ARE TREES MORE PROFITABLE THAN MAIZE? A COMPARISON OF INCOME GENERATING CROPS IN THE GUATEMALAN HIGHLANDS

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ABSTRACT

Trees can become an attractive integral component of farming systems by demonstrating that they are as profitable than traditional agricultural crops. Agroforestry systems help address the short-term profitability needs of the farmer while achieving long-term goals of maintaining yields and the environment. This study compares the profitabilities of traditional crops and an agroforestry system. A linear programming model finds an optimal farming alternatives through long-term financial analysis. The results are presented in the context of scenarios which include different discount rates and land quality classifications.

THE PROBLEM

The problem addressed in this article is rooted in a cycle of poverty that characterizes the situation of small farmers throughout the Third World. In Central America small farmers use traditional farming technologies to cultivate marginally productive lands. These land use practices lead to environmental degradation and a worsening of their quality of life conditions. Four interrelated aspects of the problem are explained below.

Cultivation of Marginal Lands

The Guatemalan highlands is a densely populated region and is home to some of the nation's poorest farmers. As with many Third World rural dwellers, agriculture is an important source of income, and for small Guatemalan farmers it is no exception. They earn their livelihood from the land and are dependent upon its ability to produce. Yet, both the land's productive capacity and the livelihood of the rural population are threatened by inappropriate cropping patterns and ever growing human pressures upon the forest and soil resources.

In the highlands of Guatemala, there has existed a belief that growing trees as a crop is not a profitable activity. For a farmer to earn income, he or she clears forest to plant maize, wheat, and other typical crops. Even if the land is not suitable for agriculture, being steeply sloped forested hillsides, the farmer's short-term needs nonetheless require tree cutting to make room for more agricultural production. Such desperate land use practices are disastrous to both the Region's economy and environment.

Economic Implications

Agricultural activity on previously forested hillsides provides only a short-term financial solution for the small farmer. After only a few years under cultivation, crop yields decrease markedly on the marginally productive land. In order to maintain previous income levels, farmers further expand the area of cropland. However, once again they are forced to cultivate marginal lands. This pattern repeats itself, creating a cycle of poverty that revolves with ever increasing speed.

High input prices (fertilizers, pesticides) and low output prices received for crops squeeze profits of the agricultural activities and exacerbate the income generating capacity problem of the small farmer. The gravity of the present Guatemalan economic crisis is reflected by some farmers and their families being forced to relocate to other regions of the country, in particular the capital and the ecologically fragile Peten.

Firewood Scarcity

In addition to chronic poverty, there exists the problem of firewood scarcity. Firewood is the primary fuel source for household cooking purposes. The diet of the Guatemalan comprises three cooked meals a day. Therefore fuelwood is rapidly consumed - approximately .83 cubic meters/month. This figure roughly translates into five 12-year old trees (16.5 cm diameter; 15 m height) burned per month per family.

Over the years, many nearby forests which previously supplied the population with firewood have disappeared to be used as fuel. Clearly, a supposedly inexhaustible resource has become scarce through overuse. As with any scarce resource, the price of firewood has risen dramatically - to the point where substitutes for the purchase of firewood are employed. One way to avoid the high cost of firewood is to simply steal trees and branches. There are numerous examples of firewood theft. In fact, all forest landowners interviewed expressed a problem of disappearing trees.

Another more legitimate substitute involves use of the non-renewable energy resource, propane. Unfortunately, the poor cannot afford the initial capital expense of a propane stove and are thereby forced to pay higher firewood prices, walk longer distances to collect it, or steal wood.

Environmental Implications

Having been converted into agricultural land or cut for fuelwood, the previously forested hillsides become susceptible to soil erosion. Rainfall carries away the good soils and essential nutrients needed for profitable harvests. Today, the ecological effects of this cycle can easily be seen throughout the countryside - with the presence of washouts, gullies and consistently brown rivers.

The loss of forest cover has many far-reaching environmental effects besides soil erosion. In many areas drinking water has become limited. During the dry season, it is not uncommon for water to be available for only a few hours a day. Sometimes there is none for days. Trees that had previously protected watersheds have been cut, resulting in rainfall not filtrating into the soil and supplying aquifers with water.

Also within the last few years there has been a noticeable climatic change in the Guatemalan highlands. According to residents there, the rains start later and end earlier, thereby shortening the growing season of traditional crops. In addition, destruction of the forest has decreased its insulating capacity. At the high altitude during the dry season, cold night air often harms young plants with frost.

Although local people do notice the degradation of their land resources, individual short-term needs of income generation impel them to cultivate marginal lands. This article addresses the problems of low income, firewood scarcity and land degradation resulting from current agricultural production practices. By demonstrating the financial benefits of trees in the farming system, a farmer can observe the incentives and become motivated to better use marginal lands. This conversion to better land use practices will achieve an important balance between resource capability and human need.

