their examination against the garden management main ideas.

Table 15: Overall recommendations and their contributions to garden management

Recommendation	Community Engagement	Decision Making	Motivation
Prioritizing Native Plants	✓	✓	✓
Including Medicinal Herbs	✓	X	✓
Producing a Variety of Food Types	✓	✓	✓
Practicing Water Conservation	✓	X	✓
Implementing a Composting Method	✓	X	✓
Maintaining a Management System	✓	✓	✓

Not every recommendation addresses every criteria, but all together the recommendations and provision of the application tables (*Tables 7-12*) can provide any interested party with the framework and tools for success in starting or improving a school garden. Below are examples of school conditions and constraints. This table is meant to provide example solutions for the various challenges schools may face, and while this list is by no means exhaustive, it is a starting point of example strategies.

Table 16: Example Garden Recommendations Based on Preexisting School Conditions

School Conditions	Garden Recommendations
Poor soil quality, reliable water supply, recurring pest issue, low space available	Small-scale binned composting for soil remission, create raised beds & treat the soil with compost, grow marigold and lemongrass in the garden as natural pest deterrents
Low water supply, good soil quality, sloped ground	Sow seeds directly in the ground, mulching with organic matter to prevent runoff & keep water in the garden beds, xeriscaping
Poor soil quality, low water supply, plentiful space	Utilizing a rainwater catchment system with recycled materials, xeriscaping, pit composting, create raised beds & treat the soil with compost

6. Conclusion

Due to a lack of access to sufficiently healthy food, student health and success in rural Ecuador is negatively affected by food insecurity. School gardens can act as a low-cost method of feeding students in need, leading to better health and educational opportunities. In Ecuador, school gardens have been utilized as a means of fighting food insecurity for years. An improved and more widespread implementation of school gardens across rural Ecuador has the potential to produce a lasting impact on students.

There are many considerations for a school garden to be successful: soil health, plantings, sustainable practices, and climate. The project team was able to make recommendations for native plants, medicinal herbs, crop variety, water conservation, composting, and garden management. These recommendations provide a guide for educating and guiding people through the possible options that can be used in a successful garden program to alleviate food insecurity. The next step to breaking the cycle of poverty is improved education, which can be achieved alongside the recommendations made in this project. Improving the education related to agriculture will increase students' chances for success, and can make it possible to rise out of poverty. Food insecurity is a burden that can last generations and lead to poverty and poor health, but by investing in students' nutrition, the cycle can be broken, leading to more fruitful rural Ecuadorian communities.

References

10 Ways Farmers Are Saving Water. (2014, August 15). https://cuesa.org/article/10-ways-farmers-are-saving-water

Andrew Coulson, Ellman, A., & Emmanuel Mbiha. (2018). *Increasing Production from the Land: A Source Book on Agriculture for Teachers and Students in East Africa*. Mkuki na Nyota Publishers. 10.2307/j.ctvh8r04g

Bauer, M., & Wilson, C. (n.d.). *Drip Irrigation for Home Gardens*. Colorado State University. Retrieved March 7, 2021, from https://extension.colostate.edu/topic-areas/yard-garden/drip-irrigation-home-gardens-4-702/

Beaulieu, D. (2019, July 15). *This Is What to Expect With Xeriscape Landscaping*. The Spruce. https://www.thespruce.com/xeriscape-landscaping-meaning-2131129

Bement, L. (2014, April 25). *6 Ways to Make Great Compost*. FineGardening. https://www.finegardening.com/article/6-ways-to-make-great-compost

Bertoli, S., & Marchetta, F. (2014). Migration, Remittances and Poverty in Ecuador. *The Journal of Development Studies*, *50*(8), 1067–1089. https://doi.org/10.1080/00220388.2014.919382

Bhargava, H. (n.d.). *Health Benefits of Carrots*. WebMD. Retrieved March 6, 2021, from https://www.webmd.com/food-recipes/benefits-carrots

Brennan, D. (2020, September 17). *Health Benefits of Peas*. WebMD. https://www.webmd.com/diet/health-benefits-peas

Buytaert, W., Sevink, J., De Leeuw, B., & Deckers, J. (2005). Clay mineralogy of the soils in the south Ecuadorian páramo region. *Geoderma*, *127*(1), 114–129. https://doi.org/10.1016/j.geoderma.2004.11.021

Cabannes, Y., & Cecilia, M. (2018). *Integrating Food into Urban Planning*. UCL Press and the

Food and Agriculture Organization of the United Nations. http://www.fao.org/3/CA2260EN/ca2260en.pdf

Coq-Huelva, D., Higuchi, A., Alfalla-Luque, R., Burgos-Morán, R., & Arias-Gutiérrez, R. (2017). Co-Evolution and Bio-Social Construction: The Kichwa Agroforestry Systems (Chakras) in the Ecuadorian Amazonia. *Sustainability*, *9*(10), 1920. https://doi.org/10.3390/su9101920

