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Articles

Population Growth and Fertilizer Use: Ecological and Economic Consequences in Santa Cruz del Quiché, Guatemala

CODY ZILVERBERG

Borlaug Institute for International Agriculture, Texas A&M University, College Station, Texas, USA

URS KREUTER

Department of Ecosystem Science and Management, Texas A&M University, College Station, Texas, USA

RICHARD CONNER

Department of Agricultural Economics, Texas A&M University, College Station, Texas, USA

The population of Santa Cruz del Quiché, Guatemala, has been growing rapidly in recent decades, thereby increasing the demand for agricultural land. Interviews and census data indicate that farmers have responded by reducing the use of fallow periods, reducing the amount of land dedicated to forest and pasture, and increasing the quantity of synthetic fertilizer applied. In particular, farmers with less land are less likely to apply organic fertilizer. Ecological consequences of these agricultural changes include loss of soil organic matter, reduced water infiltration, and concomitant increased runoff and soil erosion. An economic consequence is that farmers are more vulnerable to global price increases of synthetic fertilizer. A solution to these problems may include economic development, land redistribution, use of improved seeds, and alternative sources of fertilizer, but implementing a conservation easement program provides the most promise for achieving effective and long lasting results.

Keywords environmental degradation, fertilization practices, Guatemala, land use change, maize production, soil erosion

Concern that the world's food supply will not keep pace with the demand of growing human populations has persisted since Malthus published his famous essay in 1798. Technological advancements, conversion of previously uncultivated land to agricultural uses, and improved transportation have allowed global food production to

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Funding provided by the Norman Borlaug Institute for International Agriculture.
Address correspondence to Cody Zilverberg, Department of Plant & Soil Science, Campus Box 42122, Lubbock, TX 79409, USA. E-mail: cody.zilverberg@ttu.edu

remain ahead of demand despite regional shortfalls. For example, Asian farmers tripled cereal production since 1961 as a result of the Green Revolution (Borlaug 2002). Some argue that technological advances will continue to allow food production to meet the increasing demand of a growing global population. They claim that famines are the result of localized shortages caused by lack of access to food, rather than insufficient food production (McCalla 1998).

The technological basis for increased food production in the past half century has been the development and use of improved seed stock and the increased use of synthetic fertilizer, irrigation, and pesticides. While the resulting worldwide increase in food production has prevented mass starvation, it has not occurred without social and ecological costs. For example, small-scale farmers have often been unable to afford the cost of these new inputs. Furthermore, increased use of chemicals has raised health concerns, while increased irrigation has elevated soil salinity in some areas and lowered water tables in others. In addition, the loss of native cultivars and the impact of chemicals upon native plant and animal species raised concerns regarding biodiversity. Therefore, the Green Revolution is clearly not a panacea for meeting the growing demand for food (Falcon 1970; Shiva 1992; Pimentel 1996; Singh 2000).

Like the work of Boserup (2005), our study focuses on population increase as a cause of changes in agricultural production methods. Specifically, we focus on the local economic and ecological consequences of increases in the population density of the Santa Cruz del Quiché area (*municipio*) of Guatemala. The population of Santa Cruz has grown rapidly in recent decades, increasing the demand for agricultural land. Due to the lack of new arable land and the decline in the size of landholdings, farmers have attempted to increase productivity of their ever smaller landholdings. Agricultural intensification strategies that they have adopted to meet this challenge include increased application of synthetic fertilizer, reduced use of fallow periods following cultivation, and decreased retention of grazing lands, all of which are among Boserup's (1981; 2005) predictions. Furthermore, the population-related land pressure and associated soil degradation problems confronting Santa Cruz are also faced by many other rural communities in Latin America (Scherr 1999).

In this article we describe the events leading to the origination and adoption of these strategies, we examine their local ecological and economic consequences, and we make recommendations for the future. We hypothesize that the increasing population, which leads to smaller landholdings, has resulted in a decrease in the availability and use of organic fertilizer, the consequences of which include deterioration in nutrient cycling, soil structure, and soil moisture content.

