

OPTIMAL RESOURCE ALLOCATION FOR DEVELOPMENT
PLANNING AND POLICY FORMATION IN THE OCOA
WATERSHED, DOMINICAN REPUBLIC

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ABSTRACT

OPTIMAL RESOURCE ALLOCATION FOR DEVELOPMENT PLANNING AND POLICY FORMATION IN THE OCOA WATERSHED, DOMINICAN REPUBLIC

By

Jose Abel Hernandez Batista

The Dominican Republic is now facing a major natural resources problem, because many small hillside farmers have destroyed the natural perennial groundcover and have replaced it with short cycle crops on slopes which often surpass hundred percent. Around twenty two percent of the nation's land area is devoted to land uses ecologically inappropriate to hillside farms. These lands are seriously threatened by high soil erosion rates, caused by current cropping pattern.

The Ocoa watershed is one of the most critical watersheds in the country, where erosion levels are on the order of 500 to 1,200 tons per hectare per year, on land where not more than 10 tons per hectare per year would be considered ecologically sound in the long run.

A static linear programming model was developed to determine the optimal allocation of resources in crop production in the Ocoa watershed. Resource constraints included those dealing with land, labor, capital, soil loss tolerance (T-value), and average minimum family labor wage. Two separate models were considered: A income maximization model, and a soil loss minimization model.

Existing crop rotations and potential agroforestry activities were considered in both models. Crop enterprise data were taken from secondary sources. Agrophysical data were generated from a geographical information system. Average soil loss was estimated by using the Universal Soil Loss Equation.

Seven computer runs were made for the income maximization model. These included an increase in the T-value by two and by three; increase in farmers' own capital by 50 and 100 percent respectively; a combination 50 percent increase in farmers' own capital and 2 T-values; 100 percent increase in the net farm income for coffee; and a reduction of the discount rate from 25 percent to 15 percent for agroforestry activities.

Within the resource constraints for both models, it was found that Eucalyptus camaldulensis is the best crop to produce on slopes of 30-40 percent. The value of the optimal solution for the income maximization model represents 51 percent of the total farm income generated under the existing cropping pattern. However soil loss under this optimal program is estimated to be 8 percent of the current level. Under the soil minimization model, the value of the optimal solution is 60 percent lower than in the current situation, but the soil loss produced is only 0.002 percent of the current soil loss. The soil erosion-employment ratio is equal to 2.97, 0.11, and 5.95, for the income maximization, soil minimization model and for the

Jose Abel Hernandez Batista

current situation, respectively.

Data limitations and limitations of the model, as well as recommendations for policies and future research are discussed.

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Dedicated

to

my lovely family:

Bienvenida,

Jose Abel,

and

Maria Estefania

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CHAPTER I

INTRODUCTION

Characteristics of the Dominican Republic

The Dominican Republic shares with Haiti the island of Hispaniola, the second largest (77,914 Km²) of the Greater Antilles. The Dominican Republic occupies the eastern two-thirds of the island, which covers 48,442 Km², and is located at the 17° 36' - 19° 58' N latitude and 68° 14' - 72° 01' W longitude. See Figure 1.1 [Hartshorn, et al., 1981].

The Dominican Republic population is estimated at 5,430,879, of which approximately 50 percent live in rural areas. The average density is estimated at 112 inhabitants per Km² (ONE, 1980), and the current population growth has been estimated at 2.5 percent [ONE, 1980].

The physiographic complexity of the country provides a climate regime with variable conditions from arid to wet and low land to montane. Four major parallel mountain ranges trend northwest-south west. The central mountain extends from northwestern Haiti almost to Santo Domingo.

The amount and distribution of rainfall is an important variable affecting the agricultural production and natural vegetation. The annual level of rainfall varies from 500 mm in the dry area to 4000 mm in the wet area, mainly in the

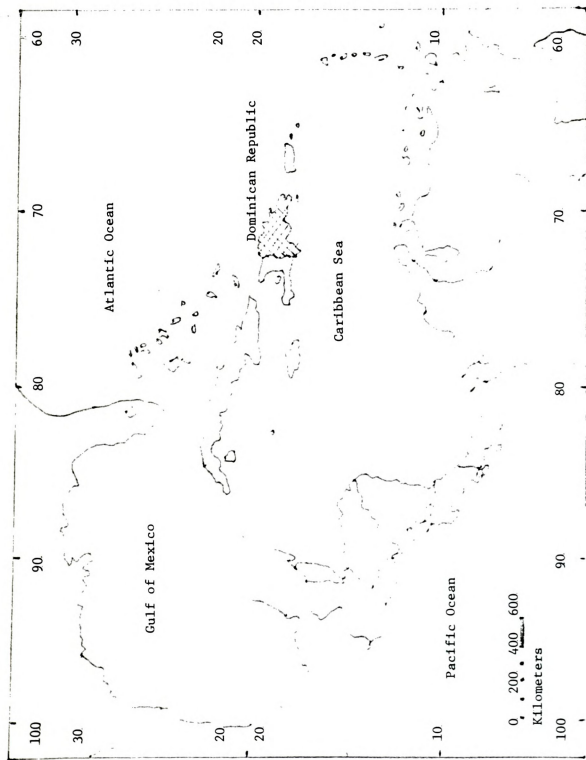


Figure 1.1. Location of the Dominican Republic

mountains. Temperature varies from 18°C to 24°C

[Lora, et al., 1983].

The Dominican Republic (DR) lies in the subtropical hurricane belt, being hit by Frederic and David during 1979, by Emily in 1986 and by Gilbert in 1988, each causing intensive natural resources damage.

The DR [Appendix A] is a Caribbean island country which is about 80 percent hilly and mountainous, with elevations from below sea level to over 3,000 meters. It was considered 100 percent forested at the term of the century, becoming 69 percent in 1946, and fell to 16 percent in 1980 [Kemp and Hernandez, 1987].

Actually the country is now facing a major natural resources problem, because many small hillside farmers who have destroyed the natural perennial groundcover and have replaced it with short cycle crops on slopes which often surpass 100 percent. It is assumed that small farmers have moved up to hillside areas, as result of the completion of the Bani-Constanza road and /or because during the 1950, a wave of population followed the lumbering companies, and the deforested land were put into farming [Hansen, no date]. A Country Environmental Profile (CEP) carried out in 1980, identifies the watershed degradation problem as the highest priority [Hartshorn, et al., 1981]. Unless some actions are taken to put this degradation problem under control, much of the soil resources used for producing the nation's food crops will be lost and water reservoirs (dams), important

sources of irrigation water and hydroelectric power, will be reduced by the high level of sediments (siltation).

The total land area of the DR is about 4.8 millions has. About 3.6 millions has. are classified as ecologically fragile and potentially critical, hilly to steep land (USDA-SCS Class IV, VI and VII) [USAID, 1981]. It has been estimated that around 1.06 millions, 22 percent of the nation's land area is devoted to land uses ecologically inappropriate to hillside farms and are seriously threatened because of high erosion rates. Without a proper treatment of this land for the next 20 years the country will face a natural resource emergency [CRIES, 1980 and USAID, 1981].

According to the CEP, massive watershed erosion on the order of 95 to 500 metric tons per hectare per year is literally drowning the reservoirs with sediments. This has been the situation of the Valdesia dam, which in just two years (1979-81), accumulated 500M^3 of sediments due to the effects of the hurricanes David and Frederic in 1979. The cost of dredging Valdesia's reservoir was estimated to be approximately $\text{US\$}3.00/\text{M}^3$ in 1985 [Southgate and Lyon, 1985].

In many watersheds large areas have been eroded down to the parent material as a result of heavy, intense rainfall. The severity of this problem was demonstrated by GODR estimates of soil loss in seven principal watersheds, which are considered to be representative of the majority of the nations' watersheds.

Data in Table 1.1 indicate that in many watersheds,

erosion is so advanced and so severe that destruction of the entire soil base could be completed easily within two or three decades.

Table 1.1 Level of Erosion in Seven Watersheds in MT/ha/year.

Watershed	Area (hectares)	Erosion (MT/Ha/year)	Erosion (Cm/Ha/year)
Las Cuevas	56,900	275	1.83
Tavera	73,700	275	1.83
Bao	93,330	346	2.31
Nizao	99,200	125	1.84
Ocoa	56,300	507	3.38
Guayubin	73,400	111	0.74
Chacuey	38,600	95	0.64

Source: The Dominican Republic Country Environmental Profile, 1981.

Technically speaking, erosion rates that are above the 10 to 30 metric tons. per hectare per year range are generally considered to be serious. However, all estimated DR erosion rates are much higher than the level of erosion that defines a problem condition and in some watersheds the rate is so high that the erosion problem has become a crisis [Hartshorn, 1981].

Due to hillside deforestation and planting of erosive short-cycle crops, the country is experiencing erosion levels on the order of 500 - 1200 tons/ha/year on land where not more than 10 tons/ha/year is considered ecologically and economically sound in the long run [Hernandez and Kempf, 1985].

Problem Definition

Description of the Study Region

The Ocoa watershed is located in the Province of Peravia, about $18^{\circ} 30'$ latitude. The Ocoa Watershed has at the north and at the west the Province of Azua, at the south the Caribbean Sea, and at the east the Nizao river watershed [SEA, 1985]. Figure 1.2 shows the location of the study region. The watershed has an area of approximately 700 km^2 ($70,400 \text{ Ha.}$), of which 19 percent has slopes greater than 50 percent, 26 percent of the area with slopes of 30 to 50 percent, 18 percent of the area has slopes of 20 to 30 percent, 9 percent with slopes of 15 to 20 percent, 6.1 percent with slopes of 12 to 15 percent, 5.3 percent with slopes of 8 to 12 percent, 8 percent with slopes of 4 to 8 percent and an area of 8.2 percent has slopes less than 4 percent [Witter, et al., 1985].

This means that over 60 percent of the watershed has slopes greater than 20 percent. It is this area where over 50 percent of the subsistence farming is carried out, generating great amount of soil erosion. The Ocoa and the Banilejo are the most important sources of superficial water in the watershed. The Ocoa river originates in the northern of the watershed, and water drains into the Caribbean Sea at the south side of the watershed.

The rainfall level in the watershed varies from 400 to 900 mm. per year in the lower part of the watershed, with a temperature of 26 to 29°C ; and from 1000 to 2400 mm. per

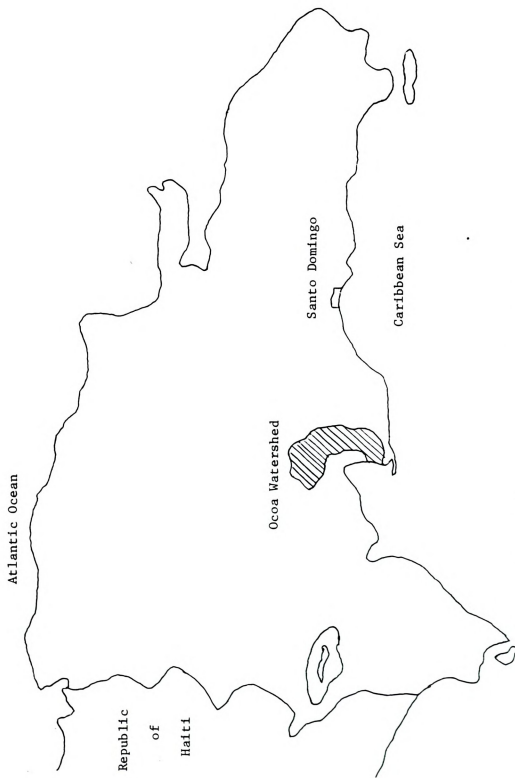


Figure 1.2. Location of the Study Area

year in the upper part, with a temperature that varies from 15 to 25° C.

The land use in the watershed has experienced a drastic change in the last forty years. The comparison of land use cover maps developed from 1946 and 1983 air photography illustrate the major changes in the watershed land use during this time period [Witter, et al., 1985].

In 1946, about 35 percent of the Ocoa area was covered by forest (conifers and broad-leaved), 8 percent and 16 percent were under intensive and extensive crops use respectively, and 29 percent of the watershed area was covered by brush. The term "cropping intensity" denotes the proportion of land planted to each crop during a year. High proportion indicate an intensive cropping patterns, while low proportion indicate an extensive cropping system.

In 1984 the land use cover of the Ocoa watershed was as follows: 7 percent of the area was covered by forest (conifers and broad-leaved), which represent a reduction of 29 percent with respect to the 1946 land use inventory; the use of intensive crops reached a 40 percent, which represents an increase of 32 percent with respect to the 1946 land use cover. But the use of extensive crops dropped from 16 percent in 1946 to 6 percent in 1984, while the area covered by brush reached 41 percent, which is a 22 percent higher than the estimated brush cover in 1946. Table 1.2 shows details. The Ocoa watershed has an estimated population of 48,610 inhabitants of which approximately

Table 1.2. Land Use Cover in the Ocoa Watershed in 1946 and 1984.

Land use	1946		1984	
	Area in km ²	%	Area in Km ²	%
Forest Conifer	74.88	10.59	37.30	5.32
Forest Broad Leaves	177.25	25.36	17.32	2.47
Intensive Crops	62.65	8.86	283.60	40.42
Extensive Crops	113.55	10.06	44.12	6.29
Brush	208.31	29.47	291.30	41.52
Natural Pasture	52.36	7.41	7.15	1.02
Improved Pasture	---	--	7.50	--
Ocoa River Bed	15.44	2.18	15.15	2.16
Urban	0.48	0.07	3.95	0.56

Source: Cries Project. Natural Resource Inventory of the Dominican Republic. Michigan State University. 1980.

34,524 live in rural areas and 14,086 live in the urban area of San Jose de Ocoa [ONE, 1981]. The movement of labor force from the urban area to the rural zone to work in agricultural activities is not significant [Hansen, no date]. Table 1.3 shows that 54 percent of the rural population is less than 17 years of age while 46 percent are adults. About 53 percent of the adults are male, representing 24 percent of the rural population. The remaining 47 percent are female, representing 22 percent of the rural population.

Total total population density in the watershed has been estimated to be 70 inhabitants per square kilometer, and the rural inhabitant density is 25 per square kilometer [USAID, 1981].

The hillside farmers forced by the population density pressure have been cultivating hillside areas, which are the only lands available within the watershed, even though those

areas are highly vulnerable to erosion.

The typical size of the target farmer family consists of a man and wife and four to six children [Hansen, no date]. The size of the farm averages about two hectares and it is located in the steep mountain slopes of the almost marginal land of the watershed. It has been estimated that about 80 percent of this steep land is in short cycle crops and about 20 percent is used for grazing.

Table 1.3. Level of Rural Population per Sex and Age in each Village in the Ocoa Watershed.

Village	Adults			< 17 Years Old	Total
	Men	Women	Total		
Arroyo Cana	1651	1464	3115	3872	6987
El Pinar	1034	917	1951	2353	4304
El Rosalito	510	452	962	1177	2139
La Cienaga	1549	1374	2923	3409	6332
La Horma	2238	1985	4223	4869	9092
Los Anones	687	610	1297	1484	2781
Los Ranchitos	685	606	1291	1598	2889
Total	8354	7408	15762	18762	34524
	53 %	47 %	100 %		
	24 %	22 %		54 %	100 %

Source: Oficina Nacional de Estadística. Censo de Población y Viviendas 1981. Santo Domingo. Dominican Republic.

The agricultural practices used by farmers are the major cause of soil erosion and nutrient loss in the watershed (507 tons/ha/year), and result in lower productivity, because approximately 3.38 cm. of soil per hectare are washed out every year [USAID, 1981]. It is assumed that this situation is one of the major cause of farmers' poverty.

Another cause of the natural resource degradation problem is the increased clearing of the natural forest for fuelwood consumption. In the Dominican Republic there is a large demand for fuelwood and charcoal, due to the high price of petroleum and to the increasing rate (cost) of the foreign exchange (dollar).

The heaviest users of fuelwood are mainly, bakeries, sugar refineries, pizzerias, laundries, meat roasters, and some rural homes; while the major charcoal consumers are urban homes, restaurants, chimi-churri stands, and small industries. On the other hand the demand for small or medium trees is made by, tobacco producers (poles and rafters), rural construction, stakes, fence posts, power poles, scaffolding, furniture, and all type of lumber [Knudson, et al., 1988]. Depending on rainfall, farmers typically have up to three annual cycles of short cycle crops such as: Peanuts (Arachis hypogea, L.), pigeon peas (Cajanus cajan, L.), beans (Phaseolus vulgaris, L.), corn (Zea mays, L.), tomatoes (Lycopersicon lycopersicum, L.), cabbage (Brossica oleracea, L.), papaya (Carica papaya, L.) plantain (Musa paradisiaca, L.), pepper (Capsium annum, L.), sweet potatoes (Ipomea batatta, L.), potatoes (Solanum tuberosum, L.), onions (Allium cepa, L.), citrus (Citrus spp.).

There are some irrigated areas in the Ocoa Watershed, a large portion of which is located in the study area, specifically in La Nuez microwatershed [SEA, 1985]. It is

estimated that approximately 20 percent of the area is under irrigation, mostly in small irrigation projects.

For purposes of this research, this microwatershed is considered as two microwatersheds, one includes irrigated land and the other includes non-irrigated land. In the irrigated land, the crop production is more intensive and the following crops are planted: strawberry, potatoes, onions, cabbage and other vegetables. The existing farming system in the Ocoa Watershed varies with the agroecological conditions of the zone. It varies from mixed cropping to relay or intercropping and sequential cropping. Mixed cropping is defined as "growing more than one species on the same piece of land at the same time, or with or short interval" [Beets, 1982 and Gomez, 1983]. Mixed cropping is found in the micro watershed Arroyo la Vaca and La Malagueta, mainly during the spring season when pigeon peas, beans or peanuts and corn are planted at the same time. Relay cropping consists on "planting crops between plants or rows of an already established crop during the growing period of the first planted crops" [Beets, 1982 and Gomez, 1983]. Relay cropping takes place during the fall season in Arroyo La Vaca and La Malagueta, when farmers plant beans or peanuts and corn within the existing pigeon peas plantation. On the other hand, sequential cropping is defined as "growing two or more crops in sequence on the same field per year" [Andrews and Kassam, 1976 and Gomez, 1983].

The succeeding crop is planted after the preceding crop

has been harvested. There is not intercropping competition, and farmers manage only one crop at a time in the same field.

The sequential cropping system is found in the upper part of the watershed, which includes La Nuez microwatershed and some areas of the boundary between La Malagueta and La Nuez micro watersheds. In La Nuez and in the boundary between La Nuez and La Malagueta, due to the climatic conditions, farmers are used to planting potatoes, cabbage and onions. On the other hand, mixed cropping and relay farming system are normally found in the remaining part of the watershed with the exception of the areas noted above.

I The mixed cropping farming system usually consists of the association of different proportion of the following crops: pigeon peas with beans and corn; pigeon peas, peanuts and corn; pigeon peas and beans; and pigeon peas and peanuts. In the Arroyo la Vaca microwatershed, pigeon peas is considered as the primary crop, and beans and peanuts are considered as secondary crops, while corn is always a tertiary crop. On the other hand, in La Malagueta, pigeon peas is a secondary crop, while beans is the primary crop.

According to a survey carried out during May in 1984 in the watershed, about 83 percent of the farmers plant beans, 57 percent plant potatoes, 53 percent plant corn as well as pigeon peas, 29 percent crop onions and 27 percent of the farmers used to crop cabbage [Poy, 1984].

In the Ocoa watershed there are two cropping seasons: Spring (April-May) and fall (August-September), leaving the land idle during the winter season (January-March).

However, where irrigation is available, farmers plant year around. Table 1.4 shows details about the planting and harvesting seasons [SEA, 1982, 1982a, 1985a, and 1988]. The land tenure system in the Ocoa watershed can be classified into two general categories. Most farmers differentiate between land to which they have legal title or believe the lands to be rightfully theirs through occupancy over time, and land to which farmer does not hold title, which includes methods such as rent, use on a loan basis or share cropping. There is land fragmentation within the watershed, which is expected to continue in the future. It is expected that land fragmentation will increase, because farmers are not interested in migrating out the watershed. On the other hand, there is a belief that "the valley is a paradise due to the pleasant climate, and because the cost, risk and uncertainty outside the valley may be too high that they can not afford" [Thomas and Watson, 1985].

Implementation of the NARMA project in the watershed has been introducing many changes in the cropping system.

- * First, there is evidence of a movement away from subsistence crops to cash crops, especially in the upper watershed, where vegetables (cabbage, onions, carrots) and potatoes are planted to meet outside demand, mainly the Santo Domingo

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Potatoes 1				xxx	xxx		++	++				
Cabbage 1				xxx	xxx		++	++	xxx		++	++
Onion 1	xxx			++					xxx			
				xxx	xxx		++	++				
Beans				xxx	xxx		++	++	xxx		++	++
Corn				xxx	xxx		++	++				
				xxx	xxx		xxx	xxx			++	++
Pigeon Peas	++	++	++	xxx	xxx						++	++
				++	++							
Peanuts				xxx	xxx		++	++				
Coffee				xxx	xxx	xxx			xxx	xxx	xxx	xxx
				++	++	++				++	++	++
Banana				xxx	xxx							
				++	++	++	++	++	++	++	++	++
Eucalyptus				xxx	xxx							
				++	++			++			++	

1 => Crops planted under irrigaez micro watershed.

xxx => Planting and ++ => Harvesting.

Source: Secretaria de Estado de Agricultura, 1982, 1982a, 1985a, and 1988.

Table 1.4. Planting and Harvesting Season for Some Crops in the Ocoz Watershed.

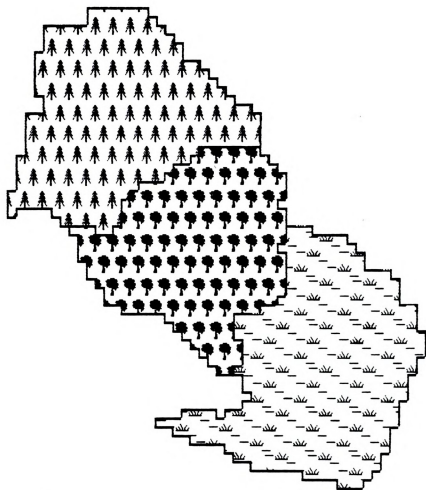
market [SEA, 1985b]. Second is the introduction and implementation of soil conservation practices on about 90 percent of the farms in the watershed. This soil conservation plan is elaborated assuming the best alternative use for that individual farm, but it does not mean that the combination of individual farm plans is the best alternative land use for the entire watershed and the whole community.

The Study Area

This research study focused on the upper part of the Ocoa Watershed, because very intensive agricultural activities take place in this area. The target area is includes three microwatersheds, Arroyo la Vaca, La Malagueta, and La Nuez which includes irrigated and non-irrigated land. For the purpose of this research, La Nuez is considered as two microwatersheds, which make a total of four microwatersheds. Figure 1.3 shows the configuration of these microwatersheds.

Over 70 percent of the total area of the study area has slopes exceeding 30 percent, which contains over 60 percent of the existing intensive and extensive agriculture [Table 1.5]. In these microwatersheds, public and private agencies as well as local communities have made great efforts to implement soil conservation practices, to reduce soil erosion generated by the production of short cycle crops on land with very steep slopes.

Because of agroclimatic conditions of each



La Nuez



La Malagueta



Arroyo La Vaca

Figure 1.3. Configuration of the Microwatershed

microwatershed, farmers follow a specific crop rotation in the study area. In La Nuez potatoes are planted in April-May and harvested in July-August, followed by cabbage that

Table 1.5. Area in Ha. by Slope Category in each Microwatershed.

Slope	La Nuez	La Malagueta	Arroyo La Vaca	Total	%
< 20	--	--	1381	1381	13%
20-30	422	369	644	1435	13%
30-40	1332	868	1633	3813	35%
> 40	1937	1993	386	4316	39%
Total	3691	3230	4024	10945	100%

Source: CRIES-GIS/MSU. Departamento de Inventario de los Recursos Naturales. SEA. Santo Domingo. Dominican Republic.

is planted in August-September and is harvested during November-December. During January farmers plant onions under irrigation, and harvesting take place in March-April. However, for those farmers lacking irrigation, their lands stay idle during those three months. Potatoes and onions are not planted during August-September because of the existing low temperature in the area during that period of time.

In La Malagueta microwatershed there is a mixed cropping and relay farming system, which is described as follows. Farmers are used to planting beans, corn and pigeon peas in April-May as well as in July-August. Corn is harvested in July and then beans are planted during July-August as relay cropping with the existing pigeon peas.

In Arroyo la Vaca microwatershed, farmers plant pigeon

peas, corn and peanuts or beans in April-May. Corn and peanuts are harvested in June-July, leaving the pigeon peas plantation. Then a relay of corn with peanuts or corn with beans is planted during June-August, within the existing pigeon peas plantation. However some farmers might not plant corn again during this season.

The spatial aggregation to be used in this study is the agroecological production zones (called Resource Planning Units or RPU), which represent areas with physical characteristics considered relatively homogeneous at the level of detail supported by land evaluation [Schultink, no date].

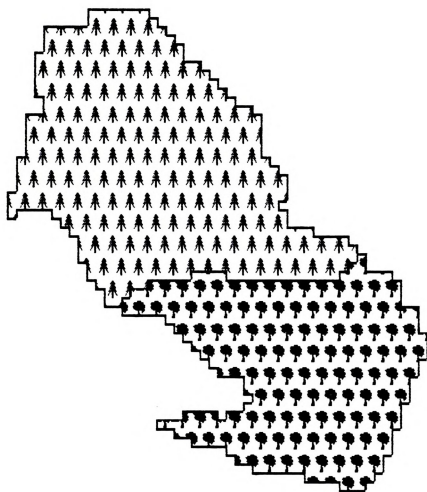
There are two agroecological production zones or RPU, the RPU 02 and the RPU 40 in the study area [Figure 1.4]. Total areas by RPU (in ha.) in the three microwatersheds are shown in Table 1.6.

