Different Agricultural Management Practices Concerning Soil Fertility: case studies of six rural Monteverde farms

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ABSTRACT

This paper reports on six case studies of small scale agricultural practices and soil fertility for six farms of Monteverde, Costa Rica. Data were collected through interviews with farmers regarding agricultural techniques and from soil. Samples from various areas of each farm were analyzed for nutrient contents (N, P, K, pH, and humus). The majority of farmers were found to be utilizing numerous techniques in order to increase soil fertility, though methods differ greatly between farms. Results indicate that organic fertilizers, compost, and manures were effective in increasing soil nutrient levels. Two foliar fertilizers were tested to assess nutrient degradation over time, and results showed an increase in nutrient concentration over time for one of these. Recommendations are made for local farmers to apply some form of compost, manure, or foliar fertilizer to increase nutrient content. Analysis of interviews which highlighted a large range in management practices leads me to recommend increased communication between farmers and citizens within the community, increased awareness of effective agricultural management techniques, and support increasing use of sustainable and organic methods of agriculture.

RESUMEN

Este manuscrito informa de seis casos de prácticas agrícolas de menor escala y la fertilidad del suelo en seis fincas de Monteverde, Costa Rica. Se colectaron datos por medio de entrevistas con granjeros con respecto a técnicas agrícolas y con la ayuda de muestras del suelo. Las muestras de suelo de varias áreas de cada granja se analizaron por el contenido de nutrimentos (N, P, K, el pH y el humus). Se encontró que la mayoría de los agricultores utilizan numerosas técnicas para aumentar la fecundidad del suelo, aunque los métodos variaron mucho entre las diferentes granjas. Los resultados indican que los abonos orgánicos, el material orgánico en descomposición y los abonos foliales fueron eficientes en aumentar los niveles de nutrientes. Dos abonos foliales se probaron para valorar la degradación de los nutrimentos a través del tiempo y los resultados mostraron un aumento en la concentración de nutrientes en uno de ellos. Se sugieren recomendaciones para que los finqueros apliquen alguna forma de material orgánico en descomposición, boñiga o abono folial para aumentar el contenido de nutrientes. El análisis de las entrevistas, que destacó una gran variedad de prácticas de administración, me lleva a recomendar una comunicación mayor entre granjeros y ciudadanos dentro de la comunidad, un aumento del conocimiento de técnicas de administración efectivas y un incentivo para aumentar el uso de métodos agrícolas sostenibles y orgánicos.

INTRODUCTION

Though tropical soils may appear to be extremely rich in nutrients and therefore ideal for farming, the reality is quite the opposite (Terborgh 1992). Despite being among the most productive and efficient ecosystems on earth, soils of tropical ecosystems are extremely infertile (Sanchez 1992). Thirty-six percent of tropical soils are classified as being low in nutrients, containing less than 10% of weatherable materials in the sand and silt fraction. Forty-three percent of tropical soils are composed primarily of Oxisols and Ultisols, highly acidic and weathered soils that lack important soluble nutrients (Eswarnan 1992). As a result of heavy and frequent rains, tropical soils experience a high degree of leaching which reduces fertility in soils. Thus, soils are deficient in minerals such as potassium, phosphorus, carbon, magnesium, and sulfur. This leaves the soil acidic and subject to a high rate of organic matter decomposition (Sanchez 1992). These nutrient and mineral deficiencies cause tropical plants to have a more difficult time obtaining and sustaining essential nutrients (Greenland 1992).

Agriculture production in the tropics is affected by this low soil fertility. Existing organic matter and available nutrients in agricultural systems are depleted rapidly, greatly affecting crop productivity (Juo 2003). In the last century, farmers in the tropics have dealt with low nutrient soils by using large amounts of imported chemical fertilizers (Altieri 1993). This reliance on chemical fertilizers in the tropics is not only having serious negative effects on the environment, but it is also a very expensive method for small farmers in the tropics who lack the financial security to maintain this investment. In addition, tropical countries have historically used a “one type fertilizer policy” for large regions that include very different soils and ecosystems (Eswarnan 1992). This approach is outdated and reflects a policy that does not accommodate state of the art scientific understanding of agricultural practices. In reality, soils types in the tropics are extremely diverse, and each type requires different management techniques (Eswarnan 1992).

Given increasing human population pressures on soil use, land degradation, and the need to produce more and more food, it is becoming increasingly important to find methods of agriculture that optimize soil fertility, and minimize dependence on expensive, commercial fertilizers (Clay 1998). Methods for sustainable agriculture in the tropics need to be explored and developed, with maintenance of soil fertility as the foundation. Sustainable agriculture is defined as using methods which minimize waste and environmental impact while also maintaining and enhancing profitability of the system (Juo 2003). In developing countries where the cost of labor is low, sustainability could be increased with a shift away from capital-led agriculture (heavy reliance of fertilizers) toward labor-led intensification techniques (Clay 1998). Benefits of organic techniques, those that utilize natural materials to enhance agricultural systems, combined with sustainable agricultural methods include improved levels of organic matter and nitrogen in the soil, yields comparable to those achieved with commercial fertilizer use, conservation of soils and water resources, less soil erosion, increased biodiversity, and reliance on a more labor intensive system (Greenland 1992). These results illustrate that sustainable agriculture methods and organic approaches are the future for tropical farmers in order to increase soil fertility, maintain productivity, and conserve water and soils over time.

Throughout the tropics, small farmers are experimenting with sustainable agricultural techniques such as utilization of organic fertilizers and compost to fertilize crops. In Monteverde, Costa Rica, such farmers are experimenting with organic methods of agriculture based on their own experiences and ideas and in some instances, based on recommendations from the University of Costa Rica (Nadkarni 2000). Unfortunately, farmers have no way to objectively assess techniques used and their impact on soils. Further, scientific literature is lacking, and generally not accessible to rural farmers.

There also exists very little national support for small scale farmers from the Costa Rican Department of Agriculture. Currently, the costs and benefits of organic versus commercial methods for nutrient control are largely unstudied, and this lack of information and education results in very little motivation for the local farmer to try more organic and/or sustainable techniques (Altieri 1993).

Given that Costa Rica is a pioneer within tropical countries in areas of conservation and sustainable development, case studies of different agricultural approaches by small scale farmers may provide a good indication of the future of agricultural systems in the Tropics. This study includes observations from visits to several rural farms in the Monteverde area in an effort to document and compile information about different techniques and agricultural methods currently being practiced along with a nutrient analysis of the soil affected by these techniques. Recommendations need to be made regarding the most effective methods for increasing soil fertility for farmers in the Monteverde area.

