Chapter 3: Study Procedures

I. Introduction

The purpose of this chapter is to describe the representative farm approach, to detail the empirical basis for the representative farm and to discuss the effects of the policies on the empirical model. The first part of the chapter will discuss previous literature on the mathematical programming approach. Following the literature discussion, the farming methods of the farms in Clarendon are detailed. The IPM systems are then described in detail for each of the three crops: hot pepper, sweet potato and callaloo. A description of the empirical model explains how the model was developed from the farming practices and enterprise budgets. Finally, incorporation of the policies into the model is detailed with tables showing the coefficient changes as a result of the policies.

II. Background and Support for the Representative Farm Approach

A mathematical model of a representative farm was used for analyzing the profitability of the IPM systems and the impacts of the policies on those economic incentives. The representative farm is a tool that gives a framework for analysis (Alston, Norton and Pardey, 1994). Since many of the IPM components for sweet potato, hot pepper, and callaloo are not verified with field trials, conclusive results on their economic impacts could not be obtained. The representative farm approach allows for modification of the analysis as more information becomes available. This study gives conclusions based on the best available information and can be adapted when additional research is available.

A review of previous literature provides the historical support for use of a mathematical programming model as a tool for economic analysis of Integrated Pest Management and for evaluating the feasibility of IPM components. Mathematical programming is a technique used to solve a system of simultaneous equations. It was developed for use in allocation of resources by the Allies in World War II. When the US government made the technique public, it became a tool for economic analysts. Mathematical optimization and simulation models can be used to evaluate behavior of farms and other agents at the microeconomic level. Micro analysis provides "a [thorough] understanding of aggregate sector behavior and of probable farmers' responses and their distributive implications" (Lee, 1983, p. 7). The economic incentives for IPM adoption and the effects of government policies on farming practices are two areas of microeconomic analysis that have been analyzed using mathematical programming.

One of the earliest studies of farm level IPM was by Casey, Lacewell, and Sterling (1975). This study evaluated the opportunities for reducing pesticide use in commercial agriculture. They did not use a mathematical programming model but instead used an enterprise budget generator to develop budgets for IPM and conventional practices. These budgets were then compared and "the data strongly indicated a yield increase" (Casey, Lacewell, and Sterling, 1975, p.63) for the production methods which included IPM techniques.

Cashman, Martin, and McCarl (1980) looked at "the impacts of possible EPA bans on selected soybean insecticides" (p. 147). The authors examined the effects on a farm firm using a mathematical programming model. Yields, net revenues and profits were analyzed for changes resulting from the insecticide bans. The results showed that a ban on one of the three insecticides used would result in a substitution of the other more costly insecticides. The authors noted in their conclusions that "any careful analysis of the possible economic impacts of bans on insecticide use required an interdisciplinary effort" (1980, p. 151).

Masud et al. (1981) examined "the value and economic impact of short season cotton production system under IPM strategies" (p. 47). The researchers constructed a linear programming model of a representative farm which has the option to produce six crops using both IPM and conventional technologies. They found that "this analysis strongly suggests that IPM programs for short-season cotton production techniques result in higher yields and net returns per acre" (p. 52).

More recently, this type of representative farm modeling was used by Martin et al. (1991) to compare three different alternative tillage systems offered as IPM components. "A linear programming model was used to determine which crop rotations and associated levels of herbicide use resulted in the highest net income for three different farm sizes using three alternative tillage systems" (p. 300). The purpose of the model was to find the optimal crop rotation that minimized chemical use by the farms because "society is becoming disillusioned with farm pesticides" (p. 299). The results from the empirical model showed that the no-till production system was substantially less profitable than the other two methods: moldboard or chisel tillage systems. "Two major factors caused lower incomes [with the no-till system]…: lower yields and higher herbicide costs" (p.306). The representative farm allowed the researchers to compare different farming methods.

Linear programming can also be used to examine only one aspect of IPM such as investing in more machinery. Jannot and Cairol (1994) evaluated the prospects of a farm investing in machinery in their 1994 study. Their study is a detailed analysis of how mathematical programming can be used to aid in the decision making process for a farm. The objective function was to maximize profits subject to a set of resource constraints. They found that "machinery is a major capital cost in most farm enterprises" (p. 187). The nominal cost of capital is an important factor when discussing IPM because IPM techniques are more labor intensive than conventional methods. If capital investments seem risky or are too high, farmers will not purchase machinery. Thus, the farmers will have more of an incentive to adopt the IPM system for a production process if IPM places less reliance on mechanical weed and insect control.

III. Farmer Interviews

Data obtained for the empirical framework were obtained, in part, from interviews with farmers in Ebony Park, Clarendon. The farmers were interviewed during the summer of 1998 and the interviews took place on location at the farms. Of the five farmers interviewed, three had knowledge about the IPM systems while two had no knowledge of IPM.

Farmers were interviewed for information regarding their production practices. Farmers were asked: what crops they plant, how much of each crop, why the quantity of acreage planted, how they planted the crops, when they planted the crops, if they irrigated the crops and frequency and method of irrigation. They were asked about quantity and source of borrowed capital. They were asked about method of land preparation, how tractor services were obtained and the number of days per month they worked.

The answers provided a basis for the constraints in the model including the risk constraints detailed later in this chapter. The information was also used to verify the coefficients for the production methods. Lastly, the results of the interviews were used to validate activities, such as purchasing water from the National Irrigation Commission, included in the model. In conjunction with cost of production estimates obtained from the Ministry of Agriculture, the interviews supplied the data for the empirical framework.

IV. Components of the Representative Farm

The IPM-CRSP program is working with small farmers cultivating ten or less acres of land as opposed to large plantations. The IPM-CRSP program has two sites in the parishes of Clarendon and St. Catherine (Labeled sites A and B, respectively on Map A1 in Appendix A). This study focused on the economic incentives for the farmers at the Clarendon site represented as Site A on Map A1. A description of the representative farm model for a small farm in Ebony Park, Clarendon is detailed below with a discussion of the crops in the model and the IPM systems for sweet potato, hot pepper and callaloo. The description will provide support for the particular choices made for the model variables and parameters.