Table 1.6. Area by RPU and Microwatershed.

Microwatershed	R P U				
	02		40		Total
	Ha.	%	Ha.	%	
La Nuez	3692	(100)	--		3692
La Malagueta	2324	(72)	906	(28)	3230
Arroyo la Vaca	347	(9)	3677	(91)	4024

Source: CRIES-GIS/MSU. Departamento de Inventario de Recursos Naturales. SEA. Santo Domingo. Dominican Republic.

The total area of La Nuez is in RPU 2. La Malagueta microwatershed has 72 percent of its area in RPU 2 and 28



RPU 02



RPU 40

Figure 1.4. RPU Map

percent in RPU 40, while in the Arroyo la Vaca microwatershed 9 percent of the area is in RPU 2 and 91 percent is in RPU 40. RPU 02 is formed by mountains with slopes greater than 30 percent, hilly with slopes between 15 percent to 30 percent and some small valley with slopes less than 15 percent.

The climate in RPU 02 can be defined as very humid, with a level of annual precipitation around 1400 mm. to 2000 mm [SEA, 1985c].

On the other hand, RPU 40 is also characterized by mountains with slopes greater than 30 percent but with soils moderately acidic. Hillsides in the RPU have slopes of 8 percent to 30 percent. The climate is humid, with a level of annual precipitation of 1300 mm. to 2000 mm [SEA, 1985]. Total areas by slope classes and RPU within each microwatershed are shown in Table 1.7.

Table 1.7. Area by Slope Category and RPU in each Microwatershed.

Category	Microwatershed					
	La Nuez		La Malagueta RPUs		Arroyo la Vaca	
	02	40	02	40	02	40
< 20	--	--	--	--	--	1381
20-30	422	--	325	44	162	482
30-40	1332	--	508	360	94	1519
> 40	1937	--	1491	502	90	296

Source: CRIES-GIS/MSU. Departamento de Inventario Recursos Naturales. SEA. Santo Domingo. Dominican Republic.

It should be noted that Arroyo la Vaca microwatershed

is much more flatter than the other microwatersheds.

In the four microwatersheds there are two predominant farm sizes, small and medium size. Small farms are those whose area is less than 2.5 has., while medium farms are those with an area greater than 2.5 has. and less than 5 has. [SEA, 1982]. However farm size is not being considered in this research, because data were insufficient.

In the same manner, two types of technology used by farmers within the target area are identified. Technology is defined as a combination of all management practices for producing or storing a crop or crop mixture. Each practice is defined by the timing, amount, and type of various technological components, such as variety, land preparation, fertilizer, or weeding [Cimmyt, 1985]. The level of technology used in the watershed can be classified as low, or traditional, and medium levels. Low technology refers to a farming system where little or no improved management technique is used. Farmers use traditional methods with little or no fertilizer or chemical inputs and no conservation practices. Under this level of technology, yields are low with high fluctuation. On the other hand, medium technology refers to operations where improved methods are implemented. It includes use of conservation practices and chemical inputs in an inconsistent or irregular manner. Hence, high technology would be characterized by use of conservation practices and chemical inputs in a consistent or regular manner. However, for

purpose of this research high technology is not considered, because it has not being identified in the Ocoa watershed.

Within the study area farmers typically crop beans, pigeon peas, potatoes, peanuts, onion, cabbage and corn. Crops are usually mixed, pigeon peas with beans and corn; pigeon peas with peanuts and corn; pigeon peas and peanuts; and pigeon peas and beans. Beans, corn and pigeon peas are produced for consumption and for sale, while peanuts, potatoes, onion and cabbage are considered cash crops, hence, are produced for sale.

In the existing farming system, potatoes and beans are considered primary crops, 72 percent and 59 percent of the time respectively. Primary crops are those crops that occupy the largest proportion in the farm and the highest participation in the total net farm income. On the other hand, secondary crops are those crops whose proportion in the farm is small and share in the total net farm income is also low. About 14 percent and 24 percent of the time that these crops were planted, they were considered as secondary crops. However, crops such as cabbage, pigeon peas, onion and peanuts are planted usually as secondary crops (Hansen, no date). Also, in the study area there is great land use potential for coffee and Eucalyptus. Actually coffee trees, and Eucalyptus are growing very well in the three microwatersheds under study. There are farmers that have small plantations of coffee and they have obtained good yields.

The Eucalyptus camaldulensis as well as Pinus occidentalis are the forest species with highest production potential for the Ocoa watershed. These two species can grow without problem in very low deep and infertile soils [Brunn, 1988]. Eucalyptus camaldulensis is one of the most planted trees in the world. It grows very rapidly, is a genetically diverse tree of large size and fairly heavy wood [Knudson, et al., 1988]. This species requires rainfall levels between 200 to 1250 mm. It is recommended for semi-arid to medium rainfall, basic or neutral soils, and can grow in any altitude in the Dominican Republic [Knudson, et al., 1988]. This recommendation is based on initial growth trials and observations of field plots and pilot project plantations carried out in the Dominican Republic. Yields of the species vary from 20 to 25M³ per ha. per year, which is assumed to be normal for the Dominican Republic [Knudson, et al., 1988]. It has been suggested that forest species such as Eucalyptus should be planted with a spacing of 3m x 3m and intercropped with annual or short cycle crops for at least two years. This agroforestry system is called Taungya, which is defined as "a growing food crops with trees, during the tree crop establishment phase" [Rachie, 1983]. This means that short cycle crops are planted until the development and growth of the trees or perennial crops, make no possible short cycle crops to grow.

Research on taungya has been done by CATIE, in Costa Rica, where seasonal crops have been combined with the

initial stages of more permanent tree raising. It has been found that taungya is more economic than planting trees alone [Budowski, 1983]. Taungya experiments carried out by CATIE include combination of *Eucalyptus* with beans, *Eucalyptus* with maize, and coffee associated with beans, and *Erythrina poeppigiana*. *Erythrina* is used for the provision of shade, fixing nitrogen and organic matter [Budowski, 1983]. The agroforestry system taungya is being used widely in the Tropic with positive results. In the Dominican Republic an agroforestry model used for hill-side farming, is the use of *Calliandra calothyrsus* intercropped with seasonal crops. Trees are planted in dense rows along the contour forming a barrier to run-off and holding some of the surface soil. Crops are planted between tree rows. It has been found that trees help to retain soil moisture, provide organic matter and increase nitrogen levels, which in turn helps to reduce fertilizer needs according to farmers [Knudson, et al., 1988]. In Africa, *Eucalyptus melliodora*, *Eucalyptus camaldulensis* and *Leucaena leucocephala* have been planted intercropped with maize, sorghum and beans during the first two years [Maghembe and Redhead, 1982]. It has been said that some *Eucalyptus* species may have very high water intake, but *Eucalyptus melliodora* and *Eucalyptus camaldulensis* did not show this characteristic in research carried out in Africa [Maghembe and Redhead, 1982].

Actually there are many farmers planting *Eucalyptus* in the micro watersheds under study. In fact, La JUNTA (The

Ocoa Development Association) is willing to finance production of this forest species in the watershed.

It has been recognized that there are some problems of managing agroforestry in the country. First, the legal right of harvesting the forest plantation is still unclear; and second the existing land tenure system, where farmers do not own the land they work. It is important to mention that, where farmers do not have title of the land there is not security or incentives to establish a tree plantation. However, the National Technical Commission of forestry (CONATEF), in coordination with the National Office of Forestry (DGF), have authorized farmers to plant and harvest forest plantation.

Objective of the Study

This research has as the first objective that of determining the resource allocation that maximizes aggregate income of the hillside farmers located in the selected microwatersheds in the Ocoa watershed. The second objective is to determine the resource allocation that minimizes soil erosion levels in the selected study area of the Ocoa watershed.

The resource allocation that maximizes farmers' income, must be achieved under a set of constraints, which are described as follows.

First, the level of soil erosion produced by the optimal resource allocation must be not greater than a tolerant level of 1 T-value (11.2 tons./ha./year),

[Wischmeier and Smith, 1978].

Second, the total amount of land available in each slope class in each agroecological production zone within each microwatershed should be used in the production of crop activities incorporated in the model.

Third, the total amount of labor required for all crops under each level of technology per two months period, must be less or equal to the labor supply available in the same period of time in the Ocoa watershed.

Fourth, the total amount of capital required per two months period for all crops under each level of technology, must be less than or equal to the total annual amount of capital available from the various sources (farmers' own capital, AgBank,, brokers and contractors) of capital.

For the objective function that deals with allocation of resources that minimize soil erosion, only the first constraint of those pointed above is modified. The others remain without modifications (land, labor and capital constraints). The first constraint for the objective function of soil erosion minimization is as follows: The minimum level of farmers' income must be greater than or equal to the aggregated family labor wage per year.

Past and Current Work in the Ocoa Watershed

The Ocoa community is characterized by its strong and well developed local participation in solving its community problems. Farmers are organized in small associations, which are incorporated into the JUNTA. The Church plays an



important role in leadership development and in the community participation effort, which is unique for in the entire country.

Because of the existent social characteristics in the Ocoa watershed, many institutions, which includes international and domestic private donors and government agencies, are carrying out rural development activities. Most of these institutions participate in the development of the Ocoa watershed through the JUNTA, by financing activities such as, health, education and reforestation.

In the last six years the SEA has been implementing a Natural Resource Management (NARMA) Project, whose objective has been to increase the income level of the hillside farmers and to reduce the level of soil erosion in the watershed.

To achieve this objective, NARMA has been helping farmers implement soil conservation practices, such as terracing, ditches, contouring, life and death barriers, as well as introducing new farming system such as agroforestry, low and non-tillage farming. NARMA has been providing production and conservation credits and some monetary and non monetary incentives to farmers to participate in the natural resource management activities of the project. An environmental education program is being implemented to make farmers aware of the natural resources deterioration problem and of alternative actions to be implemented to solve the problem.

In 1985 there was an attempt to develop an agricultural zoning in the Ocoa watershed. For this purpose, a very aggregated linear programming model was used to maximize farmers' income and minimize soil erosion [SEA, 1985d]. But the study focused mainly in land use potential, by correlating the agrophysical conditions in the watershed with crop requirements. One of the recommendations of that study was to carry out a more detailed linear programming model that incorporates different farming systems, as well as a more disaggregated regionalization, in the watershed and outside it [SEA, 1985d]. However there is not data on farming systems.

As a result of NARMA project implementation, a natural resource data base of the Ocoa watershed has been created by the SEA with technical assistance provided by MSU in the use of the GIS. The existing data base includes, topography, soil classification (soil taxonomy), climate (temperature and rainfall), agroecological production zones, current land use, road system and population.

CHAPTER II

Linear Programming Methods

Application to Agricultural Resources Allocation

The basic objective of Linear Programming is to optimize (maximize or minimize) an objective function with the variables being subject to a number of resources constraints in the form of linear inequalities. 2/

A basic assumption of linear programming is that the function being optimized and the constraints are linear [Swanson, 1980]. In general, linear programming is a computational method that determines the best plan or course of action, among many alternatives for the plan, and a specific objective exists given limited resources availability. 9)

In the linear programming model activities can be input, output, and residual coefficients. The ecological linkages are included by coefficients in the activity columns and as resource restrictions. The spatial dimension is included by dividing the study area into regions. The number of activities are defined according to the existing crops patterns in each region. Interactions among regions can be specified and a transportation model can explain some of these interactions. If mobility of labor among region is

constrained, it can be accounted by including transport cost or by including a gravity model [Osteen, 1976].

If the time dimension is not included in the model, a static linear programming is used to optimize. However if the time dimension must be incorporated, it might be handled by using dynamic programming, which optimizes by using a recursive relationship. Should be noted however that dynamic linear programming generally can not be used to handle complex natural resource problems because it is very computationally bound. Each time period is considered a stage, and each stage has a number of possible states that can be allocated to it [Agrawal and Heady, 1972].

The principle of optimality is stated as follow: "An optimal policy has the property that whatever the initial state and initial decision, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision" [Agrawal and Heady, 1972].

Linear programming can be used for problem-solving research as well as for subject-matter research, based on who is the clientele or decision makers. Problem-solving research is defined as "what ought" to be done to solve specific problem, by using positivistic knowledge and normative knowledge about values [Johnson, 1986]. Positivistic knowledge is synthetic knowledge that deals with the characteristics of conditions, situations or thing in the real world and can be observable and experienceable.

On the other hand, normative knowledge includes prescriptive knowledge as well as knowledge about values, about goodness and badness. It also includes prescriptive proposition of having to do with what ought not or ought to be done [Johnson, 1986].

Linear programming is also applied to multidisciplinary subject-matter research, in order to generate normative and non normative knowledge [Johnson, 1986]. Linear programming methods are considered a normative method in the sense that one makes prescriptions about goodness (benefits) and badness (costs) and what ought to be done in order to achieve the goal as stated in the objective function.

Previous Work Using Linear Programming

Micro Models

Linear programming models have been used to analyze efficient resource allocation at the micro level or farm level. Linear programming as a planning tool can be used as an attempt to design a normative land use at the individual farm level, by specifying a plan for maximizing the net return of an individual farm, under specified resource constraints. The resources can be constrained in quality and availability of physical environmental resources, and by social, capital and technological constraints. Linear programming also can be used to determine the least cost combination of limited resources of an individual farm [Perz-Luna, 1984].

A micro linear programming model could be static, where

price of output, technology, level of output as well as the cost of production are assumed fixed. On the other hand, micro linear programming models can be dynamic, by incorporating the time dimension into the model. The strength of micro dynamic models is that they are useful for forecasting short and medium term impacts of policies and for determining the time path for a given policy.

Macro Models

There are three preconditions required for building an interregional or macro programming models for agriculture in a particular country. First, the existence of a mathematical tool to formulate and solve the problem; second, the availability of computing facilities of the required magnitude; and third, the availability of the vast amount of basic data for various homogeneous regions [Heady and Sivastava, 1975]. But lack of availability of a high quality data base can limit the use of linear programming as planning tool.

Another factor that might limit use of linear programming is the availability of funds to collect good quality data that can be used to derive the input/output coefficients of the model. By good quality data, I mean those data able to generate valuable information.

While the use of linear programming models have been very widely used in developed countries, in less developing countries its use has been limited by the availability of computer facilities, but the most important constraint has

been a lack of high quality compatible data required for a given geographic unit in these countries.

In the case of developed countries, mainly U.S.A., linear programming has been used as a planning tool in agricultural production, at the micro level (farm), to allocate limited production factors (land, capital and labor) in an efficient way to increase production at the least cost combination of factors, or maximization of profits. 4)

At the macro level, linear programming has been used to determine the most efficient production pattern of crops and livestock production to meet the annual demand at least cost, relative to the comparative advantage among regions in the production of crops and livestock. The production distribution model specifies not only where the crops and livestock would be produced under economic efficiency criteria, but also to which destination they would flow for consumption [Brokken and Heady, 1975].

Linear programming has been used to determine the aggregate effects of government policies, such as price support, quota production and limits of land acreage, on crops production allocation [Whittlesey and Heady, 1975].

Linear programming models have been used to measure economic impacts of several types of farm programs on the income and employment generated in rural areas and agriculturally related industries in the U. S. [Sonka and Heady, 1975]. Linear programming models also have been used

to estimate environmental quality, land use and water use [Heady, et al., 1975]. The model includes restraints on nitrogen, phosphates, pesticides, animal wastes and soil loss for 23 producing regions, 51 water supply regions and 30 market regions. The use of linear programming in problems of environmental quality imposes the same types of requirements and involves many of the same problems as are encountered in its use in large scale agricultural planning problems. b1

A linear programming model with a transportation submodel has been used to evaluate the most profitable management options for a river basin. The research provided management guidelines for decision makers concerning three interdependent forest resources: first, increasing production from non-industrial, privately owned woodlands; second, maintaining or increasing wildlife habitat for small game and deer hunting; and third, protecting water quality from soil erosion for recreational purpose [Osteen and Chappelle, 1981]. b1

In developing countries linear programming has not been very widely used, but some efforts have been made to use linear programming as an agricultural planning tool [Hall and Thorbecke, 1982]. Some examples could be mentioned.

In the Dominican Republic, a cost minimization linear programming model was developed by CRIES [Johnson, 1981]. As a demand driven land resource model, it had the theoretical ability to reflect interregional comparative

advantage of agricultural land resources to the extent of estimating a competitive equilibrium under a variety of constraint sets [Johnson, 1981]. The major purpose of the model was to provide a mechanism for evaluating the suitability of available data sources for agricultural resource planning at the national level. It demonstrated the need for improving information to be derived from improved or additional data sources.

In Costa Rica a series of minimization linear programming models were developed by CRIES [Johnson, 1981]. The objective was to demonstrate the implications of selecting one data source over others for use in formal policy modeling or in actual policy decisions [Hall and Thorbecke, 1982].

The Colombia linear programming model contains a highly disaggregated commodity classification ranging from, 46 to 245 sectors in different runs of the model. The model was built in order to explore the effects of different objective functions, reflecting different combinations of output growth and income redistribution targets on the output mix [Hall and Thorbecke, 1982].

Criteria to Evaluate Alternative Models

There are eight criteria to evaluate alternative models [Osteen, 1976]. The first criterion is information output which asks if the model provides the information needs of user. The second criterion is data input which includes quantity and quality, that is, level of detail of required

data. The third criterion is the provision of policy guidelines. It considers how easily policy guidelines are developed from model outputs. The fourth criterion is the relevance of necessary assumptions. The fifth criterion is the capacity for dealing with the temporal dimension. The sixth criterion is the capacity of dealing with spatial dimension. The seventh criterion is generality, which is concerned with the extent to which the model can be generalized to a variety of problems. The eighth criterion is specificity which is concerned with how easily the model can be adapted to specific problems.

The first four criteria, the sixth and eighth criteria are applicable to the problem definition. A static linear programming model that meets some of the criteria pointed above was selected to achieve the optimal resource allocation in the Ocoa watershed. It is because linear programming models, when designed for national and regional policy analysis, provides powerful tools for tracing economic impacts of changing economic conditions [Dyke and Heady, 1985]. Linear programming models allow normative evaluation of future potentials in resource use for agriculture and their impacts on food supplies, commodity prices, farm income, and resource income [Dyke and Heady, 1985].

CHAPTER III

Research Hypothesis and Model

Research Hypothesis

It is assumed that the current natural resource degradation in the Ocoa watershed is due to existing land use conflicts, which have been generated as a result of social changes and interactions between the human social system and the environment of the natural resource ecosystem. The natural ecosystem is composed by the interaction of biophysical factors, soil, water, climate, flora and fauna. A change in one factor component can lead to changes in other components [Easter, et al., 1986].

On the other hand, the human social system includes demographic factors, social organization, economic factors, ideology and political institutions. The human environment interactions in one part of the watershed can also affect ecosystems, social systems and human environmental interactions in other parts of the watershed. In the same manner, environmental interactions outside the watershed can also affect interactions among ecosystem, social system and human environment in the watershed [Easter, et al., 1986].

It is assumed that there is some level of farmer stability in the watershed, because there is a little

incentive for adult people with few skills other than farming, to migrate and leave their land. However, due to high expectations of a higher standard of living, young people tend to migrate to the city.

In this research it is also assumed that the high rate of soil erosion is a consequence of the existing land use conflicts, which reduce the hillside farmers' income in the short and long run. It is because erosion affects chemical and physical soil properties, which in turn are assumed to reduce soil productivity levels. Loss of organic matter, deterioration of soil structure, loss of plant nutrient and lower pH are effects of erosion that affect soil productivity [Nowak, et al., 1985]. Some effects can be corrected through management practices and high production costs. However, there are some irreparable damages, such as decrease of the availability of water-holding capacity and a decreasing rooting depth to less than optimum [Frye, 1987].

Moreover, it is assumed that soil erosion also reduces the downstream residents' welfare, because of siltation of water reservoirs used to generate energy. It is assumed that sediments affects water reservoirs by reducing their storage capacity [Southgate and Lyon, 1985]. Sediments also can create problems in the generation of electricity, as well as in irrigation channels and aqueducts, used to carry water to final point of use. Sediments might increase the cost of water treatments for industrial use as well as for drinking. However downstream impact is out of the scope of

this research.

It is expected that by improving resource allocation in the upper and lower watershed, the welfare of the Ocoa watershed residents as well as residents outside the watershed will be improved.

It is also assumed that factors outside the watershed affect interaction between the social system and natural environment. Some outside factors assumed are the demand for food, price incentives (domestic and export prices), the foreign exchange rate and the price of goods and services demanded in the watershed. Erosion is a major cause of nonpoint source pollution in the region. It is also understood that agricultural nonpoint sources pollute the environment with sediment, dissolved solids, and chemical pollutants, such as fertilizers and pesticides [Clark II, 1987].

Model

A conventional static linear programming model has been used to determine the optimal allocation of resources in the production of crop activities in the target area within the Ocoa watershed. Two separate objective functions were considered in this research.

First, to maximize net farmers' income under a set of resources constraints as well as under a soil loss tolerance of 11.2 tons per ha. per year.

Second, to minimize the amount of soil loss per hectare per year in the four microwatersheds.

With the formulation of the linear programming matrix with all input and output coefficients of interest, the linear programming model provides the optimal resource allocation. This solution is defined as the baseline solution. Then, from the baseline solution the linear programming model is used to address various policies analysis questions and to explore of optimal solution to changes in coefficients and external variables.

For the purpose of developing the model, it is important to define the concept of region. The most simple and common definition of a region is the idea of the geographical area constituting an entity, that significant statements can be made about the area as a whole [Hoover, 1975]. The spatial aggregation considered in this research as the unit of analysis is the microwatershed. Each microwatershed has different land use and socio-economic patterns. Within each microwatershed, more disaggregated spatial units are considered, which are the agroecological production zones or resource production planning units (RPU).

The crop production activities being considered in the model are defined in terms of the current crops as well as some tree species with the potential to be used in forest plantation as agroforestry activities. The agroforestry concept is defined as: "any sustainable land-use system that maintains or increases total yields by combining food or other annual crops with trees, perennial crops and or

livestock on the same unit of land, either alternatively or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and ecological condition of the area" [Hamilton and King, 1983].

The forestry component is focused on two approaches, first, the perennial crop or tree output, and second the implementation of an agroforestry system, the taungya system. Eucalyptus camaldulensis is the perennial tree planted at a spacing of 3 x 3 m with beans as the taungya system. Eucalyptus camaldulensis planted alone at a spacing of 2 x 2 m is also incorporated in the model. The taungya system is allocated to slope classes 30-40 percent and greater than 40 percent within the Arroyo la Vaca La Malagueta microwatersheds. On the other hand, the Eucalyptus activity (alone) is suggested for the slope classes 30-40 percent and greater than 40 percent in non-irrigated land in La Nuez. Another taungya system being incorporated is beans with coffee and banana. Coffee is planted at a spacing of 3 x 3 m, and banana is planted as shade. Beans are produced during the first two years, when growth of the perennial crops do not allow the production of beans [Ruthenberg, 1971]. There have been experiences in Costa Rica of coffee planted 3 x 3 m with maize and beans, with positive results [Budowski, 1983]. On the other hand, intercropping of banana, coffee and beans have been used in Africa (Tanzania).

Coffee growing is adaptable to different farming systems and to different forms of mixed cropping and intercropping (Ruthenberg, 1971). Banana requires high humidity, but it is adaptable and grows on soils of poor fertility and in cooler mountain locations. Banana provides shade, ground cover or mulch and permanent cover on slopes, which help to reduce soil erosion (Ruthenberg, 1971).

The taungya system including beans, coffee, and banana is incorporated as an activity in the model for slopes 30-40 percent and greater than 40 percent using medium technology in the microwatersheds of Arroyo la Vaca, La Malagueta, and in La Nuez on non irrigated land.

The number of crops being incorporated in the model is based on my experience, and unpublished experiences of technicians that work in the Ocoa watershed.

Crops coefficients represent the various crops mixtures and types of technology currently used. Production costs are assumed to be the same for each RPU, slope class, and microwatershed.

The model represents a calendar year, depicting the cropping cycle from bare land to bare land, and takes into account the existing crop seasonality, mixed cropping, relay or intercropping and sequential cropping system in the study area.

Some of the existing crops are, pigeon peas, peanuts, beans, corn, potatoes, onions and cabbage. These crops are incorporated in the model representing different proportion

of crops association or mixed cropping. It has been suggested that where there are enterprise interactions which can not be explained or can not be quantified, the interacting enterprises should be aggregated in a joint activity [Heady and Candler, 1960]. This procedure has some advantages and disadvantages. One advantage is that aggregation might permit lessening the number of accounting restrictions. On the other hand, it has the disadvantage of increased difficulty of determining which crop within the joint activity earns income and which crops are just supporting.

The crops associations incorporated in the model are those most frequently found in the study area. As an example, the first activity (X1A111) in the model represents the combination of 20%-60%-20% of pigeon peas, peanuts, and corn in RPU 40 within slope class less than 20 percent or 1 with low or traditional technology 1 in the Arroyo la Vaca microwatershed. This means that on one hectare there is a combination of 20 percent of pigeon peas, 60 percent of peanuts and 20 percent of corn. A complete listing of activities is shown in Appendix B. Other mixed crop proportions for the first RPU or agroecological zone within each slope category using low or medium technology within the microwatershed of Arroyo la Vaca or A and La Malagueta or M, are the following:

- a) 20%-60%-20% pigeon peas/beans/corn; b) 40%-40%-20% pigeon peas/peanuts/corn; c) 50%-30%-20% pigeon peas/peanuts/beans;

d) 40%-60% pigeon peas/peanuts; e) 50%-50% pigeon peas/peanuts; f) 60%-40% pigeon peas/peanuts; h) 20%-60%-20% pigeon peas/beans / corn; i) 40%-40%-20% pigeon peas/beans/corn; j) 40%-60% pigeon peas/beans; k) 50%-50% pigeon peas/beans; l) 60%-40% pigeon peas /beans. In the RPU 2 within the micro watershed La Malagueta the crop production activities are represented by the sequential cropping of onions with onions; and potatoes with cabbage. These two farming systems are found on slope classes 2, 3, and 4, with medium technology.

