Global Sustainable Development IQP Executive Summary

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Purpose

The constant demand for coffee makes the plant disease coffee leaf rust (CLR) a significant issue among coffee plantations across the globe. The economic sustainability of our project's location, Loma Linda, Guatemala, depends on the production of coffee and they must find a way to subside the CLR epidemic. By forming Asociación Sostenible Para El Desarrollo Integral y Turistico De Loma Linda (ASODILL), a community organization driven to enhance the community's economic sustainability, the Loma Linda structured their efforts and was able to connect and form a partnership with our project sponsor Seven Hills Global Outreach (SHGO). Both organizations emphasize sustainable development, thus the goal of this project was to develop a sustainable decision making tool which would help coffee plot managers select an appropriate solution(s) to end the current coffee leaf rust (CLR) epidemic and prevent future outbreaks. To achieve this goal we sought to learn about the cause and effects of CLR, to examine CLR epidemic case studies and learn about conditions affecting its propagation and compile potential solutions, to learn about Loma Linda's plantation conditions and previous attempts of CLR mitigation, and to develop a CLR Strategy Guide to aid decision makers in Loma Linda evaluate the characteristics and feasibility of mitigation techniques and take sustainable action.

Our team chose to utilize well-documented and confirmed methods of CLR mitigation in our CLR Strategy Guide. We included our CLR Strategy Guide along with a manual and directions for its different components and respective recommendations. Our project is a collection of mitigation techniques from CLR case studies and information gathered through

interviews. We preferred to provide this information to the community of Loma Linda through the CLR Strategy Guide so that they could create an educated strategy. Our strategy guide could help the community of Loma Linda compare the various implications of mitigation techniques and strategize implementation. By sharing our knowledge rather than providing strict orders, our guide would resonate with ASODILL's principles of environmental conservation and emphasizing local capacity, as well as SHGO's partnership based approach. Our project could impact the community by dampening the CLR epidemic and salvaging the community's major source of income. We hope our investigations will inform Loma Linda about alternative solutions to the CLR epidemic, provide insight to future groups seeking a strategy to subside CLR, and that the guide can be adopted in other communities as well.

Methods

As a means of accomplishing our objectives, we used rational planning throughout our project, "a process for determining appropriate future action by utilizing scarce resources in such a way as to maximize the expected attainment of a set of given ends" (Morris, 2014). To gather information and develop the CLR Strategy Guide, we searched online databases such as ScienceDirect, JSTOR, and Google Scholar and read academic books, scholarly articles, and peer-reviewed journals to compile and compare different CLR case studies. We utilized face-to-face in-depth interviewing techniques to gather information by asking questions and clarifying the details, as well as cultivate trust with our sponsor and their partner. Through our interviews, Ms. Mattleman provided guidance and support.

Results

Thomas Robert Malthus was the first economist to propose a systematic theory of population, claiming that unchecked exponential population growth would lead to

overpopulation and quickly deplete naturally and otherwise available resources (Mebratu, 1998). In order to prevent a future catastrophe, the World Commission on Environment and Development first created the term “sustainable development” in the late 1980s in order to connect ecological consequences of human activities with environmental concerns as well as socio-political strategies related to human development issues and discuss possible strategies (Mebratu, 1998). “Sustainable development” was defined as that which “meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Commission, 1987).

After a World Summit on Sustainable Development, principles and objectives were developed in order to promote sustainable economies; one such economy, is the sustainable coffee sector. The high global demand for coffee requires a sustainable coffee economy which is exceptionally important for the economies of countries such as Guatemala, which are largely dependent upon coffee for export earnings and the goals of development (International Coffee Organization, 2014). Beginning our project, we were aware only of its location, Loma Linda, Guatemala, and the identity of our sponsor, SHGO. We learned about the regional context such as geography and climate to understand how different conditions such as climate, weather patterns, and dense shade coverage affect CLR. We found that Guatemala has a tropical climate with a long rainy season and a dry season and a varying mountainous landscape covered by dense cloud forest, creating the perfect environment for the incidence of CLR. Not only discovering locale, but understanding the motivations, biases, and political resources of interested parties (Geva-May & Wildavsky, 1997) within Loma Linda would allow us to attempt solving their problems, thus we began by reviewing background information about Guatemala to gain perspective.