MATERIALS & METHODS

General information regarding agricultural systems coupled with soil sample analysis was needed to recommend the most effective agricultural techniques used in Monteverde. To determine what agricultural methods were being practiced on each farm and why, an interview was conducted at each farm to provide a broad understanding of each farmers' agricultural approach and farming system. To compliment information gained from the interview, soil samples were collected from selected areas of areas of the farm where different agricultural methods were applied and different crops were grown, and soil sample analysis was conducted.

Study Sites

Monteverde, Costa Rica is a small tropical montane Cloud Forest community. Dairy farming is the primary form of agriculture, in association with the Monteverde Cheese Factory (Nadkarni 2000). Small, rural farms that primarily produce vegetables also exist in the surrounding community. Goods are sold locally and are an alternative to vegetables brought in from surrounding areas, for which transportation would be extremely difficult given Monteverde's bad roads. Farms range from small gardens that support a single family to farms that produce the majority of coffee sold in Monteverde. Six of these farms were selected based on community recommendations, and were included as case studies for this project.

Interview

An informal oral interview was performed at each of the six study farms and the resulting information was used to fill out a questionnaire (Appendix A). Information regarding general background of the farm, commercial fertilizer use, organic fertilizer or compost use, and pest control problems was investigated. Comparisons were made between farms, focusing on different methods of soil management and their implications for soil fertility.

Soil Sample Analysis

Soil samples were collected from several areas on each farm. Areas were selected to document different conditions: soil types, crops, or soils with different applications of fertilizer, compost, or other nutrient enrichment material. A control sample was also taken from each farm in an area with no cultivation. For each soil sample taken, nutrient tests were performed to determine nutrient levels in each area. Nitrogen, potassium, phosphorus, and pH tests were quantified by first preparing soil samples using a LaMotte soil test kit which utilizes color chart methods, and then using the prepared sample with a LaMotte water kit which utilized a spectrophotometer, in an effort to provide an accurate measurement of soil nutrient concentration. Humus levels were measured for each soil sample using only the LaMotte soil test kit.

Nitrogen: Nitrogen is required by almost all biochemical processes that compose and sustain plant life. Therefore, it is an essential nutrient for plant growth and aids in the absorption of other essential nutrients. Plants take up nitrogen in the form of nitrate and ammonium and become part of the soil through fixation from atmospheric N_2 using bacteria associated with legumes. Specifically in the tropics, nitrogen in the form of nitrate is absorbed by plants but has potential for quickly leaching out of tropical soils (Kohnke 1995).

Phosphorus: Phosphorus promotes healthy plant growth and root development, which aids in the strengthening of plants. Phosphorus deficiencies are extremely common in the tropics, as a result of high leaching (Kohnke 1995). Farmers in the tropics compensate for this by the addition of many commercial fertilizers to increase phosphorus levels (Nadkarni 2000). Phosphorus availability in the tropics is also related to soil pH, in that it becomes available to plants only when soil acidity is between 5.5 and 6.5 (LaMotte 1994).

Potassium: Potassium improves the general health of the plant (specifically in its defense against disease), aids in photosynthesis, and in the uptake of other nutrients. A deficiency in potassium also makes the soil more susceptible to leaching. Potassium also works with nitrogen, requiring one another for optimal nutrient uptake (Kohnke 1995).

pH: The tropics have generally more acidic soils, with pH's lower than 5.5. The most traditional practice to lower acidity is to add lime to the soil. Soil pH primarily affects soil organism growth and activity. Therefore, pH affects the amount of available nutrients gained from organic matter decomposition. There is large variation in optimal pH levels for different crops (LaMotte 1994).

Organic Material (Humus): The test used as a proxy in this analysis was humus, defined as the decomposition products of organic residue and materials synthesized by microorganisms (Kohnke 1994). Humus content was determined by ranking each sample on a relative scale from 1 to 5. Soil organic matter is an important source of nutrients and increases biodiversity, making it an essential element for high crop productivity in agricultural systems. Higher temperatures in the tropics create a higher rate of turnover of organic material, and larger amounts of heavy rains tend to carry this off, resulting in a greater problem maintaining organic material. Organic matter also breaks down rapidly after its addition to the soil. However, soils high in organic matter are important for phosphorus absorption, micronutrient availability, reduction of nitrogen leaching, and cation retention. Therefore, organic material can be added to soils in the tropics by use of compost, cow or chicken manure, and mulch (Greenland 1992, Kohnke 1994).

Fertilizer Preparation
Different recipes for compost and organic fertilizer were used at the Brenes farm. I participated in the creation of two different compost types, Bohaschi and a "quick compost method". I also aided in the production of two different organic, foliar fertilizers, which were then analyzed to determine nutrient degradation patterns. For the two liquid foliar fertilizers, nutrient tests for nitrogen, phosphorus and pH were performed six times over the course of two weeks to determine if there was nutrient degradation in each foliar fertilizer over time. Recipes for these fertilizers are found in Appendix B.

RESULTS

Case Study 1: Finca Santamaria
Management Practices:
Located in Cañitas (see Appendix C) at an elevation of approximately 1300 meters, the focus at Finca Santamaria (FS) is on coffee production. Owned and run by four brothers, FS is certified as a Fair Trade Sustainable Farm, and produces fair trade coffee sold through local Co-op Santa Elena. Part of the sustainable certification requires that the farm produce a variety of crops. Therefore, bananas, sugar cane, and vegetables are also cultivated. The farm produce also feeds four families and provides some food for seasonal employees. FS includes a cafeteria open to the public and offers food cooked from products grown on the farm. The Fair Trade certification restricts the use of significant amounts of fertilizers or pesticides, requires crops to be near the forest and native species are grown, and requires employment of good soil conservation practices.

