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Using GIS to Locate Areas for Growing Quality Coffee in Honduras

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USING GIS TO LOCATE AREAS FOR GROWING QUALITY COFFEE IN HONDURAS

by

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Abstract

Small-scale coffee producers worldwide remain vulnerable to price fluctuations after the 1999-2003 coffee crisis. One way to increase small-scale farmer economic resilience is to produce a more expensive product, such as quality coffee. There is growing demand in coffee-producing and coffee-importing countries for user-friendly tools that facilitate the marketing of quality coffee. The purpose of this study is to develop a prototypical quality coffee marketing tool in the form of a GIS model that identifies regions for producing quality coffee in a country not usually associated with quality coffee, Honduras. Maps of areas for growing quality coffee were produced with information on climate, soils, topography, areas vulnerable to environmental degradation, the location of current quality coffee farms, and infrastructure. The maps depict suitable coffee-growing land in portions of eight western Honduran departments.

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Chapter I. Introduction

Although coffee is one of the world's most popular drinks—over two billion cups are consumed every day—it is only grown between the Tropics of Capricorn and Cancer, and constitutes 50 percent of all tropical countries' exports. Coffee is the second most valuable and actively traded global commodity. However, inequitable profit distribution characterized the coffee trade at the end of the 20th century: in the 1980s growers received 20 percent of profits from the coffee trade and in 2000 they received only 10 percent (Tucker, 2008). When global coffee prices reached 30-year price lows in 2002, 25 million households in coffee-producing countries were adversely affected. Coffee growers' disproportionate vulnerability to global coffee prices can be traced back to 1989, when the U.S. withdrew from the United Nations International Coffee Agreement-sponsored International Coffee Organization (ICO) and the ICO stopped regulating production and stabilizing prices. Throughout the 1990s coffee production soared beyond demand, especially in low-elevation countries with potential for large-scale mechanization. Roasters and retailers exploited the oversaturated market's plummeting prices, culminating in the 2002 price lows and resulting "coffee crisis" (Francis, 2006; Tucker, 2008).

International relief organization OXFAM (derived from Oxford-based famine relief committee established in 1942) has campaigned for change in the coffee industry since 2002, and welcomed the U.S.'s re-entry into the ICO in 2004. As coffee prices make a moderate recovery in the wake of the 1999 – 2003 coffee crisis, there is growing discourse about how best to protect developing countries dependent on the coffee trade from future market and policy failures. OXFAM identified market information as a key component to augmenting small-scale farmer resilience (Daniels and Petchers, 2005). This study considers the potential for increasing small-scale farmer access to market information by developing a geographic information system (GIS) identifying suitable land for quality coffee production.

Quality coffee is distinguished from conventional coffee by its superior flavor and standards for production and trade, which tend to benefit the environment and increase farmer profits and resilience. Some examples of quality coffees distinguished by production standards include shade-grown, Organic certified, and coffee with intellectual property rights based on their region of origin, such as Hawaiian Kona. Quality coffees distinguished by standards of trade include Fair Trade certified coffees and coffee bought through transparency contracts which account for the fee or payment to each participant in the transaction. Gourmet coffee cuppings and certification schemes (e.g., Organic) are popular ways to market quality coffees, which are generally higher-priced than conventional coffees. To prevent another coffee crisis it is necessary to expand quality coffee production in the face of increased "sun-coffee" production, which contributes to deforestation and price volatility with its intensive cultivation and larger yields (tufts.edu, 2008). Quality coffee is best grown in mountainous countries because they possess the right altitude and climate for coffee cherry maturation and are incapable of the large-scale mechanized production found in low elevation tropical countries. Manual production is more sustainable than mechanized production because it reduces erosion potential and involves more discriminative harvesting.

GIS can aid coffee farming by identifying and mapping factors that influence crop productivity. GIS in the technological sense has been defined as "a computerized system for the collection, storage, manipulation, and output of information that is spatially referenced," though some would argue that GIS encompasses enough theory to be considered a science (Obermeyer and Pinto, 1994). While GIS has not been used to site suitable land for growing quality coffee in

Honduras, its application in other fields demonstrates its potential to do so.

