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PSPM 5904: PROJECT AND REPORT (DRAFT)

Developing and Using an Ethnographic Linear Programming Model of the Small Farm Livelihood System of Bohoc, Haiti

I. ABSTRACT

This project involved the development of an Ethnographic Linear Programming (ELP) model for the small farm livelihood system of the village of Bohoc, Haiti, and using the model to pre-evaluate the biological control of the sugarcane mealybug (*Saccharicoccus sacchari*) with one of its natural enemies, *Cryptolaemus montrouzieri*. This required three phases of field research: (1) a Sondeo or participatory rural appraisal to form an understanding of the livelihood systems in this part of the Central Plateau of Haiti, (2) intense interviews of a representative Bohoc farm family, and (3) interviews of four other Bohoc farm families to validate or complement the data obtained from the first family. The first draft of the ELP matrix was prepared after phase two, and the matrix was revised and expanded after phase 3. The ELP matrix accurately models the crops grown and other income-producing activities engaged in by the farm families, but may understate the percentage of available labor used and may overstate the cash accumulated. It is uncertain whether further research would enhance the accuracy of the ELP model. Despite its possible limitations, the matrix that was developed is viewed as a useful tool for understanding the small farm livelihood system that it modeled and for pre-evaluation or hypothesis testing of new agricultural activities, technologies, products, policies, or infrastructures. The pre-evaluation of biological control of the sugarcane mealybug was beneficial for purposes of illustrating the use of the ELP model, but an actual pre-evaluation of this would require further study.

II. BACKGROUND

A. Reason for Project and Concept

The idea for this project originated from my first visit to the Bohoc, Haiti, site of the Haitian American Friendship Foundation (HAFF), a Christian missionary organization.[1] Bohoc is a small village in the Central Plateau of Haiti. Although the trip was unrelated to my studies, during the trip I decided I would like to undertake a project that would satisfy my degree requirements and perhaps help the impoverished Bohoc farm families, who impressed me with their upbeat spirit and remarkable ability to survive on meager resources.

One of HAFF's missionaries, who works principally in agriculture, told me that having a tool for economic analysis would be helpful for his work. He had no analytical tool for use in giving guidance to farmers on what and how much to grow and the likelihood of success of new methodologies. I was given contact given information for someone who could possibly assist me in developing a concept for a project, Heidi HansPetersen, a University of Florida Ph.D. student in entomology and former HAFF intern. I spoke with her by telephone. She suggested that I consider developing an Ethnographic Linear Programming (ELP) model. One of her professors, Peter E. Hildebrand, Ph.D., of the University of Florida Food and Resource Economics Department, had been a pioneer in developing ELP, and she gave me his telephone number.

I then talked to Dr. Hildebrand, who provided me with some basic information on ELP and gladly agreed to assist me in developing an ELP model for Bohoc, Haiti. He was not aware of any previously-developed ELP models in Haiti. Practically all of the information on ELP included in this report came from him by telephone or email or from his works cited in Section VIII, particularly Hildebrand (2005) and Hildebrand (2006).[2]

[1] I am grateful to my friends at HAFF, including Greg and Barb Van Schoyck , Connie Curilla, and Colin and Carla Wilson for their assistance and hospitality during my visits to Bohoc. I am also grateful to my friend and superb translator, Derold Mompremiere.
[2] Dr. Hildebrand was extremely helpful to me, and I greatly appreciate his assistance.

The concept of the project was to develop an ELP model that could be used by agricultural professionals in the rural, impoverished Central Plateau, particularly in the Bohoc area, to pre-evaluate new farming options. ELP is an effective tool for that purpose and could be helpful in this area of Haiti. Households in small farm livelihood systems in developing countries such as Haiti are highly diverse and, being homes first and businesses second, are not suitable to typical economic analysis (Hildebrand, 2005). Business decisions in such systems tend to be intermixed with household or family decisions (see Norton, 2006, p, 124). Thus, the nature of these households presents a problem for conducting analyses to determine successful development strategies involving new technologies, policy changes, project ideas, or improved infrastructure (Hildebrand, 2005). ELP is a methodology specifically designed to overcome this problem (Hildebrand, 2005). ELP models account for the diversity of the households and for reproduction activities (which relate to maintaining the household and its members) as well as production activities (Hildebrand, 2005). Moreover, ELP methods can eliminate the need to make assumptions and use averages, both of which often lead to errors (Hildebrand, 2005). The ELP methodology is explained in Section IV.B below.

B. Literature review

Dr. Hildebrand has written extensively (frequently with Victor E. Cabrera, Ph.D.) on ELP models or on research in which they were used. See, e.g., Cabrera, 2002; Cabrera, 2005; Cabrera, 2006; Cabrera, 2007; Cabrera, 2008; and Hildebrand, 2005. Also, a substantial number of studies have been published on developing and using ELP in various parts of the world. See, Dr. Hildebrand's Ethnographic Linear Programming in Theses, Dissertations and Published Articles Through 2010 (Hildebrand, 2010). It appears, though, that no published ELP studies have been done for Haiti.

III. PURPOSE: I had two main goals for this project:

A. Model the small farm livelihood system of Bohoc, Haiti, using Ethnographic Linear Programming (ELP)

Most of my time on this project, by far, was devoted to accomplishing this goal. My completion of the model has required three trips to Haiti and numerous hours of work with Excel spread sheets. See Section IV for details.

B. Illustrate the use of the ELP model to pre-evaluate a new farming option

The accomplishment of this goal required completion of the model. Thereafter, I decided to pre-evaluate biological control of the "picho" insect pest of sugarcane. I learned about that pest during my field work.

IV. METHOD

A. Research: three steps, each requiring a trip to Bohoc

1. "Sondeo" (participatory rural appraisal)

This was the first phase of the research, done in November 2008. It involved participating in a team that spent four days interviewing members of a variety of small farm households in the Bohoc area, using qualitative techniques, to develop an understanding of the livelihood systems and to identify a representative household from which to obtain detailed data during the next visit. The approach used was a type of participatory rural appraisal called "Sondeo" (see Hildebrand, 1981).