CONVENTIONAL RESPONSES

Efforts to solve the environmental and economic rural crises are many. Both the private and public sectors attempt to remedy the situation in different ways. The following provides a brief explanation of four particular conventional responses to the rural crisis.

Economic/Private/Farm Household Responses

1. *Off-farm Income:* Besides expanding the amount of cultivated land, rural dwellers attempt to solve their income woes with off-farm employment. It is common for one or more family

members to work in an urban centre or produce handicrafts at home. In effect, the off-farm income supports the activities of the rural farm. But with high unemployment rates and few markets for the handicrafts, off-farm employment is not a panacea.

2. *Crop Diversification:* Recent opportunities to farm for export have sparked great interest in the highlands region. Agricultural product export companies and some local cooperatives promote crop diversification. Many farmers are now planting snow peas, broccoli, cauliflower, Brussels sprouts and other vegetables for contract. Besides the attraction of good potential earnings, the ag-export operation provides technical training and needed inputs such as seeds, fertilizer and pesticides.

As long as the farmer abides by the rules stipulated within the contract (attends to the crop properly), he or she is guaranteed a price upon harvest. Further reducing the risk, payment is calculated on a unit of land basis. Therefore the quantity of harvest does not matter. A potential disaster to the farmer like a killer frost, is essentially insured against by the ag-export company.

Not everything is coming up roses with such contract agreements. There are reports of problems concerning the responsibility for poor quality crops and non-payment to farmers by some companies. Again, the farmer is placing him or herself upon the mercy of a market. With export-oriented contract farming, the farmers are dependent not only upon the world market for the demand and price, but also on the integrity of the ag-export industry.

In regions of Guatemala closer to the capital, export crop diversification has existed since the early 1980s. It is considered a success by development agencies and the national agriculture agency, DIGESA. Unfortunately, many downsides to crop diversification are overlooked. The Regional Environmental Advisor of USAID/ROCAP has noted that while crop diversification does provide an alternative income opportunity, the new crops are not merely replacing traditional ones. Farmers continue to cultivate their maize, but now on the previously forested hillsides with grave environmental implications. *[Williams, 1991]*

Environmental/Public/International Institution Responses

1. *Reforestation:* The Guatemalan government and international development agencies have attempted to slow the ruinous effects of deforestation. Unfortunately, the efforts to solve the problem, by promoting and subsidizing the planting of trees, have received tepid acceptance by rural dwellers. The nebulous benefit of environmental preservation, considered important to the agencies, convinces relatively few rural landowners to plant trees on their scarce land.

Development agencies support local reforestation ventures by providing technical, material, organizational and financial assistance. After an initial enthusiasm where the community benefits are touted, members of grassroots organizations lose interest in managing nurseries and forests. Artificial incentives, such as food for work programs enacted by many public sector agencies, entice the citizens to remain involved. However, these programs are controversial, since they may create a dependency upon outside assistance. Statistics on reforestation efforts support this perception of the public's indifference to tree planting. Defensores do la Nuturaleza estimates that in Guatemala, only 20 per cent of all planted seedlings survive *[Lecture 1991 at the University of Vermont]*.[1]

2. *Terracing:* DIGEBAS, the national forestry institution, DIGESA, and international development agencies have promoted the construction of terraces with mixed results. Even with financial and food for work incentives, the gruelling nature of the manual labour required for their construction prevents widespread acceptance by the rural farmer. Once again, the economic benefits of such efforts are not clearly known, "*soil conservation ... helps yields but not in all cases and it is not yet possible to say by how much*". *[Villagran, 1991, p.20]* As a result, the adoption of terracing by small farmers has been minimal.

To give the reader a better idea of the conditions facing the Guatemalan small farmer, the article briefly describes their farming system in the next section.

THE GUATEMALAN HIGHLANDS FARMING SYSTEM

Staple Crops

1. *Milpa:* Maize is king in Guatemala. Farmers devote anywhere between 40-100 per cent of their cropland to it. As in many other Latin American countries, *maiz* (maize, *Zea mays*) is planted in conjunction with other crops. This multi-crop system, called *Milpa*, normally includes the following: *habas* (fava beans, *Vicia faba L.*), *frijol* (black beans, *Phaseolus vulgaria*), *chilacayote* (bottle gourd, *Curcubita sp.*), and occasionally *arveja* (peas, *Pisum sativum*).[2] Sometimes not all accompanying plants are present in the *milpa*. Recent blights of the fava bean have dramatically reduced their yield; leading some farmers to plant fewer of them dramatically reduced their yield, leading some farmers to plant fewer of them or none at all. Also, at the higher elevations, black beans do not grow.

2. *Wheat:* In the highlands region of Guatemala wheat, *trigo (Triticum aestivul L.)*, is rotated with maize on many fields especially those of marginal quality. Even though wheat is a member of the grass family like maize, the low labour and capital requirements make it an attractive rotation crop. Unfortunately, the incentives to produce have dramatically decreased during past years due to its real price decline. Statistics from the National Wheat Producers Guild (Gremial Nacional de Trigueros) mark this trend (Table 1).

