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PATTERNS OF ENERGY USE, ENERGY COST INCREASES AND THEIR IMPACTS ON CROP PRODUCTION ON THE BIG ISLAND OF HAWAII: A LINEAR PROGRAMMING APPROACH

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PATTERNS OF ENERGY USE, ENERGY COST INCREASES AND THEIR IMPACTS ON CROP PRODUCTION ON THE BIG ISLAND OF HAWAII: A LINEAR PROGRAMMING APPROACH

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By

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ABSTRACT

In recent years, drastic changes have occurred in input prices, output prices and in the institutional structure within which agricultural producers operate. These changes are largely the upshot of sharp increases in energy prices that are directly or indirectly translated into higher production costs for the farmers.

The main objective of this study is to examine the interrelationship between the energy sector and the production of three agricultural crops (sugar, macadamia nut and coffee) by small growers on the Big Island of Hawaii. Specifically, it attempts: (a) to explore the patterns of energy use in agriculture; (b) to determine the relative efficiency of fuel use by farm size among the three agricultural crops; and (c) to investigate the impacts of higher energy costs on farmers' net revenues under three output price and three energy cost scenarios.

To meet these objectives, a linear programming model was developed. The objective function was to maximize net revenues subject to resource availability, production, marketing and non negativity constraints.

The application of the model to sugar, macadamia nuts and coffee yielded the following results. With respect to sugar, indirect energy (fertilizer and herbicide) use appears to be an increasing function of farm size. Direct energy (gasoline, diesel and electricity) does not lead to a specific conclusion. In the case of macadamia nuts, both direct and indirect energy use, with the

exception of gasoline and electricity, appears to be a decreasing function of farm size. With respect to coffee, the results indicate that direct energy use is a decreasing function of farm size. However, the relationship between fertilizer use and farm size is not conclusive. Findings also reveal that sugar, with only 10% of energy cost, appears to be more vulnerable to higher energy costs than macadamia nuts and coffee with 16% and 18% of energy cost, respectively. In addition, higher energy costs tend to have differential impacts depending upon the output price.

Some of the major conclusions emerging from this study are: (a) higher energy costs have not significantly impacted on farmers' net revenues, but do have a differential impact depending on the resource endowments of each crop grower; (b) low output prices tend to reinforce the impacts of higher energy costs, whereas high prices tend to negate them; (c) farmers are faced with many constraints that do not permit factor substitution.

In terms of policy formulation, it was observed that policy makers seem to be overly concerned with the problems facing growers at the macro level, without taking into account the constraints that growers face at the micro level. These micro factors play a dominant role in the context of resource allocation. They must, therefore, be incorporated into a comprehensive energy and agricultural policy at the county and state level.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Overview

The energy problem is probably one of the most persistent issues that has aggravated the economic difficulties of both developed and developing nations in recent years. It has resulted largely from our failure in the past to identify and address some energy realities and to see clearly our energy future (54). History will record that it was the Organization of the Petroleum Exporting Countries (OPEC) that brought into sharp focus the seriousness of the energy problem and the depletable and non-renewable nature of the oil resource.

To be sure, we have reached a turning point in energy availability: the path of low energy costs and of perceived abundance of oil has been reversed to one of a continuous rising trend in energy prices. [Although the first quarter of 1982 seems to indicate a declining trend in energy prices, that is hardly any basis to warrant the conclusion that energy prices will continue to fall in the months or years ahead. For instance, Kenneth T. Derr, president of Chevron U.S.A., Inc., has pointed out that the second quarter petroleum inventory for 1982 has already registered a decline. He cautioned that "recent decline in crude oil and petroleum prices may end soon and prices may rise later this year" (56).] But the speed with which energy costs will rise in the future is largely dependent on the rate at which conventional energy resources become scarce and more difficult to find, on the technological change that lowers the cost of non-conventional energy sources, on the behavior of OPEC cartel, and the domestic energy policies of various countries (59).

Background: Problem in Perspective

The United States is still the world's largest consumer of energy. In 1978, the energy used in the U.S. economy was estimated at 78.8 quadrillion BTU's. With 5% of the world's population, the U.S. accounted for about 32% of the world energy consumption. At the same time, the entire Sino-Soviet block with 28% of the world population consumed about 31% of the world energy. Table 1 gives an intercountry comparison of energy consumption and fuel shares for the Free World with some projections for 1995.

In 1981 it was reported that U.S. net energy imports (total imports less exports) of about 9.5 quadrillion BTU decreased by 22% as compared to the 1980 level. Similarly, energy consumption dropped by 2.4% as compared to consumption during 1980. At the same time, U.S. energy import costs increased from $244,871 million in 1980 to $261,008 million in 1981, an increase of about 7% (Table 2).

It is clear from the above that although Americans have cut their use of imported oil, they still have to face higher energy costs. Hence, for American consumers in general, energy will remain a severe problem as we manage to live with the realities of the 1980's. More importantly, it may constitute the major constraint

Table 1

Free World Energy Consumption and Fuel Shares, 1978 and 1995

	1978					1995				
	Total Energy Consumed	Fuel Shares				Total Energy Consumed	Fuel Shares			
Region or Country	Quadrillion BTU	Coal (%)	Oil (%)	Gas (%)	Other (%)	Quadrillion BTU	Coal (%)	Oil (%)	Gas (%)	Other (%)
U.S.A.[a]	78.8	18	49	25	8	94.7	37	32	17	14
Canada	9.0	6	42	22	30	11.8	3	33	21	43
Japan	14.9	13	73	5	9	28.2	16	51	19	14
Western Europe	54.7	19	56	14	11	63.7	20	43	17	20
Australia/New Zealand	3.5	40	42	10	8	4.6	32	38	20	10
Total OECD	160.9	18	53	19	10	203.0	27	38	18	17
Total Non OECD	30.7	20	66	10	4	74.3	23	54	13	10
(OPEC)[b]	(6.2)	(0)	(71)	(24)	(5)	(16.8)	(1)	(68)	(30)	(1)
Total Free World[c]	191.6	18	55	18	9	277.3	26	42	16	16

a. Includes Puerto Rico and Virgin Islands

b. Included in total OECD

c. Total of OECD and non OECD

Source: U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, 1980, Vol. 3.

Table 2

Energy Consumption, Imports and Costs, 1979-1981

Years	Total Energy Consumed (Quadrillion BTU)	Total Energy Imports (Quadrillion BTU)	Total Energy Costs (Million Dollars)
1979	78.9	19.6	206,256
1980	75.9	15.9	244,871
1981	73.9	13.9	261,008

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, March 1982.

to the expansion of the agricultural sector in U.S. and the rest of the world in the years to come.

The agricultural sector, in general, encompasses various activities ranging from on-farm production, marketing, and processing to consumption activities which require either direct energy such as diesel fuel, gas, and electricity, or indirect energy such as pesticides, fertilizers, and herbicides. In a recent study, Gopalakrishnan has addressed "the complex methodological issues involved in the accurate estimation of energy requirements" (21). It was pointed out in this study that a uniform definition of the term "production" and energy data disaggregation are essential to determine the energy requirements of different products on a comparable basis. For these purposes, an energy flow model (Figure 1) showing the linkages of various activities has been developed in this study to deal with the estimation of direct and indirect energy inputs in the agricultural sector (21).

Energy inputs of farming have increased enormously during the past 50 years (58). The decrease in farm labor use has been offset in part by the growth of support industries for the farmer. These changes on the farm have led to a variety of other changes in the U.S. food system. For instance, in the past 50 years, canned, frozen, and other processed foods have become the major items of the American diet. At present, the food processing industry is the fourth largest energy consumer of the Standard Industrial Classification grouping (54). Transportation associated with the food

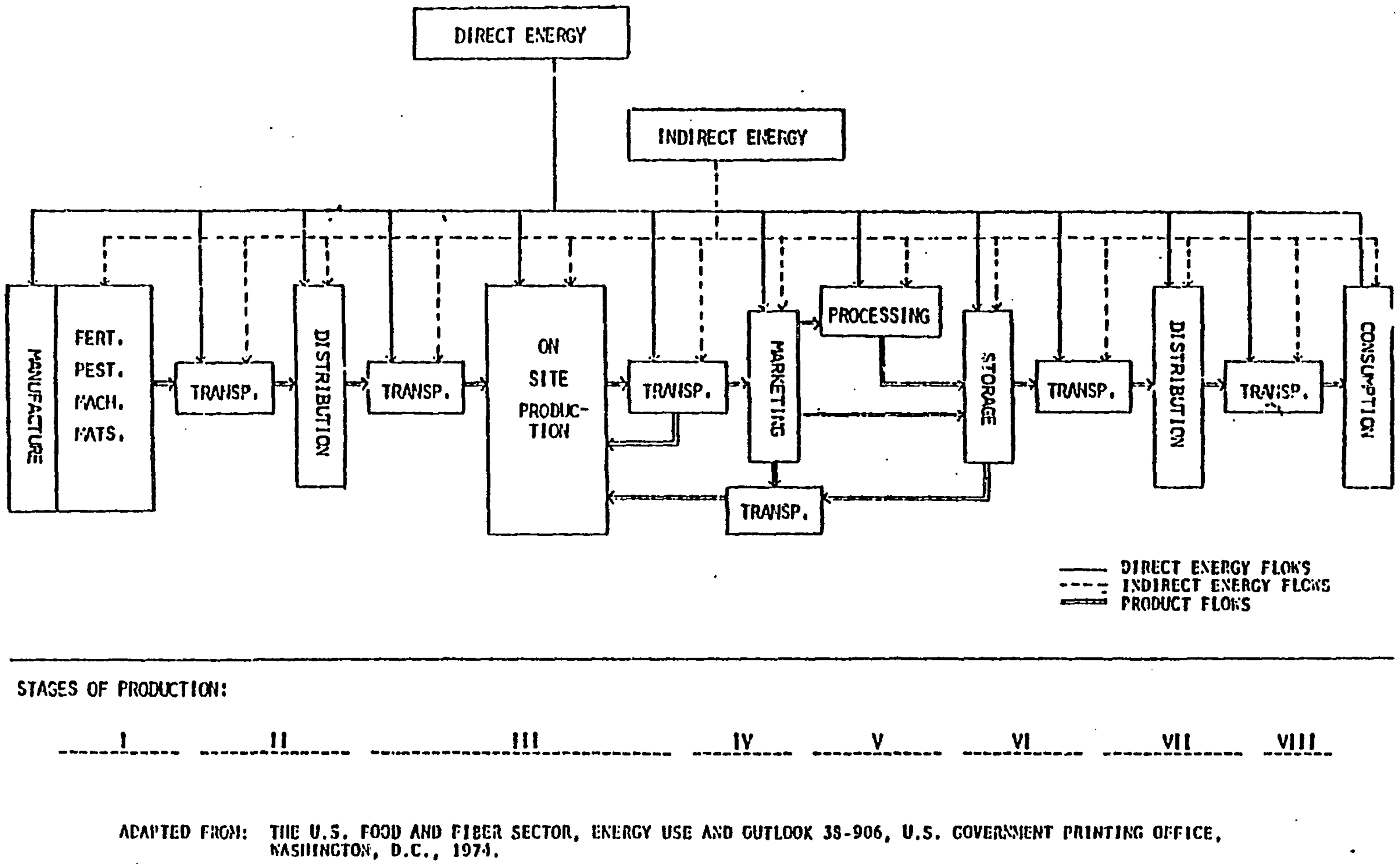

Figure 1. Energy Flow Model for Agriculture (21)

system has grown apace, and the proliferation of appliances still continues in homes, institutions, and stores. Even farmers purchase most of their food from markets in town (68). Thus, energy inputs have become so integral to modern agriculture that increases in energy costs are likely to have severe impacts on food production and agricultural income (57).

From 1973 through 1978, direct energy cost in American agriculture rose as follows: gasoline 173%; diesel fuel 280%; fuel oil 89%; LP gas 144%; natural gas 242%; and electricity 70% (16). Consequently, most farmers are faced with higher energy bills which are automatically translated into higher costs of production and higher prices for consumers. Table 3 shows the trends in fossil fuel prices.

Problem Statement

Agriculture constitutes a significant sector of the State economy. In 1980, its total farm value reached $989.4 million, the highest within the decade. Sugarcane, pineapples, and macadamia nuts continue to be the leading agricultural crops in the State. From 1979 to 1981, the farm value of sugarcane showed an 11% decrease due to the substantial fall in sugar prices. On the other hand, the farm value of pineapple surged, with a record $76.6 million as compared with the 1979 level of about $69 million. Similarly, returns from diversified agriculture registered an 11 percent increase from the previous year. With the exception of cattle, receipts from nursery products ($27.4 million) and macadamia nuts

Table 3

Fossil Fuel Prices in U.S., 1960-1978
(Cents per Million BTU)

Fuel	1960	1965	1970	1972	1973	1974	1975	1976	1977	1978, prel.	Percent Change 1960-1970	1970-1973	1973-1978
Current Dollars													
Composite[a]	30.0	28.5	32.5	36.8	43.2	72.4	86.4	94.9	107.4	114.9	8.3	32.9	116.0
Crude Oil	49.7	47.0	52.1	58.5	67.1	118.5	132.2	141.2	147.8	154.5	4.8	28.8	120.8
Natural Gas Liquids	55.2	48.1	50.7	56.0	72.4	124.9	116.7	141.0	173.9	(NA)	-8.2	42.8	(NA)
Natural Gas (dry)	13.5	15.1	16.6	18.1	21.2	29.7	43.0	56.9	77.4	90.0	23.0	27.7	324.5
Bituminous Coal[b]	15.3	17.5	25.5	31.9	35.5	66.4	82.9	83.9	89.5	97.8	39.3	30.2	175.5
Anthracite Coal	33.0	35.3	47.1	53.0	50.2	98.4	137.9	147.5	154.5	162.2	42.7	6.6	223.1
Constant (1972)[1] Dollars													
Composite[a]	43.7	38.3	35.6	36.8	36.8	62.4	68.0	70.9	75.8	75.5	-22.7	12.4	88.7
Crude Oil	72.3	64.0	57.0	58.5	58.5	102.1	104.0	105.6	104.4	101.6	-21.2	11.2	60.3
Natural Gas Liquids	80.4	65.0	55.4	56.0	56.0	107.7	91.8	105.4	122.8	(NA)	-31.3	23.5	(NA)
Natural Gas (dry)	19.7	20.3	18.2	18.1	18.1	25.6	34.3	42.5	54.7	59.2	-27.6	9.9	196.0
Bituminous Coal[b]	26.6	23.5	27.9	31.9	31.9	57.2	65.2	62.7	63.2	64.3	4.9	20.4	91.4
Anthracite Coal	48.0	47.4	51.6	53.0	53.0	84.4	108.5	110.3	109.1	106.6	7.5	-8.0	124.4
1 GNP Price Deflators 1972 = 100	68.7	74.3	91.4	100.0	100.0	116.0	127.2	133.8	141.6	152.1	33.0	15.8	43.8
3 Preliminary													

a. Weighted by relative importance of individual fuels in total mineral fuels production.

b. Includes lignite.

Source: U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, Vol. 2, 1978.

($28 million) represent a significant share of diversified agriculture, edging out vegetables and melons which tallied a record of $19 million in 1981.

The State's dependence on imported oil exposes the agricultural sector to the full impacts of rising oil prices and the growing risk of supply disruptions. In Hawaii, the direct energy inputs used in the agricultural sector are basically gasoline, diesel, natural gas, liquefied petroleum and electricity. The indirect energy inputs consist of items such as nitrogenous fertilizers and pesticides. During the decade of 1970-1981, electricity and gasoline prices in the State have increased by 200% and 184%, respectively (11). These increases translate not only into direct higher energy bills, but also into indirect increases in the prices of energy-based inputs that farmers must purchase.

Since the increases in the prices of these energy resources are largely determined at the regional, national and international levels (exogenously determined), a study of their impact is essential to suggest possible adjustments or directions for the future. Exogenous forces or factors may constitute a serious threat to the continuous economic development of Hawaii.

In addition, since the implementation of various policies at the State level is partly dependent on the economic activities at the national and international levels, the assessment of these external forces and the magnitude of their impacts is essential to the formulation of meaningful policies for the State as well as for the Big Island of Hawaii.

Objectives

The basic purpose of the present study is to determine the impacts of increased energy costs on the production of agricultural crops in the county of Hawaii. The specific objectives are:

1. to identify the patterns of energy use in agriculture;
2. to determine the relative efficiency of fuel use by farm size among different agricultural crops; and
3. to explore the impacts of energy cost changes on farmers' net revenues.

Hypotheses

The general hypothesis to be tested is that the agricultural sector is sensitive to energy cost increases. The specific hypotheses to be tested are:

1. The larger the farm size, the more energy efficient it tends to be.
2. The more energy intensive the production of an agricultural crop is in relation to other crops, the more vulnerable it is to energy cost increases.
3. The lower the output price of a crop is in relation to that of other crops, the greater is the impact of higher energy costs on the farmer's net revenues.

Study Area

Introduction

In order to have reliable estimates of and meaningful insights into the patterns of energy use, energy cost increases, and their impact on Hawaiian agriculture, the Big Island of Hawaii (Figure 2) has been selected as a case study.

At least four reasons can be mentioned for the choice of the Big Island: First, the county of Hawaii with 64% of the State land area has about 569,364 acres of farmland, which represent 58% of the agricultural land in the State. Second, with the exception of pineapple, the major proportion of crops in Hawaii are grown on the Big Island. In terms of cultivated acreage, the proportions of crops grown in 1981 were as follows: sugarcane (42%), coffee (100%), macadamia nut (97%), fruits (69%), vegetables and melons (44%). Third, the Big Island of Hawaii has a variety of climates ranging from tropical rain forests to deserts and a variety of soil types. The average rainfall is about 90 inches, which is higher than the State average. Fourth, the agricultural income is second only to tourism, which is the leading income-generating sector of the county (19).