CUENCA climate: Average Temperature, weather by month, CUENCA weather averages—Climate-Data.org. (n.d.). Retrieved November 13, 2020, from https://en.climate-data.org/south-america/ecuador/provincia-del-azuay/cuenca-875185/

Driver, P. (2014, January 6). *8 Benefits of Cover Crop in Organic Farming*. Frog Hollow Farm. https://www.froghollow.com/blogs/news/11356713-8-benefits-of-cover-crop-in-organic-farming

Duncan, D., Collins, A., Fuhrman, Ni., Knauft, D., & Berle, D. (2016). The Impacts of a School Garden Program on Urban Middle School Youth. *Journal of Agricultural Education*, *57*(4), 174–185. https://doi.org/10.5032/jae.2016.04174

Ecuador | World Food Programme. (n.d.). Retrieved March 5, 2021, from https://www.wfp.org/countries/ecuador

Espinosa, J., Moreno, J., & Bernal, G. (2018). *The Soils of Ecuador*. http://dx.doi.org/10.1007/978-3-319-25319-0

Garalli, B., Foley, M., & Sather, R. (n.d.). *A Guide to Common Medicinal Herbs—Health Encyclopedia—University of Rochester Medical Center*. Retrieved March 7, 2021, from https://www.urmc.rochester.edu/encyclopedia/content.aspx?contenttypeid=1&contentid=1169

Gliessman, S. (2015). Saving Seeds and Saving Culture. *Agroecology and Sustainable Food Systems*, *39*(6), 599–600. https://doi.org/10.1080/21683565.2015.1025894

Global Nutrition Report | Country Nutrition Profiles—Global Nutrition Report. (2020, July). https://globalnutritionreport.org/resources/nutrition-profiles/latin-america-and-caribbean/south-america/ecuador/

Guoxun Chen, Wang, T., Yan Zhang, Fang Yang, & Heqian Kuang. (2018). The Impact of Egg Nutrient Composition and Its Consumption on Cholesterol Homeostasis. *Cholesterol*, *2018*, 22. https://doi.org/10.1155/2018/6303810

Hackett, M., Zubieta, A. C., Hernandez, K., & Melgar-Quiñonez, H. (2007). Food insecurity and household food supplies in rural Ecuador. *Archivos Latinoamericanos De Nutrición*, *57*(1), 10–17.

Histosols. (n.d.). Retrieved November 13, 2020, from http://geo.msu.edu/extra/geogmich/histosols.html

How to Make a Bee Friendly Garden. (2021, January 9). Gardener'sWorld.Com. https://www.gardenersworld.com/plants/how-to-make-a-bee-friendly-garden/

Iannotti, L. L., Lutter, C. K., Stewart, C. P., Riofrío, C. A. G., Malo, C., Reinhart, G., Palacios, A., Karp, C., Chapnick, M., Cox, K., & Waters, W. F. (2017). Eggs in Early Complementary Feeding and Child Growth: A Randomized Controlled Trial. *Pediatrics*, *140*(1). https://doi.org/10.1542/peds.2016-3459

Jane Sherman. (2005). Setting up and running a school garden. *Food and Agriculture Organization of the United Nations*.

Krans, B. (2020, June 3). *Balanced Diet: What Is It and How to Achieve It*. Healthline. https://www.healthline.com/health/balanced-diet

Lemon Balm, 19.3 oz (2-Pack), Live Plants – Bonnie Plants. (n.d.). Retrieved March 7, 2021, from https://bonnieplants.com/product/lemon-balm/

MacLeod, M. J. (n.d.). *Ecuador | History, Geography, & Culture*. Encyclopedia Britannica. Retrieved October 27, 2020, from https://www.britannica.com/place/Ecuador

McCarty, J. (2013). *REAL School Gardens Program: Learning Gardens and Teacher Training to Improve Student Engagement and Academic Performance in Low-Performing Elementary Schools*. *4*, 8.

Mohammadpour, P., Mahjabin, T., Fernandez, J., & Grady, C. (2019). From national indices to regional action—An Analysis of food, energy, water security in Ecuador, Bolivia, and Peru. *Environmental Science & Policy*, *101*, 291–301. https://doi.org/10.1016/j.envsci.2019.08.014

Mora, D. E., Campozano, L., Cisneros, F., Wyseure, G., & Willems, P. (2014). Climate changes of hydrometeorological and hydrological extremes in the Paute basin, Ecuadorean Andes. *Hydrology and Earth System Sciences; Katlenburg-Lindau*, *18*(2), 631. http://dx.doi.org.ezpxy-web-p-u01.wpi.edu/10.5194/hess-18-631-2014

Paute River Basin (Ecuador)—BASIN INFO – Web based River Basin Information system. (n.d.). Retrieved November 13, 2020, from http://www.basin-info.net/river-basins/paute-river-basin-ecuador

Pollination and Bee Plants. (2007). In *Beekeeper's Handbook* (pp. 1–8). https://web.archive.org/web/20070930020735/http://gears.tucson.ars.ag.gov/beeclass/Pollination.pdf

Prasad, R. (1999). Sustainable agriculture and fertilizer use. *Current Science*, *77*(1), 38–43.