With the reform policies of the nineteen eighties, the government began to release public lands into private hands. New landholders received five or ten acre plots from the government along with a house in a forty-nine year lease agreement. As a result of this distribution pattern, most small farmers cultivate five to ten acres. Land that is owned or leased from the government is taxed at a compensated agricultural rate as discussed in the previous chapter. Within the model, farmers can use a maximum of ten acres.

At the start of the growing season, farmers need to purchase seeds, fertilizer, tractor services and other inputs. Farmers in Ebony Park borrowed heavily, ranging from $JM4000 to $JM60,000 or $JM80,000, in the 1980's but stopped within the past seven to eight years because of the uncertainty associated with borrowing money from local banks. The farmers needed collateral against the loans while not knowing if they would be able to pay the loans back at the end of the season. The farmers increasingly replied upon their own or their family members' savings to reduce the chance of losing collateral. The model forces farmers to pay an interest rate, equal to the passbook savings rate, on all of the money that they use to reflect the opportunity cost of using the money for growing crops rather than investing it in a bank.

All crops respond to supplementary irrigation. The National Irrigation Commission (NIC) controls the rates charged to farmers for the use of water. However, the area of Ebony Park lies near a river and all of the farmers have purchased water pumps. They have set irrigation systems and simply pump the water from the river to their fields. They do not pay the National Irrigation Commission but instead purchase gasoline to use in the irrigation pumps. In the model, farmers must irrigate their crops using the water pump or buy water from the NIC. The method for determining the cost of irrigation is discussed later in this chapter.

Because of the mild year round weather, Jamaican farmers have a variety of crops they can grow. These include, but are not limited to: banana, citrus fruits, sugar cane, coffee, coconut, pimento, yams, vegetables, sweet potatoes, hot peppers, mangos, papayas, pineapple, legumes, assorted condiments such as callaloo, cassava root, pumpkin, and cereals. The household farms in the Clarendon parish can not grow coffee and banana because of soil type and available land.

The crops included in the representative farm model were: sweet corn, cassava, pumpkin, sweet potato, hot pepper, callaloo and sugar cane. Callaloo was not grown in plots of land larger than one half of an acre. Four of the farmers had farms of ten acres while the fifth had only five acres. None of the farmers marketed their own production to US buyers but instead relied upon middlemen for exporting crops. Local sales were accomplished through direct interaction with buyers at markets nearby or through "higglers", local buyers who would then transport the harvest to markets.

Below is a discussion of the cropping systems for the crops included in the model. The outlines for the growing seasons were obtained through expert interviews (Lawrence, 1998b), (Clark-Harris, 1998) and (Martin, 1998) and verified by farmers. The interviews provided the majority of the information necessary for the construction of and justification for the model as outlined below. First, the conventional ways of producing the three IPM crops: hot pepper, sweet potato and callaloo are discussed as well as the non-IPM crops: corn, pumpkin, cassava and sugar cane. Following the description of the cropping systems is a discussion regarding the changes in production practices as a result of a farmer choosing to grow the specific crop using the proposed IPM technologies. Enterprise budgets for these activities can be found in Appendix B.

IV a. Cropping Systems in the Representative Farm

The growing season for corn begins with the spring rains in April and ends in August or September. April is the month for land preparation and the purchasing of seeds and other crop materials. Land preparation can either be by forking or with a tractor. Forking is a process by which a laborer uses a pitch fork to turn over the land. A tractor can do the same thing in less time and, depending on the person-days required for a field, cost less than hiring labor for forking. After the field is turned, animal manure is added as a fertilizer and the crop is planted in May. Three weeks after planting, a farmer begins to spray the crop with insecticides and continues spraying weekly until the end of the season. The crop is fertilized with sulfate of ammonia once in June and July while the field would be weeded once in June. The corn is harvested in August and September. A one acre field of sweet corn can yield approximately 3,000 pounds total. The field is then left fallow until the next planting season. Most farmers will not plant the same crop in the same field two years in a row. The crop rotation does not take a definitive schedule but instead is chosen by the farmer according to many variables including: relative prices received, relative input costs, land available and expected weather conditions.

Pumpkin has a similar season to corn. The land is prepared and fertilized with manure in April. The seeds are planted in May and a few weeks later the field is weeded manually. June is the last month for weeding because after that time the crop cover is mature enough to shade the ground and prevent further weeds from growing. The crop is sprayed in June with insecticides and fungicides and the farmer continues spraying weekly for the remainder of the crop season. The crop is fertilized in July with sulfate of ammonia. August begins the harvesting season which continues through September. A one acre field of pumpkin yields approximately 7,000 pounds of pumpkin. After the harvest season, the field is left fallow until a farmer plants another crop other than pumpkin.

Cassava is planted after the May rains begin when the ground is moist. Therefore, the crop and land preparations are finished in April. The preparations include: turning the field and spraying it with an herbicide, and cutting and drying the sticks used for growing new cassava plants, roughly 4,000 sticks are needed for a one acre crop. In May the sticks are planted and the field is fertilized. The crop is sprayed with a pesticide in July for purposes of insuring that the crop is not infested with caterpillars and slugs. The crop is weeded in August, sprayed again with pesticides in November, and weeded a final time in December. January through March is harvest season. A one-acre field of cassava can yield up to 13,440 pounds total.

Sugar cane is a perennial crop. The farmers interviewed had a few acres set aside for sugar cane production which remained in the land up to five years. After the harvesting season in March, farmers must prepare the land for the coming year beginning in April. The field is cultivated mechanically by molding (covering the old roots) or chiseling (plowing up the old roots). These are methods for aeration of the soil as well as building up the soil around the roots of the crop. The irrigation trenches are cleaned and any old or dried out cane stalks are replaced. From May until December, the field is sprayed once with an herbicide and then irrigated once per month. In January the crop is prepared for harvesting. The field is no longer irrigated to allow the crop to dry out. In March, the field is burned and the cane stalks are harvested. A one-acre field can produce 10-12 tons of sugar cane which can be refined into roughly one ton of sugar.