Production activities for the La Nuez microwatershed on irrigated land, within the RPU 2, onion, potatoes, and cabbage represent the existing sequential cropping system. This farming system uses medium technology, and is located in slope classes 2, 3, and 4.

For the La Nuez microwatershed with non-irrigated land, and within the RPU 2, the farming system is represented by the crops rotation of potatoes and cabbage on slope classes 2, 3, and 4 with medium technology.

Other column activities represent the hired labor, classified in three types, men, women and children respectively. These activities are buying activities and are represented by transfer functions. These activities carry a negative sign in the objective function or C row, and their numerical values are the prices of labor type per day.

Transfer rows occupy rows in the model in a manner

similar to constraints, with the exception that column entry for a transfer rows in the right hand side (RHS) is zero. The transfer row has the function of transferring services or output of one activity to another activity in the model [Beneke and Winterboer, 1973]. For the purpose of the model, family labor per class is considered the transfer function or transfer row. In this case, family labor in its three categories are the selling activities, whose coefficients in the objective function or C row is the anticipated price of family labor class per day, with a positive sign. Hence, there are three column activities that represent the transfer activities of family labor classes, men, women and children respectively.

The family labor transfer activity appears in the row negative sign with the amount of labor per class available, because it contributes to the supply of hired labor [Beneke and Winterboer, 1973].

Price of capital by sources are represented as activity columns. These activities are buying activities and are represented by transfer function. Thus, these activities have a negative sign in the objective function, and their coefficients represent the prices of capital for each source.

The RHS column or B column shows the availability of each resource constraint. It also shows the constraint on the transfer rows.

Associated with the crop production activities there

are several sets of resource constraints. First, restrictions on the amount of land available in each microwatershed; second, restrictions on the availability of supply of labor, family and hired labor (by months); third, restrictions on capital availability by source; fourth, the soil loss tolerance; and fifth, a minimum income level per family per year.

The labor constraint represents the supply of labor force available in the rural area. It is defined in terms of person-day of family and hired labor, classified as men, women, and children available in a given time period. Even though it is assumed that labor is not a critical constraint, it is taken into account in order to determine the level of unemployment in the watershed. Family labor is taken into consideration to estimate the level of income earned by the family and its participation in the maximization of net farm income.

Another important type of resource constraint is based on various land restrictions, which are defined according as the total area of land available per slopes category in each microwatershed and RPU. These includes restrictions for irrigated land areas and for non irrigated land areas.

Another resource constraint is the amount of capital available from formal and informal sources for the production of each crop in the Ocoa watershed. As it can be observed, there are three sources of capital, besides the farmers' own capital; Agbank, brokers, and contractors.

Contractors just finance the production of peanuts. However, farmers have traditionally used this capital source to cover the production expenses of any joint activity including peanuts.

Another resource constraint being considered in the model is the level of soil loss tolerance (T-value), which is measured in ton/ha/year. The T-value is defined as "the maximum level of soil erosion that will permit a high level of crop productivity to be maintained economically and indefinitely" [Wischmeier and Smith, 1978]. From the point of view of soil quality conditions, T-value should never exceed 11.2 tons per hectare annually [Larson, et al., 1987]. However there are limitations in the estimation of the T-value, including agronomic, economic and social limitations [Nowak, et al., 1985] .

Agronomic Limitations of T-value

The T-value is based primarily on topsoil thickness, physical properties of the soil, gully prevention, organic-matter reduction, and plant nutrient losses [Wischmeier and Smith, 1978]. In the U.S.A. most T-values range from 1 to 5 tons per acre. For some soil scientists T-values are consistent with soil-development rates. Another factor to consider in defining a T-value is the slope-gradient of the terrain [Nowak, et al., 1985], but it has not been taken into account in the definition of the T-value used in this research.

Economic Limitations of T-value

One of the economic limitations of the T-value is that it does not include off-site effects of erosion or externalities. Thus, for policy analysis it is useful to determine how erosion control keyed to T-value affects farmers' income [Nowak, et al., 1985].

Social Limitations of T-value

What constitute an excessive soil erosion is determined by the socioeconomic and political consequences of that erosion [Nowak, et al., 1985]. The definition of excessive soil loss is a social matter of the interaction between the natural process of soil formation and the economic value of the agricultural production practice.

A social consideration in the use of T-values as policy instrument arrives when we consider who land is being eroded. This is the case of fragil land with low T-value, which are likely to be brought into production by farmers with few of the necessary management skill and economic resources. Thus, defining excessive erosion solely on the basis of T-value would bear relatively heavily upon the operations of these poor lands, if only because of the magnitude of the erosion problem that hillside farmers are facing, but a because some will lack the capital and knowledge to apply appropriate conservation technologies [Nowak, et al., 1985].

For the purpose of this research, different T-values are being considered in order to take into account agronomics, economic and social effects of each T value.

The average soil loss coefficient incorporated in the linear programming model is estimated outside the model by calculating the Universal Loss Equation (USLE) (Wischmeier and Smith, 1978). The USLE is a comprehensive technique available to land management planners for estimation of average annual erosion rates for a range of rainfall, soil, slope, crop, and management conditions and to facilitate selection of alternative land use and practice combinations that will limit erosion rates to acceptable levels (Meyer, 1984). It involves six major factors that affect upland soil erosion by water: rainfall erosiveness, soil erodibility, slope length, slope steepness, cropping and management techniques, and supporting conservation practices.

The USLE equation is as follows:

$$A = R \times K \times L \times S \times C \times P$$

where,

A is the predicted soil loss per unit area, computed by multiplying values for the other six factors. It includes eroded soil that is deposited before it reaches down slope streams or reservoirs.

R is the rainfall and run-off factor for a specific location. It is expressed in average annual erosion index units.

K is the soil erodibility factor for a specific soil horizon. K is expressed as soil loss per unit of area per unit of R for a unit plot. An unit plot is 72.6 feet long

with a uniform 9 percent slope, maintained in continuous fallow, with tillage when necessary to break surface crusts.

L is a dimensionless slope-length factor, not actual slope length. L is expressed as the ratio of soil loss from a given slope length to that from a 72.6 feet slope length under the same conditions.

S is a dimensionless slope-steepness factor. S is expressed as the ratio of soil loss from a given slope steepness to that from a 9 percent slope under the same conditions.

C is a dimensionless cover and management or cropping-management factor. C is expressed as a ratio of the soil loss from the condition of interest to that from tilled continuous fallow.

P is a dimensionless supporting erosion-control practice factor. P is expressed as a ratio of the soil loss with practices, such as contouring, stripcropping, or terracing, to that with farming up-and-down slope [Meyer, 1984].

The USLE and Its Limitations

The use of USLE have some limitations [Foster, 1988]: First, it does not accurately estimate erosion for a specific storm event, season, or year; second, it does not estimate erosion by concentrated flow; third, it does not estimate on-site deposition; fourth, it does not estimate sediment concentration in the run off; and fifth, it does not provide information on sizes, densities, surface area

and other characteristics of the sediment required to estimate potential disposition and adsorption and transport of chemicals by sediment.

Even though its limitations are extensive, the USLE is currently and likely will continue to be for years the only practical equation available for estimating erosion on farm fields.

Research Method

Data Collection

For the purpose of this research, secondary data were used instead of the collection of primary data. It has been understood that by obtaining primary data from the study area at the aggregated level specified in this study, a better picture of the situation in the Ocoa watershed could be developed. However of various factors, such as as time constraints and costs of gathering primary data, it was necessary to use secondary data in this study.

Agrophysical data for spatial aggregation into microwatersheds, slope categories and agroecological zones were provided by the Geographical Information System (GIS) in the SEA. The existing Geographical Information System files for the Ocoa watershed provided the RPU or agroecological zones classification. Figure 2.1 shows the process of obtaining agrophysical data. It was necessary to digitize the microwatershed map, in order to determine the area and the configuration of the three microwatersheds. Figure 2.2 shows the combination of RPU and microwatersheds.

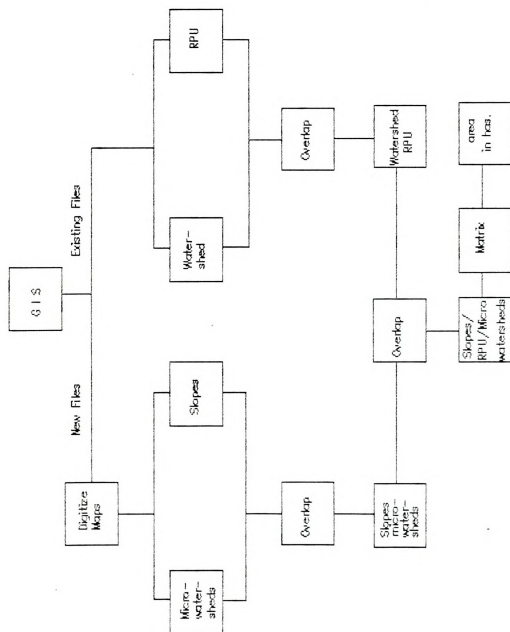
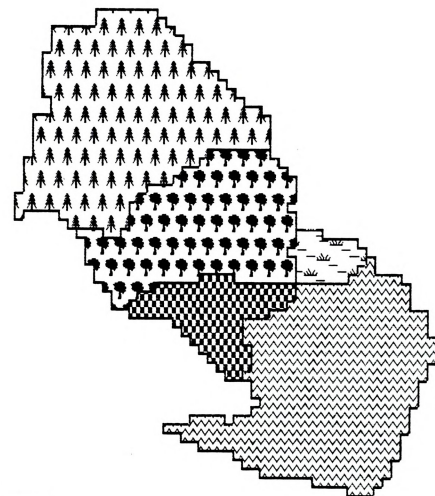


Figure 2.1. GIS Process Used in the Spatial Determination of Agrophysical Data.



RPU 02 in La Nuez



RPU 02 in La Malagueta



RPU 02 in Arroyo La Vaca



RPU 40 in La Malagueta



RPU 40 in Arroyo La Vaca

Figure 2.2. Microwatershed and RPU

The topographic map was digitized in order to aggregate the slope categories of the microwatersheds into four classes, less than 20 percent, 20 to 30 percent, 30 to 40 percent and greater than 40 percent.

New files for microwatersheds and agroecological zones or RPU's were developed using the GIS available in the SEA. Then the combination of microwatershed and RPU was overlaid with the slopes map to generate data in ha. about slope classes per microwatershed in each RPU [Table 1.6].

The number of crop activities, the farming systems and crop rotations represent the existing condition in the study area, as well as the potential agroforestry system alternatives. In the study area there is not an unique farming system, nor a unique mixture of crops. Thus, this research takes into account different crop combinations of sequential crops that might be found in the study area.

Secondary data about crop budgeting represent regional and in some cases national averages of crop production costs. Some modifications were made in order to represent the current situation in the study area. Another limitation of the enterprise activities is that in many cases they have been prepared for single or individual crops, which differ from those included in existing farming systems in the Ocoa watershed.

Because of data limitations, production costs for the crop activities incorporated in the linear programming model are estimated by calculating the percentage of each crop

within each mixed cropping activity. Then, this percentage is used to estimate the proportion of the total cost of a given farming system from the regional average single crop production cost. In this manner, labor requirements, and all other variable costs are estimated. The total production cost of the mixed cropping system activities is estimated by adding the proportion of cost of each crop within the joint activity.

The amount of labor type (i.e., men, women, and children) in the farm operation were estimated by interviewing farmers and technicians (i.e., primary data). Following this procedure, the amount of men/day, women/day and children/day required to carry out specific operation of the production process was estimated. In most cases, it was found that planting and chemical applications, were usually done by men, while harvesting is done by women and children. Men participate in harvesting, but to a less extent.

Farm labor is supplied by two sources, family labor and hired labor. Family labor includes the household heads, wives, and children that work on the farm according to Erbaugh, 1983. In 1983, 50 percent of farmers reported that wives helped with farm labor, and 54 percent of farmers reported that children helped in the farm operation [Erbaugh, 1983]. These percentages were applied to the families in the watershed to derive the number of working wives and children.

Within the study area there are 624 farms [ONE, 1984].

October 1887

1st of the month - 1000

2nd of the month - 1000

It is assumed that there are the same number of families. The current average family size in the Ocoa watershed is six, it includes husband, wife and four children (ONE, 1981). The supply of family labor is estimated by multiplying the number of farms by average family size. Under the assumption that only 50 percent of wives and only 54 percent of children help in the farm, it was estimated family labor supply consists of 324×0.6 women/day, 1348×0.5 children/day, and 624 men/day. No seasonal variation is assumed. This assumption might be questionable, but there were not other data source available at this time to estimate seasonal labor supply.

Technical coefficients for each production activity in the model are obtained from government publications of farm budgeting enterprises (SEA, 1985a, 1988, and AgBank, 1987). These farm budgets provided the estimates of labor required for farm operations during the production stage.

In defining labor supply periods, the time span for a critical operation is considered (Heady and Candler, 1960). It is assumed that a period of two months is an appropriated time span where each agricultural operation can be done. Labor requirements are estimated each two months, and reflects only those months where labor is needed (Heady and Candler, 1960).

For the forestry and agroforestry enterprises incorporated in the model, the net present worth (NPW) was calculated. The NPW is defined as " the present worth of

the benefits less the present worth of the costs, expressed as an annual value". On the other hand, present worth is "the value at present of an amount to be received or paid at some time in the future". It is calculated by discount factor, given by the formula: $\frac{1}{(1+i)^n}$, where, i is the discount (interest) rate, and n is the number of years [Gittinger, 1982].

The technical coefficients and net farm income of the forestry and agroforestry component were discounted to year one, and represent the net present value of benefits and costs during five years period. A discounted interest rate of 25 percent per year is used, to reflect the opportunity cost of capital and the inflation rate [Brunn, 1988].

The annual gross farm income is calculated using 1988 farm gate price from the watershed [Appendix B]. Net farm income incorporated in the objective function or C row is calculated by subtracting total production cost (excluding fixed costs) from the gross farm income.

Capital requirements for each farm operation, such as land preparation, seeds, chemical inputs, as well as labor, are estimated at 1988 market prices. For the purpose of this research, the number of farm operations have been aggregated as follow, land preparation, planting, weeding, chemical inputs, seeds, chemical application, harvesting and handling, and irrigation. As noted above four sources of capital, have been financing agricultural activities in the Ocoa watershed. First, the own farmers' capital, whose

opportunity cost of capital has been estimated at 15 percent; second, the AgBank, which has an interest rate of 25 percent; third, Contractors, whose interest rate has been estimated to be zero; and fourth, Brokers, who lend money at an interest rate approximately 125 percent.

In the Ocoa watershed there are two main contractors that finance the production of peanuts. These are "La Manicera" and "Lavador", which represent the two important oil firms in the country that use peanuts in the production of oil for cooking. La Manicera and Lavador are the only buyers of peanut. They are the only capital source for the production of peanut. Moreover, farmers have to get peanut seeds from the contractor in order to sell their production. In fact, contractors provide all inputs for the peanut production, including seeds, chemical inputs, land preparation as well as cash for weeding, harvesting and manipulation. There is not a nominal interest rate charged for money lent by Contractors. For this reason the interest rate is assumed to be "zero". However, farmers have to give back to contractors one hundred pounds of dry peanuts in the shell per each twenty five pounds of peanuts seeds. The market value of the amount of peanuts given by farmers have been subtracted from the net farm income of each production activity that includes peanuts to reflect the cost of money.

For 1988 contractors had a total budget of approximately RD\$500,000.00 for the production of peanuts in



the study area. Because peanuts usually are not planted as a single crop, it is feasible to use this capital to finance associated crops.

The Agbank in Ocoa has been financing the production of beans, potatoes, pigeon peas, onions, cabbage, corn and trees. During 1986 the AgBank had a portfolio of RD\$ 6,650,658.00 to finance agriculture activities in the Ocoa. Only 73 percent of this amount was given as credits to farmers for production of crops during that year. The Agbank portfolio for 1988 increased to RD\$ 8,150,658.00, in order to finance tree production activities. This extra RD\$ 1,500,00.00 was provided by the JUNTA from the Natural Resources Investment Found (Firena) (SEA, 1986).

It is estimated even by Agbank officers, farmers and extension workers, that the AgBank loan covers only approximately 70 percent of the total production cost incurred by farmers in crop production. The remaining 30 percent is financed as follows. 20 percent is financed by own farmers' capital and 10 percent is provided by brokers.

Based on the above observations and assumptions, the amounts of capital per source available for financing the agricultural production activities were estimated. [See Table 3.11].

Coefficients for the Soil Loss Equation have been taken from different sources, the USDA Handbook # 537, from the soil and water monitoring plots carry out by the Land and Water Department of the SEA in the Ocoa watershed, and

from government publications [SEA, 1985d and Paulet, et al., 1978]. For the calculation of the USLE, it is assumed that the length of the slope (L) without conservation practice is equal to 100 meters for each type of slope class [SEA, 1985d]. However when conservation practices are applied, the length (L) is equal to 20 ms. for the slope category less than 20 percent and 10 ms. for the other slope classes [SEA, 1985d]. See Table 3.2, 3.3, 3.4, 3.5, and 3.6.

Table 3.1. Amount of Capital Available per Source, 1988.

Sources	Total Amount in RD\$
AgBank (1)	8,150,658.00
Brokers	665,065.00
Own Farmers'	1,330,131.00
Contractors (2)	500,000.00

(1) It includes RD\$ 1,500,000.00 for forestry and agroforestry (2) Only finance the production of peanuts, or any crop combination with peanuts.

Source: Informal communication with capital sources.

Table 3.2. Coefficients for the USLE Equation for Short Cycle Crops With Conservation Practices (Hillside Ditches) in RPU 40.

Slope	R	K	L	LS	C	P
< 20	650	.53	20 ms	2.25	.6	.55
20-30	650	.53	10 ms	3.45	.6	.80
30-40	600	.53	10 ms	6.00	.6	.95
> 40	600	.53	10 ms	9.00	.6	.95

In the taungya system the short cycle crop is not being considered in estimating the C factor of the USLE equation. Because it was assumed that perennial C factor was likely to be more significant than including the short cycle crop.

Table 3.3. Coefficients for the USLE Equation for Short Cycle Crops with Conservation Practices (Hillside Ditches) in RPU 02.

Slope	R	K	L	LS	C	P
< 20	750	.53	20 ms	2.25	.6	.55
20-30	850	.53	10 ms	3.45	.6	.80
30-40	950	.53	10 ms	6.00	.6	.95
> 40	950	.53	10 ms	9.00	.6	.95

Table 3.4. Coefficients for the USLE Equation for Short Cycle Crops with Conservation Practices (Hillside Ditches) Under Irrigation in RPU 02.

Slope	R	K	L	LS	C	P
< 20	900	.53	20 ms	2.25	.6	.55
20-30	1000	.53	10 ms	3.00	.6	.80
30-40	1100	.53	10 ms	6.00	.6	.95
> 40	1100	.53	10 ms	9.00	.6	.95

Table 3.5. Coefficients for the USLE Equation for Taungya and Forest Activities with Conservation Practices (Hillside Ditches) in RPU 40.

Slope	R	K	L	LS	C	P
30-40	600	.53	10 ms	6.00	.003	.95
> 40	600	.53	10 ms	9.00	.003	.95

Table 3.6. Coefficients for the USLE Equation for Taungya and Forest Activities with Conservation Practices (Hillside Ditches) in RPU 02.

Slope	R	K	L	LS	C	P
30-40	950	.53	10 ms	6.00	.003	.95
> 40	950	.53	10 ms	9.00	.003	.95

The L coefficient for traditional practice has been

estimated in 100 percent for all slope classes. The LS factor for all slope categories, < 20 percent, 20-30 percent, 30-40 percent, and > 40 percent becomes equal to 4.5, 11.5, 17.1 and 22.92, respectively. On the other hand the P factor is equal to one.

Mathematical Model

The mathematical model is defined as follows:

First Objective Function:

Maximize.: Farmers' Income

$$\text{MAX.: } \sum_c \sum_t \sum_f \sum_s \sum_a \sum_m R_{ctfsam} \cdot X_{ctfsam}$$

Subject to :

$$\checkmark \text{ Land : } \sum X_{ctfsam} \leq \sum X_{sam}$$

$$\checkmark \text{ Labor: } \sum AMULL_{ctfsam} \cdot X_{sam} \leq AMUL$$

Capital:

$$\text{Agbank: } \sum K^{ab}_{ctfsam} \cdot X_{sam} \leq K^{ab}$$

$$\text{Brokers: } \sum K^b_{ctfsam} \cdot X_{sam} \leq K^b$$

$$\text{Contractors: } \sum K^C_{ptfsam} \cdot X_{sam} \leq K^C_p$$

$$\text{Farmers: } \sum K^O_{ctfsam} \cdot X_{sam} \leq K^O_c$$

$$\text{Soil Erosion: } \sum A_{ctfsam} \leq T\text{-value}_m$$

where,

c = crop activity (109)

t = level of technology (2)

1- Low or traditional technology

2- Medium technology

f = farming system (5)

1- Single crop in rotation (4)

a- Onions with Onions

- b- Potatoes with Onions
- c- Potatoes with Cabbage
- d- Onion, Potatoes and Cabbage

2- Mixed cropping and relay (12)

- a- 20%-60%-20% pigeon peas/beans/corn
- b- 40%-40%-20% pigeon peas, peanuts and corn.
- c- 50%-30%-20% pigeon peas, peanuts and corn.
- d- 40%-60% pigeon peas/peanuts
- e- 50%-50% pigeon peas/peanuts
- f- 60%-40% pigeon peas/peanuts
- h- 20%-60%-20% pigeon peas/beans/corn
- i- 40%-40%-20% pigeon peas/beans/corn
- j- 40%-60% pigeon peas/beans
- k- 50%-50% pigeon peas/beans
- l- 60%-40% pigeon peas/beans

3- Taungya: Eucalyptus with beans

4- Forest plantation of Eucalyptus

5- Taungya: Beans with coffee and banana

s = slope category (4)

- 1- < 20%
- 2- 20%-30%
- 3- 30%-40%
- 4- > 40%

a = Agroecological production zone or
RPU (2)

1- RPU 02

2- RPU 40

m = Microwatershed (4)

A- Arroyo La Vaca

M- La Malagueta

I- La Nuez (irrigated land)

N- La Nuez (non irrigated land)

R_{ctfsam} = Net return per ha/crop/year/ under given technology, and farming system in a given slope class within each RPU in each microwatershed. The net return is calculated outside the model by multiplying the farm gate price by the level of yield per ha. for each crop, minus its cost of production per ha.

X_{ctfsam} = Total area in ha. under crop production with specific technology level, and farming system in a given slope category and RPU in each microwatershed.

X_{sam} = Total amount of land in ha. available per slope category in each RPU within each microwatershed.

$AMUL_{ctfsam}$ = Amount of monthly units of labor (children and adults) required per crop/ha., each year, under given level of technology, and farming system in each slope category and RPU within each microwatershed.

AMUL = Total amount of monthly units of labor
(children and adults) available for all farm
activities.

K^{ab}_{ctfsam} = Total annual capital requirement per
crop/ha. from the Agricultural Bank, under
a given technology and farming system in
each slope category and RPU within each
microwatershed.

K^{ab} = Total capital available from the
Agricultural Bank per year.

K^b_{ctfsam} = Total amount of Brokers' capital/ha., used
in each crop per year farming system,
under given technology level in each slope
class of each RPU in each microwatershed.

K^b = Total amount of capital available from
brokers during the year.

K^C_{ptfsam} = Total amount of contractors' capital used
per ha. of peanut per farming system
under given technology level in each slope
class of each RPU within each
microwatershed.

K^C = Total amount of Brokers' capital available
per year.

A_{ctfsam} = Total amount of soil erosion in ton./ha per
year produced per crop, given a level of
technology, and farming system in each
slope category in each RPU in each

microwatershed.

T-value_m = Soil Loss Tolerance in ton/ha/year in each microwatershed.

The T-value indicates the soil loss tolerance or the level of erosion allowable to maintain long-term soil productivity, as well as to meet some social goals, such as environmental quality. [Pierce, 1984]

The Second Objective Function:

Minimize: Soil Loss Erosion:

$$\text{Min.: } \sum A_{ctfsam} \cdot X_{sam}$$

Subject to:

$$\text{Income: } \sum C \sum t \sum f \sum s \sum a \sum m R_{ctfsam} \cdot X_{sam} \geq \text{MLW/Y}$$

$$\text{Land : } \sum X_{ctfsam} \leq \sum X_{sam}$$

$$\text{Labor: } \sum \text{MUL}_{ctfsam} \cdot X_{sam} \leq \text{AMUL}$$

Capital:

$$\text{Agbank: } \sum K^{ab}_{ctfsam} \cdot X_{sam} \leq K^{ab}$$

$$\text{Brokers: } \sum K^b_{ctfsam} \cdot X_{sam} \leq K^b$$

$$\text{Contractors: } \sum K^C_{ptfsam} \cdot X_{sam} \leq K^C$$

$$\text{Farmer: } \sum K^O_{ctfsam} \cdot X_{sam} \leq K^O$$

where:

MLW/Y : Minimum labor Wage per Year.