Table 1. Guatemalan Wheat: Quantity Produced and Real Price, 1987-91

Year	Quantity (Tons)	Adjusted Price (O)*
1987	1,001,285	25
1988	1,100,018	27
1989	975,005	29
1990	706,198	26
1991	500,000(est.)	16

**1987 Base Year*

3. *Potato:* The Ostuncalco region is famous for *papas* (potatoes, *Solanum tuberosum*). It is the most labour and capital intensive staple crop grown in the highlands. Farmers usually plant the potato on the best quality fields - those that are flat and have sandy soils.

Other Crops

In addition to the staple crops, highlands farmers produce a variety of other vegetables for home consumption or sale. *Repollo* (cabbage, *Brassica oleraca*), *zanahoria* (carrots, *Daucus carrota*), and *cebollas* (onions, *Allium cepa*) are cultivated. Few farmers cultivate *avena* (oats, *Avena sativa*) for livestock feed and use as a rotational crop.

Animals

The typical farm has a variety of animals. Chickens, ducks, turkeys, guinea hens are produced for domestic consumption and for sale. Farms also have bovines, pigs and sheep. Beasts of burden, horses, asses, mules often help hauling firewood, fertilizers, harvests, etc. The larger animals normally eat *rastrojo*, maize stalks, and other crop greens.

Forests

Many families have their own small forests that supply firewood and *broza,* tree leaf litter. Farmers use broza as an organic material to improve soil quality. There are also municipal and communal forests that belong to the people, however tree cutting there is not normally permitted. The forests are guarded and permission to cut trees is obtained through political channels and connections.

Agroforestry

Farmers in the highlands region have practised agroforestry techniques for many years. Their use of a local tree, *sauco (Sambucus mexicana),* as a green manure is common. *[Wilken, 1987, p.61]* Growing within the fields, the trees are pruned to maintain a small size and provide organic material to the soil. The leaves decompose quickly and serve as a source of nitrogen.

Guatemalan farmers sometimes construct fences using living tree posts. Also, they intercrop fruit trees and let an occasional tree grow to a large size within their fields. However, a systematic harvesting of trees is rarely practised in the highlands.

METHODOLOGY

Procedures for the farming system analysis involve two steps. First, data collection by personal interview and second, data analysis using accounting technique and a linear programming model.

Data Collection

1. Traditional Crops: A questionnaire covering a wide range of socio-economic concerns, served as a framework for the personal interview. This questionnaire was divided into four sections. The first section queried the farmers agricultural activities, detailing the production process such as the inputs and outputs of crops and animals. Second, farm infrastructure and farm income characteristics were examined, including farm size, land tenure, farm costs and product prices. The third component concentrated on the forestry component of the farming system, encompassing the usage and cost of fuelwood and other forest products, and the distance to supplies. Fourth, the questionnaire turned to the money flows of rural farmers, investigating budgeting issues.

The interviews were conducted with the help of the Guatemalan agriculture and forestry institutions. Local extension agents aided in the process by being present at interviews. This greatly assisted in building trust between researcher and farmer, thereby increasing the reliability of the information gathered. When the farmer did not easily understand Spanish, the agriculture representative helped by translating *Mam,* the local Mayan language.

It is hoped of every researcher to collect true, unbiased data. However, by working with the agricultural representatives and letting them select which farmers to interview, the study sacrificed randomness. Those farmers chosen were likely to be better educated, more productive and wealthier than the general agrarian population. Nevertheless, their ability to provide information on the cropping activities, farm inputs, yields, and constraints of their own farm and the regional farming system greatly assisted the building of a valid data base.

The study covered 35 farmers in the town of San Juan Ostuncalco emphasizing an intensive research effort. This approach yielded a complete analysis and understanding of the individual farming systems. Socio-economic and agricultural productivity studies conducted by La Universidad de San Carlos, DIGESA, BANDESA and USAID provided base line references to confirm the validity of the data *[Figueroa 1980; USAID 1984; Morales 1987; Prado 1987; BANDESA 1986, 1992; DIGESA 1989, 1992].* The research period was approximately three months, conducted in January, February and March 1992.

2. Agroforestry Component: A paucity of *taungya* agroforestry projects within the Guatemalan highlands required an alternative approach to collect data. The data for the two components of agroforestry systems, agricultural crop and tree, were collected separately. All agriculture data came from the Ostuncalco field interviews. Yet in order to achieve a composite growth rate of different aged trees and estimate the complex interaction between understorey crops and shade, the forestry component compiled data from two other towns in addition to San Juan.