Sweet potato has a growing season of eight months beginning in July when slips are collected from mature plants. Slips are the last six to eight inches of the vines of a fully grown plant. The slips are planted in July and develop into a producing plant within four months. During the months of August, September and October, the fields are fertilized, irrigated and weeded on a weekly basis. Herbicides and fertilizers are the chemicals used for these tasks.

The harvest season begins in November and lasts through February. A farmer will be contacted by a distributor when an order is needed. The farmer will then hire out labor in order to fulfill the contract. Contracts can range from 500 pounds to 2000 pounds per contract. On average, an acre of sweet potato can produce 1000 pounds of potatoes per month. The crop is harvested twice a month. The harvest season continues until March when the field is abandoned. As with the other fields, the area will lay fallow for at least two months at which time the farmer can then grow an alternative crop.

Hot peppers begin their growing cycle in the month of May. Farmers will buy seeds from nearby farmers or use seeds from a previous crop. The seeds will be sown into seedling beds in June for germination. The seed beds are fertilized once a week and are sprayed with insecticide until the seedlings are planted in August. The farmer will prepare the field by turning the soil and adding manure. The seedlings are planted in August and are fertilized at this time with a chemical fertilizer. The field is irrigated weekly throughout the remainder of the growing season. Insecticides are applied on a regular bi-weekly basis until the crop is abandoned. In September and October, the farmer will fertilize and apply herbicide once per month.

November is the first month of the harvest season lasting until March. The peppers are hand picked once a week. The harvest depends on: contracts solicited from exporters, market orders from distributors, crop loss from pests and local demand for peppers. Harvests vary from 300 pounds a week to 1500 pounds a week in peak season for a one-acre plot for a total of 2,600 pounds per year. In February or March, depending on pest damage, the field is abandoned until the next growing season.

Callaloo is an amaranth vegetable whose leaves are eaten. It can be consumed raw, boiled or steamed and in its cooked form it appears similar to spinach. It has long been a part of the traditional diet among Jamaicans and only recently has gained momentum as a non-traditional export crop. Since the growing season is 40-60 days after planting, many farmers use callaloo as a rotational crop beginning and ending at any month of the year.

Seeds for a crop are obtained through "seedling trees". These are callaloo plants that have reached maturity. The seeds are extracted from the plant and cultivated into seedlings in a seed bed. Fungicides and insecticides are applied to the seed bed to prevent outbreaks of insects and fungi on the seedlings. The land is prepared with the use of a tractor at this time. In the second month, the seedlings are planted into raised beds or directly into flat ground and fertilized once with a chemical fertilizer. The field is irrigated once a week beginning in this month and continuing until the end of harvest season. In the third month, the crop is fertilized once while fungicides and insecticides are applied once a week. The chemical treatments continue on schedule until the end of harvest season. The farmer can begin to harvest the crop which consists of removing the stalks for market. Harvest season lasts from three to six months and a one acre field can yield an average of 11,000 pounds total.

Table 3.0 below summarizes the highlights of the ten production systems incorporated in the model. The following section will describe the IPM systems in detail to support the entries of the IPM production systems.

Table 3.0 Summary of per acre crop enterprises in Ebony Park, Clarendon

Crop production method	Gross revenue	Total cost	Returns to fixed resources	Total labor	Total cost of chemicals[a]	Annual recommended irrigation quantities[b]
Units	$JM[c]	$JM	$JM	People-days	$JM	Total hours
Corn	24,000	23,400	600	25	4,900	520
Pumpkin	56,000	33,715	22,285	41.55	4,680	520
Cassava	80,640	50,900	29,740	71	3,400	208
Sugar cane	42,000	40,500	1,500	8	4,300	364
Conventional sweet potato	31,200	21,296	9,904	22	3,800	312
IPM sweet potato	40,800	22,212	18,588	22	3,800	364
Conventional hot pepper	120,000	48,436	71,564	45.5	13,250	416
IPM hot pepper	156,000	56,811	99,189	61.25	10,250	416
Conventional callaloo	43,750	30,268	13,482	29.5	3,800	208
IPM callaloo	56,875	31,543	25,332	30.75	2,950	208

a. Chemicals include costs of fertilizers, herbicides, insecticides, and pesticides.
b. With the exception of IPM sweet potato, none of the crops require irrigation. However, supplemental watering will enhance crop yields and all of the farmers interviewed used irrigation.
c. Exchange rate of $JM35:$US1

IV b. Integrated Pest Management Systems

The IPM-CRSP program in Jamaica works with three crops: callaloo, sweet potato and hot pepper. As mentioned in Chapter 2, each of these crops has specific IPM packages that farmers can adopt to reduce pesticide usage by farmers. IPM-CRSP is working with CARDI to develop and teach local farmers the techniques that can be used to reduce the pesticide level.

The IPM packages discussed below represent the best available technologies for farmers. These IPM technologies are not presently used by the farmers on any crop. Farmers have access and knowledge about some of the methods, but some of the components are still in the experimental stage. The information presented here is the best available on the proposed IPM components. The empirical model developed with this study can be adapted as better IPM systems are secured.

The IPM package for sweet potato is the nearest to completion of the three crops. The major pests of the sweet potato are the sweet potato weevils, *cylas formicarious*. IPM components include: cultural, biological and chemical (Lawrence, 1998b). The chemical components are to reduce the quantity of pesticides used by educating farmers in action threshold levels. The biological component is for farmers to use sex pheromone traps to attract the male sweet potato weevils. In addition, researchers are evaluating USDA strands of sweet potato resistant to the weevil under Jamaican conditions.