The team on which I participated was formed and led by Heidi HansPetersen as part of her doctorate thesis work. It was coincidental and fortunate that this Sondeo was organized at the time I needed to begin my research. The participants were divided into three interview teams, each with three to four members and a local national guide and translator. Participants rotated among the interview teams. The teams randomly selected households and farmers for informal interviews. Interview team members took notes between (not during) interviews and gathered with other interview team members in the evenings to discuss trends, gaps in the information, cultural factors affecting the process, and modifications that were needed for the next day's interviews.

A livelihood system is the composite of all activities available to all the households in the system from which they can secure their livelihood (Hildebrand, 2005). Agriculture obviously being the key component of the livelihood systems in the Bohoc area, the focus of the Sondeo was on appraising the local cropping and livestock k systems. A special emphasis was given to pest management.

Several draft reports on the Sondeo were prepared based on the interview notes. The most recent draft is cited in Section VIII and set forth in its entirety as Appendix A (HansPetersen, 2010). It lists nine authors, all of whom were participants in the Sondeo. I am the second listed author; the first is Heidi HansPetersen, who wrote the majority of the report. I wrote perhaps 15% of the report, including much of the livestock and economic activities sections. Because the methodology and results of the Sondeo are included in detail in the appended report, I have not included those details here.

2. Obtain detailed data from one representative household

The concept of this phase of the research, done in November 2009, was to obtain from a designated representative household detailed information on all activities and constraints relevant to its livelihood. The goal of this phase was obtain from this family sufficient data for an ELP model. That required detailed information on all the available farm and non-farm activities available for Bohoc families for securing their livelihoods. The family necessarily had to have been one that could provide that information. The family I chose, based on the recommendation of HAFF missionaries, was the family of Bohoc farmer Fabius Jean.

I prepared for this research by drafting a rough sketch of my projected ELP matrix and by outlining the subjects on which I wanted to inquire and the information I wanted to obtain. Then when I arrived in Bohoc, I spent about 6 hours per day for five days with Fabius and his family at their home or farm. Most of my time was spent interviewing Fabius at his house (and it got tedious for both of us), but I also interviewed his wife, Germanie and some of the children. Also, through visits to his farm and strolls through his yard (called "lakou"), I got first-hand observations of his crop and livestock methods.

My interviewing process was informal and involved no charts or surveys. It produced much specific data, but by its nature included many estimates and approximations. I made handwritten notes, from which, when I returned, I compiled an Excel spread sheet on the family's agricultural activities. Given the goal of this research phase, my interviews of Fabius and his family were not limited to his family's activities. One reason Fabius' family was recommended as the designated family is that Fabius is very knowledgeable about, not only the activities in which he engages, but also about the farm and non-farm activities that are available for Bohoc families.

During the interviews of Fabius and his family, I obtained detailed information on:

1. Household composition.
2. Available land and other resources.
3. Crops grown and their quantities.
4. Livestock kept and their quantities.
5. Marketing of crops and livestock.
6. Amounts consumed to feed family and amounts sold.
7. Non-farm income producing activities and options and other sources of revenue.
8. Non-farm household activities.
9. Food requirements.
10. Non-food requirements.
11. Expenses.
12. Roles of the various household members in the farm and non-farm activities.
13. Time spent by various household members on farm and non-farm activities.
14. Financial needs and goals.

The Fabius (it is customary to refer to the family by the husband's first name) household consisted of Fabius; Germanie; 6 daughters, ages 10 to 23; 5 sons (1 adopted), ages 8 to 18; and 1 granddaughter, age 3, who stayed sometimes with Fabius and sometimes with her mother. Tragically, Fabius had another son, Fabno, who was killed in the earthquake of January 2010 while in college in Port-au-Prince. Thereafter, the community support for Fabius and his family during their period of grief was remarkable. This photograph, taken in October 2010, shows Fabius and Germanie in front of their new house, built with the assistance of members of his community:

Figure 1 Fabius and Germanie at their new home

At the time of these interviews, the Fabius family lived in a smaller house than the one shown in the photograph. It consisted of only several rooms with mud walls and floors. Like most homes in Bohoc, it had no electricity, and like all homes, it had no plumbing. Gas lamps provided some light at night. An outhouse was in the lakou. The cooking, with wood, was done in a sheltered area in the lakou. Fabius owned the house outright, so he did have a rent or other house payment. The mud walls had to be repaired about three times per year, and other repairs had to be made. Fabius made his own repairs.

The size of the family's lakou was about 1/8 kawo. A kawo (sometimes spelled "karo") is about 3.19 acres (HansPetersen, 2010). On the lakou, as is typical in Bohoc, the family grew fruits and vegetables for home consumption and kept chickens and pigs. As is also typical, the pigs were occasionally slaughtered for family consumption (a special occasion), but like other livestock, served the function of a savings account that can be sold during lean times when the family has no other source of money. (See Norton, 2006, p. 127, for a discussion of "lean seasons.") The chickens used were primarily for eggs for the family, sometimes for meat for the family, and occasionally for the market.

Fabius rented a farm of about 1 kawo near his house. He used about half of it for crops and about half for pastureland for livestock. On the farm he grew maize, peanuts, and 3 kinds of beans, using intercropping. Atypically, he did not grow sugar cane, the area's biggest money crop. The livestock he kept on the farm consisted of a bull and some goats.

Germanie and the older children contributed to the farming, but it was by no means a principal duty for them. The children had more time for farming in the summer, when they were not in school.

Germanie typically spent about 2 hours per day cleaning house and sometimes got help from the children. Cooking was a family activity, with Germanie, the older children, and Fabius participating. The task of getting water from a neighbor's well or the community well several times per day was shared by Germanie and the children. The older children gathered wood for cooking. This took about an hour for a child about 3 times a week. Fabius and Germanie spent time in the morning and evenings helping their children with school work and biblical studies.

Fabius supplemented his farming income with woodwork. Among the items he made and sold were coffins, doors, and furniture. Germanie's embroidery brought a little income to the family. According to Fabius, other typical non-farm income generating activities in Bohoc were charcoal production and market commerce engaged in by women who bought and sold food, clothes, and household items at the local markets.

Fabius' family could not raise all of its food. The family had to buy rice, flour, and oil and sometimes had to buy beans, corn, and other items. The weekly expense for food for the family for what Fabius called the "good months" was about $300 (Haitian dollars)[3] and for the other months was about $700 to $800. Using $2,000 per month as a requirement for food, the annual requirement was $24,000.