This model differ from the first model, Income Maximization, in the sense that the soil erosion constraint in the first model becomes the objective function in the minimization model. The other characteristic was that the objective function in the first model becomes a constraint in the second model, with RHS equal to the minimum

aggregated family labor wage per year, MLW/Y.

The MLW/Y was calculated under the assumption that the work year consists of nine months of 20 days each. It was also assumed that the percentage of family labor actually working distributed as follows: 100 percent of family men, 50 percent of women, and 54 percent of children. The basis MLW/Y was estimated in RD\$ 4,155,120.00. This inference regarding aggregate wages has been made because of insufficient data, and the scope of this research does not permit overcoming this data limitation.

The Matrix

The size of linear programming matrix used in this model was 119 columns including the RHS, and 41 rows including the first row of the objective function. The crop activities are represented in the matrix by 109 columns. Appendix D indicates the complete detailed linear programming matrix. Columns 110 to 115 represent six labor activities. Columns 116 to 118 represent three capital activities. Appendix C indicates the complete detailed matrix.

Similarly, the first row of the matrix represents the value of the objective function. The rows 2 to 5 show four soil slope categories in microwatershed A. Rows 6 to 8 show three soil slope categories for the Arroyo la Vaca microwatershed. Similarly, rows 9 to 14 show three soil slope categories for the La Nuez microwatersheds on non-irrigated land and on irrigated land respectively. Figure

2.3 indicates the data aggregation system used in in this research.

On the other hand, the hired labor constraint is shown in rows 15 to 32. While rows 33 to 35 represent three transfer rows for Fmen, Fwomen and Fchildren respectively. Rows 36 to 39 represent the soil loss tolerance constraint for each one of the four microwatershed. Similarly, rows 40 and 41 represent two transfer functions for capital sources, Agbank and brokers respectively. Finally, rows 42 and 43 represent the capital constraint for contractor and farmers' own capital.

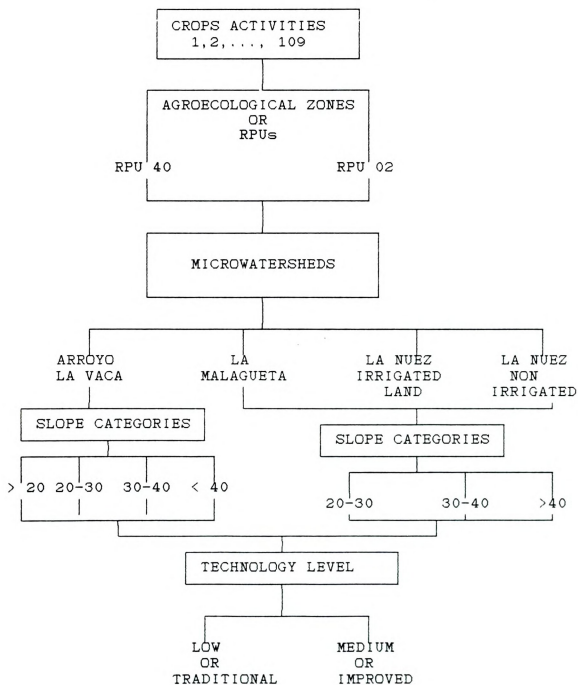


Figure 2.3. Data Aggregation System.

CHAPTER IV

Analysis of the Results

First Model: Maximize Farmers' Income

In model 1, the objective function was to maximize farmers' income, under a set of resource constraints. The set of resource constraints included: those dealing with land, labor, capital and soil loss tolerance. The optimal solution for the first model of maximizing net farmers' income, reached a value of RD\$ 5,228,844.00. The optimal solution was found at iteration 18. This amount was achieved by bringing into the optimal solution five real activities. Each microwatershed brought one real activity into the solution, except the La Nuez microwatershed, which had two real activities.

For the Arroyo la Vaca microwatershed, the optimal program indicated 39.22 has. for the production of pigeon peas associated with beans in a proportion of 50-50%, to be produced within the agroecological zone 40, in slope category less than 20 percent, with traditional technology (X10A111).

For the La Malagueta microwatershed, the optimal program indicated the production of 20.53 has. of pigeon peas associated with beans in a proportion of 40 percent of

pigeon peas and 60 percent of beans, within the agroecological zone 40, with slopes of 20 to 30 percent using traditional technology (X21M121).

As can be observed, only activities with traditional technology were brought to the optimal program for the La Nuez and La Malagueta microwatersheds. The use of improved technology, which included the use of soil conservation practices, were not considered as part of the optimal solution. This means, that even though the use of soil conservation practices reduce soil loss, the level of profitability was not enough to become part of the optimal program for those two microwatersheds. For the La Nuez microwatershed with irrigated land, the optimal solution indicated an area of 3.81 has. for the production of onions, potatoes and cabbage under irrigation in the agroecological zone 02, in the slope category of 20 to 30% using improved or medium technology (X26I222) was brought into the program. Although this activity has a very high value objective function, however it produces a high level of erosion, which restricted the level of this crop activity in the optimal solution.

For the La Nuez microwatershed with non-irrigated land, two real activities came into the optimal solution. First, 206.94 has. were indicated for the forest production of Eucalyptus in the agroecological zone 02, with slopes 30 to 40 percent, using traditional technology (X27N231). This large area is justified in the optimal solution because of

the high value of the coefficient in the objective function associated with a low production of soil loss equal to 22.31 tons per ha. per year.

Second, the optimal program indicated an area of 11.02 has. for the production of potatoes and cabbage in the agroecological zone 02, within the slopes of 20 to 30 percent using an improved or medium technology (X29N222). This small area is explained by the high level of erosion generated by this activity, even though it has high value in the objective function. Table 4.1 shows the values of these real activities.

Table 4.1. Real Activities in the Basis Solution for Maximizing Net Farmers' Income.

Real Activities	Area (hectare)	Contribution to the Objective Function (RD\$)	Soil Loss (Ton/Year)
X10A111	39.22	291,200.66	45,046.00
X21M121	20.53	123,908.20	36,175.94
X27N231	206.94	3,772,998.37	4,633.44
X29N222	11.02	676,600.78	20,306.49
X26I222	3.81	364,497.60	8,265.10

Shadow Prices or Marginal Value Products

In the estimation of the optimal solution of maximizing net farmers' income, there are some shadow prices or marginal value products (MVP) associated to some limiting resources, such as labor, capital and soil loss tolerance (T-value).

For those limiting resources that have a direction of "less than or equal to", the MVP or shadow price indicate

in how much the value of the objective function will increase, if one additional unit of the limiting resource is made available.

The value of the objective function will increase in RD\$210.72, if the amount of hired male labor available during May-June increases by one unit. On the other hand, there is a very high MVP for male family labor. If the amount of Fmen increase 624 units, the value of the objective function will increase by RD\$131,505.20. It is important to point out that the Fmen constraint is a transfer function with a RHS coefficient equal or greater than zero. However, the amount of male family labor is 624 man-days. This amount has been added to the male hired labor, in order to utilize male family labor first, because of its low price. Thus, the MVP for Fmen represents the amount on which the net farmers' income will increase if an additional 624 man-days of male family labor are made available. Similarly, an increase in Fwomen and Fchildren by one unit, will increase the value of the objective function by RD\$11.00 and RD\$8.00 respectively. The same interpretation is made for the T-value for the Arroyo la Vaca, La Malagueta microwatersheds and La Nuez microwatershed with irrigated land. An extra unit of soil loss allowed in those three microwatersheds will increase the value of the objective function by RD\$1.68, RD\$0.30, and RD\$3.03 respectively. On the other hand, if the amount of farmers' own capital increases by one unit (RD\$1.00), the

MVP of that extra peso is RD\$345.68. This means that the value of the objective function will increase by the amount of the MVP. Table 4.2 shows details of the MVPs.

Table 4.2. Shadow Prices or Marginal Value Product for Some Limiting Resources for Net Income Maximization.

Resource	MVP in RD\$
Hmen May-June	210.72
Fmen	131,505.20
Fwomen	11.00
Fchildren	8.00
T-value Microwatershed A	1.68
T-value Microwatershed M	0.30
T-value Microwatershed I	3.03
Agbank Capital	- 0.00
Brokers' Capital	- 0.00
Farmers' Capital	345.68

There are some resource constraints that have zero MVP. This means that these resources are not exhausted by the optimal program. Thus value of the objective function will remain unchanged, if an additional units of those resources is added. Those resources are considered surplus and do not modify the objective function value of the optimal solution. Table 4.3 shows resources having a MVP or shadow price equal to zero.

As noted before, the MVP or shadow price information tell us how much the value of the objective function will increase if one or more unit of that specific resource constraint is made available.

The basic solution of maximizing net farmers' income will remain stable if the value of the production activities

change within an allowable range. Table 4.4 shows the

Table 4.3. Resource Constraint Surplus with Zero MVP.

Resource Constraint	Surplus
Slope 1 Land in Microwatershed A	1,341.80
Slope 2 Land in microwatershed A	644.00
Slope 3 Land in microwatershed A	1,633.00
Slope 4 Land in microwatershed A	386.00
Slope 2 Land in microwatershed M	348.47
Slope 3 Land in microwatershed M	868.00
Slope 4 Land in microwatershed M	1,993.00
Slope 2 Land in microwatershed I	80.19
Slope 3 Land in microwatershed I	264.00
Slope 4 Land in microwatershed I	387.00
Slope 2 Land in microwatershed N	326.98
Slope 3 Land in microwatershed N	859.06
Slope 4 Land in microwatershed N	1,550.00
Hmen Labor in Jan-February	7,919.86
Hmen Labor in Mar-April	1,731.97
Hmen Labor in Jul-August	6,314.11
Hmen Labor in Sept-October	7,294.43
Hmen Labor in Nov-December	7,672.36
Hwomen Labor in Jan-February	7,107.07
Hwomen Labor in Mar-April	7,408.00
Hwomen Labor in May-June	7,216.22
Hwomen Labor in Jul-August	6,897.03
Hwomen Labor in Sept-October	7,408.00
Hwomen Labor in Nov-December	7,026.02
Hchildren Labor in Jan-February	18,495.96
Hchildren Labor in Mar-April	18,612.18
Hchildren Labor in May-June	18,646.78
Hchildren Labor in Jul-August	18,065.64
Hchildren Labor in Sept-October	18,370.57
Hchildren Labor in Nov-December	17,979.95
T-value Microwatershed N	8,133.13
Contractor Capital	5,000.00

allowable change in the values of the real activities coefficients in the objective function. It shows that the value of the real activity X10A111 in the objective function can decrease by RD\$112.899 and increase up to infinity, and the value of the optimal solution will remain unchanged. Similarly, the value of the real activity X21M121 in the

objective function is allowed to decrease by RD\$57.099 and to increase up to infinity without changing the value of the optimal solution.

Table 4.4. Stable Value of the Basic Optimal Solution with Allowable Range of Changes in the Coefficients of the Real Activities in the Objective Function.

Real Activities	Current Coefficient (RD\$)	Allowable Range Change RD\$	
		Increase	Decrease
X10A111	7424.80	Infinity	112.90
X21M121	6035.47	Infinity	57.10
X27N231	18232.33	947.40	0.00
X29N222	61397.53	4743.85	17,931.27
X26I222	95643.56	Infinity	6,582.37

On the other hand, the coefficient of the real activity X27N231 in the objective function can increase by RD\$947.40 with no decrease, in order to leave the optimal solution value unchanged. In the same manner, the real activity X29N222 coefficient can increase up to RD\$4,743.85 and decrease by RD\$17,931.27 and the value of the optimal solution will remain stable. The value of the optimal solution will remain unchanged when the current coefficient of the real activity X26I222 in the objective function increases up to infinity and decreases by RD\$6,582.37.

Table 4.5 shows the range within which the coefficient of the variables in the objective function are allowed to change and the value of the basis optimal solution remains stable. As can be observed, coefficients of those variables that did not become part of the optimal solution are allowed

to increase up to infinity without affecting the value of the optimal solution.

Table 4.5. Allowable Range Changes in the Objective Function Coefficients without Changing the Basic Optimal Solution for the First Model.

Variables	Current Coefficient RD\$	Allowable Range Change RD\$	
		Increase	Decrease
X1A111	4,649.53	2,570.13	Infinity
X1A121	3,231.93	6,950.15	Infinity
X1A122	3,436.00	7,456.12	Infinity
X1A131	2,168.73	9,806.65	Infinity
X2A111	5,107.73	3,203.39	Infinity
X2A121	3,717.33	5,624.20	Infinity
X2A122	4,013.01	5,085.57	Infinity
X2A131	2,582.93	8,551.90	Infinity
X2A132	2,390.61	11,225.90	Infinity
X3A111	6,827.17	289.98	Infinity
X3A121	4,821.57	3,325.99	Infinity
X3A122	5,158.73	6,863.86	Infinity
X3A131	3,424.77	6,519.55	Infinity
X3A132	3,223.73	10,946.85	Infinity
X4A111	5,578.70	2,398.89	Infinity
X4A121	4,053.50	4,954.50	Infinity
X4A122	4,528.01	6,920.14	Infinity
X4A131	2,821.50	7,979.80	Infinity
X4A132	2,505.01	10,778.99	Infinity
X5A111	6,188.67	1,940.53	Infinity
X5A121	4,315.07	4,844.54	Infinity
X5A122	4,524.99	7,068.58	Infinity
X5A131	3,032.67	7,644.56	Infinity
X5A132	2,757.19	10,984.38	Infinity
X6A111	6,543.27	1,489.67	Infinity
X6A121	4,567.67	4,495.69	Infinity
X6A122	4,791.81	7,061.33	Infinity
X6A131	3,243.67	7,612.99	Infinity
X6A132	3,009.21	11,118.36	Infinity
X6A142	1,510.01	14,875.68	Infinity
X7A111	6,132.47	1,625.54	Infinity
X7A121	5,229.07	3,559.62	Infinity
X7A122	5,820.13	5,641.12	Infinity
X7A131	3,683.47	6,898.52	Infinity
X7A132	4,034.13	9,575.11	Infinity
X8A111	3,965.68	3,776.41	Infinity
X8A121	5,081.34	3,691.15	Infinity
X8A122	5,557.11	6,349.34	Infinity
X8A131	3,437.34	7,128.46	Infinity
X8A132	3,920.11	10,134.33	Infinity

Table 4.5. (cont'd).

Variables	Current Coefficient	RD\$	Allowable Range Change RD\$	
			Increase	Decrease
X8A142	2,200.11		14,113.30	Infinity
X9A111	7,317.47		112.90	Infinity
X9A121	6,035.47		2,425.31	Infinity
X9A122	6,633.62		5,316.98	Infinity
X9A131	4,055.47		6,198.61	Infinity
X9A132	4,900.62		9,197.97	Infinity
X9A142	2,836.62		13,520.94	Infinity
X10A121	5,972.80		2,482.41	Infinity
X10A122	9,703.24		2,475.88	Infinity
X10A131	4,060.80		6,187.71	Infinity
X10A132	4,748.24		9,578.88	Infinity
X10A142	2,784.24		13,801.85	Infinity
X11A111	7,497.96		1,987.01	Infinity
X11A121	5,875.96		2,707.41	Infinity
X11A122	6,341.96		6,173.78	Infinity
X11A131	4,031.96		6,344.71	Infinity
X11A132	4,564.00		10,099.73	Infinity
X11A142	2,700.96		14,221.74	Infinity
X12A131	14,042.88		6,876.49	Infinity
X12A141	13,914.88		7,016.40	Infinity
X13A131	18,232.33		1,406.51	Infinity
X13A141	18,232.33		1,418.41	Infinity
X14A132	5,211.97		34,422.01	Infinity
X14A142	5,211.97		34,433.30	Infinity
X15M132	5,211.97		34,403.51	Infinity
X15M142	5,211.97		34,405.55	Infinity
X16M232	8,896.62		30,721.24	Infinity
X16M242	8,895.97		30,725.14	Infinity
X17M131	14,042.88		6,857.03	Infinity
X17M141	13,914.88		6,987.19	Infinity
X18M131	18,232.33		4.31	Infinity
X18M141	18,232.33		6.47	Infinity
X19M121	5,229.07		1,134.39	Infinity
X19M122	5,820.13		3,700.86	Infinity
X19M132	4,034.13		5,876.13	Infinity
X19M141	3,324.45		3,025.32	Infinity
X20M121	5,081.34		1,265.96	Infinity
X20M122	5,557.11		4,409.08	Infinity
X20M132	3,920.11		6,435.53	Infinity
X20M141	3,115.31		3,988.26	Infinity
X21M122	6,633.62		3,376.73	Infinity
X21M132	4,900.62		5,499.18	Infinity
X21M141	8,364.80		426.94	Infinity
X22M121	5,972.80		57.10	Infinity
X22M122	9,703.24		536.82	Infinity
X22M132	4,748.24		5,881.27	Infinity
X22M141	2,016.65		4,769.52	Infinity

Table 4.5. (cont'd).

Variables	Current Coefficient RD\$	Allowable Range Change RD\$	
		Increase	Decrease
X23M121	5,875.96	282.10	Infinity
X23M122	6,341.96	4,233.52	Infinity
X23M132	4,564.96	6,399.97	Infinity
X23M141	3,665.96	3,248.37	Infinity
X24M222	38,288.74	26,719.42	Infinity
X24M232	23,888.74	41,922.75	Infinity
X24M242	9,488.74	56,902.98	Infinity
X25M222	28,017.37	21,095.47	Infinity
X25M232	16,977.37	32,938.93	Infinity
X25M242	7,217.37	43,279.16	Infinity
X26I232	77,643.56	26,371.05	Infinity
X26I242	59,484.56	52,006.75	Infinity
X27N241	18,232.33	0.00	Infinity
X28N232	8,895.62	30,715.76	Infinity
X28N242	8,895.62	30,715.76	Infinity
X29N232	41,557.53	19,840.00	Infinity
X29N242	22,997.53	38,400.00	Infinity
Hmen	-15.00	225.72	Infinity
Hwomen	-12.00	12.00	Infinity
Hchildren	- 9.00	9.00	Infinity
Fmen	14.00	Infinity	Infinity
Fwomen	11.00	Infinity	Infinity
Fchildren	9.00	Infinity	Infinity
Agbank Capital	0.10	Infinity	Infinity
Brokers' Capital	1.05	Infinity	Infinity

It is important to mention that even if the change in the objective function coefficient is out of the allowable range, it does not mean that the associated variable will become part of the optimal solution. However, this change might modify the value of the optimal solution.

As can be observed, in Table 4.5 some coefficient can increase up to infinity as occurs for variables such as, Fmen, Fwomen, Fchildren, Agbank and Brokers, and the value of the objective function remain unchanged.

Table 4.6 shows the RHS allowable ranges of increasing

and decreasing within which the value of the optimal solution will remain stable. As it can be observed, much of the RHS coefficients are allowed to increase up to infinity. However, the labor variable Hmen for May-June is only allowed to increase by 1,204.97 man-days and can be decreased by 511.38 man-days and the optimal solution in the basic remains unchanged. Similarly, the labor variable Fmen RHS coefficient is allowed to increase by 1.93 man-day. While, the RHS coefficient for the labor variables Fwomen and Fchildren are allowed to increase up to infinity and zero decrease, and the value of the optimal solution remains stable.

The T-value for the Arroyo la Vaca microwatershed is allowed to increase by 736,997.00 tons per year without altering the value of the optimal solution. Similarly, the T-value for the La Malagueta microwatershed can increase by 614,042.60 tons/year and to decrease by 36,176.00 tons/year (to become equal zero). In the same manner, the T-value for the La Nuez microwatershed with non-irrigated land is allowed to increase up to infinity and decrease by 8,133.13 tons/year and the value of the optimal solution in the basic does not change. On the other hand, the coefficient of the T-value for the La Nuez microwatershed with irrigated land can increase by 17,217.32 tons/year and to decrease by 6,883.09 tons/year, and the value of the optimal solution remains stable.

Table 4.6 shows that the RHS for the capital resource constraint from contractor can increase up to infinity and to be reduced up to RD\$5,000.00. Furthermore, Farmers' own capital is allowed to increase by RD\$471.25 and to decrease by RD\$1,156.937, without altering the value of the optimal solution in the basis.

Second Model: Minimization of Soil Loss

The objective function of the second model is to minimize soil loss under a set of constraints, including, minimum labor wage per year, land, labor and capital.

The optimal solution had a value of 3,222.48 tons of soil loss per year (14.14 tons/ha./year) for the area under study. The forest production of Eucalyptus was the only production activity indicated in the optimal solution. The model indicated an area of 227.90 has. for the forest production of Eucalyptus camaldulensis in the Arroyo la Vaca microwatershed in the agroecological zone or RPU 40, within slopes 30 to 40 percent, using traditional technology (X13A131). The production of 227.90 has. of Eucalyptus minimize soil erosion and meet the constraint of the aggregate minimum labor wage.

Shadow Prices or Marginal Value Product

The MVPs associated with some limiting resource in the minimization of soil loss, are shown in Table 4.7. The interpretation is made in the same way as it is done in the income maximization model above. The MVPs are very small,

Table 4.6. Allowable Range of Changes in the RHS, without Changing the Value of the Optimal Solution. First Model.

Resource Constraint	Current RHS Coefficient	Allowable Range Change	
		Increase	Decrease
Slope 1 Land in A	1,381.00	Infinity	1,341.00
Slope 2 Land in A	644.00	Infinity	644.00
Slope 3 Land in A	1,633.00	Infinity	1,633.00
Slope 4 Land in A	386.00	Infinity	386.00
Slope 2 Land in M	369.00	Infinity	369.00
Slope 3 Land in M	868.00	Infinity	868.00
Slope 4 Land in M	1,993.00	Infinity	1,993.00
Slope 2 Land in I	84.00	Infinity	84.00
Slope 3 Land in I	264.00	Infinity	264.00
Slope 4 Land in I	387.00	Infinity	387.00
Slope 2 Land in N	338.00	Infinity	338.00
Slope 3 Land in N	1,066.00	Infinity	1,066.00
Slope 4 Land in N	1,550.00	Infinity	1,550.00
Hmen Labor Jan-Feb	8,354.00	Infinity	7,919.86
Hmen Labor Mar-Apr	8,354.00	Infinity	1,731.97
Hmen Labor May-Jun	8,354.00	1,204.97	511.38
Hmen Labor Jul-Aug	8,354.00	Infinity	6,314.11
Hmen Labor Sep-Oct	8,354.00	Infinity	7,294.43
Hmen Labor Nov-Dec	8,354.00	Infinity	7,672.36
Hwomen Labor Jan-Feb	7,408.00	Infinity	7,107.07
Hwomen Labor Mar-Apr	7,408.00	Infinity	7,408.00
Hwomen Labor May-Jun	7,408.00	Infinity	7,216.22
Hwomen Labor Jul-Aug	7,408.00	Infinity	6,897.03
Hwomen Labor Sep-Oct	7,408.00	Infinity	7,408.00
Hwomen Labor Nov-Dec	7,408.00	Infinity	7,026.02
Hchildren L. Jan-Feb	18,762.00	Infinity	18,495.96
Hchildren L. Mar-Apr	18,762.00	Infinity	18,612.18
Hchildren L. May-Jun	18,762.00	Infinity	18,646.78
Hchildren L. Jul-Aug	18,762.00	Infinity	18,065.64
Hchildren L. Sep-Oct	18,762.00	Infinity	18,370.57
Hchildren L. Nov-Dec	18,762.00	Infinity	17,979.95
Fmen Labor	0.00	1.93	0.00
Fwomen Labor	0.00	Infinity	0.00
Fchildren Labor	0.00	Infinity	0.00
T-value Microwat. A	45,068.80	73,6974.70	45,068.80
T-value Microwat. M	36,176.00	61,4042.00	36,176.00
T-value Microwat. N	33,073.00	Infinity	8,133.00
T-value Microwat. I	8,265.00	17,217.00	6,883.10
Agbank Capital	0.00	0.00	0.00
Brokers' Capital	0.00	0.00	0.00
Contractor Capital	5,000.00	Infinity	5,000.00
Farmers' Capital	9,709.96	471.25	1,156.94

Table 4.7. Shadow Prices or Marginal Value Products for Some Limiting Resource in the Minimization of Soil Loss.

Resource	MVP in Ton
Fmen Labor	0.010856
Fwomen Labor	0.008531
Fchildren Labor	0.006204
Brokers' Capital	- 0.000002
MLW/Y	- 0.000776

thus to add an additional unit to those limiting resource, the change in the value of the objective function would not be significant.

Table 4.8 shows the allowable range of changes in the coefficients of the objective function, without changing the value of the optimal solution. As can be observed, all coefficients are allowed to increase up to infinity, except for the activity X13A131, which is the only real activity in the optimal solution.

Table 4.8. Allowable Range Changes in the Objective Function Coefficients without Changing the Basic Optimal Solution for the Second Model.

Variable	Current Coefficient RD\$	Allowable Range Change RD\$	
		Increase	Decrease
X1A111	4,649.53	Infinity	4,645.92
X1A121	1,762.11	Infinity	1,759.60
X1A122	1,409.62	Infinity	1,406.95
X1A131	2,828.80	Infinity	2,827.11
X2A111	1,149.20	Infinity	1,145.23
X2A121	1,762.11	Infinity	1,759.23
X2A122	4,013.01	Infinity	4,009.90
X2A131	2,828.80	Infinity	2,826.80
X2A132	2,687.36	Infinity	2,685.51
X3A111	1,149.20	Infinity	1,143.91
X3A121	1,762.11	Infinity	1,758.37

Table 4.8. (cont'd).