The cultural practices include: scouting, field sanitation, quick harvesting, clean planting material, removal of alternative hosts, and irrigation. Scouting is an activity whereby the farmer randomly checks a few plants throughout a field as a way to determine if pests are present. Scouting reduces unnecessary spraying of pesticides. Field sanitation includes removal of infected plants usually after a harvest. The infected plants are then burned to prevent further spread of the pest throughout the field. Quick harvesting is a harvesting method whereby the farmer harvests the crop when it is ready as opposed to prolonging harvest[1]. Prolonging a harvest allows the farmer to control the revenue cash flow. The IPM system promotes quick harvesting because leaving sweet potato in the ground encourages pest population growth. A farmer using clean plant material is using only plant slips that are known not to be infected with pests. Alternative hosts are crops in abandoned fields near the present field which have not been cleaned of the sweet potato plants, especially those on the edges of the bordering field. Removing these alternative hosts reduces the chance that the pests will migrate from a nearby field. Finally irrigation is included because it reduces the propagation rate of insects requiring dry air to multiply.

Experiments with the IPM systems on sweet potato have shown no significant increase in marketable yields (Lawrence, Bohac, and Fleischer, 1997) because of the emergence of another pest, the white grub. Estimated increases in yield without the white grub infestation are 25% to 35% (Lawrence, May 1998b). Currently research on the white grub is concentrating on "two chemical insecticides to manage grubs and their effect on non-target organisms. This chemical approach to management of soil grubs is seen as a short term intervention as the use of a more biological approach such as resistant varieties as well as biopesticides are currently being considered" (Lawrence, Bohac and Weeks, 1997, p. 202). Table 3.1 summarizes the production changes between the conventional and IPM production practices for sweet potato.

[1] Quick harvesting requires storage of the crop. Storage costs were not estimated and therefore the returns to the sweet potato IPM package may be overstated.

Table 3.1 Annual input and yield production changes per acre resulting from adoption of the sweet potato Integrated Pest Management system

IPM components	Total production changes per acre	Total cost/revenue increase $JM[a]
Pheromone traps	Increase labor by 4 people-days	2,000
Pheromone traps	Increase material cost by $JM500	500
Field sanitation	Increase labor by 2 people-days	1,000
Irrigation	Increase water use by 32 hours	256
Clean planting material	Increase labor less than 1 people-day	Less than 500
Removal of alternative hosts	Increase labor less than 1 people-day	Less than 500
Scouting	Increase labor less than 1 people-day	Less than 500
Quick harvesting	Decrease labor by 6 people-days	-3,000
Total IPM changes		
Cost changes	Increase total cost per acre of 3.5% from $JM20,336 to $JM21,092	Increase total cost by $JM756
Yield/Revenue changes	Increase in Yield of 30% per acre from 2,600lbs to 3,4000lbs	Increase in total revenue by $JM9,600

a. Nominal exchange rate of $JM35:$US1

As Table 3.1 above illustrates, the IPM components for sweet potato increase water usage by 32 hours per acre. The total labor however, does not change over the cropping season. The pheromone traps and field sanitation raise the labor hours needed and quick harvesting decreases the labor requirements. The cost of material inputs is raised by $JM500 because the farmer must purchase pheromone traps. The combined increases lead to an increase in total cost of 3.5% or $JM756[2]. The use of the IPM system, though, leads to an increase in harvestable crop by 30% from 2,600

[2] The increased cost is understated because storage costs and additional labor to harvest the higher yield were not considered.

pounds per acre total to 3,400 pounds per acre total. At a farmgate price of $JM12 per pound, total revenue is increased by $JM9,600.

The Scotch Bonnet hot pepper has the next most complete IPM package for farmers. The main pests attacking the hot pepper crop are the following viruses: tobacco etch virus, potato virus Y and *Cercospora*. Recently mites have been discovered on the pepper plants prompting new research in Year 6 of the IPM-CRSP program. The hot pepper IPM package includes: cultural, mechanical, biological and chemical components. The chemical component of the IPM package is to reduce the quantities of insecticides used. The insecticide reduction[3] is an integral part of the pest management for the viruses. The biological component for the pest management viruses is substitution of the West Indian Red pepper for the Scotch bonnet pepper. The West Indian Red pepper is more resistant than the Scotch Bonnet to the viruses. The cultural practices include: field sanitation, scouting, pulling infected plants, and intercropping the pepper with corn. The mechanical component is to use sticky traps to monitor aphids and to screen the seed bed with wire mesh. This IPM package is estimated to increase the growing season by at least an additional month as well as increase yield by 30% (Martin, May 1998). Table 3.2 is shown below and highlights the changes in production from adopting the hot pepper IPM system.

[3] Reducing insecticide is the only IPM component suggested for countering the mite problem on hot peppers.

Table 3.2 Annual input and yield production changes per acre resulting from adoption of the hot pepper Integrated Pest Management system

IPM components	Total production changes per acre	Total cost/revenue increase $JM[a]
Reduction of insecticide	Lowers cost of materials	-3,000
Reduction of insecticide	Reduce labor by 8 people-days	-4,000
Sticky traps	Raises cost of materials	3,000
Screening seed bed	Raises cost of materials	500
	Increases labor by 1 people-day	500
Field sanitation	Increases labor by 12 people-days	6,000
Scouting	Increases labor by 9.75 people-days	4,875
Pulling infected plants	Increases labor by 1 people-day	500
Total IPM changes		
Cost changes	Increase in total cost per acre of 15.2% from $JM46,720 to $JM55,095	Increase total cost by $JM8,375
Yield/Revenue changes	Increase yield by 30% per acre from 10,000lbs to 13,000lbs	Increase in total revenue by $JM36,000

a. Nominal exchange rate of $JM35:$US1

With the IPM system for Scotch Bonnet hot peppers, farmers increase their total usage of labor by 15.75 People-Days per acre. As with the sweet potato IPM system, the hot pepper IPM system increases the cost of materials by $JM3,500. This increase is a result of farmers purchasing sticky traps and screens for the seed beds. The cost of chemicals, however, is decreased by $JM3,000 because of the reduction of insecticide used. The total increase in the cost of materials is $JM500. Insecticides are applied only 25% as often with the IPM system as with the conventional system. The total cost per acre of the IPM hot pepper system increases 15.2% from $JM46,720 to $JM55,095. Yield is increased by 30% from an average of 10,000 pounds per acre total to 13,000 pounds per acre total. At the farmgate price of $JM12 per pound of hot peppers, the increased yield leads to an increase in total revenue of $JM36,000.