Land Conflict

Current land use is a product of historical events. In Guatemala, the Spanish conquest decimated Native American populations and the region's new rulers seized much of the most productive land. Following Guatemalan independence in 1821, the country's political elite continued to expropriate land from indigenous subsistence farmers, resulting in unequal land distribution (Black and Needler 1983). The increasing scarcity of arable land for subsistence farmers and the increase in rural populations led to the cultivation of increasingly steep slopes (Castañeda 1998).

In the 1950s, reformist politicians attempted to transform Guatemala from a feudal economy to modern capitalism through changes in agricultural policy and by breaking up agricultural monopolies, especially the United Fruit Company. However, within a few years, the reforms were reversed by the entrenched elites and the remaining inequalities led to a civil war that lasted from 1960 until 1996. El Quiché, the subject of this research and the state in which Santa Cruz is located, was one of the hardest hit areas, where many civilians were murdered or forced to flee their homes by government forces (Falla, 1994).

Santa Cruz del Quiché

The *municipio* of Santa Cruz del Quiché, located 2021 m above sea level (Guatemala Dirección General de Cartografía 1962), includes the city of Santa Cruz and the surrounding villages and rural area. More than 82% of the *municipio*'s residents identify themselves as Mayan (Guatemala Instituto Nacional de Estadística 2003a), most speak K'iche' as their first or only language, and much of the rural population is illiterate.

The soils of the region are characterized as sandy clay loam with a topsoil depth of 20 cm, a clay subsoil that is plastic when wet and hard when dry, good drainage, average soil moisture-holding capacity and fertility, and slopes commonly ranging from 10 to 20 degrees (Simmons et al. 1959). Two "special problems" for managing these soils were identified by Simmons et al. (1959, 612): "maintaining organic material" and "combating erosion." Today deep scars on steep slopes are evidence of massive soil erosion.

Pre-Columbian Guatemalan agriculture included cultivation of maize, beans, chili peppers, and squash with such high levels of productivity that population densities may have reached contemporary levels (Perez-Brignoli 1989). In 1989, the population of Quiché was approximately 400,000 and the population of Santa Cruz was over 35,000 (Guatemala, Instituto Nacional de Estadística 1994). Nearly 50 years ago, Simmons et al. (1959) described agricultural characteristics in the region that are still prevalent. They noted the dominance of subsistence cultivation of maize and beans on small plots, work done with hand tools, severe erosion of cultivated areas, and productivity that was not meeting its potential. In addition, they stated that the 3.5-ha average landholding was inadequate to support a family of 5. They suggested that the best use of land would be livestock production, taking care not to overgraze pastures in order to avoid further erosion. Contrary to these recommendations, in the early 1970s, Falla (1972) reported that most residents in neighboring San Antonio Ilotenango still depended on intercropped maize, beans, lima beans, and squash, and only a few of the once large flocks of sheep remained, leading to a lack of natural fertilizer.

Today landholdings are generally smaller than the 3.5 ha reported in 1959. Maize is the dietary staple and is given first priority in production. Most farmers have a single plot of land where they intercrop maize with beans and sometimes lima beans and/or squash, and a few families maintain fruit trees. Almost all farmers use maize and bean seeds selected from the previous year's harvest. A small number use only organic fertilizer, some use only synthetic fertilizer, but most use a combination, with organic fertilizer being either actively applied by farmers or deposited by livestock. Rotating crops, irrigating, and allowing fallow periods are rarely practiced. Labor is mainly manual, with the primary tool being a large hoe that is used to prepare the soil, plant, and cultivate. Many farmers use hired labor to do some or all of the work.

Population Change

The population of the Santa Cruz *municipio* is growing rapidly. Between 1994 and 2002, the most recent years for which data are available, the average population growth rate for the Santa Cruz *municipio* was 6.3% per annum and the rural growth rate was 7.1%, both considerably greater than the national average of 3.8% (Guatemalan Instituto Nacional de Estadística 1994; 2003a). The United Nations (2006) predicts a decrease in Guatemala's annual population growth rate over the next 45 years, from 2.5% to 0.9%. Population projections for Santa Cruz were not available, so we used Guatemalan census data for 2002 and the United Nations population projections for the country of Guatemala from 2005 onward to make our own projections. Based on these calculations, Santa Cruz's rural population is projected to rise from 41,453 in 2002 to 101,458 in 2050. These values equate to population densities of 324 and 793 people km^{-2} in 2002 and 2050, respectively, compared to 122 people km^{-2} in 1950 (Guatemala Dirección General de Estadística 1950; Guatemala Dirección General de Cartografía 1962). For comparison, Rwanda, one of the world's most densely populated countries, had 351 people km^{-2} in 2005 (United Nations 2006). Such high population densities will place severe strain on natural resources in a region where poverty, malnutrition, and insufficiently sized landholdings are already serious problems.