Pujol, L. (2011, November 18). Horchata lojana: Ecuadorian herbal tea drink. *Laylita's Recipes*.

https://www.laylita.com/recipes/horchata-lojana/

RealWorld Media Inc. (2015). *A "minga" in Ecuador*. Vimeo. https://vimeo.com/10475563

Rutledge, K., Ramroop, T., Boudreau, D., McDaniel, M., Teng, S., & Sprout, E. (2011, January 21). *Xeriscaping*. National Geographic Society. http://www.nationalgeographic.org/encyclopedia/xeriscaping/

Seaman, G. (2021). *How to Start a School Garden: Your Complete Guide | Eartheasy Guides & Articles | Eartheasy Guides & Articles*. https://learn.eartheasy.com/guides/how-to-start-a-school-garden-your-complete-guide/

Smith, S. R., Wright, K., Hrncirik, L., & Deen, M. K. Y. (2017). Using the Cultivating Learning with School Gardens Curriculum in Burundi, Africa. *Journal of Extension*, *55*(4). https://www.joe.org/joe/2017august/tt8.php

Stonebrook, S. (2011). 82 sustainable gardening tips: Go beyond organic with these creative, real-world ideas for more sustainable gardening. *Mother Earth News*, *248*, 54–60.

Sugar 101. (n.d.). Www.Heart.Org. Retrieved March 6, 2021, from https://www.heart.org/en/healthy-living/healthy-eating/eat-smart/sugar/sugar-101

Sustainable green alternatives to fertilizers could boost food, energy security. (n.d.). ScienceDaily. Retrieved November 19, 2020, from https://www.sciencedaily.com/releases/2014/08/140814123846.htm

US EPA. (2013, April 17). *Composting At Home* [Overviews and Factsheets]. US EPA. https://www.epa.gov/recycle/composting-home

US EPA. (2015, August 19). *Types of Composting and Understanding the Process* [Overviews and Factsheets]. US EPA. https://www.epa.gov/sustainable-management-food/types-composting-and-understanding-process

Using Chicken Manure Safely in Home Gardens and Landscapes. (n.d.). Extension | University of Nevada, Reno. Retrieved November 19, 2020, from https://extension.unr.edu/publication.aspx?PubID=3028

Vasconcellea x heilbornii—(V.M.Badillo) V.M.Badillo. (n.d.). Plants for a Future. Retrieved March 7, 2021, from https://pfaf.org/user/Plant.aspx?LatinName=Vasconcellea+x+heilbornii#:~:text=Although%20this%20species%20is%20dioecious,flower%20is%20pollinated%5B670%20%5D

Vegetables and Fruits. (2012, September 18). The Nutrition Source. https://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/vegetables-and-fruits/

Westerfield, R. (2000). *Pollination of Vegetable Crops*.

World Bank. (2017, December 1). *Ecuador Education Statistics*. CEIC. https://www.ceicdata.com/en/ecuador/education-statistics

Zelman, K. (2019, June 19). *Health Benefits of Broccoli*. WebMD. https://www.webmd.com/food-recipes/health-benefits-broccoli

Zelman, K. M. (2011, June 21). *Tips for Reaping the Benefits of Whole Grains*. WebMD. https://www.webmd.com/food-recipes/features/reap-the-benefits-of-whole-grains

Appendices

Appendix A: Informed Consent Letter

This study will be of minimal risk. It is our goal to ensure those being interviewed feel comfortable and understand any and all participation is completely voluntary, and you may skip any questions that you do not want to or feel uncomfortable answering. This information will be made clear at the start of the interview process. Interview responses will be used to support research performed by the project team. The final paper and research will be published, but interviewees will be kept anonymous if they desire.

These interviews seek to uncover factors that contribute to food insecurity and evaluate the role of school gardens. Some of the topics covered will include what a typical meal looks like for individuals in this region, as well as frequency of meals. Interviews will not contain questions that may make participants uncomfortable. Interviews may take longer depending on a participant's willingness to share.

If you have any additional questions about the research or your participation, please feel free to contact the project team, our project advisors, or our university research office.