The country of Guatemala began a road to recovery following almost four decades of civil war. Guatemala has one of the largest yet poorest economies in Central America with serious social inequity, and has worked to achieve macroeconomic and democratic stability mainly through agriculture (The World Bank, 2014). The agricultural sector accounts for 13.5% of GDP and 38% of the labor force (The World Bank, 2014). Guatemala's major export, coffee, accounts for one-third of all revenue generated by agricultural exports and plays a significant role in the lives of Guatemalans (International Fund for Agricultural Development, 2013). However, the most recent CLR epidemic completely devastated 5% of Guatemala's coffee plantations, equivalent to 125 million coffee plants (World Coffee Research, 2013).

A general understanding of Guatemala's social dynamics and goals of development allowed us to assume the context of Loma Linda. However, to confirm our assumptions of socio-political dynamics, we chose to interview Assistant Director of SHGO Jesse Mattleman. She had the most experience in Loma Linda and maintained regular contact with political elites such as General Coordinator of ASODILL Pascual Rafael Escobar. We scheduled interviews to gain knowledge of daily life in Loma Linda including local customs, employment, challenges, and interactions with one another. Loma Linda has ideal conditions for coffee plant cultivation and relies on coffee production as its main source of income. Yet the incidence of a CLR epidemic infected a majority of the community's coffee plants, resulting in a major predicted harvest loss Approximately 30 years ago, the community faced a similar outbreak which crippled Loma Linda's main source of income for about eight years (Mattleman, Unpublished Raw Data). Without knowledge or resources to control the CLR epidemic, the newly formed community had no choice but to let the contamination run its course and eventually it subsided on its own (Mattleman, Unpublished Raw Data).

We applied knowledge of the community's values and conditions with our research of sustainable agriculture and CLR epidemic case studies to develop a CLR Strategy Guide. We found three major forms of CLR mitigation which were farming techniques, planting rust-resistant cultivars, and the use of fungicides. The community is hopeful that a solution to the CLR epidemic can be found and will find coping methods with or without that solution. We provided the CLR Strategy Guide as a means of sharing our knowledge of the mitigation techniques to help the community cope in this difficult time.

Conclusions

During our interviews, Ms. Mattleman expressed the importance of Seven Hill Global Outreach's (SHGO) partnership-based approach and emphasis of sustainable development that resonated with ASODILL's objectives. We learned that the community takes pride in their economy of organic agriculture, and that various groups with different goals could collectively agree through democratic assembly. We understood the exceptional importance of the community's coffee cooperative, and the significant threat posed by the coffee leaf rust (CLR) epidemic to their sustainable economy. By reviewing previous CLR epidemic case studies conducted throughout Central America, we learned of many different approaches including but not limited to farming techniques, hybrid coffee plant implementation, and the use of fungicides, each with different requirements and implications. CLR is a complex coffee plant disease that has evolved over time to adapt to different environments. While we were able to find mitigation techniques in particular contexts, it was important that whatever information we could convey to Loma Linda would not only be viable, but sustainable as well. In the past, experiments were conducted to investigate *H. vastatrix* and CLR to understand its life cycle and the factors which affected its propagation; different mitigation techniques discovered were as follows.

Our review of farming techniques that mitigate CLR consistently revealed that coffee plant yield, nutrient competition, and poor nutrition induce physiological stress. However, coffee plant yield has the highest effect on the spread of CLR. Plants that are too close together also not only result compete for soil nutrients, but lack sufficient ventilation to pass a CLR infection. Maintaining soil nutrition is the use of fertilizers and pH buffers is equally important to pruning and distancing coffee plants by at least 1.5 by 2.0 meters, however the most effective techniques depend on the context of the farmland. The vast surrounding rainforest and vegetation provide dense shade coverage to Loma Linda's coffee plots. Although these conditions promote the growth of high quality crops, they may also be conducive to CLR. However, the high altitude, seasonal rainfall, and andisol provide ideal conditions for the implementation of rust-resistant cultivars.