The sole formal agroforestry project studied was in Cabrican, approximately 30 km north of Ostuncalco. There a farmer has intercropped *aliso* trees (alder, *Alnus acuminata*) with maize on terraces. Besides realizing an increase in maize yield with less chemical fertilizer, the farmer has seen the *alisos* growing at a remarkable rate after being cut. The resprout has the advantage of an established root system resulting in growth rates exceeding those of virgin trees by 40-120 per cent.

In nearby Palestina, INAFOR-CATIE/ROCAP conducted a study on a small stand of aliso to determine growth rates and firewood production volumes. *[Martinez et al, 1984]*

Although that group of trees has been harvested, another stand, 11 years old, supplied valuable information concerning growth rates, density and shading characteristics. Other studies conducted in Costa Rica with aliso also provided valuable information in which to verify the field measurements. *[Hughell 1989; Camacho 1987; CATIE 1986; Murillo 1985; Juarez 1991]*

Analytical Framework

From the collected data, a composite farming system was built to be used as an analytical framework. The analysis compares and contrasts two important themes: short- and long-term profitability of land.

Part one examines the short-term profitability of land under different conventional cropping systems. A simple accounting table for all the major crops (*milpa,* wheat and potatoes) lists the labour and capital inputs, and presents the revenue (or value) of all the outputs, including the minor products.

Part two of the analytical framework, containing a proposed agroforestry component, covers a 20-year time frame. The farming system is represented within a linear programming (LP) model framework identifying two land quality categories: prime and marginal.

In order to better capture the positive benefits of traditional cropping systems, the analysis incorporates minor products. More commonly, research efforts emphasize the primary products of the land. For instance, although maize is normally grown along with other crops, the minor products (beans and gourds) are often overlooked. Furthermore, with the production of grain considered to be paramount, conventional economic analysis of a farming system ignores other products such as the stalk, husk and weeds that are used as feed for animals. These minor products, crucial to other farm activities such as livestock, have an inherent value which needs be recognized. Hence, a proper analysis observes the cropping and farming system with the integration of all farm activities and their linkage benefits. Otherwise, the analysis fails to serve the short or long-term interests of the farmer. Optimal land use is determined by a crop's profitability, available labour to complete the tasks, and a crop rotation.

1. *Short-term Accounting: Traditional Crops:* The short-term study covers a period of one year. It examines the farming activities of the principal agricultural crops for a growing season. Since some of the labour activities overlap into the next calendar year, namely maize degraining and wheat threshing, the analysis actually covers a crop production season.

All production is assumed to have an available market. Prices are determined from farmers recall of prices paid for their crops and the actual prices at the San Juan market. Transportation costs and travel time to the fields are also included on an average basis.

The Guatemalan minimum daily wage is ten Quetzales (Q10), which is worth approximately US$2. Hired farm help when found, are paid Q10/day. In the model the price of labour is valued at one-half the minimum legal daily wage rate. With almost no alternative employment opportunities available to rural dwellers, the opportunity cost of labour is not reflected by the legal minimum wage. Also, if farm labour were to be valued at the full rate, earnings from many cropping activities would be negative. Yet, farmers and their families continue to labour on the land. A wage rate of Q5 is used in the analysis, this reflects the estimate of an imputed wage. As long as there is no out of pocket loss to the farmer (capital inputs are less than ensuing revenue), he or she will continue with the toil.

The short-term comparison employs the use of two land quality categories, prime and marginal, with corresponding higher and lower crop yields. Since the primary crops (maize and wheat grain and potatoes) are the main contributors to the cropping system output value and their yields depend greatly upon land quality, only those yields change.

A high correlation between land slope and crop yield makes it important to classify the land quality. Although it was not possible to conclude that the slope of a field was the only factor in determining the land quality, it does serve so in the model. The selected yield estimators for each of the crops in marginal and prime lands reflect actual production figures collected in the field.

On the prime lands, the model optimizes the crop mix choosing from *milpa,* wheat and potatoes. Available labour and capital restricts potato production to 3 cuerdas (1 cuerda = 436 m^2 = approximately .23 hectare).

Possible cropping activities are fewer on the marginal lands. Since potatoes require a great capital inversion in comparison to the other alternatives, their inherent riskiness exclude them from being planted on any land but the best. Therefore, the model chooses from two alternatives: *milpa,* and wheat on prime land.

Land cost depends upon its quality and its proposed use. On prime land, potato production commands the highest price Q50 per crop, or Q100 per season. The yearly cost for *milpa* follows at Q40, and next wheat at Q30. Land costs are lower for marginal lands: *milpa* Q15, wheat Q10.

2. *Long-term Optimization: Traditional and Tree Crops:* A farm with 25 cuerdas of land serves as the representative for the model. Two land qualities are represented: 10 cuerdas are prime land and 15 fall into the marginal land category. In comparison to the conventional agriculture activities which are more familiar, the agroforestry component with its tree crop is complex, and therefore requires a detailed explanation of its workings and simplifying assumptions within the optimization model.