Variable	Current Coefficient RD\$	Allowable Range Change RD\$	
		Increase	Decrease
X3A122	1,409.69	Infinity	1,405.69
X3A131	2,828.80	Infinity	2,826.14
X3A132	2,687.36	Infinity	2,684.86
X4A111	1,149.20	Infinity	1,144.87
X4A121	1,762.11	Infinity	1,758.96
X4A122	1,409.69	Infinity	1,406.38
X4A131	2,828.80	Infinity	2,826.61
X4A132	2,687.36	Infinity	2,685.41
X5A111	1,149.20	Infinity	1,144.40
X5A121	1,762.11	Infinity	1,758.76
X5A122	1,409.69	Infinity	1,406.18
X5A131	2,828.80	Infinity	2,826.45
X5A132	2,687.36	Infinity	2,685.22
X6A111	1,149.20	Infinity	1,144.13
X6A121	1,762.11	Infinity	1,758.56
X6A122	1,409.69	Infinity	1,405.97
X6A131	2,828.80	Infinity	2,826.28
X6A132	2,687.36	Infinity	2,685.03
X6A142	4,031.04	Infinity	4,029.86
X7A111	1,149.04	Infinity	1,144.28
X7A121	1,762.11	Infinity	1,758.05
X7A122	1,409.69	Infinity	1,405.18
X7A131	2,828.80	Infinity	2,825.94
X7A132	2,687.36	Infinity	2,684.23
X8A111	1,149.20	Infinity	1,146.12
X8A121	1,762.11	Infinity	1,758.17
X8A122	1,409.69	Infinity	1,405.38
X8A131	2,828.80	Infinity	2,826.13
X8A132	2,687.36	Infinity	2,684.32
X8A142	4,031.04	Infinity	4,029.34
X9A111	1,149.20	Infinity	1,143.52
X9A121	1,762.11	Infinity	1,757.43
X9A122	1,409.69	Infinity	1,404.55
X9A131	2,828.80	Infinity	2,825.66
X9A132	2,687.36	Infinity	2,683.56
X9A142	4,031.04	Infinity	4,028.84
X10A111	1,149.20	Infinity	1,143.44
X10A121	1,762.11	Infinity	1,757.49
X10A122	1,409.69	Infinity	1,402.66
X10A131	2,828.80	Infinity	2,825.65
X10A132	2,687.36	Infinity	2,683.68
X10A142	4,031.04	Infinity	4,028.88
X11A111	2,298.40	Infinity	2,292.59
X11A121	1,762.11	Infinity	1,757.55
X11A122	1,409.69	Infinity	1,404.77
X11A131	2,687.36	Infinity	2,684.23

Table 4.8. (cont'd).

Variable	Current	Allowable Range Change RD\$	
	Coefficient RD\$	Increase	Decrease
X11A132	4,564.00	Infinity	4,560.46
X11A142	4,031.04	Infinity	4,028.95
X12A131	14.14	Infinity	4.52
X12A141	21.22	Infinity	11.55
X13A141	21.22	Infinity	7.08
X14A132	13.44	Infinity	9.40
X14A142	20.16	Infinity	16.12
X15M132	13.44	Infinity	9.40
X15M142	20.16	Infinity	16.12
X16M232	21.27	Infinity	14.37
X16M242	31.91	Infinity	25.01
X17M131	14.14	Infinity	4.47
X17M141	21.22	Infinity	11.60
X18M131	14.14	Infinity	0.00
X18M141	21.22	Infinity	7.08
X19M121	1,762.11	Infinity	1,758.06
X19M122	1,409.69	Infinity	1,405.18
X19M132	2,687.36	Infinity	2,684.23
X19M141	1,717.20	Infinity	1,714.62
X20M121	1,762.11	Infinity	1,758.17
X20M122	1,409.69	Infinity	1,405.38
X20M132	2,687.36	Infinity	2,683.56
X20M141	4,243.20	Infinity	4,238.26
X21M121	1,762.11	Infinity	1,757.43
X21M122	1,409.69	Infinity	1,404.55
X21M132	2,687.36	Infinity	2,683.56
X21M141	4,243.20	Infinity	4,238.26
X22M121	1,762.11	Infinity	1,757.48
X22M122	1,409.69	Infinity	1,402.17
X22M132	2,687.36	Infinity	2,683.68
X22M141	4,243.20	Infinity	4,241.64
X23M121	1,762.11	Infinity	1,757.55
X23M122	1,409.69	Infinity	1,404.77
X23M132	2,687.36	Infinity	2,683.82
X23M141	4,243.20	Infinity	4,240.38
X24M222	1,843.43	Infinity	1,813.74
X24M232	4,478.93	Infinity	4,460.40
X24M242	6,382.48	Infinity	6,375.12
X25M222	1,843.43	Infinity	1,821.70
X25M232	4,478.93	Infinity	4,465.76
X25M242	6,382.48	Infinity	6,376.88
X26I222	2,168.75	Infinity	2,094.57
X26I232	4,926.83	Infinity	4,866.61
X26I242	7,390.24	Infinity	7,344.11
X27N231	22.39	Infinity	8.25
X27N241	33.59	Infinity	19.45
X28N232	21.27	Infinity	14.37

Table 4.8. (cont'd).

Variable	Current Coefficient RD\$	Allowable Range Change RD\$	
		Increase	Decrease
X28N242	31.91	Infinity	25.01
X29N222	1,843.43	Infinity	1,795.81
X29N232	4,478.93	Infinity	4,446.70
X29N242	6,382.93	Infinity	6,365.10
Hmen Labor	0.00	Infinity	0.02
Hwomen Labor	0.00	Infinity	0.01
Hchildren Labor	0.00	Infinity	0.01
Fmen Labor	0.00	Infinity	Infinity
Fwomen Labor	0.00	Infinity	Infinity
Fchildren Labor	0.00	Infinity	Infinity
Agbank Capital	0.00	Infinity	Infinity
Brokers' Capital	0.00	Infinity	Infinity
Contractor Capital	0.00	Infinity	0.00

The allowable ranges of change for the RHS of the set of constraints in the minimization of soil loss, without changing the value of the objective function, are shown in Table 4.9. The interpretation of the coefficients is made in the same manner as in the maximization model.

Sensitivity Analysis

A sensitivity analysis was carried out by modifying the RHS of some resource constraints. Several runs were made to determine the impact of the implementation of different policies. Values of each run are shown in Table 4.10.

Run 1. The policy analyzed in this run consisted of an increase in the soil loss tolerance from 1 T-value (11.2 tons/ha/year) to 2 T-values (22.4 tons/ha./year). As result of changing the soil loss tolerance from 1 T-value to 2 T-values, the value of the optimal solution in the income

Table 4.9. Allowance Ranges of Change in the RHS, Without Changing the Value of the Optimal solution. Second Model.

Constraint	Current RHS Coefficient	Allowable Range Change Resource	
		Increase	Decrease
Slope 1 Land in A	1,381.00	Infinity	1,381.00
Slope 2 Land in A	644.00	Infinity	644.00
Slope 3 Land in A	1,633.00	Infinity	1,405.10
Slope 4 Land in A	386.00	Infinity	386.00
Slope 2 Land in M	369.00	Infinity	369.00
Slope 3 Land in M	868.00	Infinity	868.00
Slope 4 Land in M	1,993.00	Infinity	1,993.00
Slope 2 Land in I	84.00	Infinity	84.00
Slope 3 Land in I	264.00	Infinity	264.00
Slope 4 Land in I	387.00	Infinity	387.00
Slope 2 Land in N	338.00	Infinity	338.00
Slope 3 Land in N	1,066.00	Infinity	1,066.00
Slope 4 Land in N	1,550.00	Infinity	1,550.00
Hmen Labor Jan-Feb	8,354.00	Infinity	8,354.00
Hmen Labor Mar-Apr	8,354.00	Infinity	1,936.37
Hmen Labor May-Jun	8,354.00	Infinity	696.61
Hmen Labor Jul-Aug	8,354.00	Infinity	7,442.40
Hmen Labor Sep-Oct	8,354.00	Infinity	8,354.00
Hmen Labor Nov-Dec	8,354.00	Infinity	8,354.00
Hwomen Labor Jan-Feb	7,408.00	Infinity	7,408.00
Hwomen Labor Mar-Apr	7,408.00	Infinity	7,408.00
Hwomen Labor May-Jun	7,408.00	Infinity	7,408.00
Hwomen Labor Jul-Aug	7,408.00	Infinity	7,408.00
Hwomen Labor Sep-Oct	7,408.00	Infinity	7,408.00
Hwomen Labor Nov-Dec	7,408.00	Infinity	7,408.00
Hchildren L. Jan-Feb	18,762.00	Infinity	18,762.00
Hchildren L. Mar-Apr	18,762.00	Infinity	18,762.00
Hchildren L. May-Jun	18,762.00	Infinity	18,762.00
Hchildren L. Jul-Aug	18,762.00	Infinity	18,762.00
Hchildren L. Sep-Oct	18,762.00	Infinity	18,762.00
Hchildren L. Nov-Dec	18,762.00	Infinity	18,762.00
Fmen Labor	0.00	296,794.30	0.00
Fwomen Labor	0.00	377,738.20	0.00
Fchildren Labor	0.00	519,390.00	0.00
Agbank Capital	0.00	0.00	Infinity
Brokers' Capital	0.00	0.00	Infinity
Contractor Capital	5,000.00	Infinity	5,000.00
Farmers' Capital	9,709.96	Infinity	1,446.19
MLW/Y	4,155,120.00	378,001.80	4,155,120.00

Real Activities

Runs	X10R111	X13R131	X18M131	X21M121	X22M122	X25M222	X27N231	X29N222	X26I222	TOTAL	% Change
BASIC:											
a)	39.22			20.53			206.94	11.02	3.81	281.52	-
b)	291.20			123.91			3,773.00	676.60	364.40	5,229.11	-
RUN 1:											
a)	78.44			41.06			187.37	5.95	7.62	320.44	14
b)	582.40			247.82			3,416.19	365.32	728.80	5,340.53	2
RUN 2:											
a)	117.65			61.59			167.81	0.89	11.43	359.37	28
b)	873.53			371.72			3,059.57	54.64	1,093.21	5,452.67	4
RUN 3:											
a)	36.91	185.75				19.62		17.94	3.81	264.03	-6
b)	274.05	3,386.66				549.70		1,101.47	364.40	5,676.28	9
RUN 4:											
a)	36.91	185.75				19.62		17.94	3.81	264.03	-6
b)	274.05	3,386.66				549.70		1,101.47	364.40	5,676.28	9
RUN 5:											
a)	78.44		128.88			26.53		35.88	7.62	295.32	5
b)	582.40		2,349.78			257.43		2,202.94	728.80	6,624.83	27
RUN 6:											
a)	39.22			20.53			206.94	11.02	3.81	281.52	-
b)	291.20			123.91			3,773.00	676.60	364.40	5,229.11	-
RUN 7:											
a)			225.63					10.79	3.81	240.29	-15
b)			6,611.56					662.48	364.40	7,638.45	46

a) Value in ha.

b) Contribution to the Objective Function are in Thousands RDS.

Table 4.10. Value of the Real Activities of the Sensitivity Analysis in the Income Maximization Model, and their Contributions to the Objective Function.

maximization model became equal to RD\$ 5,340,728.00. This represents an increase of 2.14 percent (RD\$ 111,884.00), with respect to the net income value achieved in the basic optimal solution.

The variable X10A111 was brought into the solution with a value of 78.44 has., which is twice the value indicated in the basic optimal solution. In the same manner, the optimal program also indicated a value of 41.06 has., which is double the value indicated in the basic. Similarly the activity X26I222 remained in the optimal program with a value of 7.62 has., which is twice the value indicated in the basic optimal program.

On the other hand, activities X27N231 and X29N222 remained in the optimal program with a value of 187.37 has., and 5.95 has., respectively. Both values are 9.46 percent and 54 percent smaller than in the values indicated in the basic optimal solution.

Run 2. The policy analyzed was to allow an increase in the soil loss tolerance, from 1 T-value (11.2 tons/ha/year) to 3 T-values (33.6 tons/ha/year). It was found out that by increasing the T-value up to 3, the value of the optimal solution increased by 4.28 percent (RD\$ 223,765.00), with respect to the value of the basic optimal solution. It is important to mention that when the value of the optimal solution was compared with the value obtained when the RHS was 2 T-values, it was 2.09 percent higher. However the total soil loss generated was 139.33 percent higher than in

the basic optimal program and 41.03 percent greater than in the 2 T-values optimal solution. Table 4.11 shows the total soil loss in tons per year produced by each run in the sensitivity analysis for the income maximization model.

The variable X10A111 remained in the optimal program with a value of 117.65 has., which is three times the value in the basic optimal solution. Similarly, the variable X21M121 remains as part of the optimal solution with a value of 61.59 has., which is also three times its value in the basis solution. Furthermore, the variable X26I222 remained as part of the optimal solution. The program indicated a value of 11.43 has. The value of these three variables increased in the same proportion as the RHS was increased.

The activity X29N222 also remained in the optimal program, however its value decreased from 11.02 has. in the basis to 0.89 has. Another variable included in the optimal solution as the soil loss tolerance was increased to 3 T-values, was the activity X27N222. The optimal program indicated a value of 167.81 has. This value is 18.90 percent lower than its value in the basic optimal program.

Run 3. The policy being considered was a 50 percent increase in capital resources available to farmers. As result of this increase, the optimal program reported a value of RD\$ 5,676,519.00 as the maximum level of net income. This value is 8.56 percent higher than the net income level indicated in the basic optimal solution. However with respect to the soil loss generated, the program indicated an

Variable	BASIC	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7
X10M111	45,046	90,132	135,138	42,420	42,420	90,092	45,046	
X13M131				2,626	2,626			
X18M131						1,823		3,191
X21M121	36,176	72,352	108,528				36,176	
X22M122						2,911		
X25M222				36,176	36,176	32,043		
X27N231	4,633	4,195	3,758				4,633	
X29N222	20,306	10,968	1,631	33,073	33,073	66,143	20,306	19,896
X261222	8,265	16,526	24,795	8,265	8,265	16,530	8,265	8,263
Total	114,426	194,173	273,850	122,560	122,560	204,811	114,426	31,350
% Change	-	70	139	7	7	79	0	-72

Table 4.11. Soil Loss in Tons per Year Produced in each Run for the Sensitivity Analysis in the Income Maximization Model.

amount of 122,560 tons per year. The amount of soil loss produced by this optimal program was compared with the amount generated by the baseline solution. It was found out that by increasing capital resource by 50 percent, the soil loss just increased by 7.11 percent. It is also 41.51 percent smaller than the amount of soil loss produced by the 2 T-values optimal solution.

The optimal program indicated that only three real activities from the basic program remain in the optimal solution. These are, X10A111 with a value of 36.91 has., which is 5.84 percent lower than in the basic optimal program; the X26I222 with a value equal to 3.81 has., which is the same as in the basic; and finally, the program indicated a value of 17.94 has. for the activity X29N222. This value is 6.29 percent higher than it was in the basic optimal solution.

The activities X21M121 and X27N231 dropped out of the optimal program. However two new activities are brought into the optimal solution, X25M222 and X13A131. The program indicated a value of 19.62 has. and 185.75 has. respectively.

Run 4. The policy analyzed in this run consisted of a 100 percent increase in the farmers' capital resource. The optimal program indicated that the effect caused by an increase in 100 percent in capital resource, is the same as the effect caused by a 50 percent increase. Thus a increase in capital resource beyond than 50 percent have zero MVP.

Run 5. The policy being considered was the combination of 50 percent increase in farmers' capital and an increase in the soil loss tolerance by 2 T-values. The optimal solution for this run indicated a value of RD\$ 6,625,220.00, at interaction 20. This represent an increase of 26.70 percent (RD\$ 1,396,376.00) with respect to the net income value achieved in the basic potimal solution.

The variables X21M121 and X27N231 were eliminated from the optimal solution. On the other hand, three new real activities were brought into the optimal program. The X18M131 with a value of 128.88 has.; the variable X22M122 with a value of 26.53 has; and X25M222 with a value of 17.97 has.

The optimal program indicated a value of 78.44 has., for the real activity X10A111, which is twice the value in the basic optimal solution. The optimal program also indicated the variable X29N222 with a value of 35.88 has.. It is also 100 percent higher than its value in the basis solution. Finally, the variable X26I222 is in the optimal solution with a value of 7.62 has., which is twice its value in the basic optimal solution.

By increasing the T-value from 1 to 2, the optimal net farmers' income is achieved with a production of soil loss equal to 209,545 tons per year. The total soil loss in this run is 83.13 percent greater than the amount generated in the basic optimal solution.

Run 6. The policy being analyzed was a 100 percent

increase in the value of the coefficient of coffee in the objective function. The optimal solution achieved under this modification was the same as the optimal solution indicated in the basic optimal program. The value indicated was RD\$ 5,228,844.00. The same activities brought into the basic solution, were indicated in this optimal program at the same intensities. This means that considering all variables indicated in the model, the coffee activity did not enter in the optimal solution, even though its coefficient was increased by 100 percent.

Run 7. A 10 percent reduction in the discount rate from 25 to 15 percent used to calculate the NPV of the agroforestry activities. As a result of this modification in the value of the agroforestry coefficients in the objective function, the value of the optimal solution for the maximization of net income became equal to RD\$ 7,638,444.20. This means an increase of 46.08 percent in the value of the basic optimal solution. This 46.08 percent was justified by incorporating a new activity in the optimal solution. The new activity X18M131, was brought to the optimal program with a value of 225.69 has. This activity contributed in a 86.56 percent to the value of the optimal solution.

Other activities brought to the optimal program were the activity X26I222, which remained in the optimal solution with the same value (3.81 has.) as in the baseline optimal solution. And finally, the activity X29N222, which

remained in the optimal solution with a value of 10.79 has. It is slightly reduced (by 0.22 has.) from its original value in the basic optimal solution.

It is important to point out that the increase in the value of the objective function was associated with a reduction on the total soil loss. The total soil loss produced in this run represents a 27.40 percent of the total soil loss produced in the basic optimal solution for the net income maximization.

For the environmental impact model or soil loss minimization model, two runs were made by increasing the minimum labor wage per year, in order to evaluate the impact on soil loss. Table 4.12 shows details of these runs.

Table 4.12. Real Activities in the Second Model (in has.).

Variables	Basis	RUNS	
		Run 1	Run 2
X13A131	227.90		
X10A111		18.30	75.81
X18M131		218.35	200.45
X26I222		11.63	11.74
Area (has.)	227.90	248.28	288.00
Value (tons/year)	3,222.48	49,329.27	115,424.30

The first run was to increase the minimum labor wage per year, so that it was identical to the value of the net farmers' income per year indicated in the basic optimal solution. As result of this, the optimal program indicated a value for the optimal solution equal to 49,329.27 tons per year of soil loss. This amount is only a 43.11 percent of the

soil loss produced in basic optimal solution for income maximization. However this value when compared with the basic for the soil loss minimization, it is 15.30 times higher. An important point here is that the maximum income achieved in the basic optimal solution for the income maximization model can be obtained by incorporating into the optimal program the activities that produce lower soil loss. Activity X10A111 was brought into the optimal solution with a value of 18.30 has. whose value decreased by 50 percent as it was in the basic optimal solution. In the same manner, the activities X18M131 and X26I222 were indicated in the optimal solution. This optimal program indicated a values of 218.35 has. for the activity X18M131, and 11.63 has. for the activity X26I222. The activity X18M131 was not in the basic optimal solution for the income maximization model. The activities X22M121, and X27N231 and X29N222 were not included in this optimal program.

The second run consisted of increasing the minimum aggregate labor wage for the region equal to the value of the optimal solution when the soil loss tolerance was 2 T-values (RD\$ 5,340,728.00).

The algorithm indicated a value of 115,424.30 tons per year as optimal solution that minimizes soil loss and at the same time meets the aggregate minimum family labor wage assigned in this run.

The optimal program indicated a value 75.81 has. for the activity X10A111, which was 4.14 times higher than the value

indicated in run 1. Similarly, the activity X18M131 also remained in the optimal program with a value of 200.45 has. This value is 8.20 percent lower than its value in run 2. Finally, the activity X26I222 remained in the optimal solution with a value of 11.74 has., which was a little higher than its value indicated in run 2 for the minimization model.

CHAPTER V

Summary and Conclusions

Summary

This research had two primary objectives. First, to determine the optimal resource allocation that maximizes farm income of hillside farmers in the study area within the Ocoa Watershed. The second objective was to determine optimal resource allocation that minimizes the level of soil loss.

For the income maximization model, the set of resource constraints included: land resource disaggregated into four slope categories and four microwatersheds; labor resource disaggregated into three classes: men, women and children (under the category of family and hired labor); capital supplied by four sources, own farmers capital, Agricultural Bank, brokers and contractors; and the soil loss tolerance was estimated for each microwatershed assuming a 1 T-value of 11.2 tons per ha. per year.

For the environmental quality model that minimizes soil loss, the minimum labor wage per year was included as a resource constraint and the constraint relating to soil loss tolerance was deleted. Net farm income then became a resource constraint, as well as the other resource

constraints relating to land, capital and labor.

Six criteria were used to evaluate the selected model:

1) The model provides information needed by users; 2) required data is expressed at in appropriate levels of detail terms of quantity and quality; 3) model outputs serve as a basis for policy guidelines; 4) relevance of necessary assumptions of the model; 5) capacity to deal with the spatial dimension; and 6) ease of adoption of the model to solve specific problems.

A static linear programming model meeting these criteria was developed to calculate the optimal resource allocations in the Ocoa watershed (LINDO₁ was the software used in this research). Linear programming models provide detail for tracing economic impacts of erosion. Furthermore, when designed for regional analysis, they become powerful tools for tracing economic impacts of changing economic conditions. They also allow normative evaluation of future potentials in resource use for agriculture and impacts on commodity prices, farm income and food supply.

Agrophysical and agro-economic secondary data were incorporated in the model. Agrophysical data were generated by using the GIS, while agro-economic data were taken from government sources.

Results

The static linear programming model under the objective

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of maximization of net farmers income achieved an optimal solution of RD\$ 5,228,844.00. This value is 25.84 percent greater than the estimated minimum labor wage per year.

However, the value achieved under the optimal resource allocation in the basic solution represents 51.41 percent of the total farm income generated under existing conditions in the Ocoa watershed. The current total farm income was generated by manipulating production data provided by the SEA. The total area was estimated by dividing total production by an average yield reflecting different slope classes and type of technology. It was necessary because the data given by the SEA, were gathered considering only a traditional technology, and not slopes effect were considered. In this manner, the total area indicated in the basic optimal solution is equal to 26.91 percent of the area currently being used [Table 5.1]. It is important to point out that the average soil erosion produced by this optimal program represents 7.76 percent of the total soil loss in the actual situation. Similarly, the soil erosion employment ratio in the optimal program for income maximization is equal to 2.97. This means that each person day used, 2.97 tons of soil loss are produced. However, the current soil loss employment ratio is equal to 5.97, which indicates that 5.97 tons of soil erosion are produced for each person day employed [Table 5.1]. See Figure 5.2 for details.

These results can be explained by the fact that in the

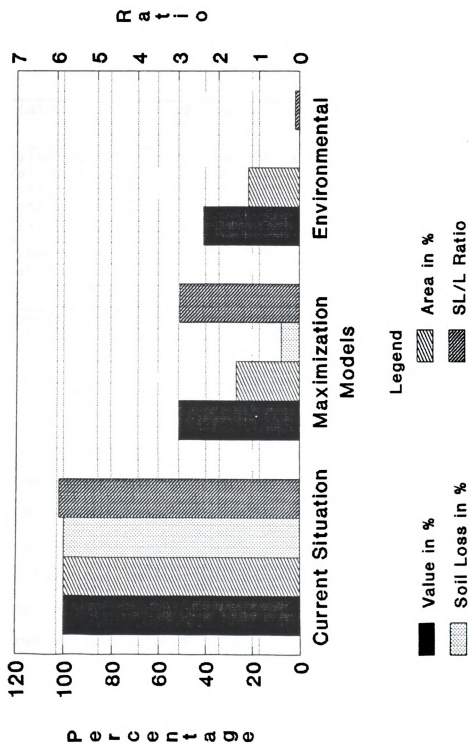


Figure 5.1. Monetary Value, Soil Loss, Area, and Soil Loss Employment Ratio.

optimal program the T-value has been constrained at 1 T-value, while in the exiting production system in the study.

Table 5.1. Monetary Value and Soil Loss in Each Model versus the Actual Situation.

Variable	Maximization Model	Environmental Model	Actual Situation
1) Value in (RD\$)	5,228,844.00	4,155,120.00	10,171,034.00
2) Value in (%)	51.41	40.85	100.00
3) Total Area (has)	281.50	227.90	1046.00
4) Total Area in (%)	26.91	21.79	100.00
5) Soil Loss (tons)	114,426.00	3222.48	1,473,814.00
6) Soil Loss in (%)	7.76	0.00*	100.00
7) Labor Used (p/day)	38,553.85	30,562.60	247,899.46
8) Labor Used in (%)	15.55	12.33	100.00
9) S.L./L Ratio (5/7)**	2.97	0.11	5.95

* Rounded two decimal numbers (0.002).

** S.L./L => Soil Loss Labor Ratio.

area there is not such a constraint.

The optimal program indicated that only five activities should be produced. First, for the production of pigeon peas and beans in a proportion of 50-50 percent in Arroyo la Vaca microwatershed, within RPU 40 with slope category less than 20 percent using low technology (X10A111), an area of 39.22 has. was indicated. Second, for the production of pigeon peas and beans in a proportion of 40-60 percent in La Malagueta microwatershed, within RPU 40 with slope category 20-30 percent using low technology (X21M121), an area of 20.53 has. was indicated. Third, a forest production activity growing Eucalyptus camaldulensis in La Nuez microwatershed, within RPU 02 with slopes 30-40 percent using low technology (X27N221), was brought into the optimal

program with an area of 206.94 has. Fourth, the program also allocated an area of 11.02 has. for the production of potatoes rotated with cabbage in La Nuez microwatershed, within RPU 02 with slopes 20-30 percent, using medium technology (X29N222). Finally the production of onions, potatoes and cabbage in La Nuez microwatershed (irrigated land) within RPU 02 with slopes 20-30 percent using medium technology (X26I222), was indicated by the optimal program with a value of 3.81 has.