These results, along with those of Table 3.0, reflect only the production changes to the hot pepper crops from adopting the hot pepper IPM system. In addition, a farmer using the hot pepper IPM system would need to grow .14 of an acre of corn for every one acre of IPM hot pepper. Therefore, the total revenues, costs and returns to fixed resources would reflect a combination of the IPM hot pepper crop as well as the corn acreage grown.

The callaloo package is the least tested but is still supported by the research (Clark-Harris, Reid, and Fletcher, 1997). The main pest affecting the callaloo crop is lepidoptera larvae. The IPM package includes: chemical, mechanical, cultural, and biological components. The chemical recommendation is to reduce applications of insecticide. The biological component is to develop a more resistant callaloo plant. Cultural practices include: field sanitation, scouting, regular weeding, and timing of planting. IPM callaloo is not planted in May when conventional callaloo is planted because during the summer months, when the callaloo fully matures, the pest population is the highest. To avoid more damage by pests, the IPM system for callaloo recommends not planting in May. The mechanical component is to completely screen the seedlings while in the seed bed. The timing of pesticides, combined with the cultural practice of scouting, will decrease the quantity of pesticides used from a liter per acre to about a half of a liter per acre and will increase the effectiveness of each application. Yields are estimated to increase by 30% (Clark-Harris, June 1998). Table 3.3 lists the IPM components for callaloo and the production changes that will occur as a result of a farmer using the system[4].

[4] The production changes as a result of callaloo IPM are listed on a per acre basis for consistency with Tables 3.1 and 3.2. However, farmers plant callaloo on a per square basis where one square is equal to one tenth of an acre.

Table 3.3 Annual input and yield production changes per acre resulting from adoption of the callaloo Integrated Pest Management system

IPM components	Total production changes per acre	Total cost/revenue increase $JM[a]
Field sanitation	Increases labor by .25 person-day	125
Scouting	Increases labor by 2.5 people-days	1,250
Regular weeding	Increases labor by less than 1 people-day	0
Screening seedlings	Increases labor by 1 people-days	500
	Increases material cost	1,500
Timing of pesticide applications	Reduces labor by 2.5 people-days	-1,250
	Lowers material cost	-850
Total IPM changes		
Cost changes	Increases total cost by 4.3% from $JM28,266 to $JM29,541	Increase total cost by $JM1,275
Yield/Revenue changes	Increases yield by 30% from 8,750 lbs. to 11,375 lbs.	Increase in total revenue by $JM13,125

a. Nominal exchange rate of $JM35:$US1

Similar to the other IPM systems, farmers using the callaloo IPM system will increase their labor usage by 1.25 People-Days per acre or 4%. The callaloo system also decreases chemical usage by $JM850. This decrease is a result of the lower amount of insecticide used. Material costs are also increased by the amount needed to purchase the seedling screens. In 1998 the cost of the screens was $JM1,500 per acre. Total cost increases by 4.3% or by $JM1,275. Total average yield increases with the callaloo system by 30% from 8,750 to 11,375 pounds per acre total. At the farmgate price of $JM5 per pound, a farmer's total revenue is increased by $JM13,125 per acre.

The growing season cycle was obtained through interviews with government officials and documents, scientists working on the IPM project and farmers. The farm model developed was representative of all of the gathered data. The model analyzed the profitability of the IPM systems and was intended as a framework for evaluating the IPM systems available to the farmer. Results from previous research and interviews with scientists, government officials and farmers provided data on the conventional and IPM production practices. Because of the evolving research of the IPM systems for hot pepper, sweet potato and callaloo, the increases in labor requirements and yields, as well as the decreases in chemical usage, were estimated for the model. Sensitivity analysis will be completed, individually and combined, for the three variables.

If the adoption of the IPM systems by the farmers lowers the variable costs of production or increases yields, farmers could increase exports and raise their returns to the applied resources. Increased returns would be an incentive for farmers to adopt the IPM systems. The empirical framework described below was designed to evaluate the incentive to farmers to adopt IPM. The model was implemented as a representative farm in Ebony Park, Clarendon.

V. Empirical Model Used in the Study

The mathematical representation of the representative farm is as follows:

Objective Function: Max $\pi = CX$

Constraints: $AX \leq b$

$X \geq 0$

Where:

π is the returns to fixed assets for the representative farm,

C is the m x 1 matrix of input and output prices a farmer faces,

X is the 1 x n matrix of quantities of inputs used and outputs produced,

A is the m x n coefficient matrix relating quantities of inputs needed to produce a fixed set of outputs, and

b is the 1 x n matrix of maximum quantities of resources available to the farmer

The model can be segregated into two main categories: the objective function with associated production and marketing activities and constraints.

V a. The Objective Function

The objective function is maximizing the returns to the fixed resources above variable costs. Variable cost, or operating capital, is the cost for annual production of crops and includes the purchasing of seeds, fertilizers, pesticides, hired labor, and water. Variable costs are incurred only when the crops are produced. The fixed resources are defined as: owner labor and management, land, and investment capital. All costs and returns to applied resources in the model and the subsequent analysis were in 1997 dollars with an exchange rate of $JM35 to $US1.

The objective function was simplified to be the returns above variable cost to the owner's labor and management, land and capital. Owner labor and management were the number of work days supplied by the farmer and his family. Owner labor and management were excluded from the objective function because they were assumed to be fixed at forty-five work days per month. Forty-five work days per month were chosen as the maximum quantity of owner labor supplied based on estimates from the farmer interviews. The maximum total quantity of owner labor represents the time devoted to the agricultural production process including work days of strenuous labor as well as supervision of other farming activities such as irrigation.