Chapter II. The Research Problem and Review of Literature

The objective of this research is to determine if a GIS model will identify suitable land for quality coffee production in a country that is generally not considered for the international quality coffee market. GIS is used as a data synthesizing and decision-support tool in many fields. Land use planners use GIS to create spatial optimization models that synthesize data for several elements into clusters of favorable attributes to determine the best parcel of land for a certain use (Ligmann-Zielenska, Church, and Janowski, 2008). Natural resource planners monitor pollution with models that display the spatial distribution of the phenomena of interest and their corresponding weight of importance. For instance, University of Nebraska-Lincoln researchers studied groundwater pollution by identifying parameters necessary to facilitate pollution and assigned each a value and weight of importance (Aronoff, 1991). After each parameter's value was multiplied by its weight and added to the others, the end value represented each specific location's likelihood for groundwater contamination.

Quality coffee is already being grown in Honduras, yet small-scale farmers have little technical assistance in doing so compared with small-scale farmers in other countries. The U.S. Agency for International Development (USAID) finances a regional Quality Coffee Program, (QCP) which intends to increase the capacity of Central American and Caribbean countries to compete in the global quality coffee market. QCP activities are guided by its Marketing Advisory Group, including industry giants such as Sarah Lee and Volcafe, and by partnerships with a wide variety of businesses, governmental, and non-governmental organizations. Some current partnerships exist with coffee competitions such as the Star Cupper Program, certifiers such as the Rainforest Alliance, religious relief services, and the U.S. Geological Survey (USGS). In 2003, the QCP's first year of operation, the program's efforts to 1) connect quality coffee buyers with producers and 2) provide technical assistance to developers added an estimated total $400,000 to small-scale producers' profits throughout the participating countries. The USGS offers extra technical assistance to QCP-participating countries Guatemala, Costa Rica, and the Dominican Republic with its provision of the GeoCafe internet mapping server. An internet mapping server is a software-based marketing and certification system enabling the sharing of GIS information over the internet. Leonidas Batista, head of the Coffee Board in the Dominican Republic, has stated "the new specialty coffee market demands timely and accurate information, the provision of which can be greatly facilitated by the use of information tools and data sets that can be integrated on the Web by Internet Map Servers" (USGS, 2005; esri.com, 2004).

A GIS tool like GeoCafe may be produced for Honduras from data on the country's range of variables desirable for quality coffee cultivation. A simple additive model of variables relevant to quality coffee production in Honduras, paired with spatial information on the location of operating quality coffee farms could assist in optimizing the location of new specialty coffee farms. The end product, a map and query tool of a country's regions for growing quality coffee, could potentially encourage landowners to consider growing coffee if they possess a coffee-suitable parcel of land and inform roasters of farmers growing desirable cultivars.

Desirable value ranges for data used in the GIS model were determined from literature on coffee growing conditions, and constitute the thesis model's physical feature suitability index. Physical features necessary for quality coffee production include: altitude range of 400 – 1700 meters; annual temperature range between 16 – 24° C; annual precipitation range of 1,000 –

4,400 mm; and gently sloping (5-24 percent), moderate to well-drained slightly pH-acidic (6-7) soils (Illy, 1995). Access to infrastructure can be the most important factor for small-scale quality coffee producer success. Proximity to roads, urban areas, and farms or cooperatives recognized for quality coffee production suggest acceptable accessibility to infrastructure. Current land uses and regions determined for conservation are also considered in assessing farm development feasibility (see Table 1 in Appendix for a list of variables).

In order to determine 1) if a GIS model identifying suitable land for quality coffee production can be produced for Honduras and 2) if room for expansion in Honduran quality coffee production exists, the afore mentioned necessary physical and infrastructural features were layered in a map and compared to areas where quality coffee is currently being produced in Honduras.