(a) Optimization Model: Profit Maximization. There are three principal ways to maximize profits of tree crops: the utilization of agroforestry systems, the selection of fast growing multipurpose trees and intensive shade management.

(i) *Agroforestry Systems:* The first approach to making a long-term tree project more attractive, is to *frontload* the project's initial years with some income. While the trees are growing, it is possible to cultivate agriculture crops in between, hence the term agroforestry. Income generated by the agricultural crops makes the agroforestry system productive during a time when ordinary forestry projects realize no such benefits.

In the model, the agroforestry system requires relatively few trees so that the initial investment of labour, land and capital is small, thereby lowering the risk of the venture. As the trees crop matures, the cultivation of traditional crops decreases. This inverse relationship is described in more detail below (Intensive Shade Management).

Unlike the above mentioned traditional cropping activities and the sauco agroforestry system, the agroforestry system being treated with the linear programming model is a composite of land use activities found in the Guatemalan highlands. The proposed system functions as a hybrid of the *taungya,* or forest plantation farming, and alley cropping agroforestry systems.

Taungya[3] agroforestry system have caught the attention of some within Guatemala *[Ordonez, 1980]* and CARE personnel. However, little quantification of benefits have been examined or explained.

(ii) *Multi-purpose Tree - The Aliso.* Since the sauco is a tree that produces low quality firewood, a more versatile tree is used for the purposes of this study. One of the most attractive trees to use in highlands' agroforestry system is the *aliso* (alder, *alnus acuminata*). The tree has many positive characteristics. It is good firewood, grows rapidly, produces *broza,* and fixes nitrogen in the soil through its roots. For these reasons, the *aliso* is considered by many farmers to be a very desirable species.

On the negative side, the *aliso* is susceptible to frost damage. When young, the aliso needs protection or it may die from exposure to freezing temperatures; even at more mature ages it can be *burned.* Perhaps *sauco,* which can be propagated cheaply via stakes, could be used as protection while the *alisos* are immature. The *rastrojo,* dry maize stalks, which had been growing alongside the seedlings would also make excellent low-cost production.[4]

Although it may be possible to place a value upon the clear air and water produced by the *alisos*, these potential benefits do not address the immediate concerns of the farmer and are placed aside. Also, additional products of trees other than firewood, such as posts, are difficult to value and may not have a large potential market. However, the trees do produce leaf litter which is in high demand and much valued by farmers to improve soil quality. The model includes the value of the tree's broza production, which is related to the size of the tree. By including *broza* as a product during growing stages, a more true value of the tree component is captured.

(iii) *Intensive Shade Management:* The proposed system attempts to maximize the production potential of the land by simultaneously producing agricultural crops and forest products on the same piece of land. However, trees do have a major negative effect upon crops-shade. The surrounding crops need much light in order to produce a good harvest. It is therefore necessary to annually estimate and try to minimize the quantity of shade cast by the growing trees.

Shade can be minimized by paying careful attention to the tree crop rows. This is achieved by careful pruning and by aligning the rows to take advantage of geographical and meteorological phenomena of the region. Since Guatemala has a latitude of approximately 15°N, the sun travels almost directly overhead during the growing season (Spring - Autumn equinox). Consequently, the shade pattern moves in a linear east-west fashion. It is also important to note that the understorey crops receive the much needed sunshine primarily during the morning. After midday, clouds build up and the daily rains begin. It appears that traditional crops are adapted to receiving the half days of bright light. Nevertheless, a lack of morning sunshine retards the growth of crops that are located to the west of any tall objective. Throughout the countryside, stunted plants can be seen on the western side of any tree or house.[5]

By planting the trees in a wide grid pattern following the points of the compass, the shaded region will cover the area in three stages:

Stage 1: During the first years the trees shade an area to the west and under the tree while crops on the eastern side will be little affected by tree shading. As the trees grow, the shadows will become longer and wider, slowly decreasing the productive agricultural area.

Stage 2: At this time fewer crops can be grown between the trees following the east-west orientation. In effect, there are strips of shade and crops, both running in an east-west orientation.[6] The farmer can minimize the width of the tree strips by pruning branches that grow over the crop area. With wide spacing between the trees and additional pruning, agricultural activity can continue until the branches are left to grow uninhibited.

The severity of the tree branch pruning depends upon the goal of the farmer, either fast tree growth or more agriculture activity. Taken to an extreme favouring agricultural activity, farmers can rigorously prune branches that cover the crop strips. In effect, they create a rectangular foliage region, thereby minimizing shade. When tree growth becomes paramount, the branches can grow unrestrained. Even if the trees are drastically pruned during the initial years, new growth can quickly extend branches in all directions.

Stage 3: The tree canopy is closed and crops cannot be cultivated. Trees continue to grow until they begin to compete for light with each other. This is also the time when tree growth starts to wane. Therefore, the trees are harvested when competition between them arises.