Organic fertilizer used to increase phosphorus levels in the soil is applied twice a year to all crops. A compost pit fed by kitchen and plant waste has been generated and the compost produced will be applied to vegetable crops at the start of the rainy season this year (Appendix D). Problems with pests and insects are minimal due to effective foliar fertilizers used as insecticides. Coffee fungus is also controlled by application of a foliar fertilizer consisting mostly of molasses. Crop rotations are made with each planting cycle, and are observed to increase soil quality.
Soil Analysis:

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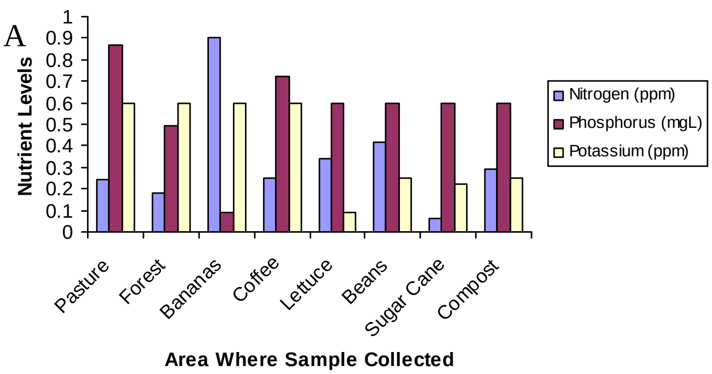

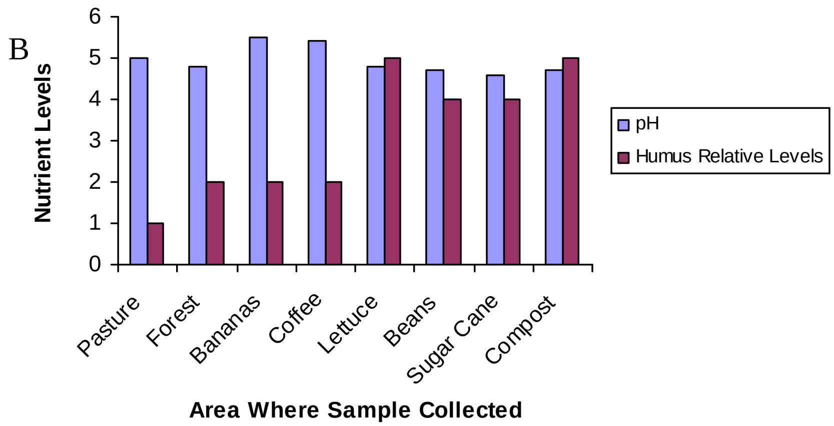

FIGURE 1: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of Finca Santamaria in Cañitas, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

On FS, nitrogen levels were highest for soils sampled from the bean patch (0.42 ppm) and banana patch (0.9 ppm) and lowest in soil sampled from sugar cane (0.06 ppm). Potassium levels were lowest in soil supporting lettuce (0.09 ppm), but comparable in all other samples collected, which had concentrations approximately 0.5 ppm. Phosphorus levels were lowest in soils where banana trees are planted (0.09 ppm) as compared to control areas (0.87 ppm). Soil acidity (pH) was higher (more basic) with values around 5.5 in areas where bananas and coffee were planted, as compared to the control area with a pH of 5.0 (see Figure 1).

Case Study 2: Finca Brenes

Management Practices

The Brenes farm is located in La Cruz, at an elevation of approximately 1400 meters (see Appendix C). The farm is run by four families, with 20 hectares for production of vegetables, and ten hectares for conservation. On Finca Brenes (FB), strong value is placed on the importance of the forest and its potential positive impact on the land, soil, and productivity of the farm. Between ten and fifteen different vegetables are grown at any given time. Produce is sold to restaurants, supermarkets, local schools, bars, and directly to local citizens. Though all of the produce is organically grown, it is sold at a price comparable to vegetables grown inorganically and imported from other parts of Costa Rica.

Three years ago FB began to apply foliar fertilizers to increase nutrient concentrations and for use as an insecticide, on an “as needed” basis. Five different foliar fertilizers are used, each for a different purpose. Three different recipes of compost are made as well, and used on all parts of the farm (Appendix B). Locations and types of crops are also rotated yearly, and are reported to increase soil quality. Nutrient levels are analyzed yearly by the Costa Rican Ministry of Agriculture and results are taken into consideration when determining the type of foliar fertilizer or compost to use for specific crops and areas of the farm. The farm also incorporates tourism by representing a "Model farm" for different uses of organic agriculture and forests walks and tours.

Soil Analyses

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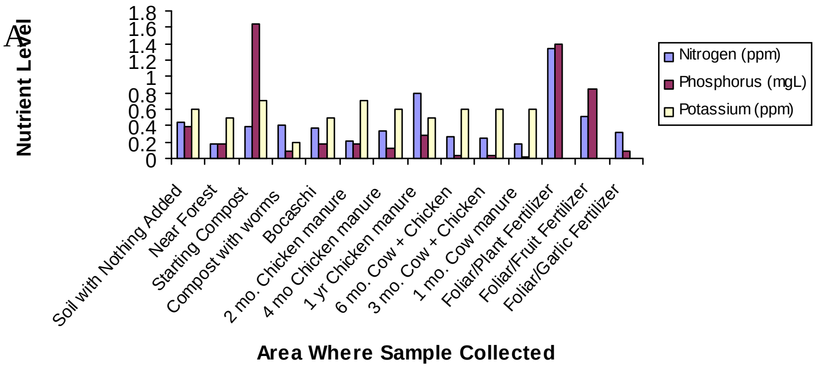

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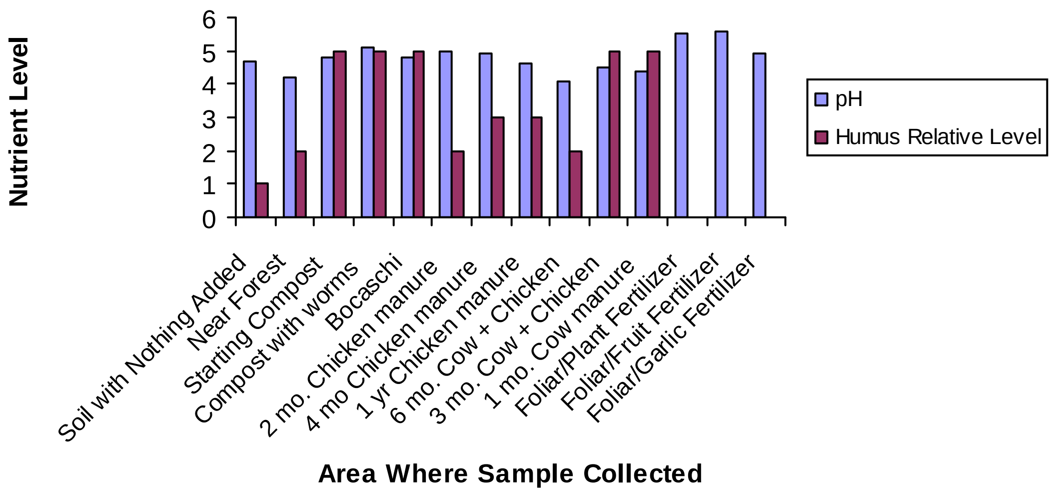