Chapter III. Study Site and Data Sets

Figure 1 Location of Honduras

My study area is located in Honduras, a fairly mountainous country that has temperate forests well suited for growing *Coffea arabica*, the most widely produced coffee species, for manual harvest (Osgood, 2007). Aside from the promising physical features, Honduras is an intriguing study location because it rapidly grew from producing two percent of Central American coffee exports in 1940 to being the world's sixth largest coffee producer in 2007. Such rapid expansion of agricultural output, according to a 2008 report released by the U.S. Embassy, "is straining Honduran capacity to process the beans" (U.S. Embassy, 2008). Of all resources found to be in short supply, labor shortages appear to be the most challenging to increasing quality coffee production. Increasing numbers of Honduran laborers have been attracted to relatively stable, higher-paying occupations offered by factories in San Pedro Sula, opportunities in the U.S., or produce plantations in the Comayagua Valley near the center of the country. Labor accounts for one-third of small-scale producer costs, and ninety percent of Honduran coffee producers are small-scale. Improving small-scale producers' ability to produce a higher-priced product with adequate access to market information is essential to attracting labor and further investment in infrastructure (Tucker, 2008).

Honduras (15 N, 86.3 W) is slightly larger than the U.S. state of Tennessee and shares borders with Guatemala, El Salvador, and Nicaragua on the Central American isthmus. More than 53 percent of its 7.6 million citizens live below the poverty line, and roughly one million jobs depend on the coffee industry (U.S. Embassy, 2008). Elevation ranges from sea level to 2,800 meters and annual precipitation ranges from 1,000 to 2,800 mm in the interior mountains where coffee is produced (britannica.com, 2008). Forest cover and suitable climate have enabled quality coffee production in Honduras since coffee was introduced to Central America in the18th century. Recent developments have increased accessibility to its production and consumption. Assistance from state institutions like the Honduran Coffee Institute (IHCAFE), established in 1970, international coffee competitions like Cup of Excellence, operating in Honduras since

2004, and wireless technology provide information and forums for producing and marketing quality coffee. The growing demand for quality coffee in the U.S. and Europe can find satisfaction with Honduran coffee; most of Honduran coffee is shade-grown and 15 – 20 percent is certified under a quality coffee scheme (U.S. Embassy, 2008).

The ArcGIS 9.3 software package was used for data compilation and analysis. All data used are in the World Robinson projection and World Geodetic System 1984 (WGS 84) Datum to ensure minimal cartographic distortion. Data sets obtained for analysis are as follows:

- Central America outline
- Honduras country and department outlines
- Monthly average temperatures 1998 – 2007 for 22 weather stations in Honduras, Guatemala, Nicaragua, and El Salvador
- NOAA Global Precipitation Normals 1961 – 1990 for 12 weather stations in Honduras, Guatemala, Nicaragua, El Salvador, and Cuba
- Elevation (90 meter DEM)
- Slope (percentage in meter units)
- Soil pH and drainage (Soil and terrain database for Latin America and the Caribbean SOTERLAC 1:5M resolution)
- Central American Vegetation and Land Cover Classification raster coverages
- World Wildlife Fund-designated conservation priority area raster coverages
- Roads (primary, secondary, and unclassified)
- 2008 Cup of Excellence (COE) coffee competition ranking farm locations
- Regional Cooperative for Organic Growers of the Mountains (RAOS) and New Eden Agricultural Cooperative Ltd. (COARENE) Locations

- Satellite Image of current COE farm, La Guinellera

The above data sets were used to produce a “Thesis Model” of suitable land for quality coffee production through the following steps. Temperature decadal averages and precipitation 30 year normals values were interpolated with ArcGIS’s spatial analyst inverse distance weighting (IDW) tool. The spatial analyst tool computed slope from a 90 m cell resolution digital elevation model (DEM). ArcGIS’s raster calculator tool produced a suitability model of all areas encompassing desired data ranges, and was clipped out of intersected suitable pH and drainage polygons. Coverages of land use and ecosystems that the World Wildlife Fund (WWF) considers threatened or needing protection were overlaid with the initial suitability model to determine which risk areas should be excluded from the model. A one km buffer on roads demonstrated suitable areas’ access to facilities and markets.