The Big Island is the youngest in the Hawaiian Archipelago and the largest county of the State, covering an area of 4,038 square miles. Different geologic and climatic conditions on the island have resulted in the classification of 70 different soil series and 12 miscellaneous land types combined into 14 soil groupings. The Big

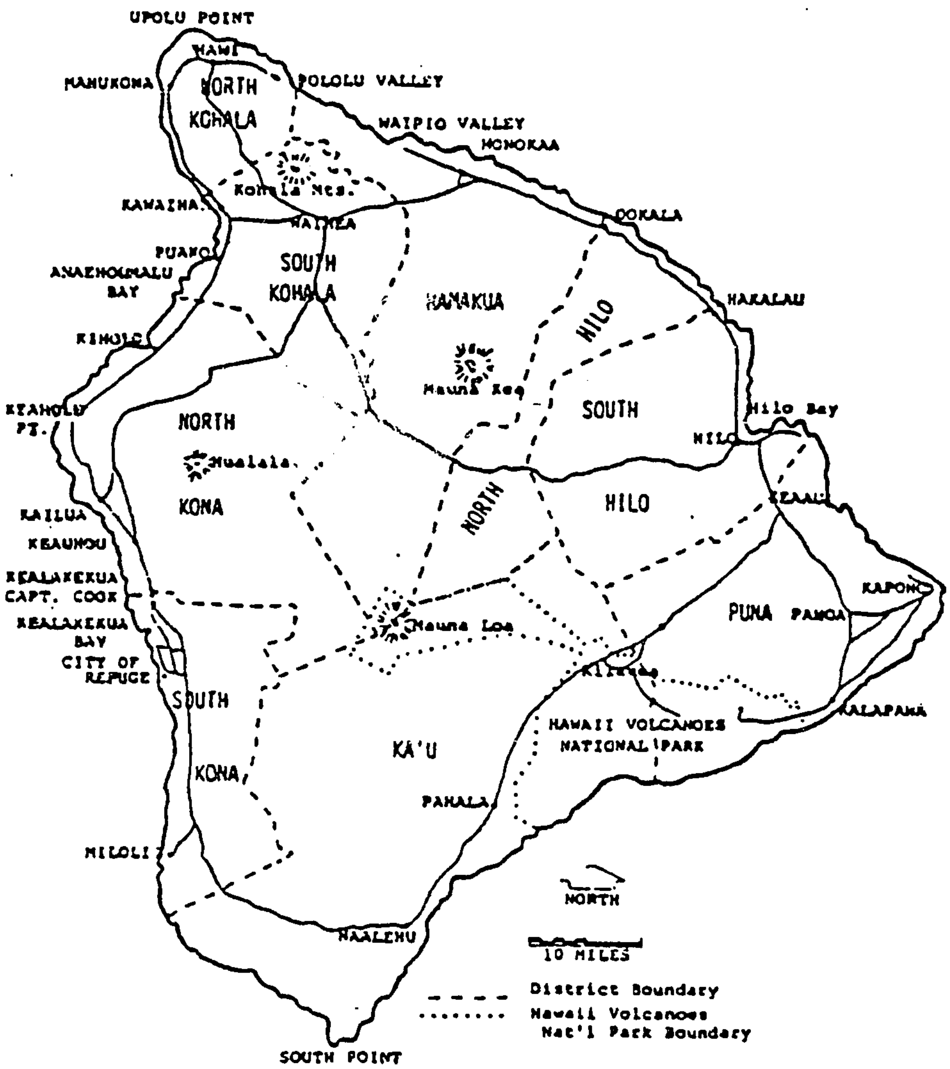

Figure 2. The Big Island of Hawaii

Island also has a large variety of climates. It has almost eight times Oahu's volume of ground water and almost nine times Oahu's volume of surface water (19).

More than 20% of the Big Island's 93,700 inhabitants are employed in the agricultural sector. The per capita personal income of the county is currently estimated at about $8,586 (19). Tourism, the leading income generator of the county, has been experiencing a deep slump in recent years. This, coupled with uncertain sugar prices, continues to affect the economy of the Big Island (67).

Agriculture and Energy

Agriculture plays an important role in the economic development of the Big Island of Hawaii. The island's energy supply sources are varied and range from imported oil to indigenous energy sources.

AGRICULTURE

The principal agricultural crops on the Big Island of Hawaii are sugarcane, coffee and macadamia nuts. A detailed discussion of each of these crops is presented below.

Sugar

The Hawaiian sugar industry consists of 330 farms which control or lease about 216,000 acres. The industry is the third largest in the State and its contribution to the farm sector is approximately $385 million. The Big Island is the largest growing area in the State (Table 4). Sugar, the leading agricultural commodity of the county, is largely grown along the Hamakua Coast and Kau district. The growing and processing of sugar on the island

Table 4

Sugarcane Acreage, Production and Value of Sales in Hawaii, 1981

Island	Cane Acreage (acres)	Raw Sugar (tons)	Value of Sales (1000 dollars)
Hawaii	90,489	384,234	151,572
Kauai	45,801	236,118	83,267
Maui	47,147	254,374	100,478
Oahu	32,662	172,815	68,262
Total	216,099	1,047,541	413,768

Source: Telephone Interview with HSPA, 1982.

is dominated by Kau Sugar Co., Hilo Coast Processing Co. (HCPC), Davies Hamakua Sugar Co. and Puna Sugar Co. In 1981, the total contribution of the industry to the county's economy was approximately $220 million. However, 1981 was an exceptionally bad year for the sugar industry. The unusually low sugar price plunged the sugar industry into a severe crisis. The current and expected losses are so large that the sugar industry is considering a variety of measures, including reduction in acreage, increases in efficiency and reduction in labor costs.

Macadamia Nuts

The macadamia nut industry consists of 464 farms which control or lease about 12,510 acres (26). It is an important agricultural crop with an annual farm value of approximately $28 million (Table 5). Virtually all the crop is grown on the Big Island of Hawaii. However, some acreage is being added on Maui, although there will be no harvest there for another five years. The industry has a very promising future. The current and the expected price of nuts is good, and growers are expecting a larger crop in 1982. Producers agree, however, that additional promotion is needed in the face of increasing supply.

Coffee

Coffee is also an important industry in Hawaii. In 1981, its farm value was estimated at $4.5 million. The industry at present consists of 625 farms which control or lease about 1800 acres (Table 6). Virtually all coffee is grown on the Big Island. In recent

Table 5

Macadamia Nut: Acreage, Production and Value in Hawaii, 1981

Island	Acreage	Production (1,000 pounds)	Value (1,000 dollars)
Hawaii	12,510	35,800	27,566
Kauai/Maui/Oahu	1,190	200	154
Total	13,700	36,000	27,720

Source: Hawaii Agricultural Reporting Service, 1982.

Table 6

Coffee: Acreage, Production and Value in Hawaii, 1981

Island	Acreage	Production (1,000 pounds)	Value (1,000 dollars)
Hawaii	1,800	2,240	4,480
Total	1,800	2,240	4,480

Source: Hawaii Agricultural Reporting Service, 1982.

years, coffee production has experienced a continuous decrease. To combat this decline in the industry, efforts were made to market Kona coffee as a gourmet item at prices substantially above those of grocery-store grades (19). This, combined with the interplanting of coffee and macadamia nuts, promises a bright future for the industry in the years to come.

ENERGY

The State of Hawaii is highly dependent on foreign sources for its energy needs. With 92% of its energy derived from imported oil, of which 64% comes from foreign sources, Hawaii remains one of the most vulnerable states to the full impacts of rising oil prices and the growing risk of supply disruptions (12). The degree of these impacts varies, however, from county to county depending on its resource endowments. The Big Island has an exceptionally varied source of energy which consists of biomass, geothermal power, ocean thermal energy conversion, wind power and hydroelectric power (28).

Biomass

Biomass is an important alternate form of energy that continues to contribute markedly to the State's quest for energy self-sufficiency (22, 23, 24). The Big Island of Hawaii has a varied source of biomass. The biomass sources that hold out promise as important sources of energy on the Big Island are sugarcane, macadamia nut shells, coffee pulp, eucalyptus and leucaena. Estimates of the total contribution of these biomass crops have varied somewhat. However, recent studies indicate that the Island of Hawaii currently generates about 45% of its electricity from biomass sources. Hawaii's biomass resources have the potential of supplying 15% of the State's total energy by 2005 (12).

Geothermal Power

Geothermal power is getting increasing attention as a source of electric power generation. In 1981, the first generator began operation with a promise to supply 3000 KWH to the State's utility grid. The plant, located in the Puna district, is a joint effort of the Federal government, the State, the County of Hawaii and the Hawaiian Electric Company (HECO). Recently, the plant has been hit by a series of malfunctions and equipment failures. These have resulted in the reduction of output and increased rate to an average of 62 cents per month per residential customer (30).

Ocean Thermal Energy Conversion (OTEC)

The Ocean Thermal Energy Conversion (OTEC) system is another promising energy source on the Big Island. In 1980, the U.S. Department of Energy (DOE) issued a Program Opportunity Notice for a closed cycle OTEC pilot plant of at least 40 megawatts (28). Changes in Administration, reorganization of the DOE, and drastic cutbacks of energy research funds placed the project on hold for over a year. However, it was recently announced that funding for the first phase, conceptual design, will be forthcoming for two Hawaii-based projects.

The OTEC potential, its technology development, engineering problems, economics, environmental effects, legal issues, political concerns, sociological concerns and policy implications and recommendations have already been assessed by the Hawaii Natural Energy Institute (HNEI) in 1981.

Wind Power

The Big Island appears to have one of the best wind regimes in the world. Its total energy potential is equal to many times the county's needs. The Department of Meteorology, University of Hawaii, in conjunction with the Hawaii Natural Energy Institute (HNEI), has been leading a resource assessment program for the past decade. This has resulted in the establishment of a Wind Energy Application Network (WEAN) Program designed to assess the wind power potential. Wind Farms Ltd. has plans to establish 8 large wind machines, producing 500 kilowatts each, at an area on Parker Ranch just west of Kahua Ranch on the Big Island. Hawaii Electric Light Co. (HELCO) has agreed to purchase an equivalent of 4 megawatts of electricity from Wind Farms Ltd. The growing interest in wind farm development and its energy potential continues to attract many mainland firms to Hawaii (28).

Hydroelectric Power

Hydroelectric power is also an important source of energy on the Big Island. The Island's rainy northern and eastern areas provide sites for several hydroelectric facilities. Most of the facilities, however, do not have any storage capacity and therefore operate depending on river flow. Consequently, their full potential is reached only under ideal conditions. For instance, the hydroelectric plant on Wailuku River, which was expected to produce up to 3.4

megawatts of electricity, was unable to utilize its full potential due to drought conditions this year (28). This clearly indicates that good environmental conditions are necessary for the full realization of hydroelectric generating capacity. Although it appears that the expansion of hydroelectric capacity on the Big Island is feasible, the economics of such an undertaking are unlikely to be favorable in comparison with a number of alternative strategies (12). The total contribution of hydroelectricity to the County's utility grid is currently about 0.9%.

Although the Big Island is richly endowed with indigenous sources of energy, their full development is not necessarily attractive due to cost considerations. Consequently, in the very short term, energy resources will remain the critical inputs in the expansion of agricultural output.

Structure of the Study

The study is organized into five chapters. The first chapter presents an overview of the problem and study area, and states the objectives and the hypotheses of the study. The second chapter is devoted to the review of earlier findings as they relate to the study. The third chapter discusses the analytical framework. Specifically, it examines the procedures of data collection, and the application of a linear programming model to sugar, macadamia nuts and coffee. The fourth chapter analyzes the study results and the policy recommendations, and the fifth chapter presents the summary and conclusions of the study.

CHAPTER II

REVIEW OF LITERATURE

In the early seventies and following the 1973 OPEC oil embargo, several studies have emerged relating agricultural production to energy use. Instead of attempting an exhaustive survey of all these studies, representative studies have been chosen for review.

Hirst (33) provides some of the first estimates of food-related energy requirements in the United States. He used data from the 1963 U.S. input-output tables to determine the quantities of energy consumed in the agricultural, processing, transportation, wholesaling and retailing, and household sectors for personal consumption of food. The study concluded that the energy used by the U.S. food cycle constituted about 12% of the national energy budget. Processed fruits and vegetables were identified to be particularly energy-intensive with regard to both their caloric intake and their protein content. Flour and cereals, fresh vegetables, and dairy products, on the other hand, were shown to require relatively small energy inputs per unit of food nutrient.

Following the 1973 OPEC oil embargo, many studies appeared purporting to show that U.S. agriculture is an efficient user of energy. A common argument running through these studies is that the use of energy-based inputs may be less in the future than in the past and may constitute a severe threat to agricultural output, with long-run implications for productivity.

Perelman (57) suggested that if efficiency is measured in terms of energy input (energy requirements) in production, then U.S. agriculture comes out very poorly. Measuring efficiency in terms of conservation of energy, Perelman concludes that U.S. agriculture appears to result in a net energy drain.

Pimentel (58) and Steinhart (68) conclude in separate studies that food production costs are higher in the U.S. than in other countries with less energy-intensive agricultural production technology; furthermore, the same study concludes that known petroleum reserves would be rapidly exhausted if U.S. agricultural technology were employed to produce a high-protein diet for the entire world population.

The oil crisis also provided an impetus for a series of mathematical programming studies of the national and regional impacts of both increased energy costs and energy shortages on agriculture. An exhaustive list of such studies is not provided here. However, representative studies are reviewed to illustrate the efforts in this area.

Dvoskin and Heady (15) analyzed United States agricultural production under limited energy supplies, high energy costs, and expanding agricultural exports. High energy costs as well as energy shortages were found to have a significant impact on both regional crop production and regional income distribution. An energy crisis in the form of reduced energy supplies or higher energy costs or both would have a severe long-run impact on irrigated farming in the western United States. The study concluded that higher energy costs might actually prevent farmers from applying water to their irrigated crops. Also Dvoskin and Heady concluded that the real hope for irrigated farming in the long run lies in increased agricultural exports and ample energy supplies to agriculture. Higher exports promise farmers higher returns for their output and these more than offset high energy prices; moreover the study showed that a major part of higher exports must come from irrigated farming and increased fertilization, both of which are energy intensive operations.

Adams, King, and Johnston (1), in 1977, analyzed some of the impacts of increases in energy costs and reductions in energy supplies on the product mix of field crops and vegetables in California. A quadratic programming model including risk is used to evaluate the effects of increased energy costs and reductions in fertilizer and fuel supplies. The model includes a demand matrix of nine field crops and 28 seasonal vegetables. The study attempted to isolate the welfare implications of energy changes on producers and consumers. The major findings of the empirical investigation suggest that alternative energy policies have strong differential impacts. For example, the impact of increased energy costs was found to fall primarily on producers, whereas the impact of reduced fuel supplies was found to fall primarily on consumers. The study raised some key questions about the impact on agriculture of any proposed energy program.

Another study by Casey, Lacewell, and Jones (6) provided an analysis of the regional effects on agricultural output and producer net returns for varying levels of fuel restrictions in the Southern High Plains of Texas. Fuel shortages were found to have different effects on agricultural output and producer net returns depending on the nature of the shortage (in season, at harvest, or for irrigation).

Diesel fuel shortages up to about 15%, during the growing season and/or harvest, have little effect on output and net returns, given that the farmers adopt a reduced tillage strategy during the growing season. In contrast, output and associated net returns were found to be much more sensitive to irrigation fuel (natural gas) shortages than to diesel fuel shortages, both in season and at harvest. This is explained by the dependence of agricultural production on irrigation and the inability to make adjustments that would maintain yields with less irrigation water. To supplement estimates of minimum output and net return reductions expected at various fuel levels, the authors suggest additional research to quantify production shifts and associated net returns that occur with increasing fuel costs.

Mapp and Dobbins (49) examined the impact of increasing natural gas prices on the pattern of irrigated crop production, farm net income and the quantity of water pumped through time for representative farms in the Oklahoma Panhandle. Increasing natural gas prices were found to have several potential effects. First, they increased the cost of pumping irrigation water, and other things being equal, reduced the level of net returns associated with irrigated crop production. Second, shifts from high to moderate levels of irrigation occurred due to changes in the water table and pumping costs. Third, increasing natural gas prices prompted a shift to dry cropland production. About a two-thirds reduction in net returns accompanied increasing natural gas prices and the shift to dry cropland production. In addition, the following studies deserve particular attention in the context of the proposed investigation.

Merlin (50) provided some of the latest findings in the area. Using a static linear programming model, the author analyzed the effects of increases in energy prices on net revenues from crop production. When all activities, except energy prices, are fixed at their 1977 levels, net revenues declined to $2.3 million with each 25 percent increase in the overall cost of energy. When energy prices reach 206.1 percent above base levels, total production costs equal gross return and net revenue is zero. The study concluded that the impact of rising energy prices is more severe at greater pumping depth than for shallow irrigation wells.

Commoner et al. (10) analyzed the energy requirements for producing fourteen different field crops in twenty-nine different situations. They found that along with energy price increases during 1970, the cost of other crop production inputs rose just as rapidly. The comparative energy input costs of different crops are measured as "Energy Vulnerability Index." This index compares the increase in energy input costs to 1) the change in price received for the crops, and 2) the change in total variable production costs.