FIGURE 2: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of Finca Brenes in La Cruz, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

As can be seen in Figure 2, the highest levels of nitrogen were found in locations of the farm where chicken manure had been applied. Nitrogen levels appear to increase over time in those areas to which chicken manure had been applied. Soil with chicken manure applied two months ago had lower nitrogen (0.22 ppm) than soil applied a year ago, with a concentration of 0.8 ppm. There was a small decline in nitrogen concentration over time for those places where both chicken and cow manure were applied (0.27 ppm down to 0.25 ppm). The plant foliar fertilizer also had high nitrogen (1.34 ppm).

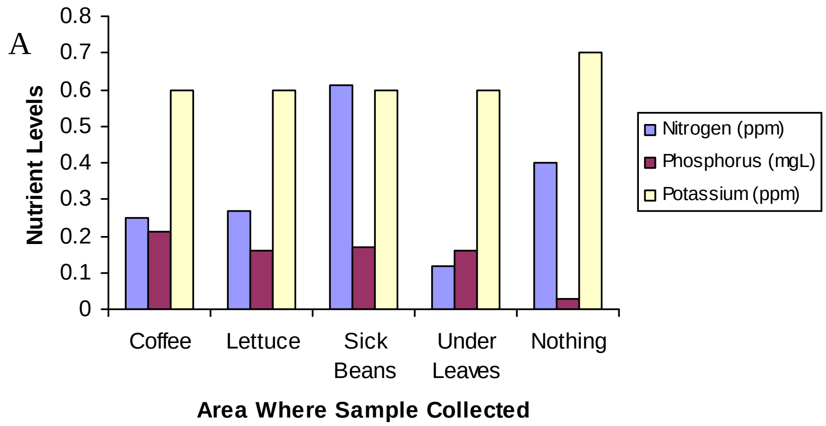
Potassium analysis showed comparable levels between all forms of fertilizers and composts (0.5-0.6 ppm), however compost with worms had a lower level (0.2 ppm). Phosphorus levels were high for the starting compost and both plant foliar fertilizers (1.64, 1.34, and 0.84 mg/L respectively). Results also indicate a decrease in phosphorus concentration for soils sampled from all other areas of the farm. Soil pH levels were relatively constant, about 5.0, throughout the farm. Relative levels of humus were high for compost that had not yet been applied to the soil as compared to the control area. Humus levels increased over time for those soils where both chicken manure and a mixture of chicken manure plus cow manure was applied, as seen in Figure 2.

Case Study 3: Finca Castro

Management Practices:

The Castro vegetable farm is located in San Luis (see Appendix C), at an elevation of approximately 1000 meters, and has been owned and operated for ten years by Hernan Castro. Señor Castro's agricultural philosophy is for a commitment to the production of totally natural produce. He sells all of his produce directly to locals in the community who also value vegetables completely free of pesticides and fertilizers. Señor Castro also forgoes organic fertilizer and compost for his crops. His entire farm is covered with mulch, in the form of weeds and leftover plant parts. This mulch is applied both for pest control and to increase soil quality. About half of the crops are either not sold or lost to pests and viruses, though even this decreased yield provides a sufficient income for this one man operation. Señor Castro does not foresee making any changes to his agricultural techniques in the future.

Soil Analyses



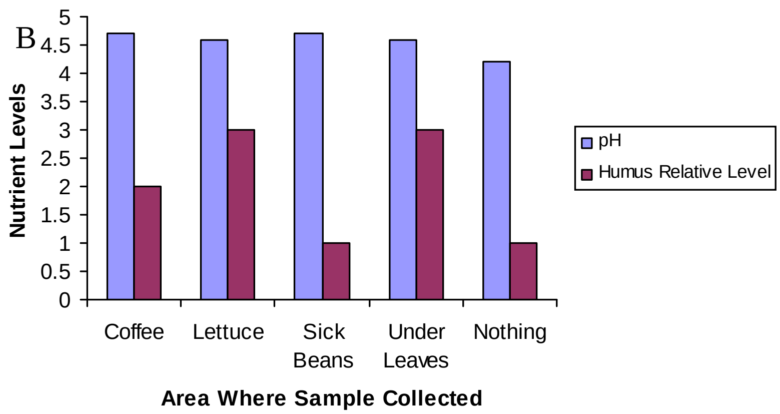


FIGURE 3: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of Finca Castro in San Luis, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

Not surprisingly, nitrogen levels were highest in soil planted with beans (0.61 ppm). Compared to soil samples collected in areas with no cultivation (0.4 ppm), soils from areas planted with coffee and lettuce had lower levels (0.25 and 0.27 ppm respectively) of nitrogen. Soil potassium levels were constant throughout the farm, around 0.6 ppm, but all these soil samples collected from active areas showed lower potassium levels than the control sample (0.7 ppm). Phosphorus levels were comparable throughout the farm, all areas having higher levels (0.16 - 0.21 mg/L) than the control area (0.03 mg/L). The pH of soil from active areas of the farm was more basic than the area not cultivated. Humus levels were high for the soil sampled under the leaves used as mulch (relative value of 5), and low for the area with sick beans (relative value of 1). All nutrient levels were significantly higher for the soil sample taken in a mulched area (Figure 3).

Case Study 4: Escuela Creativa

Management Practices:

Five years ago, a small vegetable garden was started at the Cloud Forest School in Monteverde, situated at an elevation of approximately 1100 meters (see Appendix C). The objective of the garden is to provide an educational tool that demonstrates organic and sustainable methods of agriculture. At some point in the school year, all students participate in the planting, maintenance, or harvesting of vegetables. No fertilizer is added, but two types of compost (with and without worms) are used during every planting season (Appendix E). Compost is applied directly under the plant base and in holes dug between each row of vegetables, three meters apart. Rows of vegetables and furrows containing holes of compost are rotated each planting season, and crops within the garden are also rotated. Pest problems are dealt with by planting biological pest controls such as basil, oregano, or rosemary, which act as natural insecticides, and are reported as being successful.