Physical feature ranges observed at the 26 top farms in the 2008 COE competition and two prominent Honduran coffee cooperatives determined the physical feature suitability index for a second model, “COE-COOP-Demonstrated Model.” A second model displaying areas of current quality production and the physical conditions of those areas is helpful in calibrating the idealized thesis model (see Table 2 below for Model index comparison).

Variable	Thesis Model	COE-COOP-Demonstrated Model
Altitude (m)	400-1700	1220-1790
Annual Temperature Range (C)	16-24	18.6-25.2
Annual Precipitation (mm)	1000-4400	892.8-2592.7
Slope (percent)	5-24	3.1-51.8
Drainage	moderate-well	well-excessive
pH	6-7	6.5-7.1

Table 2: Physical Feature Suitability Indices

A cupping at Cultiva Coffee in Lincoln in February 2009, hosted by Ian McCarthy, sampled coffee from the top five COE farms of 2008 and added an extra dimension of research to determining Honduras's potential for quality coffee production by 1) indicating the level of quality currently offered by Honduran producers and 2) exhibiting altitudinal affects on flavor quality. Expert roaster Ian McCarthy provided flavor profiles for the second through fifth-ranked farm samples. The second through fourth-ranked farms are in the Santa Barbara department, and the fifth is in the La Paz department.

Error is inherent in data sets and analysis methods used. The only available climate data for Honduras are outdated, slope and elevation values were derived from a coarse 30m x 30m cell resolution grid, and actual locations of COE farms were approximated to the nearest municipality given. Inverse distance weighting analyses of climate data may slightly depress value ranges and have other error potential.

Chapter IV. Results

The Thesis Model found suitable areas for growing quality coffee in portions of eight western Honduran departments: Santa Barbara, Copan, Ocotepeque, Lempira, Intibuca, La Paz, Comayagua, and Francisco Morazon. The COE-COOP-Demonstrated Model found suitable areas for growing quality coffee in these eight departments as well as three others; Yoro, Olancho, and El Paraiso (see Figures 2 and 3). There is considerable overlap between the two models' findings, but the COE-COOP-Demonstrated Model found more suitable areas, most likely because of its physical feature index's lower precipitation ranges and steeper slope ranges.

The suitable area found through the Thesis and COE-COOP-Demonstrated models looks small in relation to the country's total area. When examined with ArcGIS's measuring tool it appears that the smallest suitable parcels are at least 500 ha, or almost 16 times the largest size of a typical small-scale coffee farm (small-scale farms are usually less than 30 ha; one ha is a little smaller than two U.S. football fields). Suitable parcel sizes for both models may be due to error from using 90 m cell resolution data, or may fairly accurately reflect the physical features where they are located. Land use coverage indicates the areas found suitable by both models are in the sparsely inhabited, forested interior mountains where most coffee is currently grown (see Figure 4).

Most of the land found suitable by the two models is in the dry, montane, or pine-oak forests, which have earned conservation priority from the WWF (see Figure 5). In fact, most of Honduras, including the capital Tegucigalpa and economic center San Pedro Sula, is covered with conservation priority areas. The Thesis Model's suitable areas within conservation priority areas cannot reasonably be excluded from prospective farm development because less conservation-friendly activities, such as urban development, are currently taking place in those areas. However, the Thesis Model's suitable areas that are not in conservation priority areas should be considered optimal locations for prospective farm development (see Figure 6). The Thesis Model's two suitable parcels (totaling approximately 1,000 ha) that are not in a conservation-priority area are in the northwestern part of the country, in the Santa Barbara department, where many top-ranking COE farms are currently located, including 2008 participants El Guinellera, San Jose, and El Plan. El Guinellera and El Plan farmers spend about an hour transporting the coffee harvest by pickup to the nearest facility or exporter, and all farms are interested in agro-forestry, or growing diversified products on their land, such as timber. A satellite image of the La Guinellera farm area, viewed from 15.19 km altitude, indicates forested, mountainous terrain in that region, with infrastructural access to the northwest (see Figure 7).