Under the second objective of improving environmental quality, the optimal program indicated that the minimum soil loss could be achieved by producing only forest of Eucalyptus camaldulensis in the Arroyo la Vaca microwatershed, within RPU 40 with a slope greater than 40 percent using low technology (X13A131). An area of 227.90 has. was indicated by the optimal program to meet the estimated minimum labor wage per year. The area indicated in this optimal program represents approximately 21.79 percent of the amount of land actually used.

The minimum soil loss indicated by the optimal program was 3,222.48 tons per year. This amount of soil loss represents 2.82 percent of the total soil loss produced by the basic solution of the income maximization baseline solution, and 0.002 percent of the total soil loss produced within the existing condition [Table 5.1]. The amount of person labor days used in this optimal program represents 12.33 percent of the current situation and 79.27

percent when compared to the basis optimal program for the income maximization model. On the other hand, the soil loss labor ratio calculated is equal to 0.11, which indicates that 0.11 tons of soil loss are produced for each person day used. This optimal program represents the lowest soil loss labor ratio when compared to the income maximization model and to the current situation.

A number of computer runs were made for the income maximization model in order to evaluate sensitivity of the optimal solution given a change in policies.

Run 1: Income maximization under a soil loss tolerance of 2 T-values. Other resource constraints remained the same as in the basic.

Run 2: Income maximization under an increased soil loss tolerance to 3 T-values and other resource constraints remaining unchanged.

Run 3: Income maximization with 50 percent increase in resource capital available to farmers. Remaining resource constraints were unchanged.

Run 4: Income maximization under a 100 percent increase of resource capital available to farmers without changing other resource constraints.

Run 5: Income maximization under a combination of 50 percent increase in capital resources available to farmers and an increase of soil loss tolerance to 2 T-values.

Run 6: Income maximization under a 100 percent increase in net farm income for coffee. Other resource constraints

were unchanged.

Run 7: Income maximization with a modification of the discount rate from 25 percent to 15 percent for agroforestry activities.

The maximum level of net return was indicated in run 7, which is 46.09 percent greater than the optimal value in the baseline solution. However, the level of soil loss produced was 72.61 percent lower. In the same manner, runs 1 and 5 both have the same income maximization value, which is 26.70 percent greater than in the basic, and produce a soil loss equal to 83.13 percent greater than the amount produced in the basic optimal solution. In runs 1, 2 and 3 the total net return to farmers' income increased by 2.14, 4.28 and 8.56 percent respectively. However, the amount of soil loss produced by run 1 was 69.97 percent higher, while run 2 was 139.33 percent higher, and in run 3 the total soil loss was a 7.11 percent higher with respect to the amount produce by the baseline solution.

Similarly, both runs 3 and 4 have the same value for income maximization, and soil loss. Net farm income increased by 8.56 with percent with respect to the value of the basis optimal solution, while the soil loss increased by 7.11 percent with respect to the amount produced by the baseline solution. Finally the optimal value for income maximization and soil loss indicated in run 6 were the same as in the basic optimal program.

On the other hand for the environmental quality model,

two runs were made to evaluate the sensitivity of the optimal solution.

Run 1: Minimize soil loss with a modification of the resource constraint of MLW/year equal to the value of the basic optimal solution of the income maximization model. Other resource constraints were unchanged.

The optimal program for this run indicated that the level of income indicated in the basic optimal solution for income maximization could be achieved by decreasing the level of soil loss by 43.11 percent. The value of the objective function indicated by the optimal program was 49,329.27 tons per year. The model indicated a value of 218.35 has. for the forest production of Eucalyptus camaldulensis. in La Malagueta microwatershed, within RPU 40 with slopes 30-40 percent, using low technology (X18M131). This activity produces an average soil loss of 14.14 tons per has. per year. Two other activities were indicated in the optimal solution. First, the production of pigeon peas and beans in a proportion of 50-50 percent in the Arroyo la Vaca microwatershed, within RPU 40 with slope category less than 20 percent, using low technology (X10A111), under an area of 18.30 has. Second, the program indicated the production of 11.63 has. of onions, potatoes, and cabbage in La Nuez microwatershed irrigated land, within RPU 02 with slopes 20-30 percent using medium technology (X26I222).

Run 2: This run consisted of increasing the minimum aggregate labor wage for the region equal to the value of

the optimal solution achieved when the soil loss tolerance was 2 T-values (RD\$ 5,340,728.00).

The algorithm indicated a value of 115,424.30 tons of soil loss per year for the optimal solution. It is 0.87 percent higher than the soil loss generated in the basic for income maximization. On the other hand, it is 40.56 percent lower than the total soil loss indicated in run 2 for income maximization, when 2 T-values were used as a constraint.

To accomplish the aggregate minimum labor wage assigned in this run, the optimal program indicated a value of 75.81 has. for the production of pigeon peas and beans in the proportion of 50-50 percent in Arroyo la Vaca microwatershed, within slopes less than 20 percent in RPU 40, using low technology (X10A111). The optimal program also indicated a value of 200.45 has., for the forest production of Eucalyptus camaldulensis in La Malagueta microwatershed, within RPU 02 with slope category 30-40 percent, using low technology (X18M131). Similarly the production of 11.63 has., of onions, potatoes and cabbage under irrigated land in La Nuez microwatershed, within RPU 02 with slopes 20-30 percent, using improved or medium technology (X26I222).

Conclusions

The results generated by the two models used in this research, the income maximization and the soil loss minimization indicated great differences in optimal programs achieved. The contrasting optimal programs

represent the existing conflicting goals between individual farmers and regional or national administrators. Income maximization might be the greater concern to individual land managers, which involves the use of crops with high net farm income in the short run, associated with high soil erosion. On the other hand, national administrator might be concerned with crop production that improves societal welfare over the long run, and at the same time protects the environment.

The optimal program indicated a very small area should be dedicated to the production of potatoes, cabbage and onions in La Nuez on irrigated land, because of the high soil loss that this crop rotation produces. The optimal program also indicated that the crop combination pigeon peas, peanuts and corn was not profitable. The only crop combination indicated in the optimal solution was the production of pigeon peas and beans in the Arroyo la Vaca microwatershed, when planted in a proportion of 50-50 percent.

It was also indicated that coffee production did not come into the optimal program, even after increasing its net farm income by a 100 percent (Run 6). However, production of Eucalyptus camaldulensis, leads in area all crop activities indicated in the optimal solution for the La Nuez microwatershed on non-irrigated land.

The production of Eucalyptus camaldulensis, was the only activity indicated by the optimal program that minimizes soil loss. This activity was assigned to the

Arroyo la Vaca microwatershed.

Implementation of the optimal program indicated by the income maximization model will reduce the existing level of total income by approximately 50 percent, while in the environmental model it is reduced to 60 percent, because of more restrictive soil loss constraint. Under both optimal program farmers will be worse off than currently, because of reduction of income level, which in turn is due to the soil loss constraint. However, a better environmental quality could be achieved if the optimal program are implemented.

The region will lose the national leadership in the production of potatoes, and its position in the production of cabbage, if the income maximization optimal program is carried out. This might create a decreased supply of these products in the Santo Domingo market, causing an increase in price, which might give incentive to farmers to move back to their original production plan, unless strong incentives to farmers to follow the optimal plan are implemented. However the level of erosion per job created is lower than in the current situation, which would allow to improve the downstream environmental conditions in the region.

Implementation of commercial plantations of Eucalyptus camaldulensis., as indicated by the environmental optimal program will create a shortage of food in the region as well as in the Santo Domingo market. However the level of erosion will be reduced drastically.

The erosion employment ratio is very low, 0.11 tons

per each person day employed. With the implementation of this optimal program, it is expected that Ocoa people would migrate to urban zones, especially to the city of Santo Domingo, because crop production will be not allowed.

Furthermore, because the plantation of Eucalyptus camaldulensis, is new in the area, the success in this forestry activity might be limited by the lack of training that farmers and technicians have in forest plantation management, as well as by the existing land tenure system.

Limitations of the Model

Usefulness of the model for resources allocation in the Ocoa watershed might be limited by some assumptions of the linear programming model:

- 1) The assumption of linearity, which means that all proportions remain constant in the production activity, regardless the level of crops combination and the type of rotation in the activity. Diminishing returns should be taken into consideration to handle this situation by constraining the production levels of the activity.
- 2) The additivity assumption, which means that there is no interaction between activities. The additivity assumption is also applied to crops mixture and crops rotation, but in the real world those interactions among crops take place.
- 3) Constant prices and costs for inputs and outputs were assumed in this model, which means that there is no recognition of variation in the characteristics of inputs and outputs. However, this is not realistic, because not

all farmers have the bargaining power for purchasing inputs as well as selling their outputs. 4) The way in which some resource constraints have been defined in the model might affect its usefulness. It could be true in the case of the soil loss tolerance, which has been defined at the microwatershed level. However, this resource constraint should be more flexible in order to consider a soil loss tolerance that represents the current soil quality condition at the slope category level, according to the current soil quality in each microwatershed. Another resource constraint that should be reformulated is the total land available for production. This resource constraint should be modified in order to restrict the production in areas ecologically fragile. This approach was not follow in this model because of lack of data reflecting the existing soil quality condition in the study region. 5) The static condition of the model, which means that the time dimension is not considered, might also affect the usefulness of the model for future resource allocation in the Ocoa watershed. However, this can be overcome by the use of use of pseudodynamic linear programming and recursive linear programming models.

The use of a recursive model is more complex, because it requires one to generate impacts outside the model and then incorporate those outputs as inputs in the recursive model as time impact. Recursive linear programming solve for each time period separately (Osteen, 1976). The first

time period is optimized, then this solution become a constraint of the next time period. In a recursive linear program, a sequential solution process is conducted for all periods being considered. The optimal solution for each time period is constrained by the optimal solution for prior periods.

Use of the pseudodynamic model is less complex, because those time impacts can be incorporated directly as an activity column through the use of an interest rate, to bring a stream of costs and benefits to one point in time. In this case the level of soil erosion must be measured in monetary values and a social discount rate is used as an activity column to estimate the net present value foregone because of soil erosion. In the pseudodynamic linear programming algorithm, NPV for costs and returns must be calculated to generate the objective function coefficients. The time period being considered must be the same for all activities included in the model. Similarly, outputs and resources constraints must be estimated for each time period (Osteen, 1976). There by the pseudodynamic linear programming algorithm will optimize the expected stream of monetary value over a given time period, already defined.

Data Limitations

Some assumptions made in generating the data set used in this research might limit the usefulness of the results:

- 1) The total cost, including the technical coefficients for labor and inputs used in each production

activity, represent modifications of national averages to reflect an approximation of the existing conditions in the study area. 2) The total supply of family labor, classified by men, women and children, was estimated based on the results reported by a survey carried out in the study area [Erbaugh, 1983]. 3) Non complementarity in crop mixtures was considered in the estimation of yield per crop. Yields and costs were estimated assuming each crop was planted alone. Cost did not reflect the impact of the slope on crop production. 4) The production of banana was assumed to have a MVP equal to zero, because there was not a market price for that the type of banana grown in the area, which is of low quality. However, because the banana crop is consumed by the farmers' family, the MVP should be greater than zero. 5) It was assumed that farmers had the management knowledge required to produce agroforestry activities. 6) The average soil loss was estimated using the USLE, might not show the real soil erosion taking place in the region. This can overcome by incorporating soil loss data generated by existing soil and water monitoring plots in the area.

Recommendations for Formulation of Policies

Under the resource constraints specified in the two models, Eucalyptus camaldulensis is the best enterprise to produce on slopes 30 to 40 percent. The production of Eucalyptus camaldulensis was included in the optimal programs both when maximizing farmers' income and when



minimizing soil loss. However, the existing land tenure system and forestry legislation might constraint the reception that farmers might give the suggested production system [SEA, 1985e].

It is suggested that some incentives or subsidies to increase the net return to farmers should be considered. These are necessary to compensate for the reduction in yield of Eucalyptus and agricultural crops if the taungya system is used. It is required because crop yields decrease over time and drop to zero at year two as the Eucalyptus plantation growth. Similarly, Eucalyptus yields decrease, as the planting spacing is increased to 3 x 3 m to allow for agricultural crops production during the first two years. On the other hand, some disincentives for the production of those high erosive crops should be taken into consideration in order to improve environmental quality and maintain a sustained yield condition over time.

The production of pigeon peas with beans in a proportion of 50-50 percent is suggested on slopes lower than 20 percent. Both optimal programs indicated that the family labor resource is a major constraint, but in general, there is a large hired labor surplus in the Ocoa watershed. Therefore, implementation of any of these optimal programs will increase the level of unemployment in the region, as is indicated by the labor use figures in both situations.

Some policies that should be considered in view of this situation include: 1) Human resources settlement in other

production regions where labor is limited, in order to reduce the level of unemployment; 2) Implementation of agrarian reform should be considered to take place outside the region, to produce substitute crops for those crops whose production has been eliminated in the Ocoa watershed; 3) Agrarian reform that assigns ownership property rights to farmers to provide incentive to invest in soil conservation, should be considered for implementation in the watershed; 4) Another action to be considered to reduce unemployment and migration to urban area is to develop small craftwork industries in the area. 5) Small enterprises for making cabinetwork and furniture from Eucalyptus should be financed in the region. The final product could be sold in the Santo Domingo market, and also might be exported.

It is important to mention that as any policy, the implementation of either of the two optimal programs imply transaction costs, which include all costs involved in the process of planning, implementation, monitoring and policy enforcement. However, something must be done to reduce the deterioration of the watershed, which, if current use continues, will in a very short time lose all of its topsoil. To create 1 inch (2.54 cm.) of topsoil from the upper subsoil of well-managed, productive cropland takes 30 years (Poincelot, 1986)

Recommendations for Future Research

A static linear programming model reflects effects of a situation in a given period of time. This model is limited



in that does not take into account the impact that soil erosion has on farmers' income over time, as a result of yield reduction.

It is suggested that future research in this matter should consider models that incorporate farm size and time dimensions, as well as other activities such as forage and livestock. It is also important to incorporate the effects of soil erosion on yield.

It is also suggested that agroeconomic data reflecting slope, technology, crop mixture, farm size and change over time be gathered in a consistent manner, to create a time serie data. Data reflecting those characteristics discussed above are important to facilitate use of the pseudodynamic linear programming model. By incorporating these data, the optimal solution might indicate the appropriate technology and the optimal crops mixture for each slope category and for each farm size type. Availability of this information may help decisions makers to evaluate the performance of the agricultural sector, as well as to evaluate different alternatives actions for achieving regional and national goals.

Additional model improvement could be accomplished by incorporating micro agroecological conditions reflecting variations of slope classes and soil textures, which in turn affect surface runoff, soil moisture recharge, and soil moisture availability for crop growth.

APPENDICES

APPENDIX A

GLOSSARY

Appendix A-1. Glossary.

DR	Dominican Republic.
USDA-SCS	United State Department of Agriculture. Soil Conservation Service.
GODR	Government of the Dominican Republic.
CEP	Country Environmental Profile.
CRIES	Comprehensive Resource Inventory and Evaluation System.
MT/ha	Metric Ton per Hectare.
SEA	Secretariat of State Of Agriculture, DR.
NARMA	Natural Resource Management Project.
GIS	Geographical Information System.
MLW	Minimum Labor Wage
MSU	Michigan State University.
RPU	Resources Planning Units.
CATIE	Centro de Agricultura Tropical para la Investigacion y Ensenanza.
JUNTA	Asociation para el Desarrollo de San Jose de Ocoa.
CONATEF	Comision Nacional Technical Forestal.
DGF	Direccion General de Foresta.
RHS	Right Hand Side.
T-value	Value of the Soil Loss Tolerance.
USLE	Universal Soil Loss Equation.
Ha.	Hectare (2.471 acres).
RD\$	Dominican Republic Peso. US\$1.00 = RD\$6.00.
QQ	Quintal equal to 100 pounds.
f.d.p.	Feet Dozen of Poles.
NPW or NPV	Net Present Value

Appendix B

DESCRIPTION OF ACTIVITIES

Appendix B-1. Description of the Crops and Noncrops Activities Incorporated in the Linear Programming Matrix.

Activities	Description
X1A111	Farming system 1, pigeon peas/peanuts/corn in a proportion of 20-60-20% per unit of hectare in microwatershed Arroyo La Vaca (A), within the RPU 40 (1), slope category less than 20% (1), using traditional or low technology (1).
X1A121	Farming System 1, in microwatershed (A), within RPU 40 in slope category 20-30% (2) using traditional technology.
X1A122	Farming system 1, in microwatershed (A), within RPU 40 in slope category 20-30% using medium technology.
X1A131	Farming system 1, in microwatershed A, within RPU 40 with slope category 30-40%, using low technology.
X2A111	Farming system 2, pigeon peas/peanuts/corn in a proportion of 40-40-20% in microwatershed A, within RPU 40 with slope category less than 20 %, using low technology.
X2A121	Farming system 2, in microwatershed A, within RPU 40 and slope category 20-30% using low technology.
X2A122	Farming system 2, in microwatershed A within RPU 40 and slope category 20-30% using medium technology.
X2A131	Farming system 2, in microwatershed A, within RPU 40 and slope category 30-40% using low technology.
X2A132	Farming system 2, in microwatershed A within RPU 40 and slope category 30-40% using medium technology.
X3A111	Farming system 3, pigeon peas/peanuts/corn in a proportion of 50-30-20%, in microwatershed A, within RPU 40 and slope category less than 20% using low technology.
X3A121	Farming system 3, in microwatershed A, within RPU 40 and slope category 20-30% using low technology.
X3A122	Farming system 3, in microwatershed A, within RPU 40 and slope category 20-30% using medium technology.
X3A131	Farming system 3, in microwatershed A, within RPU 40 and slope category 30-40% using low technology.
X3A132	Farming system 3, in microwatershed A, within RPU 40 and slope category 30-40% using medium technology.

Appendix B-1. (cont'd).

Activities	Description
X4A111	Farming system 4, pigeon peas/peanuts in a proportion of 40-60%, in microwatershed A, within RPU 40 and slope category less than 20% using low technology.
X4A121	Farming system 4, in microwatershed A, within RPU 40 and slope category 20-30%, using low technology.
X4A122	Farming system 4, in microwatershed A, within RPU 40 and slope category 20-30%, using medium technology.
X4A131	Farming system 4, in microwatershed A, within RPU 40 and slope category 30-40%, using low technology.
X4A132	Farming system 4, in microwatershed A, within RPU 40 and slope category 30-40%, using medium technology.
X5A111	Farming system 5, pigeons peas/peanuts in a proportion of 50-50%, in microwatershed A, within RPU 40 and slope category less than 20% using low technology.
X5A121	Farming system 5, in microwatershed A, within RPU 40 and slope category 20-30%, using low technology.
X5A122	Farming system 5, in microwatershed A, within RPU 40 and slope category 20-30%, using medium technology.
X5A131	Farming system 5, in microwatershed A, within RPU 40 and slope category 30-40%, using low technology.
X5A132	Farming system 5, in microwatershed A, within RPU 40 and slope category 30-40%, using medium technology.
X6A111	Farming system 6, pigeon peas/peanuts in a proportion of 60-40% in microwatershed A, within RPU 40 and slope category less than 20% using low technology.
X6A121	Farming system 6, in microwatershed A, within RPU 40 and slope category 20-30% using low technology.
X6A122	Farming system 6, in microwatershed A, within RPU 40 and slope category 20-30% using medium technology.
X6A131	Farming system 6, in microwatershed A, within RPU 40 and slope category 30-40% using low technology.
X6A132	Farming system 6, in microwatershed A, within RPU 40 and slope category 30-40% using medium technology.
X6A142	Farming system 6, in microwatershed A, within RPU 40 and slope category greater than 40% using medium technology.
X7A111	Farming system 7, pigeon peas/beans/corn in a

Appendix B-1. (cont'd).

Activities	Description
	proportion of 20-60-20% in microwatershed A, within RPU 40 and slope category less than 20%, using low technology.
X7A121	Farming system 7, in microwatershed A, within RPU 40 and slope category 20-30%, using low technology.
X7A122	Farming system 7, in microwatershed A, within RPU 40 and slope category 20-30%, using medium technology.
X8A111	Farming system 8, pigeon peas/beans/corn in a proportion of 40-40-20% in microwatershed A, within RPU 40 and slope category less than 20% using low technology.
X8A121	Farming system 8, in microwatershed A, within RPU 40 and slope category 20-30% using low technology.
X8A122	Farming system 8, in microwatershed A, within RPU 40 and slope category 20-30% using medium technology.
X8A131	Farming system 8, in microwatershed A, within RPU 40 and slope category 30-40% using low technology.
X8A132	Farming system 8, in microwatershed A, within RPU 40 and slope category 30-40% using medium technology.
X8A142	Farming system 8, in microwatershed A, within RPU 40 and slope category greater than 40% using medium technology.
X9A111	Farming system 9, pigeon peas/beans in a proportion of 40-60%, in microwatershed A, within RPU 40 with slope category less than 20% using low technology.
X9A121	Farming system 9, in microwatershed A, within RPU 40 with slope category 20-30% using low technology.
X9A122	Farming system 9, in microwatershed A, within RPU 40 with slope category 20-30% using medium technology.
X9A131	Farming system 9, in microwatershed A, within RPU 40 with slope category 30-40% using low technology.
X9A132	Farming system 9, in microwatershed A, within RPU 40 with slope category 30-40% using medium technology.
X9A142	Farming system 9, in microwatershed A, within RPU 40 with slope category greater than 40% using medium technology.
X10A111	Farming system 10, pigeon peas/beans in a proportion of 50-50% in microwatershed A, within RPU 40 with slope category less than 20% using low technology.
X10A121	Farming system 10, pigeon peas/beans in a

Appendix B-1. (cont'd).

Activities	Description
	proportion of 50-50 % in microwatershed A, within RPU 40 with slope category 20-30% using low technology.
X10A122	Farming system 10, pigeon peas/beans in microwatershed A, in a proportion of 50-50% within RPU 40 with slope category of 20-30% using medium level of technology.
X10A131	Farming system 10, pigeon peas/beans in microwatershed A, in a proportion of 50-50% within RPU 40 with slope category 30-40% using low level of technology.
X10A132	Farming system 10, pigeon peas/beans in microwatershed A, in a proportion of 50-50% within RPU 40 with slope category 30-40% using medium technology.
X10A142	Farming system 10, pigeon peas/beans in microwatershed A, in a proportion of 50-50% within RPU 40 with slope category greater than 40% using medium technology.
X11A111	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category less than 20% using low technology.
X11A121	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category 20-30% using low technology.
X11A122	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category 20-30% using medium technology.
X11A131	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category 30-40% using low technology.
X11A132	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category 30-40% using medium technology.
X11A142	Farming system 11, pigeon peas/beans in microwatershed A, in a proportion of 60-40% within RPU 40 with slope category greater than 40% using medium technology.
X12A131	Farming system 12, Eucalyptus/beans (taungya) in microwatershed A, within RPU 40 with slope category 30-40% using low technology.
X12A141	Farming system 12, Eucalyptus/beans (taungya) in microwatershed A, within RPU 40 with slope

Appendix B-1. (cont'd).

Activities	Description
X13A131	category greater than 40% using low technology. Farming system 13, Eucalyptus (forest) in microwatershed A, within RPU 40 with slope category 30-40% using low technology.
X13A141	Farming system 12, Eucalyptus (forest) in microwatershed A, within RPU 40 with slope category greater than 40% using low technology.
X14A132	Farming system 14, Coffee/beans/bananas (taungya) in microwatershed A, within RPU 40 with slope category 30-40% using medium technology.
X14A142	Farming system 14, Coffee/beans/bananas (taungya) in microwatershed A, within RPU 40 with slope category greater than 40% using medium technology.
X15M132	Farming system 15, Coffee/beans/banana (taungya) in microwatershed M, within RPU 40 with slope category 30-40% using medium technology.
X15M142	Farming system 15, Coffee/beans/banana (taungya) in microwatershed M, within RPU 40 with slope category greater than 40% using medium technology.
X16M232	Farming system 16, Coffee/beans/banana (taungya) in microwatershed M, within RPU 02 with slope category 30-40% using medium technology.
X16M242	Farming system 16, Coffee/beans/banana (taungya) in microwatershed M, within RPU 02 with slope category greater than 40% using medium technology.
X17M131	Farming system 17, Eucalyptus cam./beans (taungya) in microwatershed M, within RPU 40 with slope category 30-40% using low technology.
X17M141	Farming system 17, Eucalyptus cam./beans (taungya) in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X18M131	Farming system 18, Eucalyptus (forest) in microwatershed M, within RPU 40 with slope category 30-40% using low technology.
X18M141	Farming system 18, Eucalyptus (forest) in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X19M121	Farming system 19, pigeon peas/beans/corn in a proportion of 20-60-20% in microwatershed M, within RPU 40 with slope category 20-30% using low technology.
X19M122	Farming system 19, pigeon peas/beans/corn in a proportion of 20-60-20% in microwatershed M, within RPU 40 with slope category 20-30%, using medium technology.
X19M132	Farming system 19, pigeon peas/beans/corn in a proportion of 20-60-20% in microwatershed M, within RPU 40 with slope category 30-40%, using medium

Appendix B-1. (cont'd).