(b) *Optimization Model: Assumptions and Estimation:* For ease of comparison between the traditional agriculture activities and the agroforestry system, the understorey crop is not annually rotated in the model. If wheat and milpa were cultivated on an alternating basis, the profitability results of the agroforestry system would be impossible to contrast against the other three conventional cropping systems. Also, since wheat is the least profitable crop and is quickly losing popularity in the highlands, its incorporation within the agroforestry component is eschewed. For the purpose of clarity and appropriateness to the farmer, only milpa is planted under the trees.

In order to better compare the proposed taungya agroforestry system with *milpa,* the analysis uses land costs for the agroforestry system of Q30 for prime and Q15 marginal lands.

The estimations of tree growth rate, shading effects and firewood production are as follows:

(i) *Tree Growth Rate:* Four linear functions approximate the height and diameter growth rates of the *aliso.* The following functions calculate the growth rates for virgin and resprout tree growth:

***Virgin Aliso:* (Years 1-12)**	***Resprout Aliso:* (Years 12-20)**
Height (m)=1.4(Y)	Height (m)=1.96(Y-12)
Diameter (cm)=1.5(Y)	Diameter (cm) = 2.1(Y-12)

where Y = Year after planting

Fertilizer used for the milpa also benefit the trees, thereby warranting the relatively fast growth rates stated above. The same growth rate is assumed to take place on both marginal and prime land. This is justified by fewer instances of frost damage on the sloping marginal lands.

(ii) *Shading Effects:* The proposed system requires careful management during the growth of the trees. The system begins by planting 25 trees, 4x4 meters apart on one *cuerda* of land. One major obstacle to calculating the annual crop/tree ratio is the determination of the trees' shading effects upon the surrounding crops.

During the years that the crops receive enough unobstructed light between the trees, milpa can be cultivated (years 1-9; 12-17 and 20) in an alley cropping system. The remaining years, the tree canopy is assumed to be closed, not allowing any underlying agricultural activity. In years 12 and 20, all trees are harvested before the planting season to allow for unobstructed growth and avoid potential damage to the underlying crops. The following non-linear function provides a means to approximate the shaded area:

$$\text{Area Shaded } (m^2) = T\, r^2$$

where T = # trees
= 3.14
r = annual radius of branches

Year	
1	: r = .782
2-9	: .782 + (Year -1)(.196)
10-11	: total shade - no agric. activity
12	: r = .782
13-17	: r = .782 + (Year - 12) (.313)
18-19	: total shade - no agric. activity
20	: r = .782

The cost of tree pruning is assumed to be matched and consequently erased by the value of the firewood and *broza* produced during the cuttings. Also, the analysis avoids the prediction of two abstract annual benefits of agroforestry systems. First, the nitrogen fixing capability of the aliso is accounted for only during the year after the tree harvest and second, the soil retention benefit of the trees is not included. These procedures perhaps balance out a possible favouring of the agroforestry system for not formally accounting for pruning labour cost.

(iii) *Firewood Production:* The third estimation required is the volume of firewood produced by the trees. A multiple regression equation serves to calculate the cubic meters of firewood produced by the aliso [Martinez, 1984]:

$$\text{Ln(vol)} = -9.8105 + 1.6137\ \text{Ln(d)} + \text{Ln(h)}$$

where: Ln = natural log
Vol = volume (m3)
d = diameter (cm)
h = height (m)

(c) Optimization Model: Discount Rate Scenarios: In order to evaluate the profitability of long-term use projects, financial analysis discounts the value of products that become available in the future. Yet, in order for those future products to be recognized, their value must be great so that they can be competitive against other practices that provide benefits over a shorter time (i.e. traditional cropping systems). Two procedures attempt to curtail the effects of discounting. First, the faster growth rate of the aliso resprout permits a shorter harvest rotation, thereby allowing the financial benefits to be realized sooner. Second, frontloading a forestry project does help overcome the discounting penalty by making the first years productive with agricultural crops. Nevertheless, when discount rates are high, anticipated long-term income cannot compete with near-term income.

The selection of a proper discount rate for agricultural projects in developing countries is an issue of great debate. D.A. Hoeskstra (1985) raises important issues concerning long-term financial analysis necessitated by the tree component of agroforestry systems. The question of appropriate discount rates for trees depends upon many factors determined by local conditions. Oftentimes discount rates are calculated by using the local borrowing rate or the rate on equity capital. In developing countries where these rates are extremely high, future benefits quickly lose their value. Therefore, rate selection becomes even more problematic.

He argues that in the developing countries this approach is not appropriate since not all farmers have equal access to credit nor are they all able to set aside their equity capital, which in the case of rural farmers is their land. To arrive at the discount rate representative of the small farmers' position (especially the subsistence farmers) it is necessary to assess a farmer's production trend (up or down) and per capita consumption level (well fed or poorly fed).