Soil Analyses:

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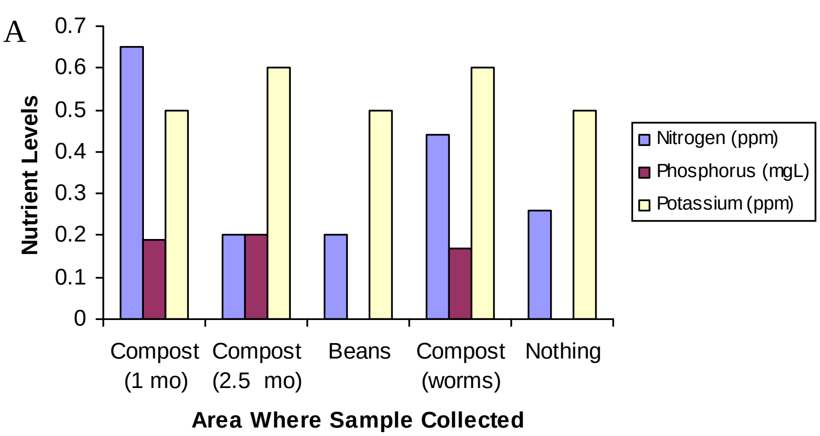

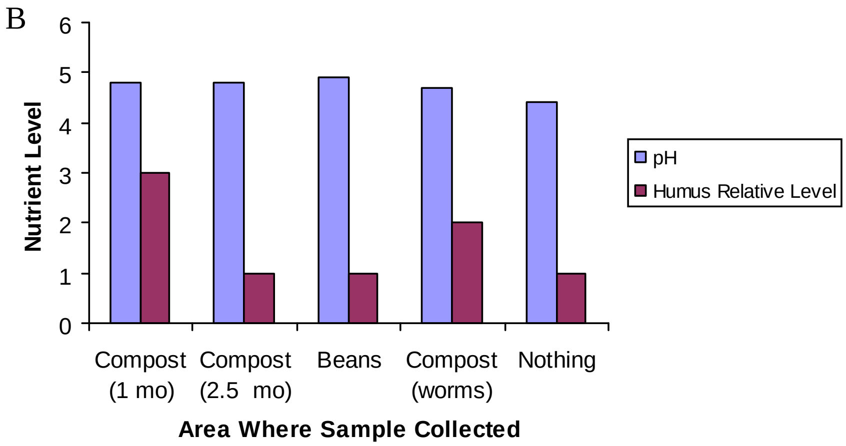

FIGURE 4: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of Escuela Creativa in Monteverde, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

Nitrogen and potassium levels were higher in both types of compost, as seen in Figure 4. Potassium levels in compost also increased over time from one month (0.5 ppm) to the two and a half month aged compost (0.6 ppm). Phosphorus levels were low for all soil samples collected from crops (0 ppm), but much higher levels were found in the compost (0.9 -0.2 ppm). Soil pH was comparable throughout all samples, around 4.7. Humus levels were highest for the one month compost and the compost with worms, with relative values of 5. Nutrient levels were highest for compost with worms, as seen in Figure 4.

Case Study 5: Joslin Farm

Management Practices:

Located near Finca Santamaria in Cañitas (see Appendix C), Harriet and Deb Joslin's small vegetable farm hosts a variety of crops. Deb, a retired soil specialist, and his wife Harriet, an avid gardener, both enjoy experimenting with different gardening techniques. Compost is created on a continuous basis using leftover organic kitchen scraps and applied to various areas of the farm (Appendix F). Commercial fertilizer high in phosphorus is used with initial plantings of all crops and on coffee plants. Three different foliar fertilizers (Appendix F) are also used sporadically. Cow manure, chicken manure, and lime are applied to scattered crops. Crops are stressed by insect and weevil problems; coffee cans are positioned around seedlings to ward off cut worms, and tomato wilting is endured. The couple has put a greater emphasis on organic gardening practices in past years because organic techniques slow decomposition more than inorganic fertilizers which are more readily washed away by Monteverde's heavy rains.

Soil Analysis:

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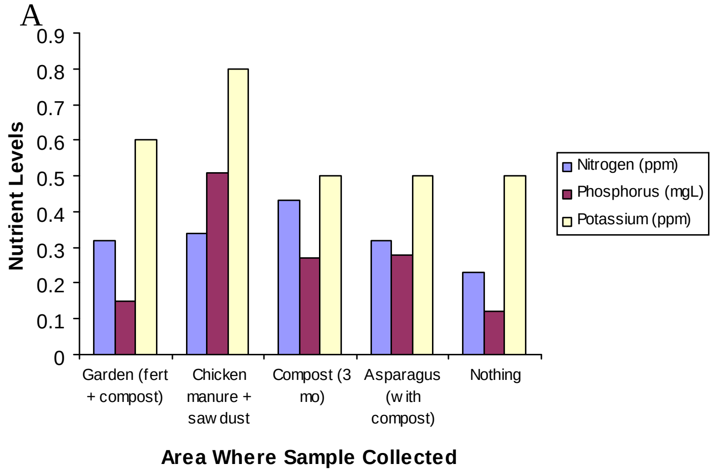

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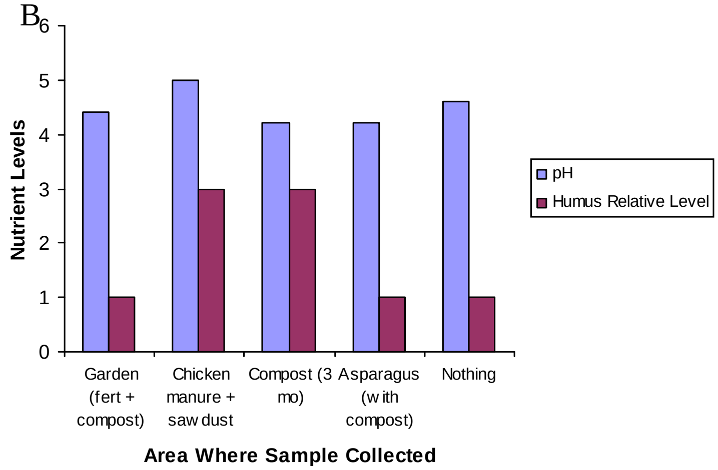


FIGURE 5: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of the Joslin farm in Cañitas, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