Simmons et al. (1959) emphasized the need for increasing the average size of landholdings because of low productivity. Instead, rural population density has more than doubled since 1950 and property size has declined. For a time, productivity gains resulting from the use of new technologies, such as synthetic fertilizer (Falla 1972), were able to compensate for the reduced size of landholdings. However, in the early 1990s yields declined and subsequently stagnated, while the population continues to increase exponentially (Figure 1).

Anecdotal information emerging from the authors' research into the relationship between agricultural technologies and conflict in Guatemala suggested the need for

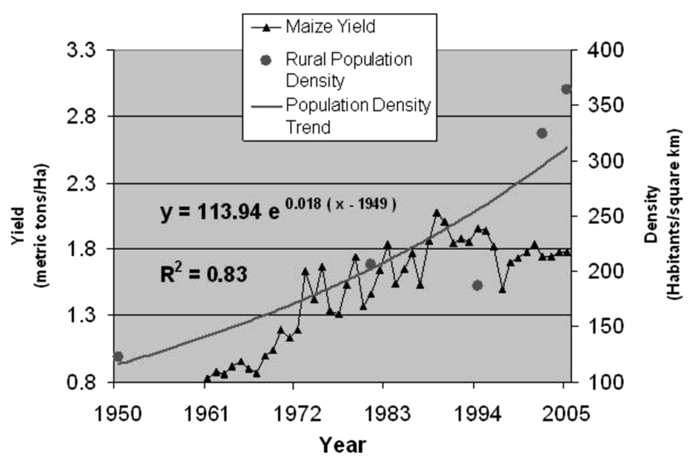

Figure 1. Guatemalan maize yield and rural Santa Cruz del Quiché, Guatemala, population density. Sources of data: Food and Agriculture Organization of the United Nations (2006), Guatemalan Instituto Nacional de Estadística (1981; 1994; 2003a), and Guatemalan Dirección General de Estadística (1950).

a more detailed investigation into the relationship between population growth, fertilizer use patterns, and the associated ecological and economic consequences. Here we report the results of a study based on structured personal interviews to investigate trends in fertilizer use and to project potential consequences.

Methodology

Structured interviews were conducted by the lead author and three local assistants, who used a standard set of questions to obtain data from largely illiterate survey participants. For participants who did not speak Spanish, questions were translated into K'iche' by the assistants and responses were recorded in Spanish. To protect respondent anonymity, no audio recordings were made of the interviews. Interviewees were initially asked to describe techniques used at various stages of production and then about specific agricultural practices.

Conducting the interviews was challenging because of local farmers' concerns about mining concessions that the government had granted to foreign businesses. Therefore, to ensure personal safety and improve interviewee cooperation the research team entered communities by accompanying the coordinators of a women's microcredit program run by Acción Cultural Guatemalteca (ACG). Thus, most interviewees were women involved with the program, but there is unlikely to have been much gender bias in our results because the survey questions did not ask about the individual's role in agricultural production or ownership—rather, the questions addressed familial farming practices and ownership. On one occasion, the team entered a village during the celebration of a development project, which provided the opportunity to interview men and women not involved with the microcredit program. Interviews were also conducted at the ACG offices in Santa Cruz del Quiché. With one exception, interviews were conducted in the communities of Choacaman, Chicabracan I, Chicabracan II, Xatinap, Pacaja II, and Pacho Lemoa or in Santa Cruz.

In total, 87 interviews were conducted. Responses of four interviewees who referred to agriculture practiced outside of the Santa Cruz *municipio* were excluded from the data set used for analysis. The responses of eight others were excluded because they provided no information about the size of their landholdings. The remaining sample size used for data analysis consisted of 75 respondents, including 61 women and 14 men.