Hoeskstra's theory is supported by Jacobs (1989) attempt to override conventional financial analysis used for maintaining environmental resources. Discounting land use projects essentially declares that the future of the land resource is worth little or nothing. When a resource's productive capacity to generate income decreases, as in the case with marginal lands, financial analysis deems the resource degradation unimportant. By using a lower discount rate for the economic analysis, future benefits will not be erased in such a drastic manner.

The optimization analysis applies several discount rates to the model, thereby determining the most profitable crop mixes under different scenarios. These results are presented in the next section.

RESULTS

Short-term Analysis: Traditional Crops

1. *Traditional Crop Yield:* Two land quality categories determine the yield of *milpa,* wheat and potatoes. On prime lands, the yields surpass those yields achieved on marginal lands by at least two times in the case of *milpa* and even more so with wheat. Since potatoes are not cultivated on marginal lands, that figure is omitted. Table 2 below summarizes the yield results.

Table 2. Traditional Crop Yield per Cuerda

	Milpa (maize)	Wheat	Potato
Prime land	4 qq.	3.5 qq.	37 qq.
Marginal Land	2 qq.	1.5 qq.	n.a.

qq. = quintal (100 lbs.)

2. *Traditional Crop Annual Profitability:* Prime and marginal land quality indexes are used to compare the profitability of traditional crops. The figures for labour costs and input purchases are the same for the two quality categories, but both the yields (which in turn effect output values) and land cost are distinct between categories. Upon calculating net profit per cuerda of land, one can easily see the difference in profit potential between prime and marginal lands and also among the cropping activities. The most lucrative venture is potato farming which demands the most inputs (labour, capital, land); the least remunerative activity is wheat

production on marginal lands. In both cases, *milpa* is superior to wheat profitability. The following tables (3 and 4) display the accounting summaries:

Table 3: Prime Land Traditional Crop Accounting per Cuerda (Quetzales)

	Milpa	Wheat	Potato
Labour Cost (Q)	46	25	140
Input Purchases	49	45	276
Land Cost	40	30	100
Output Value	196	109	750
Net Profit (Q)	61	9	234

Table 4. Marginal Land Traditional Crop Accounting per Cuerda (Quetzales)

	Milpa	Wheat
Labour Cost (Q)	46	25
Input Costs	49	45
Land Cost	15	10
Output Value	126	67
Net Profit (Q)	16	(-3)

Long-Term Analysis: Traditional and Tree Crops

1. *Agroforestry System:* The results of the annual tree diameter and height, shaded area (m^2 and %), production volume of firewood, firewood value, and the agroforestry system annual earnings appear in the appendix. To calculate the earnings of the agroforestry system, the analysis uses a firewood price of Q54.2/m^3 and Q30/cuerda for *broza* (this figure represents production at a mature full cover forest, therefore the analysis pro-rates the production). In year 12, the firewood is worth Q245.6 and Q257 in year 20 (undiscounted).

Total earnings of the agroforestry system (undiscounted) includes firewood, *broza* and *milpa* production of the specified year. The intercropped *milpa* is analyzed on a basis which complies with the non-shaded area of the land. Average annual undiscounted earnings are Q31.7 for the agroforestry system.

2. *Profit Optimization of the Farming System:* The long-term analysis adds the agroforestry dimension to the short-term crop analysis. A 20-year time period allows the tree component of the agroforestry system to mature and provide its fuelwood and *broza* benefits for two cycles: the slower initial and the subsequent faster resprout growth.

While applying different discount rates, the model produces crop mixes for the prime and marginal lands that optimize farm earnings for the 20-year time period. The model's 25 cuerda representative farm (10 cuerdas of prime land and 15 marginal) is the framework for the profitability analysis at different discount rates.

If negative values arise within the model's objective function during the linear programming calculations, the program does not run. This restriction of LP necessitated the use of slight alterations within the model's framework. During the first year when the trees are purchased and planted, costs for that year exceeded revenues. Also when there was no agricultural activity, the broza production value did not cover the prime land cost. It was therefore essential to raise the revenues during the deficit years. This is accomplished through the normal procedure of a loan which was offset by a reduction in the tree harvest value.

Profit on the farm's prime land is peak with 3 cuerdas of potatoes (maximum allowed via labour and capital constraints) and 7 of *milpa*. Neither wheat nor the agroforestry system could compete with the income generating capabilities of *milpa* and potatoes at any applied discount rate on prime land.

The results for the marginal land depends upon the discount rate utilized. Where the model applies a discount rate below 14 per cent, the agroforestry system financially outperforms equally discounted *milpa* and wheat. At rates above 14 per cent, *milpa* production is the most profitable cropping system. Higher discount rates reduce the future value of the agroforestry system's firewood and *broza* value to the point where the discounted *milpa* becomes a greater income producer. Under no circumstances did wheat production arise in the optimization model. Results are summarized in Table 5.