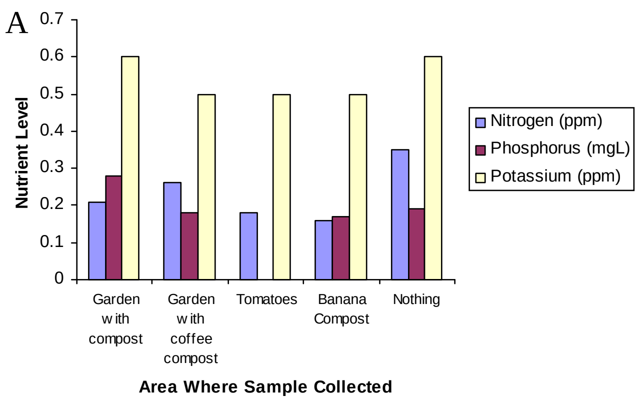
Measured nitrogen levels were highest for compost (0.43 ppm), and did not degrade significantly upon addition to soil around asparagus (0.32 ppm). Phosphorus and potassium levels were highest for chicken manure and sawdust, as seen in Figure 5. The pH measured in samples of chicken manure was high, 5.0, and the garden, compost, and asparagus had lower pH's, than the soil with no production, with a pH of 4.6. Humus levels were highest for compost and chicken manure with relative levels of 3, and lower for soils, with relative values of 1. Soil under the asparagus with a mixture of compost and fertilizer added boasted the highest nutrient concentrations in general, as seen in Figure 5.

Case Study 6: Milton Brenes' Farm

Management Practices

When Milton Brenes bought his farm in San Luis five years ago (see Appendix C), the farm produced only coffee and bananas. Currently, he produces bananas, coffee, tomatoes, beans and supports a small kitchen garden for various vegetables. Compost created from organic kitchen scraps and compost mixed with leftover coffee parts is applied in the kitchen vegetable garden (Appendix G). Compost is also applied to beans and coffee, using methods similar to those practiced in the Escuela Creativa. Holes are dug three meters apart throughout the planting site, and then filled with compost. Areas of holes and compost are then rotated with planting cycles. Dead banana shoots are used as a form of compost, and placed in the compost holes as well to increase the amount of microorganism activity. Only mulch from leftover plant parts (especially beans) and forest leaves are used for tomatoes. Rotation of crop location is used every planting season. No commercial fertilizers or pesticides are applied to any part of the farm. Tomato plants that are affected by fungus have their leaves removed, and plants such as basil, oregano, or rosemary are planted nearby for natural insecticides, and are reported to be extremely successful.

Soil Analysis:



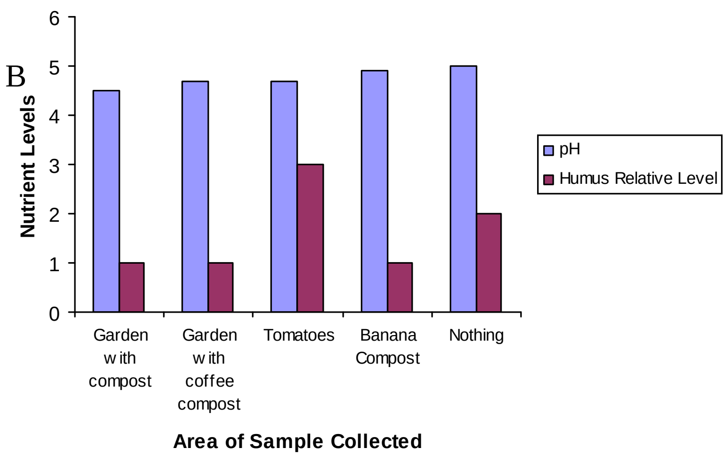


FIGURE 6: Two graphs, A & B, to show nutrient levels in selected soil samples of different areas of Milton Brenes' farm in San Luis, Costa Rica. Graph (A) shows the nutrient concentrations of nitrogen, phosphorus, and potassium in select soil samples. Graph (B) shows pH and relative humus levels of the same areas of the farm.

In general, nitrogen and potassium levels were lower for those parts of the farm that were cultivated as compared to the area that was not cultivated, as seen in Figure 6. Potassium levels were highest in compost applied to the kitchen garden (0.6 ppm) as compared to other areas (0.5 ppm). Phosphorus levels were highest in compost (0.28 mg/L), and lowest for soil sampled under tomato plants (0 mg/L). Soil pH levels were high for the control area and places where banana compost was applied (5.0 and 4.9 respectively). Humus levels were highest for the area with no cultivation, having a relative level of 3, and the soil collected under the tomatoes, with a relative level of 2. Nutrient levels of all soil tests with banana compost were significantly higher than any other area of the farm, as seen in Figure 6.

Cross Farm Analyses

Nitrogen: Soils with crops had lower levels of nitrogen for most farms (0.2 - 0.4 ppm), with the exception of beans, which had higher levels (0.4 - 0.6 ppm). Control areas also had higher levels of nitrogen in general (0.24 - 0.4 ppm). Compost and foliar fertilizers had higher levels than soils with crops (0.4 – 0.65 ppm).

Phosphorus: Phosphorus levels were significantly higher for compost, foliar fertilizers, chicken and cow manure, and banana compost (0.2 – 0.6 mg/L). Within soils with crops, coffee (0.25 mg/L) had higher levels of phosphorus than other vegetables.

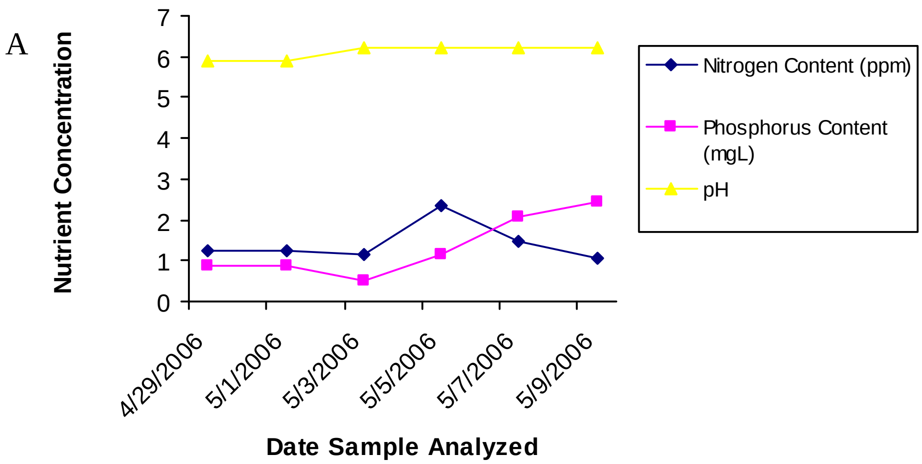
Potassium: Potassium levels were extremely variable between farms. Soils with cultivation (0.5 ppm) differed variably from the control sites (0.5-0.7 ppm). Compost from two farms had increased levels of potassium, and compost with worms was variable between farms, as seen in Figures 1-6. Beans had lower potassium levels (0.5 ppm), while chicken manure had higher levels (0.7 ppm).

pH: Soils where banana and coffee were planted was more acidic, with soil pH between 4.7 and 5.4. Foliar fertilizers and chicken manure were also more acidic, with pH values between 5.0 – 5.6. Soils of cultivated areas were variable in their comparison to the control areas between farms.