Land and investment capital were factored out of the objective function. The time horizon for the model was one year resulting in land and capital being fixed costs. The fixed costs had no influence on the production decisions or the adoption of the IPM systems. Investment capital was a fixed cost representing the long run capital needed for the production process including fences, irrigation infrastructure, land improvements, buildings, irrigation pumps and chemical sprayers. Land was the quantity of acres available to a farmer. The ownership cost of land was excluded from the objective function because land was assumed to be fixed.

In the representative farm model, the farmer could choose among seven different crops and ten production methods. The first six production methods were for the three non-traditional crops: hot pepper, callaloo, and sweet potato. A farmer could grow the three crops by the conventional methods or using IPM technologies. The last four production methods were for corn, cassava, sugar cane and pumpkin.

The first group of activities in the objective function was the various crops a farmer could choose to grow. The objective function coefficients were the initial costs for growing the crops. These initial costs included: land preparation, seeds, screens for seedlings and traps needed for the IPM systems. Combining the costs allowed for ease in model interpretation.

In Table 3.4 below, a partial matrix is shown of the IPM and Non-IPM production systems for hot pepper. The table shows the different labor requirements for the two systems. The higher labor input for the IPM production technology reflects the time increase as detailed in Table 3.2. If data on the IPM technologies change with new research, the coefficients in the Grow Pepper-IPM column can be altered to reflect the additional information.

Table 3.4 Partial Matrix of IPM and Non-IPM Systems for Hot Pepper

Units		Acres	Acres
	Obj Cj's	-5000	-5100
	Activities	Grow Pepper	Grow Pepper - IPM
	Solution	0	0
Acres	Land	1	1
$JM	Credit	-5000	-5100
Hours/Year	Water	416	416
50 Kg Bag	Fert - Pepper	1	1
Percent of Liter	Insect - Pepper	2	0.5
Percent of Liter	Herb - Pepper	0.5	0.5
People-Days	May Labor	0	1.25
People-Days	June Labor	1.5	1.25
People-Days	July Labor	1	0.75
People-Days	August Labor	9	9
People-Days	September	2.5	2.5
People-Days	October Labor	6.5	6.5
People-Days	November Labor	3.5	4.5
People-Days	December Labor	10.5	14.5
People-Days	January Labor	5.5	8.5
People-Days	February Labor	4.5	6.5
People-Days	March Labor	1	3
People-Days	April Labor	0	3
Pounds	Harvest -Pepper	10000	13000
Max acres	Hot Pepper	1.1	1.1

Callaloo was the only crop in the model that could be planted at more than one point during the year. Because of the shorter growing season of as little as six months, farmers in Ebony Park plant callaloo year round. To simulate this year-round option, the model allowed the farmer to plant callaloo in May, September and January. The production requirements did not change between the different planting months. Only the timing of the requirements was shifted. Shifting the time of planting would allow the farmer to spread limited labor among crops.

The second set of activities was the inputs necessary for the production of the crops. The inputs included: operating capital, water, fertilizers, insecticides and other chemicals, and hired labor for each month. The objective function coefficient for each input activity was the market price for that particular input. For instance, if the farmer needed to hired an extra worker for one day in June, the coefficient on hired labor for June is the market price of JM$500 a day.

As mentioned previously in this chapter, each farmer in Ebony Park owned a water pump which was used for irrigation of the fields. A price of $JM17.875 per hour was calculated based on the average pumping capacity of the pumps used by the farmers. The fuel capacity of gallons per hour was multiplied by the price of gasoline in Jamaican dollars per gallon. The result was the cost of using a pump for one hour. In addition, repairs, labor, and maintenance were added to the per hour price. Based on extension estimates (Virginia Cooperative Extension, 1997), repair and maintenance costs of the water pumps were about $JM1.5 or 8.6% of the per hour cost. The operating costs including: fuel, oil, lube and repairs were $JM19.39 per hour.

The cost of operating capital was the interest rate charged to farmers on all money used to produce the crops. The cost of borrowed capital was 13%. If farmers borrowed money, they were charged an interest rate by the Agricultural Credit Bank which is equal to the lowest Commercial Bank Passbook rate of 13% as of May 1, 1998. If farmers invested their own money into a bank, the passbook rate of 13% is what they would receive as interest. The real rate of interest was computed by subtracting the inflation rate of 10% for a final value of 3%. An explanation of the calculation is provided in Footnote 2 in Chapter 2.

The last set of activities in the objective function was the selling activities. After a field was harvested, the crop was sold. The price that the farmer received for the crop was the farmgate price as reported by the Rural Agricultural Development Authority (RADA). The separation of growing crops and selling crops allowed for the manipulation of the farmgate prices as a separate evaluation from the input prices and initial costs of production.

Table 3.5 below shows another section of the matrix. All crops yield constant harvest quantities. IPM techniques yielded an average harvest of 13,000 pounds while non-IPM systems yielded 10,000 pounds per acre of hot peppers. Corn had a yield of 3,000 pound per acre. The harvests are then sold at the market price in 1997. Hot peppers sold for $JM12 per pound while corn sold for $JM8 per pound.

Table 3.5 Partial Matrix of Selling Activities

Units		Acres	Acres	Acres	Pounds	Pounds			
	Obj Cj's	-5000	-5100	-6222	12	8		Max Profit	0
	Activities	Grow Pepper	Grow Pepper - IPM	Grow corn	Sell-Pepper	Sell-Corn			Constraint
	Solution	0	0	0	0	0		Solution	Values
Pounds	Harvest -Pepper	10000	13000		-1		=	0	0
Pounds	Harvest - Corn			3000		-1	=	0	0

V b. Constraints

The constraints were divided into two categories: resource constraints and technical constraints. The resource constraints limited the farmer's access to total land and available labor. The farmer could use no more than 10 acres of land and could work no more than 45 person-days a month. If additional labor was needed, a farmer would then have to hire off farm workers for $JM500 a day. The farmer was limited to

2,040 hours a year of water from the National Irrigation Commission (NIC) for the ten acre farm. In Ebony Park, the NIC limits farmer access to water due to operational constraints. In the model, farmers were also limited to an additional 2,040 hours a year of river water access. The model did not divide the water use to monthly or weekly quantities but instead constrained the farmer to an annual maximum.