Skold (65) presents several adjustment possibilities that farmers using pump irrigation systems should consider when faced with higher energy prices. He concluded that few producers are able to pass these increasing costs on to consumers because of the nature of agricultural markets. Likewise, there are limited opportunities to substitute other inputs for higher-priced energy inputs. Conservation measures can help to preserve pump irrigators but the impact of higher energy prices is greater for pump irrigators than for other producers.

Young (70) evaluated irrigation costs of representative wells on the Texas High Plains, with increasing energy prices along with the break-even irrigation costs for selected crops with alternate commodity prices. Pumping costs were estimated for a range of natural gas and electricity prices. He added distribution costs to pumping costs to determine total irrigation costs. A wide range of total costs was evident. He also compared the estimated break-even irrigation costs with three sets of commodity prices. His "low prices" are the approximate target or support level prices for 1978; "intermediate forces" are set at approximately 75% of parity; and "high prices" are approximately 100% of parity. The break-even cost for irrigated wheat increases from \$2.37 per acre-inch with "low prices" to \$5.52 per acre-inch with "high prices."

Short (64) used a recursive, regional, linear programming model to evaluate the effects in 1990 and 2000 of the falling water table, rising energy prices and varying exports. The model represents production alternatives with more than 2,500 rotations, each with a different relationship between yields, resource use and costs. Production is constrained principally by available land subdivided according to productivity and production costs into 216 categories in the Oglala Zone and 204 categories in the rest of the nation. The model assumes competitive equilibrium; it determines prices for land, water and endogenous crops, while other resources receive market rates of returns. The study concluded that both increased energy prices and decreased exports reduce farm income per acre attributable to irrigation. The effect of a doubling of energy prices is to increase crop prices, increase the prices of land, induce the conversion of land irrigated with groundwater to dryland, and reduce water and energy use.

Litterman (48) investigates the relationship of energy to non-energy inputs, specifically, capital, labor and intermediate materials in twenty manufacturing sectors from 1947 to 1976. To accomplish this objective, two models are used, a nonlinear static model and a dynamic linear model. The functional form of the non-linear model is a generalized Box-Cox cost function that allows estimation of elasticities of input demand, economies of scale and bias to technical change without a priori restriction. The form of the dynamic linear model is a vector autoregression with an exchangeability prior. The important results obtained from the Box-Cox cost function show that capital and energy are substitutes and labor and energy are complements in paper products, primary metals and agriculture. On the other hand, the important conclusions from the dynamic linear model indicate that in most sectors, capital increases in response to energy price increases, but this capital increase is not sustained, indicating that capital purchases are geared more toward one-time conservation measures rather than extensive changes in the production process.

Bellock (5) developed a structural model to simulate the U.S. potato industry with special emphasis on examining the interregional effects of changing energy costs. The model estimates national demands, identifies five production regions and four product forms. Covering a sample period from 1961 through 1978, the model is employed to simulate the probable impacts of changing energy prices on total production, the mix of production forms, and regional patterns of production.

The results of the estimation suggest that risk and energy costs do not significantly influence planting decisions and that supplies are generally highly inelastic with respect to expected returns. The supplies of the specific product forms from any given region are found to be linked to energy costs. Particularly, higher energy costs encourage the production of processed potatoes in the Northwest and discourage it elsewhere. However, the simulations do not reveal any significant impact of energy costs on the total production of each region. It is argued, therefore, that the failure of the model and the simulations to detect an energy cost-regional production link may be due to the existence of thresholds, below which energy costs do not impact on planting decisions.

These and many other studies have contributed to the understanding of the relationships between the agricultural sector and the energy sector, and the potential impact of energy price increases on the agricultural sector.

CHAPTER III

ANALYTICAL FRAMEWORK

This chapter examines each of the basic inputs used in the production of sugar, macadamia nuts and coffee. This includes a description of the various inputs, how they are obtained and the manner in which they are used in the linear programming model.

Procedures and Data Sources

Procedures

The basic data used in this analysis comes both from primary and secondary sources.

Comprehensive sugar data from secondary sources, sufficient to meet the objectives of the study were available. Consequently, the input and output coefficients for sugar used in this study are based largely on secondary sources. This has been supplemented, where necessary, with primary data.

On the other hand, the macadamia nut and coffee data used were obtained from surveys of macadamia nut and coffee growers on the Big Island of Hawaii. The methodology used for data collection is stratified random sampling with proportional allocation. Thus each crop is stratified by farm size. Sugar farms are divided into four size categories A, B, C, and D corresponding to less than 10, 10-49, 50-159 and 160 acres and over farm, respectively. Similarly, the macadamia nut farms are subdivided into five farm sizes A, B, C, D, and E corresponding to less than 5, 5-9, 10-19, 20-49 and 50-499 acres, respectively. Coffee farms, on the other hand, are disaggregated into three farm size categories corresponding to the first three categories of macadamia nut farms. This classification of farms by size and the use of stratified random sampling enable us to assess the technology differences among different farms and their attendant economies of scale. In order to make meaningful policy recommendations, it is crucial to take into consideration these differences. This makes stratified random sampling procedure more attractive than simple random sampling.

The best sample size was chosen by minimizing the variance using the following formula adapted from Cochran (9)

$$n = \frac{(C - C_o) \sum_{i=1}^{52} (W_h C_h / \sqrt{C_h})}{\sum_{i=1}^{52} (W_h S_h \sqrt{C_h})} \qquad (1)$$

where C = total cost; C_o = fixed cost

W_h = proportion of stratum h in the total population

S_h = variance of each stratum

C_h = cost per unit in stratum h

N_h = total population of macadamia nuts and coffee growers.

Based on the above formula, the sample size of macadamia nuts and coffee growers interviewed was computed and the results are presented in Table 7.

Table 7

Population and Sample of Farms Interviewed by Size, 1981

Size Group		Population of Farms	Sample Size
	h	N_h	n_h
A	(0-4)	330	37
B	(5-9)	64	7
C	(10-19)	36	4
D	(20-499)	29	21
E	(500+)	5	1
Total		465	52

Source: Hawaii Agricultural Reporting Service, 1981.

Data Sources

Sugar, macadamia nuts and coffee data obtained from primary and secondary sources are presented in the following sections.

SUGAR

Data used to stimulate the production of sugar by the independent growers were obtained from the cost study conducted by Holderness, Vieth, Scott and Briones in 1981 (34). This was checked against a similar study done by Holderness, Vieth and Scott in 1979 (35).

Production Input Analysis

The production of sugarcane by the independent growers on the island of Hawaii is governed by the farmer's ability to pay for his labor, rent, machinery or equipment, energy, herbicides, and fertilizers. These production input expenses constitute the major cost components.

Labor. Various farm operations, i.e., land preparation, seed planting, harvesting are performed by one or a combination of the following types of labor.

Family labor. The growing of sugarcane by independent growers is mostly a family operation involving the cultivation on an average of 23 acres. As such, the growers cultivate their cane on a part-time basis while they work primarily for the large sugar plantations. In some cases, the field work is done by the farmer and his family members on weekends and after hours. Family labor is regarded by the farmer as unpaid labor. However, in this study, it is assumed that family labor is valued at $5.00, the average wage paid to the hired workers in 1981 (Table 8).

Moreover, the findings from the study suggest that a 10-49 acre sugar farm, in general, is more labor-intensive than the other farms. This farm uses about 49.92 man hours per acre for his family labor. This is comparable to a less than 10 acre farm that uses about 45.32 man hours per acre. However, the 10-49 acre farm is about one and one-half times and two and one-half times more labor-intensive than the 50-159 and 160 acre and over farms for his family labor. Similarly, the family labor is at least three times higher than the less than 10 acre farm and is as high as that of the 160 and over acre farm (Table 9). Overall, the 10-49 acre farm is more labor-intensive than the less than 10, 50-159, and 160 acre and over farm, respectively. This seems to suggest that the small size farms are more labor-intensive than the large ones. The latter can afford capital-intensive technologies and therefore use less labor, whereas the former rely heavily on their own and family labor for their regular farm operations.

Hired labor. Another category of labor that is used in the production of sugarcane is the hired labor. It consists of labor that comes from off-farm. Traditionally, the independent growers rely heavily on their own and family labor to work on their fields. This traditional source of labor has greatly changed due to the scarcity of family labor and the change in the size of their farm operations. In fact, family labor appeared to be relatively scarce

Table 8

Farm Wage Rates by Method of Pay and Type of Work
April 12-18, 1981 with Comparisons[1]

Method of Pay and Type of Work Performed	Dollars Per Hour
All hired farm workers	6.00
Paid by other than piece-rate	5.99
Paid by hour only	5.73
Paid by hour, by cash wages only[2]	4.45
Field workers	5.17
Livestock workers	5.08
Machine operators	6.83
Supervisors[3]	8.85

[1]Perquisites such as room and board and housing are provided to some workers in all categories.

[2]Includes revised estimates for some states.

[3]Includes only hourly workers not receiving perquisites.

Source: Agricultural Reporting Service, 1981.

Table 9

Sugar: Labor Input Per Acre by Farm Size Group, 1981
(Man Hours Per Acre)

Farm Size Type	A Less than 10	B 10-49	C 50-159	D 160 and Over
Family	45.32	49.92	24.38	8.00
Hired	9.60	30.60	27.66	24.43
Total	54.92	80.50	52.04	32.43

Source: (32).

among Hilo Coast independent growers. Most of these growers are old and their children have little desire to work on the farms. In addition, the search for efficiency has induced some independent growers to adopt capital-intensive technologies that become more cost-effective on larger farms.

Custom or contract work. This constitutes an important source of labor. Because some farms do not have the financial ability to purchase their own machinery, to prepare their land, to plant, and fertilize, they enter into a contractual arrangement with the plantations that provide most of the custom or contract work needed. Viewed in this perspective, the custom or contract labor can be regarded as a substitute for hired and family labor.

Land. The land on which most of the independent producers grow sugarcane is acquired through leases either from their affiliated plantations or large land holding estates or owned in fee simple. While the former is a common practice, the latter is also a fairly common type of ownership.

In this study, the land costs as used in the production expenses include rent for the lease operator and land charge for the homesteader who holds lands in fee simple. Homesteads are usually defined as a portion of the holding, limited both as to total area and value, owned and occupied by families as their home.

The land cost by farm size group obtained in this study varies significantly from a low $51 per acre on farm A to a high $110 per acre on farm B. Although land costs on farms B and D are quite similar, they are twice and one and one-half times higher than on farms A and C, respectively. Overall, the average land cost is about $85 per acre (Table 22).

Capital. The capital input used in this study includes only farm machinery such as tractors, sprayers and trucks used on the farm. There are many ways in which the capital input is measured. First, if rental rates of various farm equipment and capital expenditures are readily available, then the latter can be deflated by the former to convert the capital spending aggregate into equipment machinery hours. The rental rate of machinery is then used as the price of capital.

Although the procedure is desirable when one capital input is considered, it becomes less satisfactory when different machinery inputs are concerned because of the variations in the rental prices of machinery. To overcome this difficulty, capital expenditures are instead deflated by an index of all the rental rates to obtain a measure of the real quantity of farm machinery used. The same weighted average of the machinery rental prices was taken as the price of capital with the weights determined by the share of each type of machinery in capital spending. Although this approach is superior to the former procedure, it neglects substitution within the capital aggregate, such as the choice between airplanes and tractors in applying fertilizers or insecticides.

Since the rental rates of various types of farm equipment are not readily available, we are unable to use this procedure to estimate the price of capital and the physical quantity of capital. Instead, the study relies on the procedure suggested by Christensen and Jorgenson (8) to construct the

$$p_k = (1-k)[q_{k_{t-1}} r_{k_t} + u_{k_t} - (1-q_{k_{t-1}})]$$

where p_k is the service price of machinery and equipment; k is the investment tax credit; q_{kt-1} is 1977 value of the tractor price index where $q_{1978} = 1$; r_{kt} is the interest rate charged for machinery and equipment; u_{kt} is the replacement rate for farm equipment.

The cost of capital was then calculated by multiplying the value of capital stock by the service price of machinery and equipment. Based on the above formula, the service price of machinery and equipment was valued at 15%.*

The analysis shows that the capital cost ranges from a low $141 per acre on farm D to $263 per acre on farm B. The capital costs on farms A and C are respectively $166 and $201 per acre (Table 22).

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*The data used to estimate the service price of capital are only available for 1978. Although this tends to understate the real price of capital, it is a more accurate figure of capital price than the current interest rate.

It may be pointed out that in the case where the machinery is owned and financed through loans, the cost of capital includes the replacement rate of capital, the interest rate charged on the loan and the taxes and insurance paid. This procedure is also an acceptable procedure and is often used in many cost studies. Christensen and Jorgenson's procedure is also used to measure capital for macadamia nuts and coffee.

Patterns of indirect energy use.

Fertilizer. Fertilizer inputs are considered as indirect energy inputs. They constitute an important part of the production expenses. The sugar growers use different types of fertilizer that are a combination of different doses of nitrogen, phosphate and potash. The different kinds of fertilizer used by the independent growers are summarized in Table 10.

Fertilizer recommendations for sugar growing by small independent producers are usually made by large plantations. As such, it is interesting to compare the amount of fertilizer used by independent growers with the guidelines suggested by the plantations (Table 11).

The application of fertilizer is usually done by hand, machine, or a combination of the two. Assuming that other variables are not held constant, the findings suggest that farm B uses more fertilizer per acre than any other farm size group in the study. Specifically, farm D uses at least 3 times less fertilizer per acre than farms A and C and approximately 4 times less fertilizer than farm B. In

Table 10

Sugar: Fertilizer Use Per Acre by Farm Size, 1981
(Pounds per Acre)

Farm Size Type	A Less than 10	B 10-49	C 50-159	D 160 and Over
A-1	953	1579	1066	548
M-104	731	968	458	548
M-28	448	-	520	-
A-5	788	732	-	-
A-4	838	1178	1043	-

Source: (34).

Table 11

Sugar: Fertilizer Recommendations by Hilo Coast Processing Company 1981 (Pounds per Acre)

Ratoon Crop			
High		Low	
M 181	700	M 181	700
A 28	350	A 1	300
A 28	450	A 1	375
A 28	400	A 1	375
A 4	350	A 4	350
A 4	300	A 4	300
Plant Crop			
M 181	950	M 181	950
A 28	300	A 1	250
A 28	450	A 1	375
A 28	400	A 1	350
A 4	350	A 4	350

Source: Hilo Coast Processing Company, 1981.

most instances, the pattern of fertilizer use per acre is higher than the amount recommended by the plantations. For example, the average amount of A-1 recommended by the plantation is about 270 pounds per acre for both ratoon and plant crop. This amount is about 3, 6, 4, and 2 times smaller than that used by A, B, C, and D farms, respectively. The results are summarized in Table 10. The patterns observed do not provide any basis to accept the first hypothesis.

Based on the unit price of different types of fertilizers used by the independent growers (Table 12), fertilizer inputs constitute the major component of the energy cost. Specifically, fertilizer expenses represent about 71%, 88%, 78% and 67% of the energy costs on farms A, B, C, and D, respectively or an average of 76% of energy costs. Consequently, farm B has the highest expenses of fertilizer per acre compared to other farms. Similarly, farm D is a more efficient user of fertilizer, since it has the least cost of fertilizer per acre.

Herbicide. Herbicide inputs are also considered indirect energy inputs. Independent sugar growers use different forms of herbicides that make it difficult to obtain an aggregate figure of herbicide use. However, disaggregated figures exist and can be seen in Table 13. For instance, all four types of farm use less than one gallon of surfactant and roundup per acre. Assuming that other variables are not held constant, the rate of use of dowpon per acre on B farm is about two times smaller than the rate of use on A and B farms, and about one and one-half times smaller than on farm C.

Table 12

Sugar: Fertilizer: Unit Price, 1981

Type	Unit	$/Unit
A-1	lb.	.15
M-104	lb.	.14
M-28	lb.	.12
A-5	lb.	.16
A-4	lb.	.16

Source: Telephone interview with C. Brewer Chemical.

Table 13

Sugar: Herbicide Use per Acre by Farm Size, 1981
(Pounds or Gallons per Acre)

	Farm Size Type	A less than 10	B 10-49	C 50-159	D 160 and Over
Dowpon	lbs.	4.26	2.26	3.80	4.00
Karmex	lbs.	5.13	5.80	7.00	8.00
Atrazine	lbs.	4.19	5.13	9.65	8.00
Roundup	gal.	0.21	0.11	0.22	-
Surfactant	gal.	0.53	0.06	0.68	1.00
TCA	lbs.	-	-	-	-
Ametryne	lbs.	2.62	1.54	2.92	-
Sticker	gal.	-	0.21	0.10	-
Paraquet	gal.	-	0.06	-	-
DCMU	lbs.	-	4.04	-	-

Source: (31).

Similarly, the rate of use of Karmex per acre is almost the same on farms A and B, whereas farms C and D use about 7 and 8 pounds per acre. However, the results do not show that the larger the farm, the less herbicide it uses. The first hypothesis is therefore rejected on that basis.

In order to obtain comparable values by farm size, dollar values of different herbicide inputs were computed. Based on the costs of the herbicides (Table 14), the results suggest that farm A has the highest herbicide expenses per acre compared to the other farm size groups. Specifically, herbicide costs are about 11%, 5%, 14% and 10% of the energy costs on A, B, C, and D farm, respectively. The average cost of fertilizer is about $25 per acre.

Patterns of direct energy use. The direct energy inputs used to grow and process sugarcane are diesel, electricity, gasoline and residual oil. These inputs are becoming more and more critical as the cost of these inputs is constantly increasing.