After completing the data collection, each respondent's farming system was categorized according to whether or not the respondent "actively" applied organic fertilizer. "Active organic" systems fertilize their crops by manually applying animal manure to the field, manually applying plant residue gathered from the forest floor, or cultivating a green manure. In addition, the respondent may or may not apply synthetic fertilizer, leave plant residue in the field, or pasture animals in the field. The second group, "synthetic and passive organic," includes those farmers who apply synthetic fertilizer exclusively or in conjunction with deposition of organic fertilizer (manure) by foraging livestock placed in the field. Also in this category was one family who utilized synthetic fertilizer, and whose only source of organic fertilizer was leguminous trees that do not require annual maintenance.

Median landholding size was calculated for each of the two fertilization categories and statistical significance of intercategory differences of property size was tested using a Mann–Whitney *U* test to account for the non-normal distribution of the property-size data.

Results

A total of 0.188 ha was both the median size of land owned by survey respondents (mean = 0.363 ha, SD = 0.060 ha) and the median amount of land cultivated by survey respondents (mean = 0.300 ha, SD = 0.031 ha). When multiplied by respondents' average maize yield of 1753 kg ha^{-1} the mean production acreage produces an annual average of 526 kg per family, which provides sufficient calories for less than 2 people (Bressani et al. 1958; Smith 1998), while respondents had, on average, 5 children (SD = 3.2). Secondary crops such as beans and lima beans were planted by many families to increase their caloric intake, but based on the authors' observations these supplements are generally insufficient to make up the caloric deficit.

Interviewees revealed three strategies for dealing with this nutritional shortfall. The first was purchasing food with earnings from off-farm employment, which averaged $29 (SD $23) per family per week at the time of the survey, but fluctuated due to the seasonal variation in the availability of employment opportunities. These earnings were used to purchase additional maize when the family's harvest had been consumed, as well as to buy clothing and school supplies.

The second strategy was to clear new land for cultivation. While data for the Santa Cruz *municipio* was unavailable, Guatemala's 2003 agricultural census indicates that from 1979 to 2003, the amount of land dedicated to pasture and forest in the Quiché *departamento* decreased by about 6,000 ha and 40,000 ha, respectively (Guatemala, Instituto Nacional de Estadística 2003b). A concurrent increase of approximately 15,000 ha occurred in the amount of land dedicated to annual and temporary crops, indicating a conversion of land cover from forest and pasture to annual and temporary crops. Despite this conversion, the combined land area of all farms declined by approximately 30,000 ha over the same time period, while the number of farms increased by 27,000, resulting in a substantial reduction in the average size of landholdings (Guatemala, Instituto Nacional de Estadística 2003b). This shift in land use was corroborated by anecdotal information gleaned from the interviewees. Such shifts are problematic when marginal lands are brought into cultivation in areas with steep slopes because they are susceptible to severe erosion. Because the best land for farming is already under cultivation, newly cleared lands typically have low productivity, a problem exacerbated by erosion.

The third strategy employed by Santa Cruz residents to compensate for insufficient maize production is to adopt more intensive farming practices. Only 1 of the 75 farmers in the data set observed a fallow period of at least 1 year. Eliminating the fallow period may reduce the short-term production problem, but the resulting decline in soil nutrient levels leads to long-run reduction in crop yields. To offset soil nutrient declines, farmers can apply higher rates of fertilizer, but this is complicated by the difficulty of obtaining fertilizer. In the past, livestock manure and decomposed forest litter were used to replenish soil nutrients and build soil structure. However, with less land being dedicated to forests and pastures, the availability of such locally produced organic fertilizers has diminished. To compensate, farmers have increasingly relied on the use of synthetic fertilizers. All but 3 of the 75 respondents indicated that they used synthetic fertilizer. Some respondents expressed gratitude for the availability of synthetic fertilizer because they could not produce a crop without it. Others preferred using organic fertilizers because of the high cost of synthetic fertilizer and the perceived deleterious side effects of using it: dependency, declining effectiveness, and sickness. However, most farmers who expressed a