Table 5 demonstrates the break-even point where the proposed agroforestry system's discounted profits equal those of traditional *milpa* production. If a discount rate less than 14 per cent is used, it is more profitable to devote the marginal lands to agroforestry systems.

CONCLUSION

This paper demonstrates the financial benefits of agroforestry systems for farmers who cultivate marginal lands. The results show that the inclusion of trees within a farming system can provide a means for greater income and can satisfy the Guatemalan farmers' desire to find alternative income generating crops. Moreover, the long-run viability of the farming system is enhanced by the utilization of trees which protects the soil resources needed for continued production.

In order to achieve greater farm profitability, the present trend of non-traditional agriculture crop promotion for external markets needs not continue. These fresh fruit and vegetable exports are not eaten by the Guatemalan populace and their cultivation undermines the farmer's land resource. The agroforestry systems that are financially justified in this analysis help satisfy household and local demands for maize and fuelwood while protecting the resource base. Also, by avoiding non-traditional crops and earning profits from an agroforestry system, more independent and local trade can take place, thereby avoiding a dependence upon national and international agriculture produce marketers.

The model's formula where trees are planted and harvested *en masse* does not have to be followed in the field. As sequential agroforestry system of establishment and harvesting would stabilize both firewood and maize production.

These results are very encouraging within the larger context of economic development. In conventional economics the tendency is to underestimate the true costs of traditional cropping systems by not incorporating negative externalities, for instance soil loss, into cost accounting procedures. In addition, the benefits of trees within a farming system are generally underestimated by not including their positive externalities, such as watershed maintenance. Recognition of these deficiencies of conventional economics further increases the significance of the research results.

Footnotes:

[1]Proyecto Agroforestal (DIGEBOS/CARE/Peace Corps) claims that their tree projects have an overall survival rate of 76% (Lopez, 1991).
[2]The term Milpa in this study is different from the huastec Mayan swidden system (Alcorn 1989), it is not "*an agroforestry system that integrates secondary successional forest with maize production*".
[3]*Taungya,* derived from a Bermese word ... is an agroforestry method widely used in East and West Africa to avoid weeding costs and sometimes clearing costs, in establishing forest plantations... Alley cropping, or alley farming, entails the planting of trees and shrubs and growing agricultural crops between them. The hedgerows, besides adding nitrogen to the soil, also provide leaf mulching [litter], fuelwood, and soil conservation benefits (Cook, 1989).
[4]Two other trees which may be good alternatives to the aliso are cerezo (cherry, *Prunus capuli*) and (eucalipto, *Eucalytus globulus*). Both species resprout and have fast growth rates, also the cerezo is resistant to frost. On the downside, the cerezo's fruit can attract children with ensuing damage to surrounding crops. The leaves of the eucalipto while being medicinal are thought to inhibit undergrowth. It is also accused of drying surrounding soil.
[5]Even though Guatemala experiences a *canicula,* a two week dry period during July, it does not make up for the lack of afternoon sunshine.
[6]On hillside, alley cropping procedures normally dictate that the trees be planted following the slope contour. However, the tree planting should heed the east-west orientation in order to maximize agricultural activity.

Table 5. Long-Term Optimization: Cuerdas Land Allocated to Cropping Systems

Land Quality	Discount Rate	*Milpa*	Wheat	Potato	Agroforest	Total Land
Prime Land	0 - 99%	7	0	3	0	0
Marginal Land	0 - 14	0	0	N/A	15	15
	14 - 99	15	0	N/A	0	15

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Appendix. Agroforestry System Results (Q = Guatemalan Quetzales)

Year	Tree Diameter (cm)	Tree Height (m)	Area: Shaded (m^2)*	Area: Shaded (%)	Firewood Vol. m3/ cuerda	Firewood Value Q/cuerda	Agroforestry System Total Earnings (Q)
1	0.5	0.2	48	11			0.6
2	1.5	1.4	48	11			12.6
3	3.0	2.8	74	17			10.5
4	4.5	4.2	109	25			9.5
5	6.0	5.6	148	34			8.5
6	7.5	7.0	194	44			7.4
7	9.0	8.4	245	56			5.6
8	10.5	7.5	303	70			3.1
9	12.0	9.0	367	84			2.8
10	13.5	10.5	436	100			1.0
11	15.0	12.0	436	100			3.0
12 cut	16.5	13.5	436	100	4.17	226	245.6
12 after	0.0	0.3	48	11			12.6
13	2.1	1.96	48	11			12.5
14	4.2	3.92	95	22			10.6
15	6.3	5.88	155	36			7.8
16	8.4	7.84	222	53			4.6
17	10.5	9.80	326	74			2.0
18	12.6	11.76	436	100			2.0
19	14.7	13.72	436	100			2.0
20 cut	16.8	15.68	436	100	4.39	238	257.5
20 after	0.0	0.3	48	11			12.6

*$436m^2$ = 1 Cuerda