Activities	Description
	technology.
X19M141	Farming system 19, pigeon peas/beans/corn in a proportion of 20-60-20% in microwatershed M, within RPU 40 with slope category greater than 40%, using low technology.
X20M121	Farming system 20, pigeon peas/beans/corn in a proportion 40-40-20%, in microwatershed M, within RPU 40 with slope category 20-30% using low technology.
X20M122	Farming system 20, pigeon peas/beans/corn in a proportion 40-40-20%, in microwatershed M, within technology.
X20M132	Farming system 20, pigeon peas/beans/corn in a proportion 40-40-20%, in microwatershed M, within RPU 40 with slope category 30-40% using medium technology.
X20M141	Farming system 20, pigeon peas/beans/corn in a proportion 40-40-20%, in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X21M121	Farming system 21, pigeon peas/beans in a proportion 40-60%, in microwatershed M, within RPU 40 with slope category 20-30% using low technology.
X21M122	Farming system 21, pigeon peas/beans in a proportion 40-60%, in microwatershed M, within RPU 40 with slope category 20-30% using medium technology.
X21M132	Farming system 21, pigeon peas/beans in a proportion 40-40-20%, in microwatershed M, within RPU 40 with slope category 20-30% using medium technology.
X21M141	Farming system 21, pigeon peas/beans in a proportion 40-40-20%, in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X22M121	Farming system 22, pigeon peas/beans in a proportion of 50-50% in microwatershed M, within RPU 40 with slope category 20-30% using low level of technology.
X22M122	Farming system 22, pigeon peas/beans in a proportion of 50-50% in microwatershed M, within RPU 40 with slope category 20-30% using medium technology.
X22M132	Farming system 22, pigeon peas/beans in a proportion of 50-50% in microwatershed M, within RPU 40 with slope category 30-40% using medium technology.
X22M141	Farming system 22, pigeon peas/beans in a

Appendix B-1. (cont'd).

Activities	Description
	proportion of 50-50% in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X23M121	Farming system 23, pigeon peas/beans in a proportion of 60-40% in microwatershed M, within RPU 40 with slope category 20-30% using low level of technology.
X23M122	Farming system 23, pigeon peas/beans in a proportion of 60-40% in microwatershed M, within RPU 40 with slope category 20-30% using medium technology.
X23M132	Farming system 23, pigeon peas/beans in a proportion of 60-40% in microwatershed M, within RPU 40 with slope category 30-40% using medium technology.
X23M141	Farming system 23, pigeon peas/beans in a proportion of 60-40% in microwatershed M, within RPU 40 with slope category greater than 40% using low technology.
X24M222	Farming system 24, rotation of onions and onions in microwatershed M within RPU 02 with slope category 20-30% using medium technology.
X24M232	Farming system 24, rotation of onions and onions in microwatershed M within RPU 02 with slope category 30-40% using medium technology.
X24M242	Farming system 24, rotation of onions and onions in microwatershed M within RPU 02 with slope category greater than 40% using medium technology.
X25M222	Farming system 25, rotation of potatoes and onions in microwatershed M within RPU 02 with slope category 20-30% using medium technology.
X25M232	Farming system 25, rotation of potatoes and onions in microwatershed M within RPU 02 with slope category 30-40% using medium technology.
X25M242	Farming system 25, rotation of potatoes and onions in microwatershed M within RPU 02 with slope category greater than 40% using medium technology.
X26I222	Farming system 26, rotation of onions, potatoes and cabbage in microwatershed I within RPU 02 with slope category 20-30% using medium technology.
X26I232	Farming system 26, rotation of onions, potatoes and cabbage in microwatershed I, within RPU 02 with slope category 30-40% using medium technology.
X26I242	Farming system 26, rotation of onions, potatoes and cabbage in microwatershed I, within RPU 02 with slope category greater than 40% using medium technology.
X27N231	Farming system 27, Eucalyptus (forest) in

Appendix B-1. (cont'd).

Activities	Description
	microwatershed N, within RPU 02 with slope category 20-30% using low technology.
X27N241	Farming system 27, Eucalyptus (forest) in microwatershed N, within RPU 02 with slope category 30-40% using low technology.
X28N232	Farming system 28, Coffee/beans/banana (taungya) in microwatershed N, within RPU 02 with slope category 30-40% using medium technology.
X28N242	Farming system 28, Coffee/beans/banana (taungya) in microwatershed N, within RPU 02 with slope category greater than 40% using medium technology.
X29N222	Farming system 29, rotation of potatoes/cabbage in microwatershed N, within RPU 02 with slope category 20-30% using medium technology.
X29N232	Farming system 29, rotation of potatoes/cabbage in microwatershed N, within RPU 02 with slope category 30-40% using medium technology.
X29N242	Farming system 29, rotation of potatoes/cabbage in microwatershed N, within RPU 02 with slope category greater than 40% using medium technology.
Hmen	Hired male labor.
Hwomen	Hired women labor.
Hchildre	Hired children labor.
Fmen	Male family labor.
Fwomen	Women family labor.
Fchildre	Children family labor.
Farmers'	Farmers' own capital.
Agbank	Agricultural Bank.
Contract	Contractors or peanuts buyers (La Manicera and Lavador) that finance the production of peanuts.
Brokers	Participants in the agricultural marketing system that borrow money to farmers.

Appendix C

FARM GATE PRICES IN RD\$ (1988)

Appendix C-1. Farm Gate Prices in RD\$ (1988).

Crops	Price	Unit
Coffee (Coffea arabica)	375.00	QQ
Onion (Allium cepa)	300.00	QQ
Pigeon peas (Cajanus cajan)	130.00	QQ
Banana (Musa sapuntum)	-----	--
Beans (Phaseolus vulgaris)	160.00	QQ
Corn (Zea mays)	35.00	QQ
Peanuts (Arachis hypogaea)	44.00	QQ
Potatoes (Solanum tuberosum)	80.00	QQ
Cabbage (Brassica oleracea)	2.00	ea.
Eucalyptus camaldulensis	9.00	f.d.p.

APPENDIX D

LINEAR PROGRAMMING MATRIX

D-1. Linear Programming Matrix

MAXIMIZE: 4649.53 X1A111 + 3231.93 X1A121 + 3436 X1A122 +
 2168.73 X1A131 + 5107.73 X2A111 + 3717.33 X2A121 + 4013.01
 X2A122 + 2582.93 X2A131 + 2390.61 X2A132 + 6827.17 X3A111 +
 4821.57 X3A121 + 5158.73 X3A122 + 3424.77 X3A131 + 3223.73
 X3A132 + 5578.7 X4A111 + 4053.5 X4A121 + 4258.01 X4A122 +
 2821.5 X4A131 + 2505.01 X4A132 + 6188.67 X5A111 + 4315.07
 X5A121 + 4524.99 X5A122 + 3032.67 X5A131 + 2757.19 X5A132 +
 6543.27 X6A111 + 4567.67 X6A121 + 4791.81 X6A122 + 3243.67
 X6A131 + 3009.21 X6A132 + 1510.01 X6A142 + 6132.47 X7A111 +
 5229.07 X7A121 + 5820.13 X7A122 + 3683.47 X7A131 + 4034.13
 X7A132 + 3965.68 X8A111 + 5081.34 X8A121 + 5557.11 X8A122 +
 3437.34 X8A131 + 3920.11 X8A132 + 2200.11 X8A142 + 7317.47
 X9A111 + 6035.47 X9A121 + 6633.62 X9A122 + 4055.47 X9A131 +
 4900.62 X9A132 + 2836.62 X9A142 + 7424.8 X10A111 + 5972.8
 X10A121 + 9703.24 X10A122 + 4060.8 X10A131 + 4748.24 X10A132
 + 2784.24 X10A142 + 7497.96 X11A111 + 5875.96 X11A121 +
 6341.96 X11A122 + 4031.96 X11A131 + 4564 X11A132 + 2700.96
 X11A142 + 14043.88 X12A131 + 13915.88 X12A141 + 18232.33
 X13A131 + 18232.33 X13A141 + 5211.97 X14A132 + 5211.97
 X14A142 + 5211.97 X15M132 + 5211.97 X15M142 + 8896.62
 X16M232 + 8895.97 X16M242 + 14043.88 X17M131 + 13915.88
 X17M141 + 18232.33 X18M131 + 18232.33 X18M141 + 5229.07
 X19M121 + 5820.13 X19M122 + 4034.13 X19M132 + 3324.45
 X19M141 + 5081.34 X20M121 + 5557.11 X20M122 + 3920.11
 X20M132 + 3115.31 X20M141 + 6035.47 X21M121 + 6633.62
 X21M122 + 4900.62 X21M132 + 6364.8 X21M141 + 5972.8 X22M121
 + 9703.24 X22M122 + 4748.24 X22M132 + 2016.65 X22M141 +
 5875.96 X23M121 + 6341.96 X23M122 + 4564.96 X23M132 +
 3665.96 X23M141 + 38288.74 X24M222 + 23888.74 X24M232 +
 9488.74 X24M242 + 28017.37 X25M222 + 16977.37 X25M232 +
 7217.37 X25M242 + 18232.33 X27N231 + 18232.33 X27N241 +
 8895.62 X28N232 + 8895.62 X28N242 - 15 HMEN - 12 HWOMEN - 9
 HCHILDRE + 14 FMEN + 11 FWOMEN + 8 FCHILDRE + .1 AGBANK +
 1.05 BROKERS + 95643.56 X26I222 + 77643.56 X26I232 +
 59484.56 X26I242 + 61397.53 X29N222 + 41557.53 X29N232 +
 22997.53 X29N242

SUBJECT TO:

2) X1A111 + X2A111 + X3A111 + X4A111 + X5A111 + X6A111 +
 X7A111 + X8A111 + X9A111 + X10A111 + X11A111 <= 1381

3) X1A121 + X1A122 + X2A121 + X2A122 + X3A121 + X3A122
 + X4A121 + X4A122 + X5A121 + X5A122 + X6A121 + X6A122 +
 X7A121 + X7A122 + X8A121 + X8A122 + X9A121 + X9A122 +

Table D-1. (Cont'd).

X10A121 + X10A122 + X11A121 + X11A122	<=	644
4) X1A131 + X2A131 + X2A132 + X3A131 + X3A132 + X4A131 + X4A132 + X5A131 + X5A132 + X6A131 + X6A132 + X7A131 + X7A132 + X8A131 + X8A132 + X9A131 + X9A132 + X10A131 + X10A132 + X11A131 + X11A132 + X12A131 + X13A131 + X14A132		
	<=	1633
5) X6A142 + X8A142 + X9A142 + X10A142 + X11A142 + X12A141 + X13A141 + X14A142		
	<=	386
6) X19M121 + X19M122 + X20M121 + X20M122 + X21M121 + X21M122 + X22M121 + X22M122 + X23M121 + X23M122 + X25M222 + X24M122		
	<=	369
7) X15M132 + X16M232 + X17M131 + X18M131 + X19M132 + X20M132 + X21M132 + X22M132 + X23M132 + X24M232 + X25M232		
	<=	868
8) X15M142 + X16M242 + X17M141 + X18M141 + X19M141 + X20M141 + X21M141 + X22M141 + X23M141 + X24M242 + X25M242		
	<=	1993
9) X26I222	<=	84
10) X26I232	<=	264
11) X26I242	<=	387
12) X29N222	<=	338
13) X27N231 + X28N232 + X29N232	<=	1066
14) X27N241 + X28N242 + X29N242	<=	1550
15) 12.15 X25M222 + 12.15 X25M232 + 12.15 X25M242 + HMEN - 624 FMEN + 113.92 X26I222 + 113.92 X26I232 + 113.92 X26I242	<=	8354
16) 16.28 X1A111 + 16.28 X1A121 + 43.43 X1A122 + 16.28 X1A131 + 17.6 X2A111 + 18.84 X3A121 + 40.85 X3A122 + 18.84 X3A131 + 40.85 X3A132 + 17.34 X4A111 + 17.34 X4A121 + 41.3 X4A122 + 17.34 X4A131 + 41.3 X4A132 + 18.34 X5A111 + 18.84 X5A121 + 40.85 X5A122 + 18.84 X5A131 + 40.85 X5A132 + 19.57 X6A111 + 19.57 X6A121 + 40.4 X6A122 + 19.57 X6A131 + 40.4 X6A132 + 40.4 X6A142 + 15.97 X7A121 + 26.93 X7A122 + 15.97 X7A131 + 26.93 X7A132 + 18.15 X8A111 + 18.15 X8A121 + 31.5 X8A122 + 18.15 X8A131 + 31.5 X8A132 + 31.5 X8A142 + 10.35 X9A111 + 10.35 X9A121 + 17.36 X9A122 + 10.35 X9A131 + 17.36 X9A132 + 17.36 X9A142 + 11.45 X10A111 + 11.45 X10A121 + 19.64 X10A122 + 11.45 X10A131 + 19.64 X10A132 + 19.64 X10A142 + 12.54 X11A111 + 12.54 X11A121 + 43.84 X11A122 +		

Table D-1. (Cont'd).

12.54 X11A131 + 21.92 X11A132 + 21.92 X11A142 + 30.55
 X12A131 + 30.55 X12A141 + 28.16 X13A131 + 28.16 X13A141 +
 56.39 X14A132 + 56.39 X14A142 + 56.39 X15M132 + 56.39
 X15M142 + 56.39 X16M232 + 56.39 X16M242 + 30.55 X17M131 +
 30.55 X17M141 + 28.16 X18M131 + 28.16 X18M141 + 15.97
 X19M121 + 26.93 X19M122 + 26.93 X19M132 + 15.97 X19M141 +
 18.15 X20M121 + 31.5 X20M122 + 31.5 X20M132 + 18.15 X20M141
 + 10.35 X21M121 + 17.36 X21M122 + 17.36 X21M132 + 10.35
 X21M141 + 11.45 X22M121 + 19.64 X22M122 + 19.64 X22M132 +
 11.45 X22M141 + 12.54 X23M121 + 21.92 X23M122 + 21.92
 X23M132 + 12.54 X23M141 + 29.16 X24M222 + 29.16 X24M232 +
 29.16 X24M242 + 9.88 X25M222 + 9.88 X25M232 + 9.88 X25M242 +
 28.16 X27N231 + 28.16 X27N241 + 56.39 X28N232 + 56.39
 X28N242 + HMEN - 624 FMEN + 34.96 X26I222 + 34.96 X26I232 +
 34.96 X26I242 <= 8354

17) 26.28 X1A111 + 26.28 X1A121 + 26.73 X1A122 + 26.28
 X1A131 + 18.76 X2A111 + 18.76 X2A121 + 24.01 X2A122 + 18.76
 X2A131 + 24.01 X2A132 + 11.77 X3A111 + 11.77 X3A121 + 22.72
 X3A122 + 11.77 X3A131 + 22.72 X3A132 + 20.53 X4A111 + 20.53
 X4A121 + 27.5 X4A122 + 20.53 X4A131 + 27.3 X4A132 + 19.53
 X5A111 + 19.53 X5A121 + 26.2 X5A122 + 19.53 X5A131 + 26.2
 X5A132 + 17.48 X6A111 + 17.48 X6A121 + 24.28 X6A122 + 17.48
 X6A131 + 24.88 X6A132 + 24.88 X6A142 + 12.49 X7A111 + 12.49
 X7A121 + 14.81 X7A122 + 12.49 X7A131 + 14.81 X7A132 + 12.09
 X8A111 + 12.09 X8A121 + 16.13 X8A122 + 12.09 X8A131 + 16.13
 X8A132 + 16.13 X8A142 + 10.5 X9A111 + 10.5 X9A121 + 15.67
 X9A122 + 10.5 X9A131 + 15.67 X9A132 + 15.67 X9A142 + 10.31
 X10A111 + 10.31 X10A121 + 16.37 X10A122 + 10.31 X10A131 +
 16.37 X10A132 + 16.37 X10A142 + 10.11 X11A111 + 10.11
 X11A121 + 17 X11A122 + 10.11 X11A131 + 17 X11A132 + 17
 X11A142 + 38.12 X12A131 + 38.12 X12A141 + 33.6 X13A131 +
 33.6 X13A141 + 70.52 X14A132 + 70.52 X14A142 + 70.52 X15M132
 + 70.52 X15M142 + 70.52 X16M232 + 70.52 X16M242 + 38.12
 X17M131 + 38.12 X17M141 + 33.6 X18M131 + 33.6 X18M141 +
 12.49 X19M121 + 14.81 X19M122 + 14.81 X19M132 + 12.49
 X19M141 + 12.09 X20M121 + 16.13 X20M122 + 16.13 X20M132 +
 12.09 X20M141 + 10.5 X21M121 + 15.67 X21M122 + 15.67 X21M132
 + 10.5 X21M141 + 10.31 X22M121 + 16.37 X22M122 + 16.37
 X22M132 + 10.31 X22M141 + 10.11 X23M121 + 17 X23M122 + 17
 X23M132 + 10.11 X23M141 + 100.16 X24M222 + 100.16 X24M232 +
 100.16 X24M242 + 32.16 X25M222 + 32.16 X25M232 + 32.16
 X25M242 + 33.6 X27N231 + 33.6 X27N241 + 70.52 X28N232 +
 70.52 X28N242 + HMEN - 624 FMEN + 71.29 X26I222 + 71.29
 X26I232 + 71.29 X26I242 + 46.24 X29N222 + 46.24 X29N232 +
 46.24 X29N242 <= 8354

18) 20.69 X1A111 + 20.69 X1A121 + 28.84 X1A122 + 20.69
 X1A131 + 14.74 X2A111 + 14.74 X2A121 + 16.15 X2A122 + 14.74
 X2A131 + 25.4 X2A132 + 6.4 X3A111 + 6.4 X3A121 + 21.15
 X3A122 + 6.4 X3A131 + 21.15 X3A132 + 8.75 X4A111 + 8.75

Table D-1. (Cont'd).

X4A121 + 27.3 X4A122 + 8.75 X4A131 + 27.3 X4A132 + 7.3
 X5A111 + 7.3 X5A121 + 22.75 X5A122 + 7.3 X5A131 + 22.75
 X5A132 + 5.84 X6A111 + 5.84 X6A121 + 18.2 X6A122 + 5.84
 X6A131 + 18.2 X6A132 + 18.2 X6A142 + 9.16 X7A111 + 9.16
 X7A121 + 16.34 X7A122 + 9.16 X7A131 + 16.34 X7A132 + 6.68
 X8A111 + 6.68 X8A121 + 13.3 X8A122 + 6.68 X8A131 + 13.3
 X8A132 + 13.3 X8A142 + 9.16 X9A111 + 9.16 X9A121 + 16.34
 X9A122 + 9.16 X9A131 + 16.34 X9A132 + 16.34 X9A142 + 6.2
 X10A111 + 6.2 X10A121 + 7.62 X10A122 + 6.2 X10A131 + 7.62
 X10A132 + 7.62 X10A142 + 4.96 X11A111 + 4.96 X11A121 + 6.1
 X11A122 + 4.96 X11A131 + 6.1 X11A132 + 6.1 X11A142 + 8.96
 X12A131 + 8.96 X12A141 + 4 X13A131 + 4 X13A141 + 68.96
 X14A132 + 68.96 X14A142 + 68.96 X15M132 + 68.96 X15M142 +
 68.96 X16M232 + 68.96 X16M242 + 8.96 X17M131 + 896 X17M141 +
 4 X18M131 + 4 X18M141 + 9.16 X19M121 + 16.34 X19M122 + 16.34
 X19M132 + 9.16 X19M141 + 6.68 X20M121 + 13.3 X20M122 + 13.3
 X20M132 + 6.68 X20M141 + 9.16 X21M121 + 16.34 X21M122 +
 16.34 X21M132 + 9.16 X21M141 + 6.2 X22M121 + 7.62 X22M122 +
 7.62 X22M132 + 6.2 X22M141 + 4.96 X23M121 + 6.1 X23M122 +
 6.1 X23M132 + 4.96 X23M141 + 24.6 X24M222 + 24.6 X24M232 +
 24.6 X24M242 + 4 X27N231 + 4 X27N241 + 68.96 X28N232 + 68.96
 X28N242 + HMEN - 624 FMEN + 71.29 X26I222 + 71.29 X26I232 +
 71.29 X26I242 + 46.24 X29N222 + 46.24 X29N232 + 46.24
 X29N242 <= 8354

19) 20.69 X1A111 + 20.69 X1A121 + 28.84 X1A122 + 20.69
 X1A131 + 14.74 X2A111 + 14.74 X2A121 + 16.15 X2A122 + 14.74
 X2A131 + 16.15 X2A132 + 11.77 X3A111 + 11.77 X3A121 + 13.18
 X3A122 + 11.77 X3A131 + 13.18 X3A132 + 17.84 X4A111 + 17.81
 X4A121 + 19.64 X4A122 + 17.81 X4A131 + 19.64 X4A132 + 14.87
 X5A111 + 14.87 X5A121 + 16.37 X5A122 + 14.87 X5A131 + 16.37
 X5A132 + 11.89 X6A111 + 11.89 X6A121 + 13.08 X6A142 + 9.63
 X7A111 + 9.63 X7A121 + 10.87 X7A122 + 9.63 X7A131 + 10.87
 X7A132 + 7.37 X8A111 + 7.37 X8A121 + 8.27 X8A122 + 7.37
 X8A131 + 8.27 X8A132 + 8.27 X8A142 + 9.63 X9A111 + 9.63
 X9A121 + 10.88 X9A122 + 9.63 X9A131 + 10.88 X9A132 + 10.88
 X9A142 + 5.65 X10A111 + 5.65 X10A121 + 6.51 X10A122 + 5.65
 X10A131 + 6.51 X10A132 + 6.51 X10A142 + 4.52 X11A111 + 4.52
 X11A121 + 5.2 X11A122 + 4.52 X11A131 + 5.2 X11A132 + 5.2
 X11A142 + 4.52 X12A131 + 4.52 X12A141 + 34.52 X14A132 +
 34.52 X14A142 + 34.52 X15M132 + 34.52 X15M142 + 34.52
 X16M232 + 34.52 X16M242 + 4.52 X17M131 + 4.52 X17M141 + 9.63
 X19M121 + 10.87 X19M122 + 10.87 X19M132 + 9.63 X19M141 +
 7.37 X20M121 + 8.27 X20M122 + 8.27 X20M132 + 7.37 X20M141 +
 9.63 X21M121 + 10.88 X21M122 + 10.88 X21M132 + 9.63 X21M141 +
 5.65 X22M121 + 6.51 X22M122 + 6.51 X22M132 + 5.65 X22M141 +
 4.52 X23M121 + 5.2 X23M122 + 5.2 X23M132 + 4.52 X23M141 +
 100.97 X24M222 + 100.97 X24M232 + 100.97 X24M242 + 106.97
 X25M222 + 106.97 X25M232 + 106.97 X25M242 + 34.52 X28N232 +
 34.52 X28N242 + HMEN - 624 FMEN + 52.77 X26I222 + 52.77
 X26I232 + 52.77 X26I242 + 39.88 X29N222 + 39.88 X29N232 +

Table D-1. (Cont'd).

39.88 X29N242 <= 8354

20) 7.86 X1A111 + 7.86 X1A121 + 6 X1A122 + 7.86 X1A131 + 4.3 X2A111 + 4.3 X2A121 + 4 X2A122 + 4.3 X2A131 + 4 X2A132 + 3.6 X3A111 + 3.6 X3A121 + 3.3 X3A122 + 3.6 X3A131 + 3.3 X3A132 + 9.11 X4A111 + 9.11 X4A121 + 6 X4A122 + 9.11 X4A131 + 6 X4A132 + 8.89 X5A111 + 8.89 X5A121 + 5 X5A122 + 8.89 X5A131 + 5 X5A132 + 8.67 X6A111 + 8.67 X6A121 + 8.67 X6A122 + 8.67 X6A131 + 8.67 X6A132 + 8.67 X6A142 + 4.15 X7A111 + 4.15 X7A121 + 4.2 X7A122 + 4.15 X7A131 + 4.2 X7A132 + 5.98 X8A111 + 5.98 X8A121 + 2.8 X8A122 + 5.98 X8A131 + 2.8 X8A132 + 2.8 X8A142 + 6.96 X9A111 + 6.96 X9A121 + 4.2 X9A122 + 6.96 X9A131 + 4.2 X9A132 + 4.2 X9A142 + 3.5 X10A111 + 3.5 X10A121 + 7.2 X10A122 + 3.5 X10A131 + 7.2 X10A132 + 7.2 X10A142 + 7.24 X11A111 + 7.24 X11A121 + 2.8 X11A122 + 7.24 X11A131 + 2.8 X11A132 + 2.8 X11A142 + 2.57 X12A131 + 2.57 X12A141 + 34.57 X14A132 + 34.57 X14A142 + 34.57 X15M132 + 34.57 X15M142 + 34.57 X16M232 + 34.57 X16M242 + 2.57 X17M131 + 2.57 X17M141 + 4.15 X19M121 + 4.2 X19M122 + 4.2 X19M132 + 4.15 X19M141 + 5.98 X20M121 + 3.5 X22M141 + 7.24 X23M121 + 2.8 X23M122 + 2.8 X23M132 + 7.24 X23M141 + 34.8 X24M222 + 34.8 X24M232 + 34.8 X24M242 + 34.8 X25M222 + 34.8 X25M232 + 34.8 X25M242 + 34.57 X28N232 + 34.57 X28N242 + 34.22 X29I232 + HMEN - 624 FMEN + 43.95 X26I222 + 43.95 X26I232 + 43.95 X26I242 + 34.22 X29N222 + 34.22 X29N232 + 34.22 X29N242
<= 8354

21) 1.57 X1A111 + 1.57 X1A121 + 2.23 X1A122 + 1.57 X1A131 + 1.57 X2A111 + 1.57 X2A121 + 4.47 X2A122 + 1.57 X2A131 + 4.47 X2A132 + 3.94 X3A111 + 3.94 X3A121 + 5.59 X3A122 + 3.94 X3A131 + 5.59 X3A132 + 3.15 X4A111 + 3.15 X4A121 + 4.47 X4A122 + 3.15 X4A131 + 4.47 X4A132 + 3.94 X5A111 + 3.94 X5A121 + 5.59 X5A122 + 3.94 X5A131 + 5.59 X5A132 + 4.72 X6A111 + 4.72 X6A121 + 6.71 X6A122 + 4.72 X6A131 + 6.71 X6A132 + 6.71 X6A142 + 1.57 X7A111 + 1.57 X7A121 + 2.23 X7A122 + 1.57 X7A131 + 2.23 X7A132 + 3.15 X9A111 + 4.47 X9A122 + 3.15 X9A131 + 4.47 X9A132 + 4.47 X9A142 + 3.94 X10A111 + 3.94 X10A121 + 5.59 X10A122 + 3.94 X10A131 + 5.59 X10A132 + 5.59 X10A142 + 4.72 X11A111 + 4.72 X11A121 + 6.76 X11A122 + 4.72 X11A131 + 4.76 X11A132 + 6.76 X11A142 + 1.57 X19M121 + 2.23 X19M122 + 2.23 X19M132 + 1.57 X19M141 + 3.15 X21M121 + 4.47 X21M122 + 4.47 X21M132 + 3.15 X21M141 + 3.94 X22M121 + 11.18 X22M132 + 3.94 X22M141 + 4.72 X23M121 + 6.76 X23M122 + 6.76 X23M132 + 4.72 X23M141 + 10.13 X24M222 + 10.13 X24M232 + 10.13 X24M242 + 10.13 X25M222 + 10.13 X25M232 + 10.13 X25M242 + HWOMEN - 324 FWOMEN + 21.47 X26I222 + 21.47 X26I232 + 21.47 X26I242 <= 7408

22) 7.28 X25M222 + 7.28 X25M242 + HWOMEN - 624 FWOMEN + 7.28 X25N232 <= 7408

Table D-1. (Cont'd).