Appendix B: IRB Approval Letter

WORCESTER POLYTECHNIC INSTITUTE

100 INSTITUTE ROAD, WORCESTER MA 01609 USA

Institutional Review Board

FWA #00015024 - HHS #00007374

Notification of IRB Approval

Date:	02-Feb-2021
PI:	Flaherty, Patrick
Protocol Number:	IRB-21-0295
Protocol Title:	School Gardens: Providing Improved Food Security and Nutrition for Students in Ecuador
Approved Study Personnel:	Flaherty, Patrick~Elgert, Laureen~Davis, Anne~Burnham, William~Miller, Fabienne~Whitney, Lauren~Kamara, Jermoh~
Effective Date:	02-Feb-2021
Exemption Category:	2
Sponsor*:	

The WPI Institutional Review Board (IRB) has reviewed the materials submitted with regard to the above-mentioned protocol.We have determined that this research is exempt from further IRB review under 45 CFR § 46.104 (d). For a detailed description of the categories of exempt research, please refer to the IRB website.

The study is approved indefinitely unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific approval must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue. You are also required to report any adverse events with regard to your study subjects or their data.

Changes to the research which might affect its exempt status must be submitted to the WPI IRB for review and approval before such changes are put into practice. A full IRB application may be required in order for the research to continue.

Please contact the IRB at irb@wpi.edu if you have any questions.

Appendix C: *Table 5*

Table 5: Agricultural information for potential garden crops (continued in Appendix C)

Crop Name	**Native to Ecuador?**	**Space Needs**	**Water Needs**	**Soil Needs**	**Time to Yield**	**Sunlight Needs**	**Pollinator Attractivity**
Amaranth (*Amaranthus*)	Yes	Need good air circulation, plant 10-18 inches apart	No more than 1 inch of water per week	Overly Rich soil may hinder growth, use average soil	90-120 days	Partial Shade	Known to attract both bees and butterflies when in full bloom
Babaco (*Vasconcellea × heilbornii*)	Yes	Grows into a small tree of about 6 feet in height	Water sparingly after planting, soil should be allowed to dry partially between watering	Well-drained soil enriched with organic matter	2 years to maturity, followed by 8 years of producing 30-60 fruit per growing season	Partial shade to full sun	No key pollinator attracting qualities
Banana Passionfruit (*Pasiflora*)	Yes	Requires support, such as a trellis (~2m)	Regular water during growing season only	Well draining, but can grow in any soil type	2 years to maturity, followed by year round, continuous fruit production	Full sun	Beautiful red-pink flowers attractive to hummingbirds
Black Beans (*Phaseolus vulgaris*)	Yes	For plants, space 6 inches apart. For individual bean seeds, plant two inches apart	Keep soil consistently moist throughout the growing season, if necessary black beans can handle drought but overwatering can be fatal	Prefer loose, fertile soil with a pH of 6.0-7.0	80-140 days, harvest plants when the beans have turned completely brown and seeds are hard, dry, and rattle in their shells at the end of growing season	Full sun	No key pollinator attracting qualities, flowers have low sugar content
Broccoli (*Brassica oleracea var. italica*)	No	Space plants 12-24 inches apart	Keep soil consistently moist throughout the growing season, with 1-1.5 inches water applied per week	Well drained, nutrient-rich soil	80-150 days depending on variety, harvest when broccoli crowns are large but buds are still tight and have not begun to flower	Full sun, will tolerate partial shade	As broccoli is harvested before it can bloom, it is not a key pollinator attractor
Cabbage (*Brassica oleracea var. capitata*)	No	Space plants 18-24 inches apart	Keep soil consistently moist throughout the growing season, with 1-1.5 inches water applied per week	Rich well drained soil, pH between 6.5 and 6.8	80-180 days, harvest heads when they feel firm and feel solid to the touch	Full sun	As cabbage is harvested before it can bloom, it is not a key pollinator attractor
Carrots (*Daucus carota subsp. sativus*)	No	Should be spaced 3 to 4 inches apart. Grows up to 12 inches tall	1 inch deep watering each week	Mix of clay and sand, loose and well drained	30-80 days depending on variety	Partial shade	No key pollinator attracting qualities