Humus: Relative levels of humus were significantly higher, with values of four or five for compost areas, cow and chicken manures, and soils with mulching. Degradation of humus in these materials was variable over time between farms, some cultivated soils having relative values of only one, while others having values of three.

Foliar Fertilizer Analysis

For both foliar fertilizers, pH was constant over time. Foliar fertilizer two showed relatively low but constant nitrogen and phosphorus levels over time, with a slight decrease in concentrations at the end of analysis. In contrast, after one week, foliar fertilizer one showed a peak in nitrogen levels, followed by a decrease back to its original nitrogen levels. Phosphorus levels for foliar fertilizer one were relatively high and increased more or less at a constant rate over time (see Figure 7).



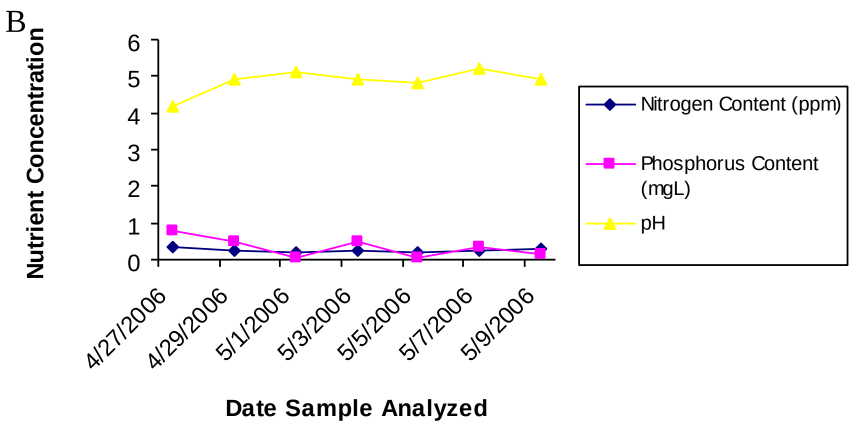


FIGURE 7: Graphs showing nutrient levels over time between two different types of plant foliar fertilizers. (A) Foliar Fertilizer 1. (B) Foliar Fertilizer 2. Nitrogen, phosphorus, and pH were tested every other day for approximately two weeks.

DISCUSSION

Though the most effective methods for increasing soil fertility throughout rural farms in Monteverde is unclear, this study has shown that farmers throughout the area are aware of its importance for the productivity of their farms. Though different agricultural practices were evaluated, and recommendations may be made for which were most successful in increasing select nutrient levels, this study was by no means a complete survey. By analysis of soil nutrients, recommendations can be made on the basis of which techniques are best only in terms of soil fertility.

Analysis of different approaches of farmers to increasing soil nutrient concentrations has shown that certain methods are more effective than others in raising nutrient levels. When evaluating methods best for overall nutrient levels, in general, most approaches between farms are comparable. Organic fertilizer or compost had no significant nutrient degradation over time before addition to crops, after which it undergoes significant nutrient losses rather rapidly, even within a month in some cases. Therefore, use of both fresh and aged compost is suggested, and may be a valuable option for farmers that need a sustainable source of organic enrichment.

Chicken and cow manure was found to have nutrient levels comparable to those of compost and organic fertilizer. Often, chicken and cow manure are already existing components of a rural farm, and are an easy, ready source of nutrients for crops. Chicken manure even showed indications of an increase in nutrient levels over time, which may be extremely beneficial for farmers seeking an application that needs to be replenished less frequently. Cow manure also showed constant nutrient concentrations over time. Therefore, it can be recommended that farmers who already have a supply of cow or chicken manure make use of this valuable source of nutrients to increase soil fertility.

More innovative methods of compost, including compost with worms or banana compost were found to have nutrient levels comparable with more traditional, kitchen scrap recipes. Therefore, it may not be cost effective to order worms from California if compost with exotic worms does not offer any major benefits over compost without. The use of banana shoots for compost may also be an excellent method for farmers who already have dead banana parts in other areas of their farm, an easy way to increase nutrient levels to those comparable with aged compost pits.

Mulching was also found to be a very useful method for increasing nutrient concentrations, though not quite as effective as compost or manure. Nutrient levels did not increase statistically as a result of mulching, but there was an increase in humus levels for those soils, specifically at the Castro Farm and for Milton's tomatoes. Nitrogen levels were found to be higher for nitrogen fixing beans, supporting many farmers practice of using leftover bean parts as mulch for increasing nitrogen levels in other areas of their farm. Therefore, mulching may be recommended for farmers as a quick, low cost option for increasing soil organic content which also cuts down on weeds.

Nutrient levels in Brenes foliar fertilizers were also found to be high, specifically showing higher nitrogen and phosphorus concentrations than compost. Plant foliar fertilizers were found to be higher in nutrients than the garlic or fruit foliar fertilizers, and therefore foliar fertilizers made from tree leaves is recommended. Between created plant Foliar Fertilizers one and two, it is recommended that Foliar Fertilizer one be used due to its increase in nutrient concentration over time. It is also suggested that the farmer wait one week for application of Foliar Fertilizer one, in order to optimize nutrient levels.

When analyzing management practices, general recommendations can be made regarding techniques used across farms that seem to be increasing their productivity and efficiency. Rotations of crops and crop locations were used by the majority of farms, and were observed to have a positive effect on the productivity and soil quality over time, therefore it is recommended. Use of commercial fertilizer on one farm did not increase nutrient levels, and therefore is not suggested and may not be cost effective when methods such as composting or mulching can be used. Given information from interviews, farms that worked actively to combat pests and viruses seemed to have a decrease in losses from those problems. Therefore, use of biological pesticides and organic foliar fertilizers used as insecticides is suggested. In total, the most effective methods to increase soil fertility are compost utilizing readily available material on individual farms. Examples of recommendations include compost made from kitchen scraps or banana shoots, leftover plant material for mulching, or chicken and cow manure.