Fabius said the family needed, in addition to money for food, about $1,000 annually for the house, $1,500 for health care, $3,000 for clothes, $1,000 for rent for the farm, and a huge amount—about $10,000--for school for the children. Considering the projected income from the farm and other income producing activities, it seemed impossible for the Fabius family to make ends meet.

During my 2010 interview of Fabius, he said his goal was to have about $10,000 to 12,000 after the fall harvests, and he needed about $3,000 to plant the next year's crop. Those goals did not seem totally unreasonable, but how the family could generate sufficient funds between planting season and harvest to satisfy what Fabius said were the family's requirements is a mystery.

For each crop that Fabius grew or could grow, the information I obtained included:

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[3] Throughout this paper, monetary amounts are given in Haitian dollars (HD). One HD equals 5 Haitian Goude (HTG) (HansPetersen, 2010). The exchange rate as of October 29, 2011, was 1 US dollar equals 40.32 HTG (http://www.exchangerate.com/currency-converter/) . Thus, $1 US dollar equaled slightly more than 8 HD.

1. Land needed.
2. Timetables.
3. Methods and costs for land preparation, planting, fertilizer (but rarely used), pest management, harvesting, storage, and marketing.
4. Labor requirements.
5. Labor provided from within the household, including hours spent and times available for the various household members, male and female.
6. Labor hired or otherwise obtained from outside the household.
7. Income.
8. Expenses.

I obtained similar information for each type livestock that Fabius kept or could have kept, including:

1. Resources needed.
2. Timetables.
3. Purchase and sale prices.
4. Feeding requirements.
5. Fencing requirements.
6. Labor requirements.
7. Labor provided from within the household, including hours spent and times available for the various household members, male and female.
8. Labor hired or otherwise obtained from outside the household.
9. Diseases and mortality.
10. Expenses.

The agricultural information I obtained is summarized in the Appendix B Excel spreadsheet. I compiled this information from my handwritten notes after I returned home from Haiti. Thus, I had no easy way to alleviate the gaps and have not attempted to do so, feeling that the gaps are insignificant in light of the information I obtained from other farmers during the final research phase.

3. Validate model by obtaining data from other households

This was the last phase of the research. It involved returning to Bohoc in October 2010 to conduct one-day interviews of five farm families. Before taking that trip, I prepared an ELP matrix based on the data I received from the Fabius family in 2009. The preparation of the ELP matrix is described in Section IV.B. The purpose of the October 2010 research was to validate and complement my model with data from households other than Fabius' family and make any revisions needed for the matrix to accurately model the livelihood system. The additional households, thus, had to be part of the same livelihood system as the Fabius family.

Ideally, I would have made the appropriate adjustments to the matrix on my laptop computer during the interview process. Unfortunately, though, that was not possible for technological reasons: Before taking this trip, I purchased software for Excel called Premium Solver that gave me enhanced capabilities for my matrix. I needed the enhanced capabilities for the necessary revisions to the matrix, but I was having technical difficulties with Premium Solver in the field in Bohoc. Thus, in the field I gathered the necessary data from the five families and made the necessary validation-process revisions to the matrix when I returned home. I do not believe completing the validation process at home rather than in the field affected the project—I do not see how the result would have been significantly different.

These interviews were different from the intensive interview of the Fabius family the previous year. The previous interview was designed to gather data on all aspects of the livelihood system. Fabius and his family members were able to provide me information on all farm and non-farm activities available to the families in the livelihood system, not just those activities in which they were engaged. In the 2010 interviews, limited to one day per family, I was simply gathering data on the activities in which the interviewed families were personally engaged. That is all I needed to validate the model.

The first family I interviewed upon my return was the Fabius family. Keep in mind that Haiti had been devastated by an earthquake in January 2010, between my initial interview of the Fabius family and my return for the 2010 interviews. I wanted to determine if the data I obtained from Fabius in 2009 were still valid. Also, I felt I needed to conduct the same limited interview of Fabius, including only the activities in which his family was engaged, that I was conducting of the other four families.

The data I obtained during the 2010 interviews were of the same nature as the data I obtained from the Fabius family in 2009. It was less extensive overall because it included only the activities in which the family was engaged, but I focused more on pests and pest damage, and I obtained more specific information on intercropping than I obtained from Fabius in 2009. The importance and prevalence of intercropping became obvious during the 2010 interviews, and perhaps the most significant adjustment I made to the matrix after the 2010 interviews was adding intercropping.

The production practices and market prices provided by Fabius in 2009 tended to be substantially the same as those obtained from him in 2010. While the information obtained from Fabius varied to some extent with the information obtained from the other farmers in 2010, I noticed no trends to indicate that the earthquake, while devastating in many ways throughout Haiti, caused any fundamental changes in the farm economy of Bohoc.

The following provides basic information on each of the five families and their activities. The specifics are set forth in the appended spreadsheets.

a. <u>Fabius</u>

My 2010 interview of Fabius and his family members showed that the family was engaged in substantially the same farm and non-farm revenue producing activities in 2010 (post-earthquake) as it was in 2009 (pre-earthquake). Having discussed the Fabius family's activities in the previous section, I will not repeat it here. The data from the 2010 interview of the Fabius household are set forth in Appendix C.

b. <u>Destorel</u>

Destorel Docteur and his wife lived in a small Bohoc home with three girls (who are not their daughters—their daughters were adults living outside the home). Destorel farmed three tracts. On one that he owned of about 1 kawo, he farmed only sugar cane. On another that he owned of about 1½ kawos, he intercropped sugar cane and plantains (an unusual combination) on 1 kawo and grew manioc on ½ kawo. On the third tract (1/2 kawo), which he rented, he intercropped maize, beans, and peanuts. In the lakou, the family, as with most Bohoc farm families, grew a variety of fruits and vegetables and kept chickens.

Figure 2 Destorel with wife and girls

At the time of the interviews, the family had a pig, 2 goats, a donkey, and a bull. Bulls are valuable plow animals.

The main non-farm income producing activity within the household was peanut butter making. Madam Destorel made the peanut butter, packed it in jars, and sold it in the community. She did not need to take it to the market; people knew she made it and came to her to buy it. The peanuts came from one of Destorel's farms.

Destorel said his year-end goal was to make $35,000. He said he needed about $10,000 to plant the next year's crop.