Kale (*Brassica oleracea*)	No	Space plants 12 inches apart	Soil should be consistently moist throughout the growing season, with 1-1.5 inches water applied per week	Moist, nutrient-rich soil with a pH of 6.5 to 6.8	50 days to maturity. Leaves can be harvested in moderation for the entirety of the plant's mature lifespan	Full sun, will tolerate partial shade	Produces many pale yellow, fragrant flowers in spring great for attracting bees
Kaniwa (*Chenopodium pallidicaule)*	Yes	Grows up to 30 inches tall	Requires 20 to 30 inches of water, but can tolerate prolonged periods of drought	Prefers loamy soils with a higher proportion of clay and a pH of between 4.8 and 8.5. Tolerates salinity	150 days	Full sun	Produce numerous tiny purple, red, yellow, or orange flowers whose color may attract pollinators but have no other key attractive qualities
Lentils (*Lens culinaris*)	No	Space plants 4-5 inches apart, plant rows 18-24 inches apart. 4-8 lentils per household member	Keep soil consistently moist throughout the growing season but does not tolerate flooding	Cannot tolerate flooded soil, requires excellent drainage	80-110 days, harvest when hard yellow pods have formed at the bottom	Full sun	No key pollinator attracting qualities, flowers have low nectar content
Naranjilla (*Solanum quitoense*)	Yes	Grows to cover an area of 8ft by 8ft	Tolerates drought, but grows better with water, should be watered regularly, does not tolerate flooding	Prefers rich organic soils with good drainage, will tolerate stony soils or those with lime	1 year to fruit production, which will then last approximately three years	Partial shade, should not be exposed to full sun	Fragrant flower clusters highly attractive to bees and butterflies
Peas (*Pisum sativum*)	No	Space plants 6 inches apart, many varieties do well growing vertically on a trellis	Keep soil consistently moist throughout the growing season, with 1-1.5 inches water applied per week	Prefers well-drained soil with compost or other organic matter. Soil pH should be 6.0 to 6.8	50 days	Full sun	Flowers lack color and fragrance, no key pollinator attracting qualities
Potatoes (*Solanum tuberosum*)	Yes	12 inches of separation on all sides. Roughy 36 square feet is enough to feed 1 person for a full year	Deep watering once per week	Loose fertile soil	10 weeks for small potatoes, 80-100 days for fully mature potatoes	Full sun	Tubular flowers attractive to butterflies
Quinoa (*Chenopodium quinoa*)	Yes	Plant in rows, spaced at least 1 foot apart. Along each row, plant 2-3 seeds every 1 foot	Needs evenly moist soil during germination. As the plants grow larger and get established, let the first few inches of soil dry between waterings	Adapts to most soils, but grows best in fertile, well-drained loam	90-120 days, wait until the plants shed their leaves to harvest at the end of the growing season	Full sun	Produce numerous tiny purple-red flowers whose color may attract pollinators but have no other key attractive qualities

Strawberry (*Fragaria x ananassa*)	No	18 inches between plants	Lots of water when planting, keep soil consistently moist throughout the growing season	Loamy soil, acidic to neutral pH	6 months to maturity. Depending on variety, fruit may be harvested year round or once a season	Full sun	No key pollinator attracting qualities, flowers do not produce much nectar
Uvilla (*Physalis peruviana*)	Yes	Grows to 2-3 feet in height, plants should be spaced at least 2 feet apart	Lots of water during growing season, very little when fruits are maturing	Well draining, sandy to loam soil	60 days, fruits can then picked every 2 to 3 weeks from January through to May	Full sun	No key pollinator attracting qualities
Tree tomato (*Solanum betaceum*)	Yes	6-10 feet between plants	Regular watering preferred, can survive a drought	Well-draining, compost preferable	1.5 to 2 years to maturity. Fruit can then be harvested for about 4 years	Full sun	Produces small, light pink blooms whose fragrance is effective in attracting insects

Information for Table 5 collated from:

Bonnie Plants. (2021, March 8). Bonnie Plants. https://bonnieplants.com/.

Gardening Know How. https://www.gardeningknowhow.com/.

Plant Care Today. (2021, February 11). https://plantcaretoday.com/.

Purdue University. Horticulture and Landscape Architecture - Purdue University. https://hort.purdue.edu/.

The Spruce. (2018, April 17). The Spruce. https://www.thespruce.com/.

Appendix D: *Table 6*

Table 6: Agricultural information for potential medicinal herbs

Herb Name	**Native to Ecuador?**	**Primary Benefits**	**Space Needs**	**Water Needs**	**Soil Needs**	**Time to Yield**	**Sunlight Needs**	**Pollinator Attractivity**
Aloe Vera or Sábila (*Asphodelaceae Liliaceae*)	No	Anti-inflammatory properties, can help soothe burns and digestive issues	Should space plants out so that each has at least 2 square feet of surrounding space	Soil must dry completely between water, may need to be potted	Cannot tolerate standing water, well drained	2 years to full size. Leaves can then be harvested in moderation anytime during the growing season	Prefers full sun but can tolerate partial shade	Rarely flowers, no key pollinator attracting qualities
Amaranth (*Amaranthus*)	Yes	Used to treat diarrhea and swelling	Need good air circulation, plant 10-18 inches apart	1 inch of water per week	Does not thrive in overly rich soil	90-120 days	Partial Shade	Flowers attract bees and butterflies
Borage (*Borago officinalis*)	No	Can act as a diuretic, decongestant, and cough soothing agent	Grows to be 1-3 feet tall and 6-18 inches wide. Space plants out 2 feet	Water seeds regularly, once established allow the soil to dry out completely between waterings	Can thrive in very poor soils. Given the choice, the plant prefers moist but well-drained soil with a pH level between 6.0 and 7.0	60 days to maturity. Leaves and flowers can then be harvested in moderation anytime during the growing season	Full sun to partial shade	Flowers known to attract bees and other pollinators
Broadleaf plantain (*Plantago major*)	No	Helps relieve cough, can act as an expectorant and also anti-inflammatory agent	Spreads easily, may be best kept in a container garden. If sowed in the ground, should be spaced apart	Soil should be kept moist until seeds sprout. Established plants require very little water	Can grow in virtually any soil type	90 days to full size. Leaves can then be harvested in moderation anytime during the growing season	Full sun or partial shade	Flowers occasionally, attracts bees
Chamomile (*Asteraceae*)	No	Good for use in herbal tea to aid with digestion, soothing coughs, rashes, and stomach pain. Also high in Vitamin A, potassium, and beta carotene	Plants should be spaced 8 inches apart, can grow to 24 inches tall	Water regularly; prefers for soil to be kept consistently moist	Fertile, well-drained, sandy loam	60 to 65 days to maturity. Flowers appear during summer, but leaves can be harvested anytime during the growing season	Full sun to partial shade	Flowers attractive to bees and butterflies
Common	No	Anti-inflammatory,	Spreads	Thrives when	Prefers rich,	80 days to	Full sun to	No key pollinator