Though results support the use of a large variety of organic systems to increase soil fertility, more coordinated efforts need to be made to share this information within the community. More communication needs to be made between farms regarding successful and effective methods for increasing soil nutrient levels. More monitoring of nutrient levels also needs to be stressed, so that the efficacy of certain methods may be assessed. The Costa Rican Ministry of Agriculture needs to become more involved with this process, and needs to give greater support to small, rural farms as opposed to its current emphasis on large scale monocultures. Within the community, more educational value needs to be given to sustainable farming. Though this study shows that many local farmers greatly value sustainability and organic agriculture methods, more education concerning the benefits of such practices need to be emphasized in the community as well, specifically for the farmer's clients. For example, grocery stores need to begin separating produce on a organic, non-organic scale, increasing awareness of what those different labels entail. Though beyond the bounds of this study, economic assessments and future studies need to evaluate the cost effectiveness of each organic technique and contrast this with soil fertility and productivity.

Increased knowledge and awareness of successful organic and sustainable techniques for both farmers and their communities is extremely important not only on a local scale, but also globally. As human pressures on soil, land degradation, and global warming continue to increase, it becoming clear that traditional agricultural practices are no longer viable for meeting needs of consumers. Therefore, it is extremely important that farmers around the world understand the most effective methods for increasing soil fertility and conserving their land for future generations.

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APPENDIX B: **Brenes Farm**

Organic Fertilizer with Worms: (takes 4-5 months.)

Soil
Leaves from the forest floor
Mix with water till holds its shape
Cover with bags
Next day, wait till temp reaches it maximum (kills the fungi and bacteria)
Add cow manure
Work in worms
Add molasses to one side of compost pit (worms are attracted to it)

Organic Compost without Worms: 8 days (makes 100 sacs)

35 sacs chicken manure
35 sacs cow manure
2 sacs ash
4 sacs of leaves from forest
10 sacs green plants leftover from garden
2 gallons colostrum
3 gallons molasses
If want to speed up process, add yeast
Wait for 8 days till temperature rises to 40-60 degrees Celsius
Spread compost out to thickness of about 10 cm
Wait till cools
Package in sacs till ready for use

Foliar Fertilizer Bocaschi: (takes 8 days)

Collect the following leaves from the forest:
Tobo: *Montanoa guatemalensis* (insecticide)
Corpachi leaves: *Croton niveus* (insecticide)
Mureseco: *Bidens pilosa* (high in P)
Uruca: *Trichilia haveanensis* (high in B)
Ortega: *Urera sp*. (insecticide)
Estrellon: ?
Guieatea: *Acnistus arborescens* (high in P, Mg)
Iguerilla: *Ricinus communis*
Fraiesillo*: Jatropha gossypilifolia* (Medicine)
Yerbillo: ? (high in N)
Fig Tree: *Ficus sp.* (high in K)
Aguaratillo: *Cinnamomum sp.* (high in Mg, K)
Chayote: *Sechium* edule (high in K)
On the ground, layer the following: One plant high in phosphorus, then molasses, then two leaves to help with parasites, then molasses, then three plants high in nitrogen, then molasses, then one plant high in boron, then one high in potassium, then one high in potassium and magnesium, then one

good for sick plants, then molasses, then cap the bucket, put a rock on top, and cover with a bag to keep away insects

Wait 5-8 days, till liquid begins to bubble

Put in strainer, strain out liquid

Mix 7 oz for every 4 gallons of water

Spray on plants

Foliar Fertilizer to Increase Phosphorus

Chicken manure

Goat and rabbit droppings

Molasses

Santa lucía leaves: *Ageratum sp.*

Molecsica: ?

Foliar Fertilizer to Increase Nitrogen

Cow manure

Vein of leaves

Legumes (Inga, Mimisoids)

Foliar Fertilizer to Increase Potassium:

Fig Leaves

Fruit Foliar Fertilizer

Banana, guajava, papaya, mangos (any non-acidic fruits)

Use a combination of three different fruits

Foliar Fertilizer: Manera Negra (*Gilricidia sepium*)

(insecticide)

Queen of the Night: *Brugmansia sp.*

Higuerelle: ?

6 Leaves Extrion: ?

Ortega

Water

Wash leaves till water smells of plants

Wait one Day

Add *Gilricidia sepium*

Wait 2-3 days

Strain out liquid

Used Straight for spray

Garlic Foliar Fertilizer

4 parts garlic to 6 parts water

Use straight for spray

APPENDIX D: Santamaria Farm

Compost:

2 sacs of compost from farm in San Luis
Add worms from California
Add coffee peels leftover from harvest
Add water until soil holds its shape
Add organic materials (from kitchens of four families and cafeteria) to either one side of bin or other
Wait until worms decompose all organic material before adding more, then add to the other side of the pit
Continue addition and mixing of compost until rainy season, when compost will be applied

Foliar Fertilizer:

Water + molasses + colostrums
Use as spray directly on plants

APPENDIX E: Escuela Creativa

Compost:

Dirt
Leftover coffee parts
Leaves from forest
Ash
Cover with soil
Molasses
Add water till holds shape

Compost with worms:

Same recipe, just add worms

APPENDIX F: Joslin Farm

Compost:

1. In a plastic garbage bin with holes
   Add dried weeds from garden
   Add organic waste from kitchen
   Wait three weeks
2. Transfer material from garbage bin to second bin
   Mix up material and add soil
   Turn once/week
   Wait three weeks
3. Remove compost from garbage bin 2, lay on tarp
   Remove coarse material
   Wait three weeks

Compost Tea:

- Mix aged, strained compost with water (one part compost to eight parts water)
- Stir once a day for a week
- Keep container covered to protect from insects
- After seven days, filter with paper towel and dilute (one part tea, six parts water)
- Water seedling plants or foliar spray the garden

Foliar Fertilizer: (from New Dawn Research Center)

- Sugar
- Hydrogen peroxide
- Spray straight onto plants

APPENDIX G: Milton Brenes Farm

Compost:

- Café grounds
- Chicken manure
- Corn
- Honey
- Native worms