In 1981, the Hilo Coast Processing Company (HCPC) harvested and processed about 113,573 tons of sugar grown on 10,803 acres. Of this, about 24,436 tons of sugar were provided by the United Cane Planter Cooperative, a cooperative of independent growers. The total acreage was estimated at 2603 acres. Similarly, Mauna Kea Sugar grew about 8200 acres and harvested about 89,137 tons of sugar.

Based on the total amount of energy used to produce and process sugarcane in 1981 (Tables 15, 16, 17), the energy inputs per acre were derived and presented in Table 18. Since the energy use figures

Table 14

Sugar: Herbicide: Unit Price, 1981

Type	Unit	$/Unit
Dalapon (Dowpon)	lb.	1.65
Diuron (Karmex)	lb.	3.25
Atrazine (Aatrex)	lb.	2.18
Roundup	gal.	69.50
Surfactant	gal.	6.35
TCA	lb.	1.10
Ametryne	lb.	3.43
Sticker	gal.	7.00
Paraquat	gal.	30.00
DCMU	lb.	1.20
Velpar	lb.	20.55
Lo Drift	gal.	17.70
2, 4-D	gal.	11.25
Sencor	lb.	9.88

Source: Telephone interview with C. Brewer Chemical, 1982.

Table 15

Sugar: Cost of Direct Energy Inputs per Acre, 1981
(dollars)

Diesel	163.02
Electricity	10.97
Gasoline	26.94
Residual oil	54.06

Source: Telephone interview with C. Brewer & Co. Ltd., 1982.

Table 16

Sugar: Direct Energy Inputs Used for Processing, HCPC, 1981

Type	Amount	Cost (dollars)
Diesel	1,381,600 gal.	1,349,700
Electricity	675,500 kwh	75,400
Gasoline	133,900 gal.	174,000
Residual oil	50,440 barrels	1,511,600

Source: Telephone interview with C. Brewer & Co. Ltd., 1982.

Table 17

Sugar: Costs and Direct Energy Inputs Used for Growing
Mauna Kea Sugar Company, Inc., 1981

Type	Amount	Cost (dollars)
Diesel	315,400 gal.	216,600
Electricity	305,200 kwh	40,100
Gasoline	68,300 gal.	90,000
Residual oil	733.6 barrels	31,600

Source: Telephone interview with C. Brewer & Co. Ltd., 1982.

Table 18

Sugar: Direct Energy Inputs per Acre by Type and Operation

	Unit	Growing	Harvesting and Processing	Total
Diesel	gal.	38.46	127.89	166.35
Electricity	kwh	37.22	62.53	99.75
Gasoline	gal.	8.33	12.39	20.72
Residual oil	gal.	3.76	49.04	52.80

Source: Telephone interview with C. Brewer & Co. Ltd., 1982.

by farm size could not be obtained from HCPC, an average figure was used to estimate the energy inputs by type and operation. The total figure was then calculated and used for all farm sizes.

The findings suggest that the energy input per acre used to harvest and process sugarcane is higher than that used for growing. Specifically, the amount of diesel used to process and harvest sugarcane is about 3 times higher than that used for growing. Similarly, the amount of electricity, gasoline, and residual oil used in harvesting and processing is about 2, one and one-half and 13 times higher than that used for growing in 1981 (Table 18).

Based on the unit price of the different forms of energy input, the cost of direct energy inputs per acre is calculated and summarized in Table 15. The cost per unit is also presented in Table 19.

Seedcane. Seedcane is a short cutting of the sugarcane stalk that is planted in furrows to establish new cane plants. For the independent growers, seedcane is an input that must be purchased or produced. Based on the cost per ton of seedcane of about $21, the seedcane expenses per acre are at least twice as small on farm A as on farm C and almost identical on farms B and D. The average cost is about $75 per acre (Table 22).

Management and overhead expenses. Management cost is an important part of the general expenses. The latter includes general farm overhead and management under the budgeting procedure and general and administrative expenses under cost accounting procedure.

Table 19

Sugar: Direct Energy: Unit Price, 1981

Type	Unit	$/Unit
Gasoline	gal.	1.30
Diesel	gal.	.98
Electricity	kwh	.11
Residual oil	barrels	43.00

Source: (26, 27).

In fact, these costs include management and executive staff office expenses, legal fees, professional fees, and association dues for the budgeting approach. Based on the National Economics Division and Statistics Service of U.S.D.A. (52), a management fee of 10 percent of total costs (excluding land charge) is assumed in this analysis. The details are summarized in Table 22.

The farm overhead expenses, on the other hand, include property insurance, financial and legal fees, business and legal time, and social security (Table 22). The above approach used to impute value to management and overhead expenses is assumed to be the same for coffee and macadamia nuts.

Output and output prices. The average yield of raw sugar and molasses by farm size group used in this study was obtained from the direct survey of independent sugar growers. The results by farm size are shown in Table 18.

To obtain the revenue, three output price scenarios were considered. The first price scenario, the current output price scenario, assumes a break-even price of $440 for raw sugar and $66 for molasses. The second output price scenario, the high ouput price scenario, assumes a 40% increase from the break-even or current output price scenario. The prices of raw sugar and molasses are set at $616 and $93, respectively. The low output price scenario, on the other hand, assumes a 40% decrease from the current output price. The prices of raw sugar and molasses are set at $264 and $40, respectively. In addition, a ten-year time series price data for

Table 20

Sugar: Average Yield, Raw Sugar and Molasses by Farm Size, 1981

Farm Size Group	Raw Sugar (96°) (tons/acre)	Molasses (tons/acre)
A	9.50	2.94
B	10.08	2.57
C	13.43	2.42
D	10.09	2.47

Source: (33).

raw sugar and molasses is presented to show the trend of raw sugar and molasses prices (Table 21).

Production cost. The production cost is a very important component of this analysis. The various cost components that make up the production cost are summarized in Table 22. These costs are considered as base period costs in this analysis.

MACADAMIA NUT

Macadamia nut cultivation is a long-term investment that requires a relatively long period between planting and bearing. Depending upon particular environmental conditions, such as the soil, the temperature and the amount of moisture and variety, macadamia trees come into bearing at 5 to 6 years of age. Because of these long waiting periods, banks and other agricultural production credit associations are reluctant to provide the necessary loans that farmers need in their first years.

The development of new macadamia orchards requires land clearing, preparation, purchase of nursery stock and continuous application of herbicides, fertilizer before and after planting. These operations constitute major expenses that have an important bearing on the decision to invest in macadamia nut cultivation.

The growing of macadamia nuts and the performance of these farm operations involves the direct or indirect use of labor inputs, indirect energy inputs such as fertilizer, herbicide and direct energy inputs such as gasoline, diesel and electricity. An analysis of these production inputs is presented in the following sections.

Table 21

Sugar: Prices of Sugar and Molasses, 1972-1982

Year	Raw Sugar 96° ($/ton)	Molasses ($/ton)
1972	158	26.10
1973	180	60.40
1974	691	58.00
1975	320	38.20
1976	234	41.80
1977	212	27.10
1978	262	50.60
1979	304	72.10
1980	554	87.90
1981	395	53.00
1982	355	58.00

Source: 26).

Table 22

Sugar: Production Cost per Acre by Farm Size, 1981
(Dollars)

Farm Size Type	A Less than 10	B 10-49	C 50-159	D 160 and Over
Labor	187.51	156.53	122.82	91.87
Contract work	274.15	410.05	778.18	435.74
Seedcane and procurement	55.65	60.46	123.90	60.69
Land cost (charge and rent)	51.43	110.46	72.99	106.32
Capital cost	166.44	262.69	201.45	140.61
Marketing processing cost	2521.28	2640.50	2281.90	2724.79
Total energy cost	501.00	577.00	450.00	400.00
Fertilizer	212.06	304.08	166.13	126.33
Herbicide	33.83	17.65	29.22	18.90
Gasoline	26.94	26.94	26.94	26.94
Diesel	163.02	163.02	163.02	163.02
Electricity	10.97	10.97	10.97	10.97
Residual oil	54.06	54.06	54.06	54.06
Repairs	25.36	103.00	108.80	956.40
Farm overhead expense	34.34	133.50	269.84	1138.00
Management	99.40	158.49	189.04	301.78
Production cost (including marketing)	1093.00	1743.00	2079.00	3319.65
Total cost	3816.00	4613.00	4599.00	6256.00

Source: (32).

Data used were primarily obtained from personal interviews with the growers. These data have been checked against the studies by Keeler and Huang (40), Keeler and Fukunaga (41), Hamilton and Fukunaga (25), and Scott and Marutani (62). These studies are useful sources that allow us to check the reliability of the data collected.

Production Input Analysis

Labor, land, fertilizer, herbicide inputs, gasoline, diesel and equipment are the major inputs that are required to cultivate macadamia nuts.

Labor. The growing of macadamia nuts by small independent growers is mostly a family operation that involves extensive utilization of family labor and seasonal hired labor. Most growers are part-time, whereas some others spend at least 40 hours a week on their farms. In some cases, the field work is done on weekends by family members. Family labor is usually considered as unpaid labor by the farmer. However, in this study, family labor is considered as a substitute for hired labor and is valued at its opportunity cost. The wage rate assumed here is $5.00 per hour, which is the wage rate paid by the farmers when additional labor has to be hired to carry out farm operations, generally harvesting.

The critical shortage of labor usually occurs between August through January. October and November are usually considered peak months, although some nuts mature every month of the year. During these periods, the scarcity of labor is very pronounced.

This explains the high rate of spoilage observed in some areas of the Big Island. Macadamia nuts have to be picked off the ground and husked within 2 or 3 days to reduce the rate of spoilage. In many instances, family labor is insufficient and has to be supplemented by "outside" labor.

The findings appear to suggest a negative correlation between farm size and the use of family labor, i.e., between small-size farms and family labor and large-size farms and hired labor. For example, farm A uses about one and one-half, 2, and 17 times more family labor than farms B, C, D, and E, respectively. Similarly, farm E uses about 9 and 19 times more hired labor per acre than farms B and A, respectively (Table 23).

Labor input is certainly a critical factor for the independent growers. The reason is that alternative employment opportunities outside agriculture, such as in tourism and construction, exist and are highly paid. However, in recent years, labor-saving mechanical harvesters have been developed for large growers or groups of cooperating growers as well as small growers. Although these harvesting devices may be attractive to large growers, they are too expensive to attract small growers.

Based on the rate of $5.00 per hour charged for labor, the labor cost constitutes an average of 60% of the production cost. In reality, most of the farmers do not impute any cost to their own and family labor. However, a realistic assessment of their

Table 23

Macadamia Nut: Labor Input per Acre by Size and Type, 1981
(Man-Hours per Acre)

Farm Size	A	B	C	D	E
Type	Less than 5	5-9	10-19	20-49	50-500
Family	340	247	218	162	20
Hired	12	25	118	200	225
Total	352	272	336	362	245

Source: Personal interview with growers, 1982.

production cost must include the opportunity cost of the scarce resource (Table 34).

Land. Macadamia nut acreage has increased significantly in recent years. From 1971 to 1980, the total and bearing acreage of macadamia nuts increased 96 and 33 percent, respectively (26). Similarly, the number of macadamia nut farms increased from 295 in 1971 to 465 in 1980, which represents a 59% increase. Of these 465 farms, about 83% consist of less than 10 acres and produce a small portion of macadamias harvested. The large portion of the total output comes from the small percent of large growers.

The land on which macadamia nut is grown is either abandoned sugar or cofee farms acquired through leases form private and public institutions or owned by the growers in fee simple. Although the former is found in most instances, the latter is a very common type of ownership that is found in Kona.

Soil, natural wind protection, elevation, rainfall and accessibility for harvesting and cultural operations are important factors to be considered in the cultivation of macadamia nuts. Although the crops have proven best adapted to mild, frost-free, subtropical climates with at least 50 inches of annual rainfall well distributed throughout the year, macadamia trees can tolerate and survive mild frosts and drought conditions. In Hawaii, macadamia trees grow best between 700 and 1800 foot elevations and where there is good, natural wind protection or adequate, planted windbreaks (25).

In addition, macadamia trees appear to grow successfully on a variety of Hawaiian soils ranging from loose volcanic lava soils to well-drained, lateritic clays. In most instances, the relatively low amounts of nitrogen, phosphorus and potassium in the soil have to be supplemented by fertilizers in order to increase yields. Leases vary in cost depending on land productivity and location. For instance, farms in central Kona close to the main highway tend to have greater rental cost than those that are not. Land cost as used in this study includes land rent and real property tax. The findings suggest an average land cost of $149 per acre, ranging from a low of $110 per acre on farm C to a high of $171 per acre on farm D (Table 24).

Capital. Capital is a somewhat difficult input to quantify in production economic theory. Empirically, depreciation and interest are often used as proxies of capital cost. Since some of the macadamia nuts growers do not allow for depreciation of their farm equipment, the value of capital is multiplied by the service price of capital developed earlier to obtain the capital cost used in the analysis. Farm equipment used to grow macadamia nut is varied. Depending on each farm situation, the type of equipment used includes a combination of husker, drier, trucks or farm trailer, power sprayer, knapsack sprayers, blower and mechanical harvester. Other miscellaneous materials include hand tools, pruning shears, sickles, picks and shovels.

Table 24

Macadamia Nut: Insurance, Interest, Land Cost, Depreciation, and Capital Cost per Acre by Size, 1981
(Dollars)

Farm Size	A	B	C	D	E
Cost	Less than 5	5-9	10-19	20-49	50-499
Insurance	105	92	144	115	124
Interest	133	89	142	150	160
Land cost (rent and tax)	116	170	110	171	162
Depreciation	300	422	156	225	190
Capital	246	268	150	170	157

Source: Personal interview with growers, 1982.

Based on the above accounting procedure, the findings suggest a negative correlation between farm size and capital cost per acre. Specifically, capital cost appears to be a decreasing function of the farm size, indicating economies of scale. For example, the capital cost on farm C is about one and one-half times smaller than the capital cost on farms A and B, respectively, and almost the same on farm E (Table 24).

Patterns of indirect energy use. This section explores the patterns of indirect energy inputs (fertilizers and herbicides) used to grow macadamia nuts.

Fertilizer inputs. They constitute a major part of the production expenses. The types of fertilizer often used by the macadamia growers interviewed are combinations of different amounts of phosphorous, potassium and nitrogen, namely 16-16-16, 14-14-14 and 10-15-20.

Although most growers use a combination of the above, based on location and the particular soil characteristics, some growers tend to concentrate on a particular type of fertilizer. For example, the A farm uses 800 pounds per acre of 16-16-16, 200 pounds of 10-15-20 and none of the other fertilizer inputs, whereas the E farm uses a combination of 260 pounds of 16-16-16, 30 pounds of 14-14-14 and 143 pounds of 10-15-20 per acre (Table 25). In any case, the results suggest that the larger the farm size, the less fertilizer it uses per acre. The rate of fertilizer use is found to be dependent on soil types, farm location and on the particular needs of

Table 25

Macadamia Nut: Fertilizer Inputs per Acre by Size, 1981

Farm Size		A	B	C	C	E
Type	Unit	Less than 5	5-9	10-19	20-49	50-500
16-16-16	lb.	800	620	617	350	260
10-5-20	lb.	200	800	640	143	143

Source: Personal interview with growers, 1982.

each farmer. The results obtained do not lead to the rejection of the first hypothesis. Fertilizer input expenses constitute an average of 42% of the energy cost. Overall, the fertilizer input expenses appear to be higher than the expenses for other energy inputs considered in this study (Table 34).

Herbicide. Weed control is perhaps the most expensive and one of the most important factors in nursery management. Pre- and post-planting weed control is often done either by power sprayers or knapsack sprayers. Failing to control weeds from the initial planting can greatly retard the growth of macadamia trees and result in increased cost of weed control. The different types of herbicides used are Paraquat, Roundup, and in some instances Atrazine, Karmex and 2, 4-D.

The findings appear to suggest a significant variation in the rate of herbicide application per acre by size depending on particular needs of the farmer. For instance, although farms B and D appear to use the same amount of Paraquat per acre, farm E uses about 2 and 5 times less Paraquat per acre than farms C and A, respectively. The larger farm appears to be more efficient than other farms, although in some cases the results are mixed (Table 27).

Based on the cost per unit (Table 28), the herbicide expenses represent about 16% of energy expenses. In addition, the herbicide appears to be a decreasing function of the farm size, exhibiting a strong economy of scale. This provides factual evidence to accept the first hypothesis.

Table 26

Macadamia Nut: Unit Price of Fertilizer by Type, 1981

Type	Unit	$/Unit
16-16-16	80 lb. bag	17.50
14-14-14	50 lb. bag	37.00
10-5-20	80 lb. bag	13.50

Source: Direct interview with C. Brewer Chemicals, 1982.

Table 27

Macadamia Nut: Herbicide Use per Acre by Type and Size, 1981
(Gallon or Pounds per Acre)

	Unit	A Less than 5	B 5-9	C 10-19	D 20-49	E 50-499
Paraquet	gal.	1.17	0.43	0.78	0.50	0.35
Roundup	gal.	0.47	0.53	0.32	0.11	-
Warfarin	gal.	-	-	0.43	0.11	0.49
2, 4-D	gal.	0.38	-	0.13	-	-
Atrazine	lb.	-	-	0.33	-	-
Diuron (Karmex)	lb.	-	-	0.43	0.11	-

Source: Personal interview with growers, 1982.

Table 28

Macadamia Nut: Unit Price of Herbicide by Type, 1981

Type	Unit	$/Unit
Paraquat	gal.	62.50
Roundup	gal.	76.00
Warfarin	gal.	11.25
2, 4-D	gal.	15.20
Atrazine	lb.	3.50
Diuron (Karmex)	lb.	16.00

Source: Telephone interview with Brewer Chemical, 1982.