The data from the Destorel interview are set forth in Appendix D.

c. Larion

Larion Francois lived in a typical Bohoc home with his wife, three daughters (ages 22, 19, and 10), and son (age 16). While Larion owned 2½ kawos of land, he only farmed ½ kawo on each of two farms. He had a relatively small planting of sugar cane (1/8 kawo) and also planted maize, pitimi, manioc, pwa lyanne (a legume), and sweet potatoes. His 1/8 kawo of sweet potatoes was a substantial planting, but he did not sell sweet potatoes; they were consumed at home and given to friends and neighbors. He intercropped maize with pitimi on one farm and maize with pwa lyanne on the other. Only sugar cane and manioc were sold. The family made cassava bread from the manioc. In the lakou, the family grew a variety of fruits and vegetable, but atypically did not keep chickens.

Figure 3 Larion and two of his children

Larion had a horse, two bulls, a cow, and five goats. To supplement his income, Larion rented his bulls to other farmers for plow animals.

Madame Larion provided supplemental income for the family by engaging in market commerce. She bought and sold a variety of farm and non-farm items at the markets of Bohoc and the nearby larger towns of Pignon and Hinch.

Larion's year-end goal was to make $20,000. He said he needed $4,000 to $5,000 to plant the next year's crop.

For details, see the data from the Larion interview set forth in Appendix E.

d. Aminot

Aminot Cadet and his wife lived in a typical Bohoc home with his stepmother. Their three sons were in college. He had a small farm of about ¾ kawo, on which he grew manioc, pwa congo, and peanuts, intercropped; and about ¼ kawo of sugar cane. Unlike most Bohoc farmers, he did not grow maize. The lakou contained the typical fruits, vegetables, and chickens. He reported that about 80% of his chickens died from a disease that was apparently Newcastle. His other livestock consisted of a pig, 4 goats, a cow, and a calf.

Figure 4 Aminot in his lakou

Aminot's year-end goal was $35,000, $18,000 of which was for college tuition for his sons. In light of the family's limited farm income and high needs, Madam Aminot was extensively heavily engaged in market commerce, taking weekly two-day trips to the Dominican Republic to buy goods for sale in the local markets. Fortunately, Aminot needed only about $3,000 to plant the next year's crop.

The data from the Aminot interview are set forth in Appendix F.

e. Dorsmans

Like the other interviewed families, the Dorsmans Docteur family lived in a small home with a lakou. Dorsmans and his wife had four children, only one of whom, a daughter of age 36, lived at home. A boy of age nine and a girl of age 3, neither of whom was their child, also lived with them.

Figure 5 Dorsmans and his wife

Dorsmans had three farms, one of about ¾ kawo and the other two about ¼ kawo each. On the farms he grew typical crops: sugar cane, maize, pwa congo, peanuts, sweet potatoes, and manioc. Unlike the other farmers, he grew his sugar cane by contract. The purchaser harvested his crop and paid $85 per barrel.

In the lakou, the family grew the typical variety of fruits and vegetables for family consumption and kept chickens. His other livestock consisted of only a pig, two goats, and a donkey.

Dorsmans said his year-end goal was to make $75,000, which seemed absolutely impossible; the family had no off-farm income and could not project earning anything close to that amount from the farm. Why his goal was that high was unclear. He reported needing only $4,000 for planting the next year's crop.

The detailed Dorsmans interview data are set forth in Appendix G.

B. Development of ELP model

1. ELP methodology

Linear programming is a mathematical optimizing procedure used to maximize or minimize an objective, subject to a set of constraints (Hildebrand, 2005). Linear programming models have been widely since the 1950s to formulate farm plans in search of the optimal solution to a problem of allocating constrained resources—usually land, labor, and capital—to alternative means of production (Hildebrand, 2005). Those models have typically been normative in that the modelers told the farmers what they ought to be doing when the model solutions differed from what the farmers were doing (Hildebrand, 2005).

ELP is different from those widely used linear programming models. ELP models, which are designed to represent real-world livelihood systems, are used by extension agents, researchers, policy makers, and infrastructure managers to assess potential project ideas and policy scenarios (Hildebrand, 2005). These models are not used to promote model solutions that differ from what the farmers are doing, but add alternative activities to existing activities to assess the likely outcome (Hildebrand, 2005).

A basic ELP matrix consists of (1) the available farm and non-farm activities and options and their resource requirements and constraints, (2) the constraints that limit farm and family activities, including fixed resources, (3) costs and returns of each modeled activity, (4) a defined objective (Hildebrand, 2006). The Excel formula "=sumproduct" can be used for this. To solve an ELP matrix in Excel, the Solver dialog box must be used. Setting up and using an ELP matrix are described in great detail in Hildebrand (2006).

2. Development of Bohoc model

To learn how to prepare an ELP model, I completed the exercises in Hildebrand (2006). The exercises begin with the development of a very simple model and end with the development of a complex multi-year model.

Having developed an understanding of ELP matrix construction, I used the data from the Fabius 2009 interviews to prepare a draft of a matrix. Before conducting those interviews, I had prepared a rough outline of a matrix, but had not actually begun to construct the Excel matrix. When I constructed the first draft of the matrix, I was using Excel's basic Solver, which has significant limitations in the numbers of variables and constraints that can be used in the matrix. Consequently, I had to make some choices on which activities to include—I simply could not include all the activities on which Fabius provided me data. I chose what I felt were the most important farm and non-farm activities based on the interviews with Fabius and his family members. After many versions and trials and errors, I finally completed a satisfactory working matrix.

Shortly before leaving for the 2010 interviews, I learned about the availability of, and purchased, Premium Solver software, which greatly expands the numbers of variables and constraints that can be included in the matrix. The 2010 interviews showed that I needed to include many more variables and constraints than were in my first draft of the matrix. Unfortunately, because I was having technical problems with Premium Solver, I was unable to use it satisfactorily during the 2010 trip. Thus, the needed expansion and modifications of the matrix had to wait until I returned and resolved the technical issues with Premium Solver. The most important change was the inclusion of various intercropping options. I had failed to grasp the importance of intercropping during my earlier visits. Intercropping involving maize, beans, peanuts, manioc, or pitimi in varying combinations, seemingly planted haphazardly, was widely prevalent in Bohoc.