All of the farmers in Ebony Park voluntarily constrain the total acreage of land for each of the crops grown. When interviewed, farmers supplied two reasons for this land restriction: price fluctuations and uncertainty with respect to being able to sell all of the quantity produced. The restriction of crop acreage was a type of risk control. This risk aversion behavior was incorporated into the model by additional constraints limiting the total acreage the farmer could grow of each crop. Table 3.6 below shows the maximum percentage of the total farm acreage planted for each crop. The percentages sum to greater than 100% because they are maximums that could be planted and not averages for a given year.

Table 3.6 Maximum percentage of total land devoted to various crops by farmers interviewed in Clarendon, Jamaican

	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Average
Total acres	10	10	10	5	10	
Sweet potato	20%	20%	20%	20%	10%	18%
Hot pepper	10%	5%	10%	5%	50%	11%
Callaloo	0%	5%	0%	5%	0%	2%
Corn	20%	15%	5%	10%	10%	12%
Cassava	20%	10%	30%	20%	5%	17%
Pumpkin	30%	20%	30%	20%	20%	24%
Sugar cane	40%	50%	60%	50%	45%	49%

Most of the farmers had at least one crop for which they did not have a specific maximum acre restriction. For instance Farmer 1 did not have a maximum for hot pepper, callaloo or corn. In these cases, the present acreage of each crop was used as the maximum acreage allowable by the farmer. If the farmer did not have any of a crop, such as callaloo, then a zero percentage was used as the maximum.

The average percentage of maximum acreage per crop over the five farms was calculated and is reported in Table 3.6. The average percentage was then converted into numeric acreage. The numeric acreage was used in the representative farm. Table 3.7 below shows the conversion.

Table 3.7 Maximum Percentage and Acreage for the Representative Farm

Crop	Percentage	Acres
Sweet Potato	18	1.8
Hot Pepper	11	1.1
Callaloo	2	.2
Corn	12	1.2
Cassava	17	1.7
Pumpkin	24	2.4
Sugar Cane	49	4.9

Table 3.7 show the maximum number of acres that a farmer would plant if he had a ten acre farm. Not specializing in any one crop allows the farmer to diversify his production which lowers his total risk. The largest maximum acreage was 4.9 acres of sugar cane. The lowest maximum was callaloo with only 0.2 of an acre allowed to be planted.

If the farmer decided to produce crops, the technical constraints forced the farmer to purchase fertilizers and other inputs required for the production of those crops. The farmer hired outside labor, borrowed money for financing, and purchased fertilizer for the crops. The technical constraints did not limit the total quantity of inputs that could be used, but instead allowed the farmer to choose the optimal quantity of inputs based on the relative prices of the inputs and outputs.

If the farmer decided to grow hot peppers, the field would need to be fertilized. The technical constraints forced a farmer to supply labor in necessary quantities for the crop, to produce all of the crop sold and to purchase a 50 kilogram bag of fertilizer, with a concentration of N,P,K of 11:22:22, for every acre of land in hot pepper production.

V c. Linear Programming Software Used

The model was solved using the Solver software package included in Microsoft Excel. Using Solver allowed for easy manipulation between tables, graphs, and the mathematical model. In addition, Solver was used to generate write-ups of the sensitivity reports. A print out of the model and tableau can be found in Appendix C.

V d. Policies Incorporated into the Model

The model was initially constructed incorporating the policies potentially affecting IPM adoption. As discussed before the seven policies were: preclearance, real exchange rate fluctuations, interest rate changes, the Common External Tariff, water rates, the duty tax concession, and credit subsidies. These policies were categorized into four areas: policies affecting input costs, policies affecting input requirements, policies affecting output prices, and policies not included in the model. The background for each policy was detailed in the previous chapter.

Table 3.8 below shows the policies and the respective parameters altered to simulate those individual changes. The policies are grouped according to the category, or categories, into which they fall.

Table 3.8 Alterations to the Farm Model Simulating Policy Changes[a]

	Original coefficients	Elimination of the water subsidy[b]	Elimination of the credit subsidy[c]	Interest rate[d]	Vehicle duty concession[e]	Common External Tariff[f]	Real exchange rate[g]	Preclearance[h]
Initial cost of machine services per acre for land preparation	$JM4,000				$JM4,450	$JM3,810	$JM3,810	
Market interest rate	25.51%			19.31%				
Subsidized interest rate	3%		25.51%	2.25%				
Market rate for water	$JM19.39							
NIC rate for water	$JM8	$JM19.39						
Total cost of chemicals for hot pepper	$JM5,750					$JM5,463	$JM5,463	
Total cost of chemicals for hot pepper – IPM	$JM2,750					$JM2,613	$JM2,613	
Total cost of chemicals for corn	$JM4,900					$JM4,655	$JM4,655	
Total cost of chemicals for sweet potato	$JM3,800					$JM3,610	$JM3,610	
Total cost of chemicals for sweet potato – IPM	$JM3,800					$JM3,610	$JM3,610	
Total cost of chemicals for pumpkin	$JM5,385					$JM5,116	$JM5,116	
Total cost of chemicals for callaloo	$JM3,800					$JM3,610	$JM3,610	
Total cost of chemicals for callaloo - IPM	$JM2,950					$JM2,803	$JM2,803	

Table 3.8 Alterations to the Farm Model Simulating Policy Changes[a] (continued)