Nettle (*Urtica dioica*)		diuretic, and pain relieving properties	easily by creeping rhizomes, and often forms dense clusters. Growing this plant in a container can prevent overgrowth	soil stays consistently moist but is not waterlogged	nutrient dense soil. Will tolerate soil of pH range anywhere from 5.0 to 8.0	maturity. Leaves can be harvested anytime during the growing season	partial shade	attracting qualities
Donkey Ear (*Kalanchoe gastonis-bonnieri*)	No	Leaves used as an anti-inflammatory, astringent, and coagulatory agent	Grows in clumps up to 1.5 feet in width and height	Drought-tolerant, soil should be allowed to dry fully between waterings	Humus-rich, well-draining soil balanced with loam, sand, and pumice	Leaves can be harvested anytime during the growing season	Partial shade	This plant's red and yellow flowers entice hummingbirds
Escancel (*Aerva sanguinolenta*)	No	Dry leaves and flowers are used for treating pneumonia symptoms, inflammations, bronchitis, asthma, and jaundice	Grows up to 2m tall, space plants 2 feet apart	Water regularly, keep soil from completely drying out	Prefers organically rich, well-draining soil	90 days to maturity	Full sun to partial shade	No key pollinator attracting qualities
Fennel (*Foeniculum vulgare*)	No	Leaves and bulbs can be eaten raw or cooked	Plants should be spaced 6 to 12 inches apart	Water regularly; prefers for soil to be kept consistently moist	Well-draining, fertile soil rich with organic matter	Leaves can be harvested anytime, bulbs can be harvested once they measure several inches across	Full sun	Flowers with many tiny yellow flowers rich in nectar and pollen, which attract a variety of pollinating insects
Iresine (*Iresine herbstii*)	Yes	Wound healing	12-18 inches in height when grown in a pot. When grow freely produces a shrub 5ft high 3 ft wide	Water deeply one per week if there is a lack of rainfall	Rich soil that drains freely	80 days to maturity	Full sun to partial shade	Rarely flowers, not a key pollinator attractor
Lemon Balm (*Melissa officinalis*)	No	Good for relaxing herbal tea, treating sleep disorders of nervous origin	Plants should be spaced 2 feet apart, but container gardening may work best as it spreads rapidly	Soil should be allowed to dry between waterings	Prefers well-draining soil of pH 6.7 to 7.3. Let soil dry between waterings	70 days to maturity. Leaves can then be harvested in moderation for the entirety of the plant's mature lifespan	Partial shade, needs protection from direct sunlight	The scent of this plant's leaves is very effective at attracting pollinators like bees

Lemon Verbena (*Aloysia citrodora*)	Yes	Good for herbal tea, aids with digestion	Grows into a small bush ~4-5ft high	Needs constantly moist soil, but does not tolerate over saturation	Rich, moist soil	60 days to maturity. Leaves can then be harvested in moderation anytime during the growing season	Full sun	Fragrant leaves and flowers are appealing to many pollinating insects. Its flowers have a high nectar, which bees and butterflies enjoy
Lemongrass (*Cymbopogon*)	No	Pest repellent properties, good for herbal tea, stalks can be eaten raw or cooked	Grows in dense clumps up to 2 meters in diameter and up to 5 feet tall. Space plants at least 2 feet apart	Prefers consistent moisture. Water when the top inch of soil becomes dry	Fertile, well-draining soil with a pH of 6.5 to 7.0	Can be harvested in moderation as soon as plants are 12 inches tall and stem bases are at least ½ inch thick, for the entirety of the growing season	Full sun	Rarely flowers, not a key pollinator attractor
Marigolds (*Calendula officinalis*)	Yes	Helps reduce minor skin inflammations, heal small wounds, and repel pests like rabbits, deer, and some insects	Space plants out 12 inches	Allow the soil to partially dry between waterings, In high heat or dry weather, ensure that plants are watered regularly	Can thrive in a variety of soil types, but prefers moderately fertile, well-drained soil	60 days to bloom	Full sun to partial shade	This plant's colorful double-crowns are effective in attracting bees, which are not affected by the smell
Mugwort (*Artemisia Vulgaris*)	No	Pest repellent properties, good for arthritis	Grows to a height of 24-48 inches,	Drier soil, not damp, well drained	Water very infrequently, does not tolerate over-wet soil	80 days to maturity. Leaves can then be harvested in moderation for the entirety of the plant's mature lifespan	Full sun	Its small aromatic flowers are attractive to moths and butterflies which dine on the mugwort's leaves and flowers
Pansies (*Viola* × *wittrockiana*)	No	Good for herbal tea	Grows in 8 inch clumps	1 inch of water per week	Prefers rich, well drained soil with a lot of organic material	60 days to maturity. Blooms during spring to early summer	Full sun to partial shade	Bright, colorful flowers very good for attracting bees