Figure 6: intercropped field in Bohoc, Haiti

I could only include combinations of intercropping by using the additional variables and constraints allowed by Premium Solver. It still, though, took dozens of attempts and much frustration before arriving at the final, working matrix, which is set forth in Appendix H. In this highly time-consuming process, each failed attempt at a feasible solution required troubleshooting. It seemed that a simple mistake, such as using -1 rather than 1 in a cell, could inject error into the entire matrix. With thousands of cells in the matrix, the chance of error in at least one cell was high, and troubleshooting was difficult.

Finishing my ELP matrix still required choices. I could have included more activities, but I did not for two reasons: First, even Premium Solver does not provide for unlimited variables and constraints. Second, it seemed to me that the difficulty in achieving a feasible matrix solution increased as the number of modeled activities increased. Therefore, with one exception, I included only activities in which the interviewed farmers or their families were engaged. The one exception was charcoal production, which is widely prevalent. (I knew that from participating in the Sondeo and from the first Fabius interview.) I do not believe that the final matrix omits any activity that is an important. Thus, by not including every conceivable activity, I do not believe I have compromised the model, and have kept it to a manageable size that produces a feasible solution.

3. Explanation of matrix

This is a five-year model. The activities are placed in the “Variables” rows. The “Amount” rows, below the variables row, display the amount of each activity provided in the model’s solution in terms of the measurement unit listed in the row below the amount row. The intercropping columns perhaps complicate the amount rows, but that will be explained below. An example of a model amount is cell E4, which sets forth the amount of sugarcane grown in the model solution in year 1, a little over .96 kawos.

The “Land” rows for each year provide the unit of land being used as a standard for each activity. Thus, cell G6 shows that the model entries for sugarcane are based on 1 kawo of land. The labor rows divide labor by gender and into 4 quarters of the year. The labor cells represent the amount of labor, in workdays, needed to produce the crop. For example, cell G8 shows that sugarcane production on 1 karo of land needs 38 days of male labor in the second quarter of year

1. Land and labor constraints are shown in column CH, labeled RHS (right hand side). Cell CH6 shows that total land for all activities is limited to 2 kawo. Cells H7 through CH14 show the limitations in total labor available, by gender and quarter, for all activities. Those figures include labor available from children old enough to work. Thus, more total labor is available during the summer, when the children are not in school. These figures represent the labor available for the modeled activities; thus, less female labor is available than male labor because typically much of a woman's day is spent on household chores not modeled.

The "Beginning Cash' rows show the amount of cash needed for the activities. For example, cell G55 shows $2100 is needed for sugarcane production in year 1. The "End Cash" cells for each activity show the price for which the product can be sold. For instance, cell H128 shows that sugarcane can be sold for $775 per barrel in year 2.

The model solution's resource use for land and labor are shown in column CI. Therefore, for year one, all 2 kawos of available land are used in the model solution (cell CI6). Labor use is similarly shown. When setting up the matrix, an "=sumproduct" formula must be entered in the column CI cells. The formula will vary from cell to cell. An example of an =sumproduct formula, entered in cell CI6 for year one land, is (D6:CF6, D$4:CF:$4).

Accounting and consumption rows are needed for activity products for which there is more than one use. These type rows are used extensively in this matrix for crops that are both sold and used for family consumption. These rows are used in conjunction with "sell" and transfer ("TR") columns. Again using sugarcane as an example, in year 2 for sugarcane, the cell G86 entry in the accounting row, -40 (a negative coefficient), is the yield per kawo. The amount not sold in year 2, but used for family consumption, is .25 barrels. That is shown in cell CH87. Since it represents a use of resources, it is a negative number. The 1 in the sell column (H86) is necessary to take sugarcane out of the accounting row, and the 1 in the transfer column (I86) is necessary to transfer sugarcane into the consumption row (see Hildebrand, 2006). This process requires a -1 in cell I87 in the consumption row because the consumption requirement is considered a "sink," as opposed to the "stock," of resources (see Hildebrand, 2006). Amounts sold and transferred in the model solution appear in the Amount rows.

In Bohoc fruits are generally grown only for family consumption and gifts. Thus, transfer columns, but not sell columns, are used for fruits (and for pumpkins, which are important to households, but are also not sold). Similarly, while livestock is generally treated like a savings account that can be cashed in when times are particularly hard, goats, pigs and chickens are not regularly sold, so only transfer columns are used for them. For non-farm activities that produce nothing for home consumption, sell columns, but not transfer columns, are used. Finally, for bulls, which are rented, but not generally sold, "rent" columns are used in a similar manner to sell columns.

Intercropping (planting multiple crops together) is widely prevalent in Bohoc. The matrix provides the prevalent intercropping combinations. The intercropping sections have transfer columns, but not sell columns. When the model solution provides for intercropping, the amount sold is shown in the column for planting the crop separately. For example, in year 3, the model solution provides for growing about .76 kawo of intercropped maize, congo beans, and peanuts (cell Y135). Consistent with the prevalent practice, the model solution for that year does not provide for growing any of those crops separately. But the amounts sold are shown in the cells for the separately grown crops (E135, T135, and W135). In fact, for that year the amounts transferred are also shown in the columns for the separately grown crops.

Special consideration is given to the perennial crops modeled, which are sugar cane and the fruit trees. When a perennial crop is planted, the land in which it is growing is not available for other crops. For purposes of this model, it is assumed that the perennial crops are planted in the first year, if at all, and not removed during the five year period. This is modeled by transferring land from year to year through the use of transfer rows and by using formulae in the RHS columns that force the quantity of the crop grown in a certain year to be the same as in the previous year. For instance, for mango in year 2, the matrix has a transfer row with a 1 in the cell in the Mango column (AR73) and the formula =AR4 is typed in the RHS column (CH73). Because fruits are generally used only for home consumption and gifts, the model does not provide a sale option for them.

Animals also require special consideration. Similarly to perennial crops, for purposes of this model, it is assumed that animals are purchased only in year 1. The purchase price per head is included in the beginning cash figure (e.g., $1310 in cell BT55 for pigs in year one). Other costs, such as feed, are also included in that figure. The annual reproduction rate per female animal is reflected in the accounting row for the animal (e.g., -8 in cell BT50 for pigs in year one). That figure is reduced by the annual mortality rate. For instance, if the annual reproduction rate is 5 per female, but the annual death rate is 20%, the figure in the accounting row will be -4.