The research showed that resistance to CLR is caused by rust-resistant genes within the genome of the coffee plant. The selective cross-breeding of rust-resistant cultivars within laboratories has provided new varieties of coffee that can withstand a CLR epidemic. While a majority of Loma Linda's coffee plants are infected by CLR, the benefit from killing the disease-ridden plants and replacing them with resistant breeds of coffee plants could outweigh the use of chemical control through fungicides. However, to effectively evaluate this possibility, they would need to perform a cost benefit analysis to compare the cost of replacement coupled with the recovery period for the new plants to yield beans with the projected loss due to infection. By utilizing hybrid plants, the community could save money otherwise spent on fungicides, however the fungicides may be effective on their own.

There are various fungicides with different levels of effectiveness and toxicity. Users must be aware that fungi can develop a tolerance to the fungicide which will nullify their

effectiveness and also recognize that fungicides can have lasting environmental implications. In order to effectively use a fungicide, it must be applied before or during the onset of a fungal infection, as well as rotated with other fungicides to prevent the development of fungal tolerance. Fungicides have a cross-resistance class which determines which fungicides are safe and effective to pair and rotate. Additionally, fungicides may be organic or inorganic, and because communities like Loma Linda value organic agriculture, users must be aware of the fungicide's classification. While fungicides may be the most effective means of CLR control, they are the most expensive and can pollute the environment which may in turn affect local ecosystems.

Lastly, the theory of natural antagonists may explain the reason that more recent CLR epidemics have not been as detrimental as that of Sri Lanka in 1869. There is a possibility of statistically significant biological control of the CLR causing fungus *Hemileia vastatrix* related to an ecosystem including ant-insect mutualisms and the white halo fungus *Lecanicillium lecanii,* however the ecosystem remains under study. The prevalence of *L. lecanii* occurring among high density populations of the scale insect *C. viridis* will result in parasitism of *H. vastatrix*. However, in order for such populations of scale insects to form, they must be tended by *Azteca instabilis.* Furthermore, the distribution of *L. lecanii* over a landscape is directly caused by the pattern of *Azteca* nest formation, as well as the soil, which acts as an environmental reservoir of *L. lecanii* propagules. There is additional complexity in ant-insect interactions, as *A. instabilis* have been observed to cease tending *C. viridis* after forced initiated *L. lecanii* epizootics, and we hope that future experiments will bring new information to light that can significantly aid coffee plantations during CLR epidemics.

We constructed our CLR Strategy Guide to aid the decision makers within Loma Linda with choosing viable mitigation techniques. It utilized the decision making approach to empower

users in the decision making process by allowing them to rank alternatives among criteria based on their interests and interpretation of the ranking systems. We tested our CLR Strategy Guide objectively and it proved successful, however those with expertise of coffee plant cultivation would understand many of the implications more than us. We conveyed our technical knowledge of the alternatives by defining ranks for particular criteria in order to share information and help the decision makers choose an alternative; this followed our sponsor's partnership-based approach. The CLR Strategy guide proved sustainable because it was flexible to situational circumstances and user perceptions, and would hopefully provide a viable recommendation. The Assistant Director of our sponsor SHGO, Jesse Mattleman, informed us that should a viable solution arrive, the town could apply for grants and outsource funding; we hope that the information and results that we have provided, will drive the community in the right direction.

Recommendations

In order to fully utilize the potential of our CLR Strategy guide, users should be aware of the following considerations:

1. **The CLR Strategy Guide should be distributed to all interested parties. The decision matrix approach was utilized users would be empowered by actively participating in the decision making process. The recommendations produced by the matrices will differ among different users, thus it is important that every person contributing to the decision making process ranks the alternatives according to their values.**
2. **We selected the alternatives within each subcategory of mitigation techniques based on our knowledge of local resources and the possibility or availability of the alternative within the region. If there are other alternative cultural methods, rust-resistant cultivars, or fungicides that are not listed in the CLR Strategy Guide that the user would like to consider, the user should utilize the appropriate matrix to rank the alternatives among applicable criteria.**
3. **The decision matrix approach was also used so that the decision makers could collaborate with their results and discuss their rationale. After completing the CLR Strategy Guide, the users should collectively discuss their results and concerns to come to a decision by majority. If a decision cannot be made, the discussion among peers may encourage a reevaluation of the descriptions of alternatives, criteria, and associated ranking systems.**