Parsley (*Petroselinum crispum*)	No	Source of iron	Space plants 12 to 18 inches, can grow up to 1 foot tall. Grows well in containers	1-2 inches per week	Rich, well drained soil	70 days to maturity. Leaves can then be harvested in moderation anytime	Full sun to partial shade	Blooms with many tiny flowers which are known to be especially attractive to bees
Pata con Panga (*Peperomia peltigera*)	Yes	Good for soothing a cough	Grows up to 12 inches high and round, plants should be spaced apart 18 inches	Let top layer of soil dry out, and then water thoroughly	Well-drained soil, does not tolerate over-saturation	80 days to maturity	Partial shade	No key pollinator attracting qualities
Rue (*Ruta graveolens*)	No	Pest repellent properties, oil used to treat insect bites, leaves used to calm stomach cramping	Plant 12-24 inches apart	Well drained soil, can even be rocky	Drought resistant, needs very little water, water deep into the soil once every 3 weeks	Harvest leaves early in the morning, when the oil content is at its peak	Full sun	Flowers with many tiny yellow flowers rich in nectar and pollen, which attract a variety of pollinating insects
Spearmint (Mentha spicata)	No	Helps soothe insomnia, cough, cramps, and decrease symptoms from some parasites and diarrhea	Plants should be spaced 2 feet apart, but container gardening may work best as this plant spreads rapidly and can overtake a garden space	Thrives in moist to slightly soggy soil. Grows best when planted near downspouts or in low, damp areas	Prefers nutrient-rich, moist soil, but will tolerate nearly any type of soil	60 days to maturity	Full sun to partial shade	Bees do not like the strong scent this plant gives off

Information for Table 6 collated from:

Bonnie Plants. (2021, March 8). Bonnie Plants. https://bonnieplants.com/.

Gardening Know How. https://www.gardeningknowhow.com/.

Happy Gringo Travel. (2021, February 19). https://happygringo.com/.

Plant Care Today. (2021, February 11). https://plantcaretoday.com/.

Purdue University. Horticulture and Landscape Architecture - Purdue University. https://hort.purdue.edu/.

Appendix E: Ana Loja Interview Questions

English:

1. Can you tell us about your experience and the work that you have done in Ecuador?
2. Can you tell us a little more about the school system in the Cuenca region? How do teachers in the area usually receive teaching material?
3. Are there any educational programs which stand out or have been very successful with local children?
4. Is there a resource that we can use to learn about the educational standards for each grade?
5. Do you have any suggestions for organizations we should reach out to regarding putting our educational reference manual on their Facebook/website?

Español:

1. ¿Usted puede contarnos su experiencia y el trabajo que ha realizado en Ecuador?
2. ¿Puede contarnos un poco más sobre el sistema escolar en la región de Cuenca? ¿Cómo suelen recibir los maestros de la zona material didáctico?
3. ¿Hay algunos programas educativos que se destaquen o que hayan tenido mucho éxito con los niños locales?
4. ¿Existe algún recurso que podríamos utilizar para aprender más sobre los estándares educativos de cada grado?
5. ¿Tiene algunas sugerencias para organizaciones que deberíamos comunicar con sobre la publicación de nuestro folleto educativo en su Facebook o sitio web?

Appendix F: Shavaun Cloran Interview Questions

1. What do you believe to be the most important aspects of nutrition and diet?
2. In your opinion, what comprises a balanced diet for school-age children (grades 1-8)?
3. In your experience, what nutrients or types of food (i.e. protein, particular vitamins, etc.) are school-age children lacking the most?
4. In your opinion, what is the most effective way to combat the issue of food insecurity and malnutrition in school-age children?
5. If you were to design a garden to support food insecure students, what crops would you choose to grow and why?
6. In your opinion, what are the best methods (i.e. informational posters, aspects of curriculum, etc.) to encourage school-age children to learn more about nutrition?