In any livelihood system, certain activities are done at certain times of year, and expenses and labor requirements vary from season to season. To reflect this "seasonality" (see Norton, 2006, p. 127), the model is divided into four quarters of the year. That requires male and female labor and beginning cash rows for all four quarters and transfer columns to transfer cash from quarter to quarter. For activities producing only once a year, such as a crop harvested only once, only one sell column is needed, but for activities producing multiple times per year, a sell column is used for each quarter.

Cash must not only be transferred from quarter to quarter, but also from year to year. That is accomplished in this matrix by a formula in the RHS beginning cash entries for years 2 through 5. The beginning cash for each of those years is the ending cash for the previous year minus $10,000. For example the formula for year two is CI55-10,000 (cell CH124). Thus, for each year, $10,000 is not transferred to the next year, but is available for family use in the year in which it is generated.

Finally, as stated above, Premium Solver is used for producing a solution to the model. The Premium Solver dialog box can be accessed through "Add-Ins" on the tool bar of computers equipped with the Premium Solver software. In the dialog box, a target cell must be set. In this matrix the target cell is CI334, in which the formula =CI59+CI128+CI197+CI265+CI333 is typed. The cells in the formula are the ones in which the year-end cash totals for each of the five years are provided. The target cell is to be maximized, meaning the goal is to maximize the total of the year-end cash figures for each year. I could have used a different target cell, such as the year-end cash figure in year 5 (cell CI333). The farmers' goals, though, are not to maximize cash after five years; if they are not mindful of the present year, they may not survive to see the fifth year. The dialog box can also include constraints. The matrix itself contains most of the needed constraints. The only ones needed in the dialog box are indicated by the signs in column CG. While helpful in the preparation and viewing of the matrix, those signs have no actual impact within the matrix, so the constraints indicated by them must be included on the dialog box. For instance, the <= sign in cell CG6 indicates that land use in year one must be less than or equal to 2 kawos. Because the sign in CG6 does not have any actual governing function in the matrix, that constraint must be inserted in the dialog box. The solution is viewed by clicking on "Solve" in the dialog box. The message "Solver found a solution" is displayed when the model is working and a feasible solution is produced. It took numerous revisions and corrections to obtain a feasible solution for this model.

C. Application of model

1. Pre-evaluation or hypothesis testing methodology

The model is used for hypothesis testing or pre-evaluation of potential new activities, technologies, policies, or infrastructures (Hildebrand, 2005). The pre-evaluation or testing is relatively simple once the matrix has been prepared and has a feasible solution. The new option is simply added to the matrix; therefore, the new option is in competition with the existing activities (Hildebrand, 2006). This involves the preparation of a revised matrix. If the option is a new activity, the necessary rows and columns for that activity must be added.

2. Pre-evaluation of biological control of mealybug in sugarcane

An insect pest of sugarcane referred to by the local farmers as “picho” or “pichon” can substantially reduce the yield. This pest was described in some of the interviews of the five families and in the Sondeo interviews. Only Dorsmans provided specific information on yield reduction, stating that picho reduced the yield from 16 barrels to 11 barrels on his ½ kawo crop. That is a yield reduction of approximately 31%. (His per kawo yield is comparatively low, even at 16 barrels per ½ kawo.)

Figure 7: sugarcane field in Bohoc, Haiti

Picho in sugarcane is in all likelihood the sugarcane mealybug, *Saccharicoccus sacchari*.[4] That it has not been definitively identified should not matter in the context of this project. The purposes of the project were to develop a working ELP model that can be used in Bohoc and to illustrate how it can be used. The purpose was not to conduct real-world pre-evaluations. The use of the model to pre-evaluate biological control of sugarcane mealybug in sugarcane is simply an illustration of how the ELP model can be used to pre-evaluate a new technology previously unavailable to the farmers.

The sugarcane mealybug attacks the sugarcane stems and feeds on the juices, weakening the plant, and also harms the plant by honeydew contamination and encouragement of sooty mold (Alam, 1972). Attacks by the pest can cause stunted growth or even death (Alam, 1972). Sooty mold is apparently what is referred to as "charbon" in Bohoc. That is another prevalent problem and yield reducer. Thus, it appears likely that the sugarcane mealybug harms the plants directly and harms them indirectly by facilitating charbon.

[4] This information came from Dr. Douglas Pfeiffer of my faculty committee.

A member of the Coccinellidae family (commonly called ladybugs, ladybirds, or lady beetles), *Cryptolaemus montrouzieri*, is a natural enemy of the sugarcane mealybug (Alam, 1972; Carver, 1987). *C. montrouzieri* can be purchased for biological control. Websites of Biological Control Systems, Inc., and ARBICO Organics advertise *C. montrouzieri* for sale and market it as the Mealybug Destroyer (Biological Control, 2011; ARBICO, 2011). According to the Biological Control Systems website, *C. montrouzieri* older larvae feed on any mealybug stage, and adults and young larvae prefer to feed on mealybug eggs (Biological Control, 2011). One *C. montrouzieri* larva can consume 250 small mealybugs (Biological Control, 2011). Adults can cover large areas by flight in search for food (Biological Control, 2011).

Biological control of a pest is the deliberate exploitation of a natural enemy of the pest (Hagler, 2000). *C. montrouzieri* being a natural enemy of the sugarcane mealybug and being commercially available, I modeled it for biological control of that pest. I used the price of ARBICO Organics, which is slightly lower than that of Biological Control (Biological Control, 2011; ARBICO, 2011). The ARBICO website recommends a release of 250 to 1,000 adults per acre, and 250 adults sell for $89 (U.S.). Mindful of the limited cash of the Bohoc farmers, I modeled this at a release of 250 adults at the price of $2271 (HD) for one kawo (using conversion rates of 3.19 acres per kawo and 8 HDs per 1 U.S. dollar). I assumed hypothetically that, through a farmer assistance program, *C. montrouzieri* could be imported to Bohoc and made available to local farmers at the U.S. market price. In the model the first release is in year 2, which is the first year of harvest of the crop. Because the Biological Control website recommends repeated releases, I modeled a second release in year 4 (Biological Control, 2011). I used Dorsmans' approximate 30% yield loss from picho as the standard and arbitrarily assumed that the release of *C. montrouzieri* would cut that yield loss in approximately half. Thus, I modeled a yield loss of only 15% through biological control with *C. montrouzieri*.