Patterns of direct energy inputs. Direct energy inputs do not contstitute a major portion of the production expenses. The growing of macadamia nut by the independent growers is not a heavily mechanized operation. Consequently, the direct energy used does not contribute significantly to the cost of production. Gasoline is mainly used to operate the trucks, power sprayers and jeep trailers used on farm. Diesel is used for operating tractors and electricity is also consumed while husking the nuts.

The findings indicate the following. Gasoline consumption on farm D is about 2, 4, 3, and 3 and one-half times smaller than on farms A, B, C, and E, respectively. Farm B, on the other hand, appears to use more gasoline per acre than any other farm considered in the study (Table 29). Similarly, the same farm consumes more diesel than any other farm considered.

The electricity relationship observed shows that farm D uses more electricity than any other farms (Table 29).

The conclusions emerging from this analysis are: first, the amount of diesel fuel consumed appears to be a decreasing function of farm size (assuming that other factors are not held constant). The larger the farm size, the less diesel it uses per acre. Second, the rate of use of gasoline and electricity, on the other hand, exhibits a U curve on which the minimum is reached on D and C fars, respectively. That is, the rate of gasoline and electricity use appears to be first a decreasing function of farm size and then starts increasing from farms D and C, respectively.

Table 29

Macadamia Nut: Direct Energy Inputs per Acre by Size and Type, 1981

	Unit	A Less than 5	B 5-9	C 10-19	C 20-49	E 50-499
Gasoline	gal.	19.17	35.00	30.40	11.00	26.93
Diesel	gal.	-	29.17	20.00	15.00	3.62
Electricity	kwh	6.67	2.50	21.00	39.25	-

Source: Personal interview with growers, 1982.

Based on the unit price of different types of direct energy, direct energy costs represent an average of 47% of the total energy expenses (Tables 30, 31, 34).

Output and output prices. The average yield of macadamia nuts (in shell) by size used in this study was obtained from personal interviews with small growers. The results are summarized in Table 33.

To arrive at the revenue, three output price scenarios were considered. The first price scenario, the current output price scenario, assumes a break-even price of 90 cents a pound. The second output price scenario, the high output price scenario, assumes a 40% increase from the break-even price. The price of macadamia nuts is set at $1.26 a pound. The low output price scenario, on the other hand, assumes a 40% decrease from the break-even price resulting in an output price of 54 cents a pound. A ten-year time series data of macadamia nut prices is also presented in Table 32.

Production cost. In this study, production cost is used in combination with gross revenue to derive net revenues. A summary of the production costs is presented in Table 34.

COFFEE AND MACADAMIA NUT INTERPLANTING

Coffee and macadamia nuts are becoming increasingly interplanted on the Big Island. In light of this, in this section, coffee and macadamia nut are being treated as joint products and it is assumed that the amounts of inputs per acre used for both crops are identical.

Table 30

Macadamia Nut: Unit Price of Direct Energy Inputs by Type, 1981

Type	Unit.	Price (dollars)
Gasoline	gal.	1.67
Diesel	gal.	1.00
Electricity	kwh	12.74

Source: Direct interview with growers, 1982.

Table 31

Macadamia Nut: Production Input Cost per Acre by Type and Farm Size Group, 1981
(Dollars)

Type	A Less than 5	B 5-9	C 10-19	D 20-49	E 50-499
Labor	1760	1360	1680	1819	1210
Land cost (including tax)	116	170	110	171	162
Fertilizer	210	272	246	101	81
Herbicide	115	67	88	42	28
Diesel	-	29	20	15	4
Gasoline	32	58.45	51	18	45
Electricity	85	32	268	497	-
Total energy cost	442	458	672	673	158
Total cost	2318	1988	2462	2654	1530

Source: Personal interview with growers, 1982.

Table 32

Macadamia Nut: Price 1972-1982

Year	Farm Price (cents per pound)
1972	23.3
1973	25.5
1974	32.0
1975	31.6
1976	36.9
1977	40.8
1978	53.8
1979	62.9
1980	72.4
1981	77.0
1982	90.0

Source: (26).

Table 33

Macadamia Nut: Yield per Acre by Size, 1981
(Pounds per Acre)

Type	A Less than 5	B 5-9	C 10-19	D 20-49	E 50-499
Yield	2649	4012	4115	4520	5759

Source: Personal interview with growers, 1982.

Table 34

Macadamia Nut: Total Cost per Acre by Type and Farm Size, 1981
(Dollars)

Farm Size	A	B	C	D	E
Type	Less than 5	5-9	10-19	20-49	50-499
Land cost and taxes	116	170	110	171	162
Labor	1760	1360	1680	1810	1210
Indirect energy inputs	325	339	333	143	109
Fertilizer	210	272	245	101	81
Herbicide	115	67	88	42	28
Direct energy inputs	117	119	339	530	49
Gasoline	32	58	51	18	45
Diesel	-	29	20	15	4
Electricity	85	32	268	497	-
Capital cost	246	268	150	170	157
Interest on operating capital	133	89	142	150	160
Total energy cost	442	458	672	673	158
Management	258	218	265	286	168
Production cost (excluding management)	2697	2345	2754	2974	1847
Production cost	2955	2563	3018	3260	2015

Source: Personal interview with growers, 1982.

Growing other marketable crops between the tree rows during the first years is not necessarily an irrational decision. First, it reduces the risk of sudden change in farm prices and, therefore incomes, if the farmer were to cultivate only one crop. Second, not only does intercropping reduce great fluctuations of farm income, but when intelligently carried out, it may even be beneficial to the trees because of improved soil fertility and weed control. However, such crops must not be planted so close to the trees as to interfere with their development. Adequate spacing of 35 to 45 feet between rows is recommended for coffee and macadamia nut interplanting (25).

Data used here were obtained primarily from personal interviews with coffee growers in Kona. These data were checked against the studies by Keeler, Iwane and Matsumoto (42), Fukunaga (20) and Baker (2). Among the coffee growers interviewed, a large percentage intercrops macadamia nut with coffee. The continuous increases in coffee and macadamia nut prices in recent years have made interplanting an attractive proposition to the growers.

Consequently, both coffee and macadamia nut growers do not know the number of acres, hours, the amount of fertilizer or herbicide, and the amount of direct energy inputs used to grow coffee or macadamia nut separately. In some instances, however, some farmers who grow coffee exclusively were interviewed and their information was used separately in this study. In those instances where intercropping is practiced, it is assumed in this study that the amount of inputs per acre used for coffee and macadamia nut is identical. However, in the analysis of the production inputs, efforts are made to describe the various inputs with special reference to the typical problem that the coffee industry is facing.

Production Input Analysis

Labor. The labor problem in the coffee industry is almost the same as that of macadamia nuts. Essentially, it centers almost exclusively on the harvesting operation. Most of the farmers must hire labor to meet at least 300 hours required on farm A, 400 hours required on farm B and 200 hours required on farm C to pick one acre of cherry coffee (Table 35).

The harvesting period is usually in September and extends through March or April. The labor is critical during these periods. The labor problem is complicated by the fact that coffee does not ripen at one time. The orchard must be harvested many times in order to obtain 75 bags of parchment and 55 bags of cherry which are the average yield of parchment and cherry per acre. The skill of the picker and the nature of the field are two major factors that determine the picking rate of the worker. Some farmers reported that a good picker can pick as many as 4 bags per day at a rate of 4 man hours per bag. The coffee picker is paid about $14 per bag of cherry coffee picked. Therefore the wage rate assumed here is about $3.50 per hour.

Land. Coffee acreage has experienced a decline in recent years to the benefit of macadamia nuts. From 1971 to 1981, the in crop and bearing acreage has decreased by 51 and 37 percent, respectively.

Table 35

Coffee: Labor Input per Acre by Farm Size, 1981
(Man-Hours per Acre)

	A Less than 5	B 5-9	C 10-19
Family	306	448	249
Hired	12	25	118
Total	318	473	367

Source: Personal interview with growers, 1982.

Similarly, the number of farms has decreased from 750 in 1971 to 650 in 1981, a 13% decline.

Bishop Estate is one of the lessors of land on which coffee is grown. The land tenure system varies somewhat, ranging from leasehold to ownership in fee simple. Land cost varies greatly from location to location. The reasons for this variation, mentioned in the discussion of macadamia nuts, are applicable for coffee as well.

The procedure used to impute value to land is identical to that used for macadamia nuts. Specifically, land cost will include land rent and real property taxes. The findings suggest that the average cost of land is about the same as that of macadamia nuts (Table 43) since macadamia nuts and coffee are interplanted.

Capital. The machinery used in coffee farms in Kona is almost identical to that used for macadamia nuts. Because of the steep slopes on which most of the farms are situated, farmers continue to use jeeps in conjunction with power sprayers. Some farmers have also mechanical driers in Kona. Other structures commonly found on Kona coffee farms are warehouses for storage and water tanks to wash the coffee. The accounting procedure used to measure capital is the same as that used for macadamia nuts.

Due to the intercropping of macadamia nuts with coffee, the capital costs are assumed to be identical for coffee and macadamia nut farms for the sizes considered in this analysis.

Fertilizer. Fertilizer is a prime determinant of yield and quality in coffee production. It constitutes an important part of the production expenses. Farms A, B and C use an average of at least 350 pounds of coffee cherry (10-5-20) in order to grow one acre of coffee. Similarly, at least 500 pounds of fertilizer Mac 8 (10-10-10) are needed to grow one acre of coffee. These results suggest that the rate of use of coffee cherry is a decreasing function of the farm size and that the use of the other fertilizer (Mac 8) appears to reach a maximum on farm B. Although the former is consistent with the first hypothesis, the latter does not provide any basis to warrant a conclusion (Table 36). The unit price of fertilizer by type is also presented in Table 37.

Herbicide. Weed control is a continuous farm operation that is becoming more and more expensive as the cost of the herbicide inputs is constantly increasing. The herbicide inputs used are varied. Farmers use Paraquat, Roundup, 2, 4-D, Atrazine and Diuron (Karmex). The findings appear to suggest a significant variation in the rate of application per acre by size. For example, farm A uses about 4 and 2 times more Paraquat per acre than farms B and C, respectively. A similar conclusion can be reached for Roundup (Table 38). In any case, the results appear to show that larger farms use less herbicide per acre than the small ones. The unit price of herbicide by type used is also presented in Table 39.

Patterns of direct energy use. Coffee growing is not a highly mechanized operation. It is rather a highly labor-intensive enterprise. Gasoline is the frequently used form of energy as the farmers drive their jeep to fertilize, spray and prune coffee plants. The

Table 36

Coffee: Fertilizer Inputs per Acre by Size and Type
(Pounds per Acre)

Type	A Less than 5	B 5-9	C 10-19
Coffee cherry (10-5-20)	405	454	230
Mac 8 (10-10-10)	200	800	640

Source: Personal interview with growers, 1982.

Table 37

Coffee: Unit Price of Fertilizer by Type, 1981

Type	Unit	$/Unit
Coffee cherry (10-5-20)	lb.	.16
Mac 8 (10-10-10)	lb.	.17

Source: Telephone interview with C. Brewer Chemical, 1982.

Table 38

Coffee: Herbicide Input per Acre by Size, 1981

Type	Unit	A less than 5	B 5-9	C 10-19
Paraquat	gal.	3.00	.71	1.14
Roundup	gal.	1.42	.58	.44
2, 4-D	gal.	.38	-	.39
Atrazine	lb.	1.00	1.00	1.00
Diuron (Karmex)	lb.	-	.40	.11

Source: Personal interview with growers, 1982.

Table 39

Coffee: Unit Price of Herbicide Input by Type, 1981

Type	Unit	$/Unit
Paraquat	gal.	62.50
Roundup	gal.	76.50
2, 4-D	gal.	15.20
Atrazine	lb.	3.50
Diuron (Kermex)	lb.	16.00

Source: Telephone interview with C. Brewer Chemical, 1982.

findings suggest that farm A uses about 1 and one-half and 2 times more gasoline than farms C and B, respectively. Consequently, the cost of gasoline used per acre is higher on farm A than on any other farm included in the study. The same pattern of electricity use can be found as we compare the three farms. Also, only farm B reported having used about 21 gallons of diesel in 1981 (Table 40). In this case, the results do not exhibit any economy of scale.

Outputs and output prices. The output of coffee that is considered in this analysis includes coffee cherry and parchment coffee. The average yields obtained are summarized in Table 41. To arrive at the revenue, three output price scenarios are identified: high, current and low output price. The current price is set at $2 a pound for parchment and $1 a pound for coffee cherry and reflects the break-even price. While the high price is set at $2.80 and $1.40 a pound, respectively, the low price is about $1.20 and $0.60 a pound and represents a 40% increase and decrease from the break-even price or current price scenario, respectively. A ten-year trend of coffee prices is also presented in Table 42.

Production costs. Production costs, excluding management cost, are summarized in Table 43. These costs are weighted against the revenue to arrive at the net revenue per acre by farm size.

The Linear Programming Model

Rapid changes in input prices, great fluctuations in farmers' income resulting from cyclical changes in crop prices and sudden

Table 40

Coffee: Direct Energy Inputs per Acre by Size and Type, 1981

	A less than 5	B 5-10	C 10-19
Gasoline (gallon)	36.20	18.02	26.25
Diesel (gallon)	-	20.84	-
Electricity (kwh)	4.59	3.22	5.00

Source: Personal interview with growers, 1982.

Table 41

Coffee: Yield per Acre by Size and Type, 1981
(Pounds per Acre)

Type	A Less than 5	B 5-9	C 10-19
Parchment	1,566	14,590	1,746
Cherry	6,967	2,968	8,250

Source: Personal interview with growers, 1982.

Table 42

Coffee Price, 1972-1982

Year	$/pound
1972	.35
1973	.50
1974	.56
1975	.46
1976	.75
1977	1.85
1978	1.38
1979	1.26
1980	1.43
1981	1.60
1982	2.00

Source: (26).

Table 43

Coffee: Total Cost per Acre by Type and Farm Size, 1981
(Dollars)

Type	A Less than 5	B 5-9	C 10-19
Land cost + taxes	116	170	110
Labor	1113	1655	1284
Indirect energy inputs	405	307	261
Fertilizer	99	209	146
Herbicide	306	98	115
Direct energy inputs	124	92	107
Gasoline	60	30	43
Diesel	-	21	-
Electricity	64	41	64
Capital cost	246	268	150
Interest on operating capital	133	89	142
Management	202	241	194
Production cost (excluding management)	2137	2581	2054
Energy cost	529	399	368
Production cost	2399	2822	2248

Source: Personal interview with growers, 1982.

price changes in their energy-based inputs are investigated here with the help of a linear programming model. In the following section, the notation, the assumptions and the general formulation of the model with reference to specific cases are presented.

Notation

The following notation is used to formulate the model as applied to sugar, macadamia nuts and coffee.

$X_{q_{ij}}$ is the number of acres of produced crop q on farm i of type j

$\delta_{lq_{ij}}$ is the average yield of processed type l of crop q per acre on farm i of type j

P_{l_q} is the price per ton or pound of processed type l of crop q

$C_{kq_{ij}}$ is the unit cost per acre of resource k used to produce crop q on farm i of type j

$d_{q_{ij}}$ is the processing cost per acre of crop q on farm i of type j

$a_{kq_{ij}}$ is the amount per acre of resource k used to produce crop q on farm i of type j

K_{lq} is the total amount of processed type l of crop q produced

B_{1q} is the minimum amount of processed type 1 of crop q sold

$R_{kq_{ij}}$ is the total amount of resource k allotted to produce crop q on farm i of type j

where q = 1, 2, 3; 1 = 1, 2, 3, 4, 5

Assumptions

The linear programming model is based on the following assumptions:

Assumption of proportionality. Linearity is assumed in both the objective function and the constraints formulation. This implies that, in the objective function, each activity taken separately is directly proportional to the level of that activity. In the constraints functions, this implies a constant return to scale.

Assumption of additivity. This implies that the total amount of all activities be equal to the sum of each activity taken separately.

Assumption of divisibility. This implies that factors can be used and commodities can be produced in fractional quantities.

Assumption of certainty. This implies that the coefficients of the model are fixed and known with certainty. Consequently, output and input prices and resource coefficients are assumed fixed, i.e., non stochastic for each scenario.

The current output price, as assumed in this study, corresponds to the break-even price. The high and low output prices, on the other hand, are assumed to represent, respectively, 40% increase and decrease from the break-even price.

In addition, it is assumed that the inputs used to grow macadamia nut and coffee, with the exception of fertilizer inputs which can be easily disassociated, are identical in an interplanting situation.

Finally, it is also assumed that the study covers only small scale growers of sugar, macadamia nut and coffee on the Big Island of Hawaii.

General Formulation of the Model

OBJECTIVE FUNCTION

The objective function is to maximize net revenues or profit derived from the production of field crops:

$$\text{Max} \sum_j \left[\left(p_{q_1} \sum_i \delta_{q_{1ij}} X_{q_{ij}} \right) - \sum_i \sum_k C_{kq_{ij}} X_{q_{ij}} - \sum_i d_{q_{ij}} X_{q_{ij}} \right]$$

subject to the following constraints.

RESOURCE AVAILABILITY CONSTRAINTS

$$\sum_j \sum_i \sum_k a_{kq_{ij}} X_{q_{ij}} \leq R_{kq_{ij}}$$

This constraint states that the amount of resource k allotted to produce crop q on farm i of type j cannot exceed the total resource available.