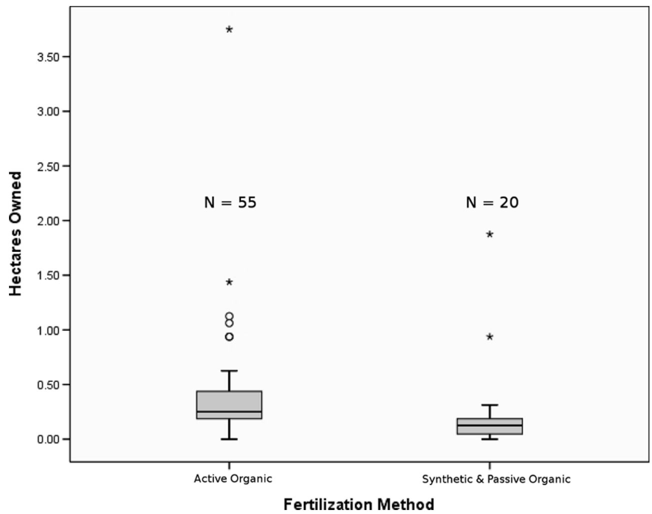

Figure 2. Relationship between landholding size and method of fertilization.

preference for organic fertilizer felt compelled to use synthetics in order to produce reasonable harvests.

The survey data presented in Figure 2 show that the respondents who actively apply organic fertilizer with or without synthetic fertilizer ($n = 55$) had about twice as much land (median = 0.250, mean = 0.408, SD = 0.074 ha) as farmers who used synthetic fertilizer exclusively or in combination with passively applied manure by grazing livestock (median = 0.125, mean = 0.239, SD = 0.098 ha) (Mann–Whitney $U = 281$, $p = .001$). In addition, it appears that there is a threshold in the range of 0.125–0.188 ha that determines whether a farmer is likely to choose "active organic" methods. Farmers with 0.125 ha or less ($n = 26$) were divided almost evenly between groups, with 46% ($n = 12$) choosing "active organic" strategies and 54% ($n = 14$) choosing "passive organic and synthetic only." However, among farmers with at least 0.188 ha, 88% ($n = 43$) chose "active organic" strategies and only 12% ($n = 6$) chose passive organic fertilization. Within the group of "active organic" landowners, those who relied entirely upon organic fertilizer ($n = 3$) had the highest median landholding size, 0.625 ha. Within the group of "passive organic and synthetic only" landowners, there was no statistical difference between those who relied entirely upon synthetic fertilizer and those who pastured animals in their fields.

Discussion

Local Ecological and Economic Consequences

Our survey sample was nonrandom due to security-related constraints in obtaining a random sample of landowners in the study area. Accordingly, our findings cannot be extrapolated to the *municipio* of Santa Cruz del Quiché population as a whole. Nevertheless, the qualitative information obtained provides some interesting insights into shifts in land use, rural property sizes, and the use of fertilizer to boost maize production.

As the rural population of Santa Cruz continues to grow during the first half of the 21st century, the average landholding will continue to shrink. Nutrient depletion is likely to increase (Drechsel et al. 2001a) as a result, while less organic fertilizer will be available. The likely response of farmers will be to continue replacing organic with synthetic fertilizer.

A local benefit of synthetic fertilizer use is maintaining higher yields compared to production based solely upon organic fertilizers. Maintaining yield levels in this way reduces the pressure to deforest additional marginal land (Borlaug 2002), which is positive for watershed protection and the maintenance of biodiversity. Conservation efforts taken by residents of Chicabracan II illustrate the value placed on watersheds in Santa Cruz: Community members recently purchased the slopes above their community and take turns guarding the forest in order to protect their water supply. Other benefits of synthetic fertilizers are that they are less bulky than organic fertilizers, require less labor to apply, and can be applied more precisely, both temporally and spatially.