Making these changes in the model was not difficult. I simply added the price of the release of *C. montrouzieri* to the production costs in years 2 and 4, meaning that the yearly cost for those years is $3821, rather than $1550 (cells G124 and G261). The 15% yield loss, as opposed to the assumed 30% standard, is shown by increasing the yield from 40 to 46 barrels (cells G86, G155, G223, and G291). The revised matrix is set forth as Appendix I.

V. RESULTS

A. The basic model

The results of the basic model are set forth in the Appendix I spreadsheet, which is basically "cut and pasted" from the basic matrix to obtain a version of the results that can fit on a printable hard copy of the paper. Also, the Appendix J Aggregated Tableau[5] presents the structure of the model in a simplified manner. The activities and constraints are grouped by similar type. In this table, the letter "A" is used for grouped activities for which there is a coefficient other than 1. "B" is for RHS coefficients. "1" is for activities for which there is not a coefficient other than 1.

According to the model solution, in the first year farmers with 2 kawos of land should be growing about .96 kawos of sugarcane and about .69 kawos of maize, peanuts, and congo beans intercropped. The rest of the land should be used for small plantings of crops for home consumption and for keeping animals. (That is the case for all five years.) The women in the household should engage in market commerce. In the solution, all of the available two kawos of land are used, but only about 44% of the available male labor and about 55% of the available female labor is used. The modeled activities produce 14,896.15 HD at the end of the year (about 1,862 U.S. dollars).

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[5] Dr. George Norton of my faculty committee assisted me with the preparation of this table.

In years 2, when the perennial sugarcane crop starts to generate income, the model solution calls for the growing of about .23 kawo of intercropped maize, peanuts, and congo beans and about .5 kawo of intercropped manioc, congo beans, and peanuts, in addition to the ,96 kawo of sugarcane. The manioc produced is used for cassava bread, which is sold. Women are not engaged in market commerce, but female labor is needed for the cassava bread. All of the available land is used, and about 50% of available male labor and about 46% of available female labor is used. The total cash at the end of the year is 38,037.57 HD (about 4,755 U.S. dollars).

In years 3 through 5, the solution provides for the growing of about .76 kawos of intercropped maize, congo beans, and peanuts in addition to the .96 kawos of sugarcane. Women conduct market commerce during each of the years. All two kawos of land are used in all three years. In each year, about 43% of available male labor and about 67% of available female labor is used. The year-end cash grows from 64,502 HD (about 8,063 U.S. dollars) for year 3, to 91,178.64 HD (about 11,399 U.S. dollars) for year 4, to 117,643.17 (about 14,708 U.S. dollars) for year 5.

B. Biological control of mealybug pre-evaluation results

Modeling biological control of sugarcane mealybug produced interesting results. In the revised model incorporating release of *C. montrouzieri*, the amount of land put in sugarcane decreases from about .96 kawo to about .82 kawo. Yet the year-end cash increases for each year.

As in the basic model, all 2 kawos of land are used, but more is used in intercropped crops to offset the decrease in land being used for sugarcane. In year one, the land used for intercropping maize, peanuts, and congo beans increases from about .69 to about .83 kawos. In year 2, the amount intercropped in those crops remains at about .23 kawo, but the land planted in manioc, congo beans, and peanuts increases form about .5 kawo to about .6 kawo. In years 3 through 5, the land used for intercropped maize, peanuts, and congo beans increases from about .76 kawo to about .90 kawo.

In the revised model, the labor used, for the most part, is about the same. The biggest difference is for female labor in year two, in which about 46% of the available female labor is used in the basic model, and about 55% is used in the revised model. As in the basic model for that year, women do not engage in market commerce, but are involved in making cassava bread.

The year-end cash increases in HD from the basic model to the revised model, though not dramatic, are worth noting:

	Basic Model	Revised (Biological Control) Model
Year 1	$14,896.15	$16,883.34
Year 2	$38,037.57	$39,192.09
Year 3	$64,502.10	$66,754.25
Year 4	$91,178.64	$92,673.17
Year 5	$117,643.17	$120,235.34
Total	$326,257.62	$335,738.20

VI. DISCUSSION

A. Results of the basic model

The solution of the basic ELP model closely models the Bohoc livelihood system in terms of the activities in which the farm families engage. The field crops typically grown for sale are sugarcane, which is the principal money crop, and intercrop plantings of maize and other crops such as peanuts, congo beans, and manioc. The model very accurately reflects those choices, providing that a farmer with 2 available kawos of land grows almost a kawo of sugarcane and devotes much of his other land to intercropping maize and other crops. Under the solution, the women engage in market commerce, reflecting a prevalent practice in Bohoc.

The model's use of all of the two available kawos of land is also reflective of the real-world practice. Bohoc farmers are small landholders and do not waste what little land they have.

The model's use of only about half of the available labor is somewhat perplexing. The farmers would likely say that they are not wasting labor and that the matrix does not accurately model labor use. However, the model necessarily uses all the labor needed to engage in the farm and non-farm activities that are part of the solution, at least according to the farmers who provided the labor requirement figures, and those activities closely model the typical real-world activities of the Bohoc farmers. It may be that the farmers understated the labor requirements or overstated the number of total available labor days, in which case the labor results of the model may be flawed. Another possibility is that the numbers of available hours listed in the matrix are erroneously high, particularly for men, who may need more time on non-modeled activities (e.g. household tasks such as home repairs) than is provided for in the matrix. But it may also be that the farmers do not need to work, and in fact do not work, all their available hours, at least not on the farm and non-farm activities that are part of their livelihood and are modeled.

The accumulated cash in the model solution may seem unrealistic. At the end of the first year, the modeled activities have generated about 1,862 in U.S. dollars, which seems reasonable. But the year-end cash for year five is about 14,708 U.S. dollars, which is a huge amount of money in Bohoc and may be overly optimistic. That figure is based on transferring all but 10,000 HD from each year's ending cash to the beginning cash for the next year. Using 10,000 instead of some other figure is somewhat arbitrary, but seems appropriate. Using a larger number would result in a different outcome. Also, the model may not sufficiently account for bad years for farming resulting from droughts or other causes and does not account for natural disasters (of which Haiti has seen plenty). Thus, the model outcome may be realistic only with five straight good farming years, which might not happen often.