PRODUCTION CONSTRAINTS

$$\sum_j \sum_i \delta_{1q_{ij}} X_{q_{ij}} \leq K_{1q}$$

This constraint states that the amount of processed type 1 of crop q produced on farm i of type j cannot exceed the total processed type 1 of crop q available.

MARKETING CONSTRAINTS

$$\sum_j \sum_i \delta_{1q_{ij}} X_{q_{ij}} \geq B_{1q}$$

This constraint states that the amount of processed type 1 of crop q produced on farm i of type j must be at least equal to the total amount sold.

NON-NEGATIVITY CONSTRAINTS

$$X_{q_{ij}} \geq 0 \quad ; \quad P_{q1} > 0$$

This constraint states that the activity levels must be either zero and/or positive.

Case 1

When q = 1, 1 = 1, 2, we have respectively raw sugar and molasses

where

i = 1, 2, - - - - , 37

j = 1, 2, 3, 4

k = 1, 2, - - - - , 8

Case 2

When q = 1, 1 = 3, we have macadamia nuts (in shell)

where

i = 1, 2, 3, - - - - , 52

j = 1, 2, 3, 4, 5

k = 1, 2, 3, - - - - , 8

Case 3

When q = 3, 1 = 4, 5, we have respectively coffee (parchment) and coffee (cherry)

where

i = 1, 2, - - - - 52

j = 1, 2, 3

k = 1, 2, 3, - - - - 8

The constraints used in the linear programming are based on the maximum amount that the loan institutions are currently willing to provide to the small growers. Although this amount varies with the expected price of the crop, its allocation among the various production inputs reflects past records that growers have established with the bank or loan institutions. Once the loan is aprpoved, any transaction by the grower must be carried out through the cooperative of independent growers to make sure that the amount is spent for the production activities specified. Consequently, the grower has no input substitution possibilities as he faces increases in the production inputs prices. Since almost every crop grower is a prospective bank borrower, the loan institution does play a key role in the success of the sugar, macadamia nut and coffee industry.

Based on interviews with loan officers, the monetary and physical resource constraints used in the linear programming model were generated. The constraints for sugar are presented in Appendix Tables 28 and 29. Similar constraints can be seen in Appendix Tables 30, 31, and 32.

CHAPTER IV

STUDY RESULTS AND THEIR POLICY IMPLICATIONS

This chapter is organized into two parts. The first part presents the study results. The second part discusses their policy implications.

Study Results

This section presents the results obtained from the study of the impacts of higher energy cost on the production of agricultural crops on the Big Island. The relationships between energy costs and the production of crops have been examined under three output price and three energy cost scenarios. The three output price scenarios are current, high and low output price scenarios. The current output price scenario corresponds to the break-even price, whereas the high and low output prices correspond to a 40% increase and decrease from the break-even price. The energy cost scenarios are EC 0, EC 50, and EC 100 indicating the base period, 50% increase and 100% increase in energy cost, respectively. For both output price and energy cost scenarios, the year 1981 is considered as the base period, since data used were for that year. Each output price scenario is examined separately under the three energy cost scenarios.

Sugar

In this section, in which energy cost accounts for about 10% of the cost of growing sugar, the impacts of higher energy cost are examined under three output price and three energy cost scenarios.

THE CURRENT OUTPUT PRICE SCENARIO

Under the current output price scenario, the raw sugar and molasses prices are set at $440 and $66 per ton, respectively. The results of the first energy cost scenario (EC 0), i.e., the base period energy cost scenario in which energy costs constitute an average of 10% of the total cost of production are presented in Appendix Table 2. The results show that given the various constraints that face all independent growers and the current cost scenario, farms A and C appear to be the optimal sizes to grow sugarcane.

In addition, all the dual values, with the exception of family and hired labor, show zero shadow price. The shadow price of labor of about $14 for family labor and $92 for hired labor reveals that only the use of labor can add to net revenues. Consequently, a reallocation of the input mix in favor of labor may lead to a greater revenue.

The second energy cost scenario is EC 50, i.e., a 50% increase in energy cost. The results show that a 50% increase in energy cost has not changed the number of acres of sugar grown and the amount of raw sugar and molasses produced. However, some changes were observed to result from a 50% increase in energy cost. The first change is an 18% reduction in the farmer's net revenues. This decrease in net revenues is smaller than the 50% increase in energy cost. This result suggests that the farmer's net income is inelastic with respect to the changes in energy costs (Appendix Table 3).

The second change that occurred in the EC 50 scenario is a reduction in the shadow price of family and hired labor. This result suggests that since energy cost has increased and the shadow price of family and hired labor has decreased, a rational farmer, i.e., the farmer who has the ultimate goal of maximizing profit or net revenue, can still utilize more family and hired labor at the expense of the more costly energy inputs. Alternatively, the farmer can use the same technology but is compelled to conserve the use of energy resources in the production process. The 50% increase in energy cost has decreased the shadow price of family and hired labor by 91% and 3%, respectively.

The third energy cost scenario (EC 100), i.e., a 100% increase in energy cost, presents a somewhat different result for the independent growers. The findings show that a 100% increase in energy cost from the base period will result in a 33% decrease in net revenues for the independent sugar growers. As a result, only farm C is found to produce sugarcane, and only hired labor appears to have a postitive shadow price. This result suggests that if the farmer's objective is solely to maximize net returns, the use of additional units of hired labor alone can increase his net returns (Appendix Table 4). These results imply that a reallocation of the input mix by substituting the binding resource (labor) for the unused resources may reduce cost and therefore may lead to greater profit for the growers.

The above discussion has led to the conclusion that higher energy costs have not severely impacted on farmers' net revenues. Whereas a 50% increase in energy cost has resulted in an 18% decrease in net revenues, a 100% increase in energy cost has reduced revenues by 33%. These results suggest that the net revenue is insensitive to energy costs under the break-even or current output price scenario (Appendix Table 24).

THE HIGH OUTPUT PRICE SCENARIO

Under the high output price scenario, the raw sugar and molasses prices are set at $616 and $93 per ton, respectively.

The first scenario is the base period energy cost scenario. According to this, the energy cost averages about 10% of the total cost of production. The results of the base period scenario are summarized in Appendix Table 5.

The results show that farms A and C continue to be the most efficient farms to grow sugarcane, given the resource constraints and the current energy cost scenario. At the optimal activity levels, farms A and C maximize their profit by utilizing all the family and hired labor, 15% of A-4 fertilizer, 10% of Roundup, 6% of gasoline, 42% of diesel, 0.02% of electricity and 0.01% of residual fuel. In addition, the dual values, with the exception of family and hired labor, have zero shadow price. For instance, the zero shadow price of fertilizer is due to the large amount of fertilizer that remains unused. Consequently, an attempt by the farmer to use more fertilizer will merely leave the farmer's net revenue unchanged. This is also true for all the direct and indirect energy resources used to produce sugarcane. Only family and hired labor have positive shadow price which implies that the use of additional units of labor will add $90 per acre to the profit in the case of family labor and $191 per acre in the case of hired labor. Labor, the binding resource, can be substituted for the unused resources and by reducing production cost increase the net revenue of growers.

The second energy cost scenario represents a 50% increase in energy cost (Appendix Table 6). The results show that a 50% increase in energy cost has not changed the number of acres of sugar and consequently the amount of raw sugar and molasses sold by farms A and C. However, the following changes were observed as a result of a 50% increase in energy cost.

The first change observed in the primal solution results in a 65% decrease in net revenue. This decline in farm net revenues is considerably less than a 50% increase in energy cost. This suggests that the farmer's net income is not sensitive to the energy cost increases under the high output price scenario. An alternative explanation is that the farmer's income is very inelastic to the changes in energy cost under the high price scenario.

The second change observed is a reduction of the opportunity cost of operator and hired labor input. Under this scenario, the opportunity cost of family and hired labor is estimated at $77 and $187, respectively. This decrease is in fact due to the higher cost of energy which implies that a rational farmer can reduce his energy consumption and use instead an additional unit of family and hired labor, since the latter will increase his net revenues.

The third energy cost scenario (EC 100), in which the average energy cost accounts for 26% of the total cost of production, has not changed the optimal solutions (Appendix Table 7). The earlier conclusions reached for the first and second scenarios are also found valid in this case. That is, although energy cost accounts for 26% of the total cost of production, the higher output price tends to negate the effects of higher energy costs. A mathematical explanation is that, although the objective function coefficients have changed, the resulting changes in the slope are not large enough to shift the objective function to another feasible solution.

Although the solutions of the choice variables have not changed, the net revenues have decreased by 13%. This suggests that under the given energy cost scenario, a 100% increase in energy cost will result in only a 13% decrease in net revenues which implies that net revenues are very inelastic to the changes in energy costs. Similarly, a 100% increase in energy costs has resulted in 29% and 4% decrease in shadow prices of family and hired labor, respectively. This implies that an additional unit of labor hired will add $64 to net revenues in the case of family labor and $184 in the case of hired labor. Alternatively, given the EC 100 scenario, the farmers can substitute energy inputs for hired and family labor and increase net revenues by $184 and $64, respectively.

THE LOW OUTPUT PRICE SCENARIO

Under the low output price scenario in which the price of raw sugar and molasses is set at $264 and $40 per ton, respectively, a sensitivity analysis is performed for the three energy cost scenarios considered. In all three cases, including the base period energy cost scenario, none of the farms is found to produce sugarcane. All the choice variables in the primal as well as in the dual are equal to zero which implies that, if the objective is to maximize net revenues, sugar production is not profitable under this scenario. The results of the base period scenario are presented in Appendix Table 8.

The above discussion leads to the conclusion that the impacts of higher energy costs appear to be more critical to farmers under low output price scenario than under current high output price scenarios. For instance, at identical increases in energy cost, say 50%, net revenues have registered an 18% decrease under the current output price scenario. In addition, a similar increase in energy cost has resulted in a 65% decrease in net revenue under the high output price scenario, whereas net revenues vanish under the low output price scenario. This suggests that low sugar prices tend to reinforce the impacts of higher energy costs whereas higher sugar prices tend to negate them (Appendix Table 25).

Macadamia Nuts

The energy input accounted for about 16% of the cost of growing macadamia nut in 1981. Labor input, the most critical input, constituted about 60% of the total cost of production. In this section, the impacts of higher energy costs on the production of macadamia nuts are examined in terms of three output price scenarios (current, high and low prices) and three energy cost scenarios (EC 0, EC 50, EC 100).

THE CURRENT OUTPUT PRICE SCENARIO

In the current output price scenario, the price of macadamia nuts is set at 90 cents per pound.

In the base period, in which the energy cost averages about 16% of the production cost, farms B and E appear to be the optimal sizes to grow macadamia nuts.

In fact, an analysis of the production expenses shows a consistency between the results obtained and the cost of production on farms B and E as compared to other farms. Specially, these two farms appear to be the least-cost producers of macadamia nuts or under given output price, the revenue maximizers. In production theory, when all farms face the same output price and the same or different input prices, farms with the least cost of production are selected as optimal farm sizes. This is the only justification for farms B and E showing up in the programming solution.

The results of the base period scenario are shown in Appendix Table 9. Although these results may appear unrealistic in light of the performance of the macadamia nut sector today, they can be justified for the following reasons.

First, these results are optimal solutions and reflect the performance of rational farms, i.e., farms that have the sole goal of maximizing net revenues. In reality, we know that macadamia nut farmers may have various economic and non-economic goals that can keep them in production, even if they are not maximizing net revenues.

Second, this study adopts a somewhat different approach to production cost accounting. Family labor has been given imputed monetary values which most farmers do not do in real life situations. Both of these are important considerations that may explain the divergence between the optimal solution and the actual situation. Viewed in this perspective, the results that are obtained here can be regarded as a framework within which the actual performance of each farm can be examined. There is, therefore, a consistency between these results and the real situation.

It is important to point out here that the solution of the dual problem shows a positive shadow price for only diesel and electricity. These shadow prices are $25 and $123, respectively. These indicate that under the base energy cost scenario, farmers can increase their net revenues to $25 for each additional gallon of diesel consumed and $123 for each additional kilowatt of electricity used to grow macadamia nuts. Since all the other resources included in the study have not been used, their shadow prices are zero and are not therefore effective in increasing the net revenues of the growers. It is implied, therefore, that diesel and electricity, the binding resources, can readily be substituted for the unused resources and the resulting decrease in cost may lead to a greater profit.

The second energy cost scenario is EC 50, i.e., a 50% increase in energy costs. The results show that a 50% increase in energy cost has not changed the optimal acreage and production obtained previously, but has resulted in a 45% decrease in net revenues. This implies that net revenues are not sensitive to the changes in energy costs or are inelastic to the changes in energy costs. However, some changes were observed in the dual solutions. While the shadow price of diesel has decreased, that of electricity has slightly increased (Appendix Table 10).

The third energy cost scenario is EC 100, i.e., a 100% increase in energy costs. The sudden increase of energy costs has not changed the optimal solutions but has merely reduced the farmer's net revenues by 9%. It has also decreased the shadow price of diesel by 64% and increased the shadow price of electricity by 2% (Appendix Table 11).

It is important to note that in all three energy cost scenarios considered, net revenues are very insensitive to the changes in energy costs. In addition, only diesel and electricity appear to be the binding constraints in all three scenarios. A general assessment of this output price scenario suggests that macadamia nut small growers are not seriously affected by higher energy cost under the current labor-intensive production technologies. However, a shift or a change in the current technology to a more capital-intensive one may affect the results, assuming that capital and energy are complementary inputs.

THE HIGH OUTPUT PRICE

In the high output price scenario, the price of macadamia nut (in-shell) is set at $1.26 a pound.

In the first series of linear programming problems in which energy costs reflect the base period, i.e., 1981 energy cost situations, farms B and E continue to be the most efficient production units. A careful look reveals that farms B and E have the least cost of production among the sizes considered in this study. The results are presented in Appendix Table 12. In addition, the solutions of the dual activities reveal that diesel fuel and electricity are in fact the bidning resources in growing macadamia nut. The shadow price of diesel is about $69 while that of electricity is about $187. Diesel and electricity are therefore potential candidates to increase net revenues. Specifically, an additional amount of diesel and electricity will add about $69 and $187, respectively, to the net revenues. Farmers may find it attractive to use more of the binding resources (electricity and diesel) and less of the unused resources which may result in a reduction of production cost and lead to greater profits for the growers.

The second energy cost scenario (EC 50), i.e., a 50% increase in energy costs, has not changed or affected the optimal solutions but has reduced the net revenues from growing macadamia nut. A 10% increase in energy cost has reduced the net revenues by 3%. This change in net revenue is very insignificant compared to the 50% increase in energy costs. This shows that net revenues are very insensitive to the increases in energy costs. Farms B and E therefore remain the optimal sizes to grow macadamia nut (Appendix Table 13).

A careful look at the primal and dual activity solutions reveals that electricity and diesel are the only binding resources, indicating a positive shadow price in the dual activity. In this case, the shadow prices of diesel and electricity are about $61 and $188, repsectively. This indicates that an additional amount of diesel and electricity consumed will add about $61 and $188, respectively, to the farmers' profits. If the objective is to increase net revenue, more attention must be given to these two energy resources. The same argument advanced earlier is also valid in this case.

The third energy cost scenario (EC 100), i.e., a 100% increase in energy costs, has resulted in only a 5% decrease in net revenue. The optimal activity levels have remained unchanged (Appendix Table 14). As explained earlier, these results must be viewed with care. First, they reflect the situation of typical farms, i.e., efficient farms. Second, it is assumed in this analysis that the overall goal of the farmer is to maximize net revenues. In real life, we know that farmers can pursue various economic as well as non-economic goals that may keep them in business, even though they are not maximizing net revenues. In addition, this study adopts a different accounting procedure, i.e., it imputes values to family labor that farmers do not in fact account for in their cost studies. These factors tend to explain why only farms B and E appear in the optimal solutions.

A close scrutiny of the high output price scenario reveals that energy cost increases have not caused a serious decrease in net revenues. This is due to the fact that energy resources are not essential inputs to grow macadamia nuts. Macadamia nut growing is in fact a labor-intensive operation in which labor cost constitutes about 60% of the production costs. These labor costs include unpaid family labor as well as hired labor. Since labor is a very expensive input on the Big Island and since only diesel and electricity appear to show positive shadow price, a substitution of capital and energy (with the exception of electricity and diesel), for labor may be a possible way to reduce production costs and therefore increase the profitability of macadamia nut production. (The underlying assumption here is that capital and energy are complementary inputs.)

THE LOW OUTPUT PRICE SCENARIO

In the low output price scenario, the output price of macadamia nuts (in shell) is set at 54 cents a pound.

The first series of linear programming problems for the base period reveal that macadamia nut production is still profitable if the farmers were to face the current input prices. The results of the base period scenario reveal that only farm E appears to be the most efficient unit to grow macadamia nut under the low output price scenario. In addition, only electricity has a positive shadow price. The results of this scenario can be seen in Appendix Table 15.

The second energy cost scenario (EC 50), i.e., a 50% increase in energy costs, has not changed the optimal levels of activity, but has reduced the net revenues by 7%. The shadow price of electricity remains positive. The results of this scenario are summarized in Appendix Table 16.

The third energy cost scenario (EC 100), i.e., a doubling of energy cost, has merely reduced the net revenues by 14% and the shadow price of electricity by 15%. Farm E remains the optimal site to grow macadamia nut under the low output price scenario. The results are presented in Appendix Table 17.

The above analysis of the macadamia nut price scenarios leads to the conclusion that higher energy costs do not have a significant impact on the production of macadamia nut in general. For instance, a 50% increase in energy costs has resulted in a 4.5% decrease in net revenue under the current or break-even price scenario, only a 3% reduction under the high output price scenario and a 7% decline under the low output price scenario. Similarly, a 100% increase in energy costs has resulted in a 9% decline in net revenue under the current output price scenario, a 15% decrease under the low price scenario, whereas only a 5% decline was observed under the high output price scenario.