23) 2.8 X1A122 + 2 X2A111 + 2 X2A121 + 2 X2A131 + 15
 X24M222 + 15 X24M232 + 15 X24M242 + HWOMEN - 324 FWOMEN +
 29.28 X26I222 + 29.28 X26I232 + 29.28 X26I242 + 7.28 X29N222
 + 29.28 X29N232 + 7.28 X29N242 <= 7408

24) 8.8 X1A111 + 8.8 X1A121 + 6 X1A122 + 8.8 X1A131 + 4
 X2A111 + 4 X2A121 + 2.8 X2A122 + 4 X2A131 + 2.8 X2A132 + 5.3
 X3A111 + 5.3 X3A121 + 6.1 X3A122 + 5.3 X3A131 + 6.1 X3A132 +
 6 X4A111 + 6 X4A121 + 6 X4A122 + 6 X4A131 + 6 X4A132 + 5
 X5A111 + 5 X5A121 + 5 X5A122 + 5 X5A131 + 5 X5A132 + 4
 X6A111 + 4 X6A121 + 4 X6A122 + 4 X6A131 + 4 X6A132 + 4
 X6A142 + 5 X7A111 + 5 X7A121 + 6.4 X7A122 + 5 X7A131 + 6.4
 X7A132 + 4 X8A111 + 4 X8A121 + 5.2 X8A122 + 4 X8A131 + 5.2
 X8A132 + 5.2 X8A142 + 3 X9A111 + 3 X9A121 + 3.6 X9A122 + 3
 X9A131 + 3.6 X9A132 + 3.6 X9A142 + 2.5 X10A111 + 2.5 X10A121
 + 3 X10A122 + 2.5 X10A131 + 3 X10A132 + 3 X10A142 + 2
 X11A111 + 2 X11A121 + 2.4 X11A122 + 2 X11A131 + 2.4 X11A132
 + 2.4 X11A142 + 2 X12A131 + 2 X12A141 + 2 X14A132 + 2
 X14A142 + 2 X15M132 + 2 X15M142 + 2 X16M232 + 2 X16M242 + 2
 X17M131 + 2 X17M141 + 5 X19M121 + 6.4 X19M122 + 6.4 X19M132
 + 5 X19M141 + 4 X20M121 + 5.2 X20M122 + 5.2 X20M132 + 4
 X20M141 + 3 X21M121 + 3.6 X21M122 + 3.6 X21M132 + 3 X21M141
 + 2.5 X22M121 + 3 X22M122 + 3 X22M132 + 2.5 X22M141 + 2
 X23M121 + 2.4 X23M122 + 2.4 X23M132 + 2 X23M141 + 22.13
 X24M222 + 22.13 X24M232 + 22.13 X24M242 + 21.92 X25M222 +
 21.92 X25M232 + 21.92 X25M242 + 2 X28N232 + 2 X28N242 +
 21.92 X29I222 + 21.92 X29I232 + 21.92 X29I242 + HWOMEN - 324
 FWOMEN + 23.7 X26I222 + 23.7 X26I232 + 23.7 X26I242 + 23.7
 X29N222 + 23.7 X29N232 + 23.7 X29N242 <= 7408

25) 2 X14A132 + 2 X14A142 + 2 X15M132 + 2 X15M142 + 2
 X16M232 + 2 X16M242 + 20.47 X25M222 + 20.47 X25M232 + 20.47
 X25M242 + 23.7 X26N222 + 23.7 X26N232 + 23.7 X26N242 + 2
 X28N232 + 2 X28N242 + 23.7 X29I222 + 23.7 X29I232 + 23.7
 X29I242 + HWOMEN - 324 FWOMEN <= 7408

26) 8 X1A111 + 8 X1A121 + 14 X1A122 + 8 X1A131 + 6 X2A111
 + 6 X2A121 + 6.8 X2A122 + 6 X2A131 + 6.8 X2A132 + 5.3 X3A111
 + 5.3 X3A121 + 6.1 X3A122 + 5.3 X3A131 + 6.1 X3A132 + 6
 X4A111 + 6 X4A121 + 6 X4A122 + 6 X4A131 + 6 X4A132 + 5
 X5A111 + 5 X5A121 + 5 X5A122 + 5 X5A131 + 5 X5A132 + 4
 X6A111 + 4 X6A121 + 4 X6A122 + 4 X6A131 + 4 X6A132 + 4
 X6A142 + 2 X7A111 + 2 X7A121 + 2.4 X7A122 + 2 X7A131 + 2.4
 X7A132 + 2 X8A111 + 2 X8A121 + 2.4 X8A122 + 2 X8A131 + 2.4
 X8A132 + 2.4 X8A142 + 3 X9A111 + 3 X9A121 + 3.6 X9A122 + 3
 X9A131 + 3.6 X9A132 + 3.6 X9A142 + 2.5 X10A111 + 2.5 X10A121
 + 3 X10A122 + 2.5 X10A131 + 3 X10A132 + 3 X10A142 + 2
 X11A111 + 2 X11A121 + 2.4 X11A122 + 2 X11A131 + 2.4 X11A132
 + 2.4 X11A142 + 2 X12A131 + 2 X12A141 + 2 X17M131 + 2
 X17M141 + 2 X19M121 + 2.4 X19M122 + 2.4 X19M132 + 2 X19M141
 + 2 X20M121 + 2.4 X20M122 + 2.4 X20M132 + 2 X20M141 + 3

Table D-1. (Cont'd).

$X21M121 + 3.6 X21M122 + 3.6 X21M132 + 3 X21M141 + 2.5$
 $X22M121 + 3 X22M122 + 3 X22M132 + 2.5 X22M141 + 2 X23M121 +$
 $2.4 X23M122 + 2.4 X23M132 + 2 X23M141 + 17 X24M222 + 17$
 $X24M232 + 17 X24M242 + 17 X25M222 + 17 X25M232 + 17 X25M242$
 $+ HWOMEN - 324 FWOMEN + 15 X26I222 + 15 X26I232 + 15 X26I242$
 $+ 15 X29N222 + 15 X29N232 + 15 X29N242 \leq 7408$

27) $1.57 X1A111 + 1.57 X1A121 + 5.4 X1A122 + 1.57 X1A131$
 $+ 3.15 X2A111 + 3.15 X2A121 + 4.17 X2A122 + 3.15 X2A131 +$
 $4.47 X2A132 + 3.94 X3A111 + 3.94 X3A121 + 5.59 X3A122 + 3.94$
 $X3A131 + 5.59 X3A132 + 3.15 X4A111 + 3.15 X4A121 + 4.47$
 $X4A122 + 3.15 X4A131 + 4.47 X4A132 + 3.94 X5A111 + 3.94$
 $X5A121 + 5.59 X5A122 + 3.94 X5A131 + 5.59 X5A132 + 4.72$
 $X6A111 + 4.72 X6A121 + 6.71 X6A122 + 4.72 X6A131 + 6.71$
 $X6A132 + 6.71 X6A142 + 1.57 X7A111 + 1.57 X7A121 + 2.23$
 $X7A122 + 1.57 X7A131 + 2.23 X7A132 + 3.15 X8A111 + 3.15$
 $X8A121 + 4.47 X8A122 + 3.15 X8A131 + 4.47 X8A132 + 4.47$
 $X8A142 + 4.94 X10A111 + 4.94 X10A121 + 5.59 X10A122 + 4.94$
 $X10A131 + 5.59 X10A132 + 5.59 X10A142 + 4.72 X11A111 + 4.72$
 $X11A121 + 6.76 X11A122 + 4.72 X11A131 + 6.76 X11A132 + 6.76$
 $X11A142 + 2 X12A131 + 2 X12A141 + 2 X17M131 + 2 X17M141 +$
 $1.57 X19M121 + 2.23 X19M122 + 2.23 X19M132 + 1.57 X19M141 +$
 $3.15 X20M121 + 8.94 X20M122 + 3.15 X20M132 + 3.15 X20M141 +$
 $4.94 X22M121 + 5.59 X22M122 + 5.59 X22M132 + 4.94 X22M141 +$
 $4.72 X23M121 + 6.76 X23M122 + 6.76 X23M132 + 4.72 X23M141 +$
 $10 X24M222 + 10 X24M232 + 10 X24M242 + 10 X25M222 + 10$
 $X25M232 + 10 X25M242 + HCHILDRE - 1348 FCHILDRE + 19 X26I222$
 $+ 19 X26I232 + 19 X26I242 \leq 18762$

28) $2.28 X2A111 + 2.28 X2A121 + 2.28 X2A131 + 2.85 X3A111$
 $+ 2.85 X3A121 + 2.85 X3A131 + 2.28 X4A111 + 2.28 X4A121 +$
 $2.28 X4A131 + 2.85 X5A111 + 2.85 X5A121 + 2.85 X5A131 + 3.42$
 $X6A111 + 3.42 X6A121 + 3.42 X6A131 + 2.28 X8A111 + 2.28$
 $X8A121 + 2.28 X8A131 + 2.85 X10A111 + 2.85 X10A121 + 2.85$
 $X10A131 + 1.14 X11A111 + 1.14 X11A121 + 1.14 X11A131 + 2.28$
 $X20M121 + 2.28 X20M141 + 2.85 X22M121 + 2.85 X22M141 + 1.14$
 $X23M121 + 1.14 X23M141 + 9 X24M222 + 9 X24M232 + 9 X24M242 +$
 $7 X25M222 + 7 X25M232 + 7 X25M242 + HCHILDRE - 1324 FCHILDRE$
 $+ 10 X26I222 + 10 X26I232 + 10 X26I242 \leq 18762$

29) $5.82 X1A121 + 2.2 X2A111 + 2.2 X2A121 + 2.14 X2A122 +$
 $2.2 X2A131 + 2.14 X2A132 + 2.14 X3A122 + 2.14 X3A132 + 3.22$
 $X4A122 + 3.22 X4A132 + 2.69 X5A122 + 2.69 X5A132 + 2.14$
 $X6A122 + 2.14 X6A132 + 2.14 X6A142 + 15 X24M232 + 15 X24M242$
 $+ HCHILDRE - 1348 FCHILDRE + 15 X24X222 + 10 X26I222 + 10$
 $X26I232 + 10 X26I242 + 7 X29N222 + 7 X29N232 + 7 X29N242$
 ≤ 18762

30) $5.7 X1A111 + 5.7 X1A121 + 5.4 X1A122 + 5.7 X1A131 +$
 $3.6 X2A111 + 3.6 X2A121 + 2.6 X2A122 + 3.6 X2A131 + 2.6$
 $X2A132 + 5.2 X3A111 + 5.2 X3A121 + 5.6 X3A122 + 5.2 X3A131 +$

Table D-1. (Cont'd).

5.6 X3A132 + 5.4 X4A111 + 5.4 X4A121 + 5.4 X4A122 + 5.4
 X4A131 + 5.4 X4A132 + 4.5 X5A111 + 4.5 X5A121 + 4.5 X5A122 +
 4.5 X5A131 + 4.5 X5A132 + 3.6 X6A111 + 3.6 X6A121 + 3.6
 X6A122 + 3.6 X6A131 + 3.6 X6A132 + 3.6 X6A142 + 5.2 X7A111 +
 5.2 X7A121 + 6.2 X7A122 + 5.2 X7A131 + 6.2 X7A132 + 4.4
 X8A111 + 4.4 X8A121 + 5 X8A122 + 4.4 X8A131 + 5 X8A132 + 5
 X8A142 + 6 X9A111 + 6 X9A121 + 7.2 X9A122 + 6 X9A131 + 7.2
 X9A132 + 7.2 X9A142 + 5 X10A111 + 5 X10A121 + 6 X10A122 + 5
 X10A131 + 6 X10A132 + 6 X10A142 + 4 X11A111 + 4 X11A121 +
 4.8 X11A122 + 4 X11A131 + 4.8 X11A132 + 4.8 X11A142 + 2
 X14A132 + 2 X14A142 + 2 X15M132 + 2 X15M142 + 2 X16M232 + 2
 X16M242 + 5.2 X19M121 + 6.2 X19M122 + 6.2 X19M132 + 5.2
 X19M141 + 4.4 X20M121 + 5 X20M122 + 5.2 X20M132 + 4.4
 X20M141 + 6 X21M121 + 7.2 X21M122 + 7.2 X21M132 + 6 X21M141
 + 5 X22M121 + 6 X22M122 + 6 X22M132 + 5 X22M141 + 4 X23M121
 + 4.8 X23M122 + 4.8 X23M132 + 4 X23M141 + 22 X24M222 + 22
 X24M232 + 22 X24M242 + 20 X25M222 + 20 X25M232 + 20 X25M242
 + 2 X28N232 + 2 X28N242 + HCHILDRE - 1348 FCHILDRE + 25.44
 X26I222 + 25.44 X26I232 + 25.44 X26I242 + 25.44 X29N222 +
 25.44 X29N232 + 25.44 X29N242 <= 18762

31) 3.22 X1A122 + 2.14 X2A122 + 2.14 X2A132 + 1.61 X3A122
 + 1.61 X3A132 + 3.22 X4A122 + 3.22 X4A132 + 2.69 X5A122 +
 2.69 X5A132 + 2.14 X6A122 + 2.14 X6A132 + 2.14 X6A142 + 19
 X24M222 + 19 X24M232 + 19 X24M242 + 19 X25M222 + 19 X25M232
 + 19 X25M242 + HCHILDRE - 2348 FCHILDRE + 33.83 X26I222 +
 33.83 X26I232 + 33.83 X26I242 + 23.83 X29N222 + 23.83
 X29N232 + 23.83 X29N242 <= 18762

32) 7.6 X1A111 + 7.6 X1A121 + 8 X1A122 + 7.6 X1A131 + 5.8
 X2A111 + 5.8 X2A121 + 6.2 X2A122 + 5.8 X2A131 + 6.2 X2A132 +
 5.2 X3A111 + 5.2 X3A121 + 5.6 X3A122 + 5.2 X3A131 + 5.6
 X3A132 + 5.4 X4A111 + 4.5 X4A121 + 4.5 X4A122 + 5.4 X4A131 +
 4.5 X4A132 + 4.5 X5A111 + 4.5 X5A121 + 4.5 X5A122 + 4.5
 X5A131 + 4.5 X5A132 + 3.6 X6A111 + 3.6 X6A121 + 3.6 X6A122 +
 3.6 X6A131 + 3.6 X6A132 + 3.6 X6A142 + 5.2 X7A111 + 5.2
 X7A121 + 6.2 X7A122 + 5.2 X7A131 + 6.2 X7A132 + 4.4 X8A111 +
 4.4 X8A121 + 5 X8A122 + 4.4 X8A131 + 5 X8A132 + 5 X8A142 + 6
 X9A111 + 6 X9A121 + 7.2 X9A122 + 6 X9A131 + 7.2 X9A132 + 7.2
 X9A142 + 5 X10A111 + 5 X10A121 + 6 X10A122 + 5 X10A131 + 6
 X10A132 + 6 X10A142 + 4 X11A111 + 4 X11A121 + 4.8 X11A122 +
 4 X11A131 + 4.8 X11A132 + 4.8 X11A142 + 3 X14A132 + 3
 X14A142 + 3 X15M132 + 3 X15M142 + 3 X16M232 + 3 X16M242 +
 5.2 X19M121 + 5.2 X19M122 + 6.2 X19M132 + 5.2 X19M141 + 4.4
 X20M121 + 5 X20M122 + 5 X20M132 + 4.4 X20M141 + 6 X21M121 +
 7.2 X21M122 + 7.2 X21M132 + 6 X21M141 + 5 X22M121 + 6
 X22M122 + 6 X22M132 + 5 X22M141 + 4 X23M121 + 4.8 X23M122 +
 4.8 X23M132 + 4 X23M141 + 17 X24M222 + 17 X24M232 + 17
 X24M242 + 17 X25M222 + 17 X25M232 + 17 X25M242 + 3 X28N232 +
 3 X28N242 + HCHILDRE - 1348 FCHILDRE + 31.22 X26I222 + 31.22

Table D-1. (Cont'd).

X26I232 + 31.22 X26I242 + 31.22 X29N222 + 31.22 X29N232 +
31.22 X29N242 <= 18762

33) FMEN = 0

34) FWOMEN = 0

35) FCHILDRE = 0

36) 1149.2 X1A111 + 1762.11 X1A121 + 1409.62 X1A122 +
2828.8 X1A131 + 1149.2 X2A111 + 1762.11 X2A121 + 2828.8
X2A131 + 2687.36 X2A132 + 1149.2 X3A111 + 1762.11 X3A121 +
1409.69 X3A122 + 2828.8 X3A131 + 2687.36 X3A132 + 1149.2
X4A111 + 1762.11 X4A121 + 1409.69 X4A122 + 2828.8 X4A131 +
2687.36 X4A132 + 1149.2 X5A111 + 1762.11 X5A121 + 1409.69
X5A122 + 2828.8 X5A131 + 2687.36 X5A132 + 1149.2 X6A111 +
1762.11 X6A121 + 1409.69 X6A122 + 2828.8 X6A131 + 2687.36
X6A132 + 4031.04 X6A142 + 1149.04 X7A111 + 1762.11 X7A121 +
1409.69 X7A122 + 2828.8 X7A131 + 2687.36 X7A132 + 1149.2
X8A111 + 1762.11 X8A121 + 1409.69 X8A122 + 2828.8 X8A131 +
2687.36 X8A132 + 4031.04 X8A142 + 1149.2 X9A111 + 1762.11
X9A121 + 1409.69 X9A122 + 2828.8 X9A131 + 2687.36 X9A132 +
4031.04 X9A142 + 1149.2 X10A111 + 1762.11 X10A121 + 1409.69
X10A122 + 2828.8 X10A131 + 2687.36 X10A132 + 4031.04 X10A142
+ 2298.4 X11A111 + 1762.11 X11A121 + 1409.69 X11A122 +
2828.8 X11A131 + 2687.36 X11A132 + 4031.04 X11A142 + 14.14
X12A131 + 21.22 X12A141 + 14.14 X13A131 + 21.22 X13A141 +
13.44 X14A132 + 20.16 X14A142 <= 45068

37) 13.44 X15M132 + 20.16 X15M142 + 21.27 X16M232 + 31.91
X16M242 + 14.14 X17M131 + 21.22 X17M141 + 14.14 X18M131 +
21.22 X18M141 + 1762.11 X19M121 + 1409.69 X19M122 + 2687.36
X19M132 + 1717.2 X19M141 + 1762.11 X20M121 + 1409.69 X20M122
+ 2687.36 X20M132 + 4243.2 X20M141 + 1762.11 X21M121 +
1409.69 X21M122 + 2687.36 X21M132 + 4243.2 X21M141 + 1762.11
X22M121 + 1409.69 X22M122 + 2687.36 X22M132 + 4243.2 X22M141
+ 1762.11 X23M121 + 1409.69 X23M122 + 2687.36 X23M132 +
4243.2 X23M141 + 1843.43 X24M222 + 4478.93 X24M232 + 6382.48
X24M242 + 1843.43 X25M222 + 4478.93 X25M232 +
6382.48 X25M242 <= 36176

38) 22.39 X27N231 + 33.59 X27N241 + 21.27 X28N232 + 31.91
X28N242 + 1843.43 X29N222 + 4478.93 X29N232 + 6382.93
X29N242 <= 33073

39) 2168.75 X26I222 + 4926.83 X26I232 + 7390.24 X26I242
<= 8265

40) - 8150.658 AGBANK = 0

41) - 486.034 BROKERS = 0

Table D-1. (Cont'd).

42) 7.2976 X1A111 + 7.2976 X1A121 + 12.1366 X1A122 +
 7.2976 X1A131 + 4.865 X2A111 + 4.865 X2A121 + 8.091 X2A122 +
 4.865 X2A131 + 8.091 X2A132 + 3.6487 X3A111 + 3.6487 X3A121
 + 6.0682 X3A122 + 3.6487 X3A131 + 6.0682 X3A132 + 7.2976
 X4A111 + 7.2976 X4A121 + 12.1366 X4A122 + 7.2976 X4A131 +
 12.1366 X4A132 + 6.0836 X5A111 + 6.0836 X5A121 + 10.1138
 X5A122 + 6.0836 X5A131 + 10.1138 X5A132 + 4.865 X6A111 +
 4.865 X6A121 + 8.091 X6A122 + 4.865 X6A131 + 8.091 X6A132 +
 8.091 X6A142 <= 5000

43) 4.86528 X1A111 + 4.86528 X1A121 + 8.359258 X1A122 +
 4.865282 X1A131 + 7.017783 X2A111 + 7.017783 X2A121 +
 11.68439 X2A122 + 7.017783 X2A131 + 11.68439 X2A132 +
 7.824841 X3A111 + 7.824841 X3A121 + 14.07357 X3A122 +
 7.834842 X3A131 + 14.07357 X3A132 + 4.97398 X4A111 + 4.97398
 X4A121 + 8.716954 X4A122 + 4.97398 X4A131 + 8.716954 X4A132
 + 6.022148 X5A111 + 6.022148 X5A121 + 10.71116 X5A122 +
 5.224648 X5A131 + 10.71116 X5A132 + 6.993357 X6A111 +
 6.993357 X6A121 + 12.63245 X6A122 + 6.993357 X6A131 +
 12.63245 X6A132 + 12.63 X6A142 + 9.240595 X7A111 + 9.240595
 X7A121 + 17.2715 X7A122 + 9.240595 X7A131 + 17.2715 X7A132 +
 9.43759 X8A111 + 9.43759 X8A121 + 17.75474 X8A122 + 9.43759
 X8A131 + 17.75474 X8A132 + 17.75474 X8A142 + 9.505095 X9A111
 + 9.505095 X9A121 + 18.16287 X9A122 + 9.505095 X9A131 +
 18.16287 X9A132 + 18.16287 X9A142 + 9.6048 X10A111 + 9.6048
 X10A121 + 18.39724 X10A122 + 9.6048 X10A131 + 18.39724
 X10A132 + 18.39724 X10A142 + 10.09746 X11A111 + 10.09746
 X11A121 + 18.98696 X11A122 + 10.09746 X11A131 + 18.98696
 X11A132 + 18.98696 X11A142 + 37.20974 X12A131 + 37.20974
 X12A141 + 36.26072 X13A131 + 36.26072 X13A141 + 71.60049
 X14A132 + 71.60049 X14A142 + 71.60049 X15M132 + 71.60049
 X15M142 + 71.60049 X16M232 + 71.60049 X16M242 + 37.20974
 X17M131 + 37.20974 X17M141 + 32.26072 X18M131 + 32.26072
 X18M141 + 9.240825 X19M121 + 17.2715 X19M122 + 17.2715
 X19M132 + 9.240825 X19M141 + 9.437935 X20M121 + 17.75474
 X20M122 + 17.75474 X20M132 + 9.437935 X20M141 + 9.505095
 X21M121 + 18.16287 X21M122 + 18.16287 X21M132 + 9.505095
 X21M141 + 9.6048 X22M121 + 18.40069 X22M122 + 18.40069
 X22M132 + 9.6048 X22M141 + 10.09746 X23M121 + 18.98696
 X23M122 + 18.98696 X23M132 + 10.09746 X23M141 + 125.3751
 X24M222 + 125.3751 X24M232 + 125.3751 X24M242 + 120.8445
 X25M222 + 120.8449 X25M232 + 120.8449 X25M242 + 32.26072
 X27N231 + 32.26072 X27N241 + 71.60049 X28N232 + 71.60049
 X28N242 + 214.18 X26I222 + 214.18 X26I232 + 214.18 X26I242 +
 149.4243 X29N222 + 149.4243 X29N232 + 149.4243 X29N242
 <= 9709.96

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