These observations suggest current quality coffee farmers near the Thesis Model optimal locations have a shared need for transportation and an interest in sustainable agriculture, and indicates a potential for the formation of cooperatives in that part of the Santa Barbara department. Cooperatives benefit farmers through the use of shared facilities and education on farming, and therefore constitute an important infrastructural asset to small-scale quality coffee farm development.

Chapter V. Discussion

The overlapping and mutually exclusive suitable areas for quality coffee production found by the idealized Thesis Model and the demonstrated COE-COOP Model raise important considerations regarding the research problem: to determine 1) if a GIS model identifying suitable land for quality coffee production can be produced for Honduras and 2) if room for expansion in Honduran quality coffee production exists. According to the considerable overlap between the two models' suitable areas, it appears that a fairly accurate GIS model identifying suitable land for quality coffee production can be produced for Honduras from data available online. The Thesis Model suitable areas not overlapped with COE-COOP Model areas, such as in northern parts of the Francisco Morazon department, suggest there may be room for expansion in Honduran quality coffee production. COE-COOP Model suitable areas not overlapped with Thesis Model suitable areas, such as in the Yoro-Olancho-Comayagua-Francisco Morazon border area near the country's center, suggests that the Thesis Model's physical feature index suitability ranges may be too stringent (see Figure 2).

The Thesis Model and COE-COOP Demonstrated models have distinct strengths and weaknesses. The Thesis Model, based on averaged, idealized conditions observed in tropical coffee-producing countries, serves as a sufficient baseline for assessing Honduras's general prospects in growing quality coffee. However, the Thesis Model may ignore features important to quality coffee production. For instance, the COE-COOP Demonstrated Model's physical feature suitability index required lower precipitation ranges and allowed for much steeper slopes. This may be due to the fact that Honduran farms 1) may not need as much precipitation as hotter, lower-elevation countries such as Vietnam and 2) can be productive in the presence of steep slopes because most producers employ manual care and harvesting. The COE-COOP Demonstrated Model, with its basis on areas where quality coffee is actually produced, is an appealing method for calibrating the idealized Thesis Model. The COE-COOP Demonstrated Model also identifies room for quality coffee production expansion by showing all the country's areas exhibiting physical features enjoyed by successful producers and cooperatives. While the COE-COOP Demonstrated Model shows a wider range of suitable areas, its basis on conditions observed at locations during one year may overstate the suitability of certain areas, if those areas enjoyed unusually pleasant climatic conditions, or perhaps an infrastructural benefit not exhibited in the physical feature suitability index (such as the aid of an agricultural extension worker).

The land suitability models produced should therefore be considered together to reduce the impact of respective flaws, and should serve as a preliminary test of a region's suitability and an encouragement to farmers owning land in areas deemed suitable. Actual farm establishment or conversion from conventional to quality coffee production requires a more holistic planning approach, including field surveys and studying indigenous or vernacular knowledge of the area's agricultural potential. Agricultural extension workers in the coffee industry are sometimes the most important factor in gaining recognition for producing quality coffee. For instance, producers near the city of Marcala (La Paz department, a two hour drive from capital Tegucigalpa) may have greater access to global quality coffee markets due to the German coffee connoisseur presence in that city since the early 20th century, as well as a hundred year history of demonstration in what product European consumers desire. Marcala-based producers also have the opportunity of marketing their coffees under the Marcala intellectual property right, which is the first (2005) "denomination of origin to be officially registered in Central America" (U.S. Embassy, 2008).

There may be increasing interest in converting or starting quality coffee farms because of concern over the country's environmental degradation from unsustainable agriculture, increasing land titling programs since the passing of the Agricultural Modernization Law in 1992, and the continued funding of economic development programs like the Honduran Sustainable Development Network (Larson, 2006; Foundation Center, 2008).