Appendix G: Dra. Gicela Monserrate Palacios Santana Interview Questions

English:

1. What are local, healthy dishes that you would recommend?
2. What do you believe to be the most important aspects of maintaining a healthy and balanced lifestyle for individuals in the Cuenca, Ecuador region?
3. How do you believe food insecurity could be combated in Ecuador?
4. In your experience, what nutrients or types of food (i.e. protein, particular vitamins, etc.) are school-age children lacking the most?
5. Would you recommend school gardens as a way to relieve food insecurity for children? What advantages/disadvantages do they have?
6. Are there any specific local crops that you would recommend growing?

Español:

1. ¿Cuáles son algunos platos locales y saludables que usted recomiende?
2. ¿Cuáles son los aspectos más importantes para un estilo de vida saludable y equilibrado en la región de Cuenca, Ecuador?
3. ¿Cómo cree que la inseguridad alimentaria podría ser combatida en Ecuador?
4. En su experiencia, ¿cuáles tipos de comida (por ejemplo: la proteína, vitaminas, etc.) carecen más los niños en las escuelas?
5. ¿Usted recomendaría los jardines en las escuelas como un buen modo para mitigar los efectos de la inseguridad alimentaria? ¿Cuáles son las ventajas y desventajas?
6. ¿Hay algunos cultivos locales que usted nos recomendaría para cultivar?

Appendix H: Elisabeth Barreto Interview Questions

English:

1. Can you describe the type of work done by El Arenal, specifically regarding education and school gardens?
2. Can you please describe some of the challenges you have experienced with maintaining gardens, especially in the Cuenca area?
3. Are there any specific design or setup ideas that are crucial to a garden's success? What are some popular foods grown in school gardens?
4. Are you familiar with the concept of the chakra andina? If so, can you explain its benefits?
5. Do you have any additional advice for us regarding this project?

Español:

1. ¿Se puede describir el tipo de trabajo realizado por El Arenal, específicamente con respecto a educación y jardines escolares?
2. ¿Puede describir algunos de los retos que ha experimentado con el mantenimiento de jardines, especialmente en la zona de Cuenca?
3. ¿Hay alguna idea específica de diseño o configuración que sea crucial para el éxito de un jardín? ¿Cuáles son algunos alimentos populares cultivados en los jardines escolares?
4. ¿Está familiarizado con el concepto del chakra andina? Si es así, ¿puede explicar sus beneficios?
5. ¿Tiene algún consejo adicional para nosotros con respecto a este proyecto?

Appendix I: Gerardina Juela Interview Questions

English:

1. Our project sponsor, Des Dizney, mentioned that in the past the Castle Foundation gifted chickens to CETAP-LUCY. How has this donation helped local schools?
2. How do you create a community dynamic in which a program such as a school garden will be able to be sustained for years to come?
3. What are some challenges that are involved with school gardens?
4. Has CETAP-LUCY used gardens for teaching or as an experiential learning space in the past? If so, what has worked, and what has not worked?
5. Can you tell us a little bit about some of the educational programs your organization has implemented that have been successful with local children?
6. Would CETAP-LUCY be interested in putting our educational reference manual on the organization's Facebook/website?

Español:

1. Nuestros patrocinadores del proyecto, Des Dizney y Bill O'Brien, mencionaron que en el pasado la Fundación Castillo regaló pollos a CETAP-LUCY. ¿Cómo ha ayudado esta donación a las escuelas locales?
2. ¿Cómo se crea una dinámica comunitaria en la que un programa como un huerto escolar podrá mantenerse durante los próximos años?
3. En su experiencia, ¿cuáles son algunos de los desafíos que han ocurrido con los huertos escolares?
4. ¿CETAP-LUCY ha utilizado jardines para enseñar o como un espacio de aprendizaje experiencial en el pasado? Si es así, ¿qué ha funcionado y qué no ha funcionado?
5. ¿Puede contarnos un poco sobre algunos de los programas educativos que su organización ha implementado que han tenido éxito con los niños locales?
6. ¿Estaría CETAP-LUCY interesado en poner nuestro folleto educativo en el sitio web/Facebook de la organización?

Appendix J: Eliza Lawrence Interview Questions

1. We understand garden management is an important component of hosting a school garden, who is typically in charge, is there a hierarchy? How are tasks for garden care delegated?
2. What are some tools to help keep people engaged in taking care of the garden?
3. Is there a schedule for things like watering and plantain cycles?
4. Other people we have spoken with mention it is really important in Ecuador to engage the community in the garden, what might be some typical roles for community members?
5. How do your gardens help support children's education and learning?

Appendix K: Elisabeth Stoddard Interview Questions

1. At the heart of our IQP project is the goal of alleviating food insecurity in the areas surrounding Cuenca, Ecuador. How do you believe local gardens can help with food security?
2. Given your experience with Turn Back Time, what are some ideas for programs to keep school-age children engaged in maintaining the garden?
3. How can a small community effectively and successfully support the sustainability of a garden?