However, there are also negative local ecological consequences associated with extensive reliance on synthetic fertilizer and with abandoning organic fertilizer use. Fertilizers derived from plants and animals provide more organic matter for maintaining good soil structure than synthetic fertilizers (Matson et al. 1997). Applications of organic matter can substantially increase infiltration and reduce runoff and erosion losses (Peoples et al. 2004). When excessive levels of nitrogen and phosphorus from organic or synthetic sources enter water sources via runoff, they can cause eutrophication and ultimately the buildup of a number of toxic substances (Cassman et al. 2002). Other functions of soil organic matter include providing organic substrate for nutrient release and contributing to water-holding capacity (Matson et al. 1997).

The transition from organic to synthetic fertilizers also has economic ramifications. Dependence upon imported fertilizer leaves farmers vulnerable to fluctuations of world fertilizer prices, which have recently increased sharply (Economic Research Service 2006). At the same time, the Central American Free Trade Agreement will eliminate the tariff on U.S. maize imports over the next 10 years (FASonline 2005), promising to make Guatemalan maize more expensive with respect to imported maize. The combination of input and output price changes does not bode well, and as one survey respondent put it, "We are concerned about buying chemical fertilizer because it reduces the money given to the woman for use in the kitchen."

Potential Solutions

Many areas of the developing world face problems associated with rapid population growth, restricted access to land, and soil degradation similar to those in Santa Cruz (Drechsel et al. 2001b; Scherr 1999; Cropper and Griffiths 1994; Meyer and Turner 1992). A single solution is not possible for the complex ecological, economic, and social problems resulting from food production shortages associated with rapid population growth in rural communities, like those in Santa Cruz. A combination of actions, however, may serve to mitigate or solve some of the most pressing issues.

Abandoning the use of synthetic fertilizer is not an option because there is insufficient locally available organic fertilizer to replace the nutrients supplied by synthetic fertilizer, while transporting large quantities of bulky organic material into remote areas like Santa Cruz to compensate for local shortfalls is cost-prohibitive. A partial solution may be the use of new organic substitutes to replace a portion of synthetic inputs. For example, the Santa Cruz-based Acción Cultural Guatemalteca is currently experimenting with the use of worm castings as maize fertilizer. Given the small size of Santa Cruz's farms, vermiculture may be a useful way to enhance soil nutrients and structure.

Over 90% of survey respondents in Santa Cruz continue to plant seeds selected from the previous year's harvest. If adopted by local farmers, new hybrid cultivars could increase yields (Evenson and Gollin 2003) while reducing the pressure to convert more forest and pasture land to crop land. Future technological advances promise even more benefits. As Giller et al. (2004, 37) noted, "There is new emphasis on a number of topics [in plant breeding] including the nutritional value of foods . . . , reducing post-harvest losses, making crops more tolerant of stresses . . . , or reducing reliance on pesticides. Crop improvement approaches that will increase yield stability and reduce yield losses contribute to increasing the efficiency with which fertilizer N is converted into economic products." A risk of switching from traditional seed selection to purchasing improved seeds is the loss of local genetic diversity, making crops more susceptible to pest and disease outbreaks. Furthermore, improved seeds may be culturally unacceptable and may require subsidies to offset higher seed costs.

Given the persistent highly inequitable distribution of land and wealth in Guatemala, where the landholding Gini coefficient is a staggeringly high 0.84 (Guatemala, Instituto Nacional de Estadística 2003b), there continues to be a pressing need for land redistribution. Distributing land to Santa Cruz's small-scale farmers would allow them to raise more animals, generate more organic fertilizer locally, and reestablish fallow periods, all of which would enhance soil health and income. However, given historical patterns and the current social and political climate, significant land redistribution is unlikely. Even if it were possible, land redistribution would be a temporary solution in the face of the current rapid rate of population growth. Furthermore, in the worst-case scenario, land redistribution could spark another civil war, which would lead to even greater environmental destruction and human misery.

Economic development and diversification are commonly cited strategies for improving agricultural income and reducing reliance on income from a single crop (Rigg and Nattapoolwat 2001; Koczberski and Curry 2005; Ureta-Bravo et al. 2006). Economic development outside of Santa Cruz could increase employment opportunities that encourage emigration out of the area. In turn, this could increase remittances sent back to families in Santa Cruz and it could reduce population pressure on agricultural land, which could encourage the consolidation of small farm plots into properties that are sufficiently large to diversify agricultural products and to allow for fallow periods. However, given the projected rapid increase in population, emigration would have to increase dramatically to reverse the current trend of declining farm sizes and conversion of marginal land to agriculture. Munroe et al. (2002) found that agricultural intensification in western Honduras led to a reduction in the use of marginal land as farmers shifted production away from maize and beans to market-oriented coffee production. This type of cash-crop production may provide an avenue to increase incomes and reduce pressure on marginal land, but it will face challenges such as the selection of a locally appropriate crop and maintaining economic competitiveness despite Santa Cruz's somewhat remote location.