The above findings warrant the conclusion that the higher the output price, the lower the impacts of higher energy costs on the farmer's net revenues. Low macadamia nut prices tend to reinforce the negative impacts of higher energy costs, whereas high prices tend to negate them. It can also be readily inferred that, although higher energy costs do have differential impacts depending on the crop price, these impacts appear to be more significant for sugar than for macadamia nuts. It can further be pointed out here that although energy cost represents about 10% of the total production cost of sugar, as opposed to 16% for macadamia nut, the resulting decrease in net revenue arising from higher energy costs is greater for sugar than for macadamia nut. Therefore, these results do not appear to warrant the conclusion that the more energy intensive the production of an agricultural crop is, the more vulnerable it is to energy costs. Crop price seems to play a more important role in the reduction of the farmer's income than do increases in energy cost as we compare sugar with macadamia nut (Appendix Table 27).

Coffee and Macadamia Nut Interplanting

Coffee is becoming increasingly interplanted with macadamia nuts on the Big Island. With the exception of fertilizer, most farmers interviewed are unable to disassociate the inputs used to grow each crop. For this reason, coffee and macadamia nuts are treated here as joint products.

However, in order to assess the impacts of higher energy costs on the production of coffee alone, it is assumed here that the inputs used to grow both crops, with the exception of fertilizer which can be easily disassociated, are identical in an interplanting situation.

In this section, the impacts of higher energy costs are examined with reference to three output price scenarios (current or break-even, high and low price) and three energy cost scenarios (EC 0, EC 50, EC 100).

THE CURRENT OUTPUT PRICE

In the current price scenario, the price of coffee (parchment) and coffee (cherry) is set at $2 and $1, respectively.

The first series of the linear programming are to measure the activity levels at the base period energy costs. In this scenario, in which the energy cost averages about 18% of the total cost of production, farms B and C appear to be the most efficient units of coffee growing. The results are presented in Appendix Table 18. It is important to point out here that these results only show the performance of the most efficient farms, given the available resources and do not have to sum up to the current acreage or current production. In fact, these results only reveal that if the objective is to maximize net revenues given available resources, farms B and C appear to be the optimal sizes and they must produce so many pounds of coffee. In reality, we know that farm A exists and grows coffee. The justification is that in the real world, farmers do not only pursue the profit maximization goal. They may pursue other economic and/or non-economic goals that may keep them in growing coffee, even though they are not maximizing net revenues. However, the profit maximization goal is assumed as the sole goal here because it reflects the general goal of the growers. The solutions of the primal problem can be seen in Appendix Table 18.

Similarly, the dual variables with the exception of the production have zero shadow price. This implies that those inputs for which the cost is zero have no alternative uses, i.e., these inputs were not fully utilized in the primal problem. Only the production activities show a positive shadow price. These reveal in the linear programming framework that the net revenue can be increased by increasing the production of coffee. These shadow prices are $1.85 and 76 cents for parchment and cherry, respectively (Appendix Table 18).

The second energy cost scenario (EC 50), in which energy cost has increased by 50% from the base period, has only resulted in an insignificant decrease in net revenues and in the shadow price of coffee (parchment) production. No other changes were observed in this scenario.

These findings show that the changes in energy costs have insignificant impacts on the net revenues of coffee growers. This decrease in net revenue, estimated at 0.08%, is far less than the increase in energy costs. Net revenues are therefore found to be inelastic to the changes in energy costs. The results of this scenario are presented in Appendix Table 19.

The third energy cost scenario (EC 100), in which energy cost has suddenly increased by 100% from the base period, has also resulted in a reduction of net revenues. This decrease, which is about 15%, is the only change observed in this scenario. The results show that net revenues are still inelastic in the face of 100% increase in energy cost (Appendix Table 20).

The major conclusion emerging from this analysis is that under the current price scenario, the net revenues obtained from the growing of coffee are not vulnerable to the increases in energy costs. This can be explained by the nature of coffee production technologies that are essentially labor-intensive.

THE HIGH OUTPUT PRICE SCENARIO

Under the high output price scenario in which the prices of coffee (parchment) and coffee (cherry) are set at $2.80 and $1.40, respectively, energy cost averages about 18% of the total cost of production in the base period.

In the first series of the linear programming problem, only farms B and C still remain the most efficient units to grow coffee. The results can be seen in Appendix Table 21.

The justification advanced earlier under the current output price scenario is also valid in this case, i.e., the optimal solutions reflect the performance of the most efficient farms, given available resources and with the singular goal to maximize profits.

The results are presented in Appendix Table 21. Only coffee production activities show a positive shadow price in the dual problem. These activities are, therefore, conducive to increasing the net revenues under this scenario.

The second (EC 50) and the third (EC 100) energy cost scenarios have resulted in only 0.05% and 0.11% decrease in net revenues, respectively. The results can be seen in Appendix Tables 22 and 23.

THE LOW OUTPUT PRICE SCENARIO

Under the low output price scenario, in which the prices of coffee (parchment) and (cherry) are set at $1.20 and 60 cents, respectively, energy costs represent about 18% of the production costs. Based on these prices, only farms B and C continue to be the most efficient units to grow coffee, given available resources. The results are presented in Appendix Table 24.

The second energy cost scenario (EC 50) has resulted in only a 1.4% decrease in net revenues, although no other changes in the optimal solutions were observed (Appendix Table 25).

The third (EC 100) energy cost scenario appears to have a significant impact on net revenues although the optimal solutions have not changed. In this scenario higher energy costs have resulted in a 2.8% decrease in net revenues. The lower output price tends to reinforce the impacts of hgiher energy costs compared to those observed under the high output price scenario. Consequently, the net revenues of the coffee growers appear to be more vulnerable to higher energy costs under the low output price scenario than the high output price scenario. The results of the third scenario are summarized in Appendix Table 26.

The above analysis has led to the conclusion that higher energy costs tend to have differential impacts depending on crop price. For instance, for coffee, a 50% increase in energy cost has resulted in a 0.08% decrease in net revenues under the current price, whereas a similar increase reduced net revenues only by 0.05% under the high crop price. However, similar increases in energy costs have resulted in a 1.4% decrease in net revenue under the low output price scenario. This confirms that low prices are associated with greater impacts arising from higher energy costs. Similarly, 100% incrseases in energy costs have resulted in a significant decline of revenues by 23% under the low crop price, whereas the observed decreases are only 0.11% and 0.15% under the high and current output price, respectively. This again confirms that low crop prices tend to reinforce the impacts arising from higher energy costs, whereas high crop prices tend to negate them (Appendix Table 27).

This analysis of the impacts of higher energy cost on the production and net revenues of the three field crops (sugar, macadamia nut, and coffee) enables us to test the second hypothesis, i.e., the more energy-intensive the production of a crop is in relation to other crops, the more vulnerable it is to energy cost increases.

Earlier in our discussion, it was shown that coffee production was more energy-intensive than that of macadamia nut and sugar. Specifically, energy costs constituted about 18% of the total cost, whereas they represented about 10% and 16% of the total cost of growing sugar and macadamia nut, respectively. Before proceeding, it is worthwhile to point out that the seemingly high energy intensity of coffee growing reflects the assumption made earlier, i.e., since coffee and macadamia nut are interplanted and that the energy and non-energy inputs cannot be dissassociated, it was assumed that input use is identical for both crops.

Based on the above information, one can conclude that at identical energy cost increases, the impacts must be greater on coffee revenues than on macadamia nut and sugar revenues. The results obtained do not appear to corroborate the hypothesis that the more energy-intensive the production of an agricultural crop is, the more vulnerable it is to energy cost increases.

Such an interpretation, however, must be made with care. The optimization problem that one is trying to solve here ia a constrained optimization problem, as opposed to a free optimization. Although the model that is used to simulate the three crops is structurally the same, the constraints that face growers are not the same. Consequently, a direct comparison may be misleading although it is usually done. However, it can be indirectly implied that at equal dollar received, sugar production or revenue is more vulnerable to higher energy cost than that of other crops. It may therefore be concluded that the above analysis does not seem to confirm the hypothesis tested.

Policy Implications

The principal findings emerging from the study results and their policy implications are examined in this section. A general scrutiny reveals that higher energy costs have not greatly impacted on the net revenues of small growers, but do have differential impacts depending on the resource endowments of each crop grower. A generally observed phenomenon is that the lower the output price, the greater the impacts on the net revenue from crop growing under given energy cost scenarios. In any case, net revenues appear to be inelastic to the changes in energy costs.

These results can be attributed to the following reasons. First, this study covers only independent small growers of sugar, macadamia nut and coffee. The production technologies of these three crops are essentially labor-intensive. Second, the production of these crops consists largely of dry farming, i.e., most of the growers do not irrigate. Both of these factors tend to minimize the potential impacts resulting from higher energy cost.

In fact, small scale growers do not usually use capital-intensive technology. Large farms, on the other hand, tend to take advantage of the economies of scale and thus could afford a capital-intensive technology. So, if the underlying assumption is that capital and energy are complementary inputs, capital-intensive production is associated with energy-intensive technology. With given technology, large growers can easily spread their cost over large acreage, whereas small growers have limited opportunities. Consequently, the impacts of higher energy costs are expected to be greater on large crop growers, since these farms are irrigated and are also capital-intensive.

On the Big Island of Hawaii, labor is a very scarce resource. Most of the independent growers, although they use a good deal of family labor, are compelled to hire additional labor to carry out their harvesting operations.

In the case of sugar, labor cost represents only 13% of the total cost of production. This relatively low cost of labor may be explained by the fact that the harvesting operations of sugar growers are mechanical and are carried out by Hilo Coast Processing Company. Consequently, the labor input that is accounted for consists largely of family labor and a small portion of hired labor.

Since labor and energy contribute almost equally to the production cost of growing sugar, i.e., the production of sugar does not appear to be either labor-intensive or energy-intensive, it is difficult to recommend any input adjustment or substitution policy for the independent growers. However, since the results of the linear programming model show a positive shadow price for labor in the dual and since labor appears to be the only input that can increase net revenue, a larger budget must be allotted to the labor input. We are not recommending here that financial or lending institutions should increase the total amount allotted to growers. Instead, we are suggesting a reallocation of the current budget or input mix in such a way that greater weight is given to the labor input. It should be noted here that the way the banks provide loans to sugar growers does not allow for input substitution at present. Farmers are loaned a fixed amount per acre to carry out specified production activities.

The results of our study suggest that a more flexible bank policy with respect to the provision of loans is in order. This is an important consideration that should be given greater emphasis in the future in order to enhance the competitiveness of sugar. Policy makers seem to be overwhelmed by the problems facing sugar at the macro level, without taking into account the constraints that growers face at the micro level. These problems are probably very crucial and should not be ignored. *Ceteris paribus*, a farm that has large input substitution possibilities is certainly in a better competitive position than one without such options as it faces increases in its energy prices. Perhaps, it provides at least a partial explanation as to why sugar growers cannot afford even a slight decrease in their crop prices.

It is important to note that this situation is in no way fully responsible for all the problems facing Hawaii's sugar industry. However, this fact should not be neglected. It must be incorporated into a comprehensive policy at the county or State level, since a relaxation of these constraints would permit sugar growers greater input substitution possibilities. This could very well reduce production cost and enhance the profitability of sugar in Hawaii and its competitiveness in the world market.

Also, in this analysis, an attempt is made to answer this question: What is the optimal size(s) at which sugar can be grown, if the objective is to maximize net revenue? The solving of the first series of linear programming model reveals that only farms A and C, i.e., less than 10 acres and 50-159 acres, are the optimal farm sizes to grow sugar under the various resource constraints. The appearance of only these farms in the solution does not mean that farms B and D should disappear. A change in current resource endowment may lead to a change in the optimal scale as reflected in the initial solution. Perhaps, the existence of these farms appears to be consistent with other economic and/or non-economic goals that are not measured in this study.

Macadamia nuts and coffee are found to be very profitable under all output price scenarios. The findings reveal that, although the labor cost of macadamia nuts and coffee averages about 60% and 55% of the total cost of production, energy costs are only 16% and 18%, respectively. The relatively large share of labor input may be explained by the labor-intensive harvesting operation.

During the interview, most of the farmers expressed their concern about the lack of pickers during harvesting operations. So labor input poses a real problem. In the face of this increasingly scarce resource, a reallocation of the farmer's budget in favor of energy inputs and therefore capital inputs (assuming capital and energy are complementary inputs) may increase the profitability of macadamia nuts.

It should be pointed out that in the linear programming model, diesel and electricity are the binding resources. These exhibit positive shadow prices in the dual and therefore are the only inputs that may contribute to an increase in net revenue. So a reallocation of the farmer's budget in favor of these inputs, mostly diesel, may greatly reduce production cost and augment the profitability of macadamia nut on the Big Island and the State.

In the case of coffee, under the current and high output prices, all that is needed seems to be an increase in the quantity of coffee that is produced to enhance the profit of the growers. It should be noted that although coffee appears to have a larger percentage of energy costs than macadamia nuts, the impacts of higher energy costs on the net revenues are greater on macadamia nut than on coffee. At least two reasons can be mentioned. First, in recent years, efforts were made to market Kona coffee as a gourmet item at a price substantially above that of grocery-store grades. Second, the constraints that face coffee and macadamia nut growers are not the same, although the model used and its assumptions are almost identical. In any case, the net revenues for both crops are inelastic to the changes in energy costs.

The algorithm of the linear programming model has also enabled us to identify the optimal scales to growth both macadamia nut and coffee. Only some farm sizes appear in the actual solutions. These do not suggest that the farms that do not appear should not exist. Their existence may be found to be consistent with other economic and/or non-economic goals that are not measured here. However, if the objective is to maximize net revenues, these results provide some indication of where the emphasis should be placed. Alternatively, these farms and their technology can readily serve as typical farms and technology against which real farm performances can be tested.

CHAPTER V

SUMMARY AND CONCLUSIONS

In recent years, drastic changes have occurred in input prices, output prices and in the institutional structure within which agricultural producers operate. These changes are largely the upshot of sharp increases in energy prices that are directly or indirectly translated into higher output prices for the consumer. Needless to say, the energy situation has exerted and continues to exert pressure on the U.S. economy by contributing to inflation.

The U.S. food system has developed into a system characterized by intensive use of energy in farm production, processing, and transportation of farm products. At each stage, energy inputs are used either in the form of gasoline, diesel, gas, electricity or in the form of pesticides and fertilizers as needed to grow, manufacture or transport the agricultural products. As the prices of these critical energy inputs in agricultural production increase, output prices have experienced cyclical changes that pose a serious threat to the farm sector.

Summary

The study examines the interrelationships between the energy sector and the production of three crops (sugar, macadamia nut, and coffee) by small growers on the Big Island of Hawaii. Specifically, it attempts: (a) to explore the patterns of energy use in agriculture; (b) to determine the relative efficiency of fuel use by size among the three field crops; and (c) to investigate the impacts of higher energy costs on the production and net revenues of the three crops on the Big Island of Hawaii under three output price and energy cost scenarios.

To meet the objectives of the study, primary and secondary data were obtained. Data collection procedure is stratified random sampling with proportional allocation, although in the case of sugar, secondary data were obtained and supplemented, where necessary, with primary data.

Each crop is stratified by farm size. Sugar farms are divided into four size categories, A, B, C, and D, corresponding to less than 10, 10-49, 50-159 and 160 acres and over farms, respectively. Similarly, macadamia nut farms are subdivided into five farm sizes, A, B, C, D, and E, corresponding to less than 5, 5-9, 10-19, 20-49, and 50-499 acre farms, respectively. Coffee farms, on the other hand, are represented by three farm categories, A, B, and C, that correspond to the first three categories of macadamia nut. This makes stratified random sampling procedure more attractive than a simple random sampling.

In addition, a linear programming model is developed to simulate the production of the three field crops under three output price and three energy cost scenarios. The model includes only production and selling activities for each farm size considered.

A summary of the major findings based on an analysis of the study results follows.

The patterns of indirect energy inputs use observed in the sugar sector appear to be an increasing function of farm size. The patterns of direct energy inputs use, on the other hand, suggest that the energy inputs per acre used for harvesting and processing operations are higher than those used for growing.

Based on the unit cost of the different types of energy inputs, energy costs account for about 10% of the total cost of growing sugarcane. The results of higher energy costs on the production of field crops reveal that sugar, with a low energy cost, appears to be more vulnerable to higher energy costs than macadamia nut and coffee with 16% and 18% of energy cost, respectively. For example, at identical energy cost increases, say 50%, the net revenues of sugar decrease by 18%, whereas the corresponding decreases are only 4.5% and 0.08% for macadamia nut and coffee under the current output price scenario (Appendix Table 27).

Higher energy costs also tend to have differential impacts depending on the output price. For instance, a 50% increase in energy costs resulted in an 18% decrease in net revenues under the current price, whereas a similar increase reduced net revenues by 6.5% under the high output price, and resulted in a loss of net revenues under the low output price. In any case, a 50% and a 100% increase in energy costs have not changed the optimal levels of activity observed at base period energy costs.

In the case of macadamia nuts, the patterns of energy use observed, with the exception of gasoline and electricity, appear to be a decreasing function of farm size. For instance, farm E (50-499 acre) uses less fertilizer per acre than other types of farm. Similar conclusions are also reached for the patterns of herbicide and direct energy use. Specifically, the rate of gasoline and electricity use takes the form of a U curve, i.e., first starts decreasing, reaches a minimum on the 10-19 acre and 20-49 acre farms and then continues to increase. The above description is based on the assumption that other variables are not held constant.