A cupping of the top three Honduran COE farms in 2008 at Cultiva Coffee in February 2009 indicated that small-scale Honduran farms are currently producing world-class gourmet quality coffees. Expert roaster Ian McCarthy provided flavor profiles for the second through fifth-ranked farm samples. The second through fourth-ranked farms are in the Santa Barbara department (where the two Thesis Model optimal parcels are located), and the fifth is in the La Paz department. Mr. McCarthy noted the second-ranked farm sample had a sharp, bright, light body; the third-ranked possessed a sweet, round, full body with amazing balance; the fourth-ranked was dry, refined, acidic, and well-balanced with dark-chocolate flavors; and the fifth-ranked offered acidic, bright ripe fruit flavors. The second and third-ranked farms' flavor profiles correlate with generalized flavor profiles given for that altitude (the fourth and fifth are located above altitudes assigned generalized profiles); floral, berry and citrus flavors are inherent to farms at 1500 m (just below second-ranked, just above third-ranked) and nutty flavors are more common to slightly lower-elevation farms at 1200 m (just below third-ranked) (terroircoffee, 2008).

Further improvements on the model include obtaining higher-resolution satellite images of areas considered for quality coffee production, including data on soil types favorable to quality coffee production such as volcanic ash and loam, and further researching desirable proximity to roads and urban areas.

Chapter VI. Conclusion

With data on climate, topography, soil, areas vulnerable to environmental degradation, and infrastructure, the Thesis Model produced found a small region in western Honduras to be suitable for growing quality coffee. This area is near farms where quality coffee is currently being grown, and is moderately accessible to roads and urban areas.

The human dimension associated with the land found suitable by the Thesis Model raises important considerations. The Thesis Model suitable region encompasses two prominent coffee cooperatives, which provide necessary processing facilities to farmers. Also within the suitable area is the La Campa municipality of the Lempira department, home to the indigenous Lenca community (see Figure 8). Lenca peoples have been historically proactive in reforestation efforts, and if they are provided a tool for increasing the conceived value of a parcel of land, Lenca peoples could potentially protect more land from unsustainable production typically promoted by democracies catering to the electorate, or current generation (Tucker, 2008; Wood and Waterman, 2008).

This study will contribute to a better understanding of how GIS can increase the agricultural precision for a product that is essential to the Honduran economy and environment at a time when sun-coffee constitutes 35 percent of statewide coffee production (tufts.edu, 2008). Also, this model suggests that Honduras has the potential to develop and benefit from an online marketing tool such as GeoCafe. The value of online marketing tools such as GeoCafe is evidenced by the fact that Costa Rican and Guatemalan coffee trades at about a seven percent premium over Honduran coffee (U.S. Embassy, 2008).The thesis model and COE models serve as prototypical models for tools which could aid international development programs such as the QCP, state programs such as IHCAFE, small-scale producers, and retailers in promoting Honduran quality coffee production, thereby increasing economic resilience for small-scale farmers.

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Appendix

CATEGORY	VARIABLE(S)	FAVORABLE RANGE	ONLINE SOURCES
Climate	Annual Average Temperature	16-24◦ C	NOAA 1998 – 2007 monthly averages
	Annual Precipitation	1,000-4,400mm	NOAA 1961-1990 normals
Topography	Elevation	400 – 1700 m	USGS Seamless Server 90 m resolution
	Slope	5 – 24%	
Soil	Drainage Quality	Moderate – Very Well	ISRIC 1:5 million resolution
	pH	6 – 7	
Land Use	Forest	Yes	CIESIN
	Scrub	No	
	Grassland	No	
	Wetland	No	
	Water	No	
	Agriculture	No	
	Agroforestry	Yes	
	Urban Forests	No	
	Urban	Yes	
Eco-regions	WWF Conservation Areas	No	CIESIN
Roads	Roads	1 km	ESRI GeoCommunity
COE farms	location	Yes	COE 2008 winning farms
Coops	location	Yes	Google Earth
Study Area	location	N/A	ESRI GeoCommunity
Honduras Outline	location	N/A	DIVA GIS
Satellite Image	Western Honduras	N/A	Google Earth

Table 1: Thesis Model Physical Feature Suitability Index
Thanks to Dr. J Merchant, Ting Chen, Natalie Umphlett