The model is no doubt imperfect in other ways. The qualitative research method used is by its nature imprecise. It could not produce perfectly accurate data on costs, prices, or labor. That is not to say it would have been possible to produce perfect data in Bohoc, Haiti, using any . other type of research. The farm families do not keep records, at least not records with any precision. The figures they gave me on costs and labor were their own estimates. The only way I attempted to verify their information was to interview other farmers. To verify the farmers' information on prices, I made no attempt to go to the markets or interview input providers or contract buyers—I simply did not have time. Moreover, I would have failed to get precise price information at local markets, where prices vary from market-to-market, day-to-day, and even hour-to-hour. Attempts to gather precise price information on the many crops and other products I was modeling would have been a near-impossible task even with unlimited time. Similarly, because the labor market is to such a large extent within the family with a complete lack of record keeping, I had no way of obtaining labor information with any precision

In addition to the lack of precision in the model resulting from unproven and unverified market, costs, and labor data, lack of precision is reflected in the varying responses I received from farm family to farm family. Because of the varying information I received, in some instances, lacking any real consensus, I was left to make subjective entries in the matrix based on what I felt was the most realistic entry, looking at all the relevant factors.

None of this means, though, that the model lacks validity or value. If I had time to re-interview farm families and interview more farm families, perhaps I could have resolved some of the possible shortcomings. But considering the inherent limitations in conducting research in Bohoc, Haiti, it may very well be that the result would not have been significantly different. In short, the final model is likely about as close to accurately modeling the small farm livelihood system of Bohoc, Haiti, as is reasonably possible.

B. Results of pre-evaluation of biological control of mealybug

The results of the pre-evaluation of the use of *C. montrouzieri* for biological control of the sugarcane mealybug, while informative, cannot be relied upon for current decision making. First, picho has not definitively been identified as the sugarcane mealybug; this pre-evaluation is conducted merely as an example of how biological control can be modeled with ELP. Second, the results are based on assumptions that would have to be supported with evidence before this control method is undertaken. Studies would need to be done to establish whether a population of *C. montrouzieri* could be established in Bohoc, Haiti, and if so, whether and to what extent it would control sugarcane mealybug. (I have assumed a population has not already been established.) According to Alam (1972), when *C. montrouzieri* and two other natural enemies were released in Barbados for biological control of the sugarcane mealybug, *C. montrouzieri* was not found during a recovery survey, meaning that a population was not established or the establishment was too low to be readily detected; only one of the other natural enemies released, *Anagyrus saccharicola* was found. A recent survey of the literature on scale insects, mealybugs, whiteflies, and psyllids as prey of coccinellids does not mention any studies on *S. sacchari* as prey of *C. montrouzieri* (Hodek, 2009). Perhaps *A. saccharicola* (not advertised on the Biological Control or ARBICO websites) would be a better choice than *C. montrouzieri* for biological control of the sugarcane mealybug in the Central Plateau of Haiti—studies would be needed to make that determination. Third, shipping, import, and customs issues would have to be resolved. This would presumably require approval at some level or agency of the Haitian government. That could include an evaluation of whether *C. montrouzieri* would be harmful to other beneficial insects. Carver (1987) stated that coccinellids should not be released into Australia because of that concern.

Nevertheless, these results have value. First of all, they illustrate the manner in which ELP operates and its value. Using the data from the basic and revised matrices, an analysis of the net sugarcane profit with and without biological control of sugarcane mealybug with *C. montrouzieri* would suggest that farmers should plant more sugarcane. The per-karo sugarcane profits over the five year period without biological control are $114,700 (HDs) and with biological control are $129,758. The model, though, calls for growing a little less sugarcane and more intercropped crops. What is the explanation for this? The explanation is likely that with biological control, sugarcane is grown more efficiently and can be grown on less land for the optimal profit when considering other options. A strength of ELP is that it considers all the modeled options as a whole (the "big picture") and does not simply evaluate options individually. A final reason the results have value is simply that they suggest that biological control of sugarcane mealybug is worth studying.

C. Further uses of the ELP model

The basic ELP model could be used as one tool in any pre-evaluation or hypothesis testing of new agricultural technologies, products, policy changes, project ideas, or improved infrastructure in Bohoc. The model should not be used as the sole tool in any such testing; by its nature it is not precise enough for that. Moreover, it can be no more accurate than the data that are entered into its cells. Thus, for it to be used as a tool in a real-world evaluation or test, sufficient research most be conducted to provide reliable data for the ELP.

For instance, to actually use this model to pre-evaluate biological control of the sugarcane mealybug, the proper research must be done to determine issues such as the likelihood of establishing a population of the natural enemy, the effect of the natural enemy on sugarcane yield, the costs of establishing a population of the natural enemy, and the effect of any environmental and governmental barriers to introducing the natural enemy.

Similarly, if a new cultivar it to be introduced, to include accurate data in the ELP matrix, sufficient tests must have been done to determine the suitability of the cultivar to the climate and soil conditions of Bohoc, on its susceptibility to pests, and on its yield. At times studies providing this sort of information may have already been done, but at other times they will have to be done.

The pre-evaluation or hypothesis testing does not have to be of a new agricultural option or technology. Governmental agricultural economic policies or regulations, for example, could also be modeled. Again, though, sufficient studies or research most have been done to insert accurate data in the matrix.

VII. CONCLUSION

Despite some limitations and possible weaknesses, the ELP matrix developed in this project should be useful as a basic model of the small farm livelihood system in Bohoc, Haiti, and as tool that can be used in the process of testing hypotheses or pre-evaluating potential new agricultural activities, technologies, products, policies, or infrastructures. If this ELP model can be used, even in some small way, to help the impoverished Bohoc farmers, the hundreds of hours that went into its development will be worthwhile.

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VIII. APPENDICES (submitted electronically only)

A. Sondeo Report

B. Fabius Data 2009

C. Fabius Data 2010

D. Destorel Data

E. Larion Data

F. Aminot Data

G. Dorsmans Data

H. Basic ELP Matrix

I. Revised (with Biological Control) ELP Matrix

J. ELP Results

K. Aggregated Tableau

L. Dr. Hildebrand ELP Exercises (Hildebrand, 2006)

M. Dr. Hildebrand's Listing of ELP Studies (Hildebrand, 2010)