Energy costs constitute about 16% of the production cost of macadamia nut. An analysis of the study results indicates that the impact of increases in energy costs does not have a significant impact on the farmer's revenues. For instance, a 50% increase in energy costs has resulted in only 4.5% decrease in net revenues under the current output price, 3% reduction under the high output price, and 7% reduction of net revenues under the low output price scenario. It was therefore found that low output prices tend to reinforce the impacts of higher energy costs, whereas high output prices tend to negate them.

In addition, although energy costs represent about 10% of the production cost of sugar, as opposed to 16% and 18% for macadamia nut and coffee, respectively, the resulting decrease in net revenues is greater for sugar than those for macadamia nut and coffee. Output price appears to play a more important role in the reduction of the farmer's income than do increases in energy costs.

In the case of coffee-macadamia nut interplanting, the patterns of input use, with the exception of fertilizer, are assumed to be identical to those of macadamia nuts.

The patterns of fertilizer use observed are not conclusive. The rate of use of coffee cherry (10-5-20) ranges from a low 230 pounds on the 10-19 acre farm to a high 454 pounds on the 5-9 acre farm. The patterns of herbicide and direct energy input use, on the other hand, show that larger farms use less energy per acre than smaller ones. For instance, a less than 5 acre farm uses about 4 and 2 times more Paraquat per acre than the 5-9 acre and 10-19 acre farms, respectively. The same patterns are also observed for Roundup. In addition, the less than 5 acre farm uses about one and one-half and two times more gasoline than the 10-19 acre and 5-9 acre farms, respectively. Similar relationships are also observed for the rate of electricity used.

Based on the unit cost of the different types of energy inputs, energy costs account for 18% of the cost of growing coffee. The results of higher energy costs indicate that coffee, with a high energy cost, appears to be less vulnerable to higher energy costs than sugar and macadamia nuts. For example, at identical energy cost increases, say 100%, the net revenues of coffee decrease by 0.15%, whereas the corresponding decrease is 9.1% for macadamia nut, and 33% for sugar under the current output price scenario. Output price is, therefore, an important variable that influences the magnitude of impacts resulting from higher energy costs.

Conclusions

The principal conclusions from the study are:

1. Higher energy costs have not significantly affected the net revenues of small growers but do have a differential impact depending on the resource endowments of each crop grower.

2. Low crop prices tend to reinforce the impacts of higher energy costs on net revenues, whereas high prices tend to negate them.

3. Sharp increases in energy costs have not changed the optimal levels of activity for the crops studied under various energy cost scenarios.

4. Larger farms do not necessarily use less energy per acre than smaller ones.

5. In the case of sugar, labor appears to be the binding resource whereas diesel fuel and electricity are the binding resources in the case of macadamia nut.

6. Farmers are faced with many constraints that do not allow factor substitution. Consequently, a reallocation of the total budget in favor of the binding resources may reduce production cost and lead to greater net revenues for the growers.

7. An increase in the total budget allotted to the independent growers, and for that matter, an increase in the resource constraints has not affected the optimal levels of crop production, but has merely increased the net revenues and the idle resources.

Model Application for Further Research

This research has enabled us to apply linear programming in a somewhat different way. The classical approach has been to apply it to study many crops simultaneously at the micro or macro level. In this study, a new way to set up a linear programming model has been developed. Each crop production has been disaggregated into different farm sizes. Each farm size is considered as a separate activity or alternate way to grow and sell the crop. Consequently, for each production activity, there is a corresponding selling activity.

There are many advantages to setting up the linear programming in this manner. First, it enables us to assess technological differences and their attendant economies of scale. In reality, technologies appear to be a function of farm sizes. Large size farms appear to be more capital intensive or less labor intensive than small scale farms. Consequently, although all of these farms are engaged in crop growing, some appear to be more efficient than others. The setting up of the linear programming in this particular manner has enabled us to address these questions.

Second, it allows us to scrutinize the whole system and identify areas of deficiency.

Third, it enables us to set up a framework in which different farms can test their performances.

Fourth, it permits us to investigate different output and input price scenarios, i.e., to study the impacts of higher energy costs on the production of each crop separately.

Fifth, although the model is used to simulate the production of small scale growers, its flexibility allows its application to large scale growers or to situations where there are irrigated or non-irrigated farms. Also, the model can easily incorporate different submodels in which output and input prices are endogenously determined.

Finally, the model can be applied to situations where output prices or input prices are uncertain and determined by uncertain demand and supply situations.

All of these are possible research areas that can be investigated with this model. Further research efforts in the field of agricultural economics are therefore needed to enhance the usefulness, the applicability and the validity of this model.

APPENDIX TABLES

Appendix Table 1

Definition of Linear Programming

Columns	
	Production Activities
PRAACRES	number of acres of sugar grown on A farm
PRBACRES	number of acres of sugar grown on B farm
PRCACRES	number of acres of sugar grown on C farm
PRDACRES	number of acres of sugar grown on D farm
PMAACRES	number of acres of macadamia nut grown on A farm
PMBACRES	number of acres of macadamia nut grown on B farm
PMCACRES	number of acres of macadamia nut grown on C farm
PMDACRES	number of acres of macadamia nut grown on D farm
PMEACRES	number of acres of macadamia nut grown on E farm
PCAACRES	number of acres of coffee grown on A farm
PCBACRES	number of acres of coffee grown on B farm
PCCACRES	number of acres of coffee grown on C farm
	Selling Activities
SRASUG	tons of raw sugar sold by A farm
SRBSUG	ton of raw sugar sold by B farm
SRCSUG	tons of raw sugar sold by C farm
SRDSUG	tons of raw sugar sold by D farm
SAMOL	tons of molasses sold by A farm
SBMOL	tons of molasses sold by B farm
SCMOL	tons of molasses sold by C farm
SDMOL	tons of molasses sold by D farm
SMACRES	pounds of macadamia nut (shells) sold by A farm
SMBCRES	pounds of macadamia nut (shells) sold by B farm
SMCCRES	pounds of macadamia nut (shells) sold by C farm
SMDCRES	pounds of macadamia nut (shells) sold by D farm
SMECRES	pounds of macadamia nut (shells) sold by E farm
SCACRES	pounds of coffee (parchment) sold by A farm
SCBCRES	pounds of coffee (parchment) sold by B farm
SCCACRES	pounds of coffee (parchment) sold by C farm
SCHERA	pounds of coffee (cherry) sold by A farm
SCHERB	pounds of coffee (cherry) sold by B farm
SCHERC	pounds of coffee (cherry) sold by C farm
	Rows
OBJ	objective function to maximize net revenues (dollars)
HIRED	opportunity cost of hired labor (dollars)
DIESEL	opportunity cost of diesel (dollars)
ELETY	opportunity cost of electricity (dollars)
PPTON	opportunity cost of coffee (parchment)
CPTON	opportunity cost of coffee (cherry)

Appendix Table 2

Sugar: Optimal Levels of Activity, Current Output Price and EC 0

Acreage (Acres)		Production (Tons)	
PRAACRES	152	SRASUG	1440
PRBACRES	0	SAMOL	446
PRCACRES	595	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	7990
		SCMOL	1440
		SRDSUG	0
OBJ	959091	SDMOL	0
FAM	14		
HIRED	92		

Appendix Table 3

Sugar: Optimal Levels of Activity, Current Output Price and EC 50

Acreage (Acres)		Production (Tons)	
PRAACRES	152	SRASUG	1440
PRBACRES	0	SAMOL	446
PRCACRES	595	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	7990
		SCMOL	1440
		SRDSUG	0
OBJ	786148	SDMOL	0
FAM	1.3		
HIRED	89		

Appendix Table 4

Sugar: Optimal Levels of Activity, Current Output Price and EC 100

Acreage (Acres)		Production (Tons)	
PRAACRES	0	SRASUG	0
PRBACRES	0	SAMOL	0
PRCACRES	630	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	8461
		SCMOL	1524
		SRDSUG	0
OBJ	642551	SDMOL	0
FAM	0		
HIRED	74		

Appendix Table 5

Sugar: Optimal Activity Levels, High Output Price and Base Period Energy Cost (EC 0)

Acreage (Acres)		Production (Tons)	
PRAACRES	152	SRASUG	1440
PRBACRES	0	SAMOL	446
PRCACRES	595	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	7990
		SCMOL	1440
		SRDSUG	0
OBJ	2669660	SDMOL	0
FAM	90		
HIRED	191		

Appendix Table 6

Sugar: Optimal Activity Levels, High Output Price and EC 50

Acreage (Acres)		Production (Tons)	
PRAACRES	152	SRASUG	1444
PRBACRES	0	SAMOL	446
PRCACRES	595	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	7990
		SCMOL	1440
		SRDSUG	0
OBJ	2496716	SRDMOL	0
FAM	79		
HIRED	187		

Appendix Table 7

Sugar: Optimal Activity Levels, High Price and EC 100

Acreage (Acres)		Production (Tons)	
PRAACRES	152	SRASUG	1440
PRBACRES	0	SAMOL	446
PRCACRES	595	SRBSUG	0
PRDACRES	0	SBMOL	0
		SRCSUG	7990
		SCMOL	1440
		SRDSUG	0
OBJ	2326002	SDMOL	0
FAM	64		
HIRED	184		

Appendix 8

Sugar: Optimal Levels of Activity, Low Output Price and EC 0, or EC 10 or EC 100

Acreage (Acres)		Production (Tons)	
PRAACRES	0	SRASUG	0
PRBACRES	0	SAMOL	0
PRCACRES	0	SRBSUG	0
PRDACRES	0	SBMOL	0
		SCRSUG	0
		SCMOL	0
		SRDSUG	0
OBJ	0	SDMOL	0
FAM	0		
HIRED	0		

Appendix Table 9

Macadamia Nut: Optimal Levels of Activity, Current Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	337	SMBCRES	1353251
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	5442693
OBJ	3347520		
DIESEL	25		
ELETY	123		

Appendix Table 10

Macadamia Nut: Optimal Levels of Activity, Current Output Price and EC 50

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	337	SMBCRES	1353251
PMCARES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	5442693
OBJ	3196898		
DIESEL	17		
ELETY	124		

Appendix Table 11

Macadamia Nut: Optimal Levels of Activity, Current Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMEACRES	337	SMBCRES	1353250
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	5442693
OBJ	3043713		
DIESEL	9		
ELETY	125		

Appendix Table 12

Macadamia Nut: Optimal Levels of Activity, High Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	337	SMBCRES	1353251
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	54442693
OBJ	5794059		
DIESEL	69		
ELETY	187		

Appendix Table 13

Macadamia Nut: Optimal Activity Levels, High Output Price and EC 50

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMEACRES	337	SMBCRES	1353251
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	5442693
OBJ	5643438		
DIESEL	61		
ELETY	188		

Appendix Table 14

Macadamia Nut: Optimal Levels of Activity, High Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	337	SMBCRES	1353250
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	945	SMECRES	5442693
OBJ	5490253		
DIESEL	54		
ELETY	189		

Appendix Table 15

Macadamia Nut: Optimal Levels of Activity, Low Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	0	SMBCRES	0
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	982	SMECRES	5653836
OBJ	1074867		
DIESEL	0		
ELETY	48		

Appendix Table 16

Macadamia Nut: Optimal Activity Levels, Low Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	0	SMBCRES	0
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	982	SMECRES	5653836
OBJ	998291		
DIESEL	0		
ELETY	44		

Appendix Table 17

Macadamia Nut: Optimal Levels of Activity, Low Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PMAACRES	0	SMACRES	0
PMBACRES	0	SMBCRES	0
PMCACRES	0	SMCCRES	0
PMDACRES	0	SMDCRES	0
PMEACRES	982	SMECRES	5653835
OBJ	919752		
DIESEL	0		
ELETY	41		

Appendix Table 18

Coffee: Optimal Levels of Activity, Current Output Price and EC 0

Acreage (Acres)		Production (Pound)	
PCACRES	0	SCACRES	0
PCBACRES	97	SCBACRES	1408416
PCCACRES	24	SCCACRES	41884
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	3057043		
PPTON	1.86		
CPTON	0.76		

Appendix Table 19

Coffee: Optimal Levels of Activity, Current Output Price and EC 50

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	0
PCBACRES	97	SCBACRES	1408416
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	3033354		
PPTON	1.85		
CPTON	0.74		

Appendix Table 20

Coffee: Optimal Levels of Activity, Current Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	97	SBACRES	1408416
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	3009762		
PPTON	1.84		
CPTON	0.71		

Appendix Table 21

Coffee: Optimal Levels of Activity, High Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	97	SBACRES	1408416
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	4410243		
PPTON	2.66		
CPTON	1.16		

Appendix Table 22

Coffee: Optimal Levels of Activity, High Output Price and EC 50

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	97	SCBACRES	1408416
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	4386554		
PPTON	2.64		
CPTON	1.14		

Appendix Table 23

Coffee: Optimal Levels of Activity, High Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	96	SCBACRES	1408415
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286570
		SCHERC	196490
OBJ	4362962		
PPTON	2.64		
CPTON	1.12		

Appendix Table 24

Coffee: Optimal Levels of Activity, Low Output Price and EC 0

Acreage (Acres)		Production (Pounds)	
PCACRĒS	0	SCACRES	0
PCBACRES	96	SCBACRES	1408415
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	1703843		
PPTON	1.05		
CPTON	.35		

Appendix Table 25

Coffee: Optimal Levels of Activity, Low Output Price and EC 50

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	96	SCBACRES	1408415
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	1680155		
PPTON	1.04		
CPTON	.34		

Appendix Table 26

Coffee: Optimal Levels of Activity, Low Output Price and EC 100

Acreage (Acres)		Production (Pounds)	
PCACRES	0	SCACRES	
PCBACRES	96	SCBACRES	1408415
PCCACRES	24	SCCACRES	41584
		SCHERA	0
		SCHERB	286510
		SCHERC	196490
OBJ	1656562		
PPTON	1.03		
CPTON	.32		

Appendix Table 27

Energy Cost Scenarios, Crop Price Scenario and Their Impacts on Net Revenues

	Percentage of Energy in Total Production Cost (%)	Decrease in Net Revenue Under EC 50 (%)	Decrease in Net Revenue Under EC 100 (%)
Sugar			
Current	10	18	33
High	10	6.5	13
Low	10	Vanish	Vanish
Macadamia Nut			
Current	16	4.5	9.1
High	16	3	5
Low	16	7	15
Coffee			
Current	18	0.08	0.15
High	18	0.05	0.11
Low	18	1.4	2.8

Appendix Table 28

Loan Program: Amount Allotted per Acre and Total Budget* (Sugar)
(Dollars)

Fertilizer	340	1,160,420
Herbicide	65	221,845
Seedcane	45	153,585
Labor	35	119,455
Planting Cost	90	307,170
Miscellaneous (Energy, Rent, Tax)	157	535,841
Total	732	2,498,316

Source: Telephone interview with First Hawaiian Bank, Hilo Branch, 1982.

*Based on the 6825 acres grown by the independent growers, 1981.

Appendix Table 29

Resource Constraints (Sugar)

Labor			Direct Energy		
Operator	11243	(hours)	Gasoline	241545	(gal)
Family	8151	(hours)	Diesel	296296	(gal)
Hired	8713	(hours)			
Fertilizer			Land	6825	(acres)
A-1	4486960	(lbs)			
M-104	1547227	(lbs)	Seedcane	7314	(tons)
M-28	309447	(lbs)			
A-5	511893	(lbs)	Capital	11392631	(dollars)
Herbicide			Production		
Dalopon	10487	(gal)	Raw sugar	367000	(tons)
Karmex	37617	(lbs)	Molasses	107000	(tons)
Atrazine	37646	(lbs)			
Roundup	410	(gal)			
Surfactant	1268	(gal)			
Ametryne	3262	(gal)			
Sticker	1585	(gal)			
Paraquat	148	(gal)			

Appendix Table 30

Loan Program: Amount Allotted per Acre, 1981
(Dollars per Acre)

	Macadamia Nut	Coffee
Pruning and Fertilizing	280	280
Spraying	250	250
Processing Fee	265	265
Harvesting	661	500
Fuel Expenses	31	31
Depreciation Cost	122	122
Insurance	50	50
Leasing Costs and Taxes	86	86
Repairs and Maintenance	18	18
Miscellaneous	537	720
Total	1900	2200

Appendix Table 31

Resource Constraints (Macadamia Nut)

Labor	637362 (hours)
Fertilizer	
F-16	9922327 (lbs)
F-20	7222871 (lbs)
Herbicide	
Paraquat	32198 (gal)
Roundup	14361 (gal)
Warfarin	12127 (gal)
2, 4-D	4888 (gal)
Atrazine	32483810 (lbs)
Diuron	6393 (lbs)
Land	12210 (acres)
Capital	2100120 (dollars)
Direct Energy	
Gasoline	40797 (gal)
Diesel	22797 (gal)
Electricity	22580 (kwh)
Production Constraints	33270000 (lbs)

Appendix Table 32

Resource Constraints (Coffee)

Labor	910517 (hours)
Fertilizer	
Mac-8	12439388 (lbs)
10-5-20	8100650 (lbs)
Herbicide	
Paraquat	31652 (gal)
Roundup	16156 (gal)
2, 4-D	4488 (gal)
Atrazine	19490 (lbs)
Diuron	4265 (lbs)
Direct Energy	
Gasoline	45333 (gal)
Diesel	18926 (gal)
Electricity	22283 (kwh)
Land	1800 (acres)
Capital	2100120 (dollars)
Production	1450000 (lbs)

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