In an analysis of natural resource management projects in Central America, Ureta-Bravo et al. (2006, 274) found that agricultural incomes can be improved by "the adoption of soil conservation practices and structures and of forestry systems" and they recommended that this type of investment become "an integral part of... development strategies designed to alleviate rural poverty in Central America." The question is, how can such conservation strategies be funded? A conservation easement is a policy instrument that could be used to promote both soil conservation and forestry through land use restrictions funded by external conservation entities. For example, communities of farmers could sell conservation easements on their land that would require them to maintain a certain percentage of pasture and forest in exchange for payments from the conservation organization that obtains the easements. These conserved areas would not exclude human use; rather, they would be "working" pastures and forests that provide economic returns to their owners through their sustainable use while also acting as sources of organic fertilizer. Additional restoration programs could repair lands that are severely damaged. Once returned to health, these lands could be added to the easement for further payments and could also contribute to the provision of organic fertilizer material.

One advantage that a conservation plan holds over land redistribution is that it can provide a long-term solution for environmental problems. Long-term or permanent contracts for conservation easements that can be effectively enforced could ensure that a certain percentage of land remains in pasture or forest regardless of the extent of land fragmentation. As a result of the conservation program, soil health would improve through the integration of greater quantities of organic matter into the soil; runoff and erosion would be reduced, diversity of the ecosystem would be maintained or increased, and incomes would be supplemented. Funding for such a program could come from international sources, such as the recent debt-for-nature swap involving Guatemala, the United States, and The Nature Conservancy (The Nature Conservancy 2007). Under this agreement, Guatemala committed to investing in the conservation of ecologically important areas over the next 15 years in return for a $24 million foreign debt write-off. One of these areas, the "Sierra Madres Volcanoes," lies on Santa Cruz's southern border and faces many of the same problems, including deforestation and the fragmentation of agricultural land. Although this debt-for-nature swap will not provide funds for conservation in Santa Cruz, it illustrates an innovative approach to solving similar problems and provides a template for the way foreign financial aid could be made available to Santa Cruz. Creative solutions such as this have also allowed The Nature Conservancy to acquire land for conservation in Chile, and to aid in the valuation of Chilean land for conservation, in collaboration with businesses (Ginn 2005).

Conclusion

Santa Cruz del Quiché, Guatemala, faces serious economic and ecological challenges as a result of rapid population growth that is projected to continue well into the future. Peasant farmers divide their land among their children, the consequence of which is an increasingly large number of small farms. Data and anecdotal evidence suggest that small-scale farmers tend to practice more intensive agriculture, and devote less land to pasture, forest, and fallow periods.

Consequences of such changes are that unsuitable land is brought under annual cultivation and less organic matter is available to fertilize crops, leading to the greater reliance on synthetic fertilizers and more intensive land use that exacerbate the problems of soil erosion, runoff, and water contamination. Furthermore, the added expenditure on fertilizer places a strain upon the limited household budgets.

Economic development, land redistribution, improved seeds, and alternative sources of fertilizer would help to address the problems, but each faces unique implementation difficulties in Guatemala and other Latin American countries.

The greatest opportunities for mitigating the deleterious effects of increased population pressure on rural land may come from a program of conservation easements that would convert land under annual crop production to forest and pasture in order to more effectively protect the steep slopes and the soils of Santa Cruz. This type of easement-based change in land use would reduce erosion, pollution, and poverty while improving soil health and increasing biological diversity. While the budgets of the national and local governments are obviously limited in their abilities to enact such a plan, international funding for similar programs is available. One example is the recent debt-for-nature swap that included The Nature Conservancy and the governments of the United States and Guatemala.

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