	Original coefficients	Elimination of the water subsidy[b]	Elimination of the credit subsidy[c]	Interest rate[d]	Vehicle duty concession[e]	Common External Tariff[f]	Real exchange rate[g]	Preclearance[h]
Total cost of chemicals for cassava	$JM3,400					$JM3,230	$JM3,230	
Total cost of chemicals for sugar cane	$JM4,300					$JM4,085	$JM4,085	
Total labor usage for hot pepper	45.5 ManDays							57 ManDays
Total labor usage for hot pepper – IPM	61.25 ManDays							75.5 ManDays
Total labor usage for pumpkin	41.55 ManDays							52 ManDays
Total labor usage for sweet potato	22 ManDays							27.5 ManDays
Total labor usage for sweet potato – IPM	22 ManDays							27.5 ManDays
Total labor usage for callaloo	29.5 ManDays							37 ManDays
Total labor usage for callaloo – IPM	30.75 ManDays							38.4 ManDays
Total labor usage for cassava	71 ManDays							88.7 ManDays
Exportable harvest – hot pepper	10,000 Pounds							11,000 Pounds
Exportable harvest – hot pepper – IPM	13,000 Pounds							14,300 Pounds
Exportable harvest – pumpkin	7,000 Pounds							7,700 Pounds

Table 3.8 Alterations to the Farm Model Simulating Policy Changes[a] (continued)

	Original coefficients	Elimination of the water subsidy[b]	Elimination of the credit subsidy[c]	Interest rate[d]	Vehicle duty concession[e]	Common External Tariff[f]	Real exchange rate[g]	Preclearance[h]
Exportable harvest – sweet potato	2,600 Pounds							2,860 Pounds
Exportable harvest – sweet potato – IPM	3,400 Pounds							3,740 Pounds
Exportable harvest – callaloo	8,750 Pounds							9,625 Pounds
Exportable harvest – callaloo – IPM	11,375 Pounds							12,512 Pounds
Exportable harvest – cassava	13,440 Pounds							14,784 Pounds
Export price – hot pepper	$JM12/Pound						$JM11.4	$JM12.3
Export price – hot pepper – IPM	$JM12/Pound						$JM11.4	$JM12.3
Export price – pumpkin	$JM8/Pound						$JM7.6	$JM8.2
Export price – sweet potato	$JM12/Pound						$JM11.4	$JM12.3
Export price – sweet potato – IPM	$JM12/Pound						$JM11.4	$JM12.3
Export price – callaloo	$JM5/Pound						$JM4.75	$JM5.13
Export price – callaloo - IPM	$JM5/Pound						$JM4.75	$JM5.13
Export price – cassava	$JM6/Pound						$JM5.7	$JM6.15

a. For explanation of changes see Table 2.1.
b. A water rate policy change eliminated the water subsidy to farmers.
c. The credit subsidy change eliminated the interest rate subsidy to farmers.
d. Interest rate change reduced the real interest rate by 25%.
e. The elimination of the vehicle duty concession raised the price of mechanical imports by 20%.
f. A reduction in the CET by 11.25% caused the price of all imports to fall by 5%.
g. The real exchange rate appreciated by 5% causing the price of imports and exports to fall by 5%.
h. With the preclearance policy farmers inspect their crops before shipping them to the preclearance station.

Table 3.9 lists the components of the cost of machine services and the changes in each component as well as the total cost as a result of changes in the duty concession rate, the CET and an appreciation of the real exchange rate. Machine services are rented when farmers need to prepare the field and include: transportation of the tractor to the field, labor to operate the tractor, the tractor, and a plow.

The itemized listing by the Virginia Cooperative Extension (1997) provided support for the breakdown in Table 3.9. The results from Table 3.9 were used in Table 3.8. A detailed description follows of how each policy simulation was chosen and incorporated into the conceptual framework.

Table 3.9 Itemized Listing of the per Acre Cost for Tractor Services and Plowing

	Percent	Initial Cost $JM	Duty Concession Change[a] $JM	CET or Real Exchange Rate Change[b] $JM
Fuel	25.1	1,004	1,004	953
Oil	2.2	89	89	84
Repairs	21.9	877	877	833
Fixed Costs[c]	46	1,840	2,210	1,748
Labor	4.8	192	192	192
Total Cost	100	4,000	4,370	3,810

a. Duty concession eliminated.
b. CET lowered by 11.25% or the real exchange rate appreciates by 5%.
c. Fixed costs include: depreciation, taxes, insurance, housing and interest.

The initial costs were obtained through interviews with farmers and government officials. The percent breakdown was based on the Virginia Cooperative Extension reports and interviews with farmers and CARDI scientists. The calculations estimating the changes were obtained by multiplying the initial cost category by the respective percent change. For instance, fixed costs rose by 20% with the elimination of the duty concession, therefore $JM1,840 rose by 20% to $JM2,210.

Duty Concession: The duty concession affected the price on imported machinery for farm use. All imported goods are subject to duty charges. The duty concession of 20% allows farmers to pay 80% of the duty on the imported good[5].

As Table 3.9 illustrates, the duty concession only affects the fixed cost portion of the total cost of machinery services. The elimination of the duty concession was modeled by raising the fixed cost portion by 20% to $JM2,210[6]. As a result of the elimination of the duty concession, the importer paid 100% of the duty on the good and not 80%. The additional charges were passed directly to the farmer.

Common External Tariff: The CET affects all imports into Jamaica. A 11.25% drop in the CET caused a 5% fall in the prices of imported inputs[7]. These imported inputs are the chemicals sprayed on the fields and the portions of the machinery services that are imported: the tractor as reflected by fixed costs, fuel, oil and repairs which need imported machinery parts. The parameter changes for the items of the machinery services are shown in Tables 3.8 and 3.9. The cost of all chemicals, including pesticides and fertilizer, fell by 5%.

According to the Uruguay Round negotiations, the maximum percentage of the CET will fall by 20% over the next seven years. When asked, government officials agreed that the CET reduction was feasible (Pike, 1998b)

Exchange Rate: A change in the real exchange rate affected three areas: the prices of imported chemicals, the cost of machinery services and the export prices received by farmers. An appreciation in the real exchange rate would lower the prices

[5] For instance, if a tractor price was $JM50,000 and the combined Stamp Duty was 60% of the tractor price, or $JM30,000, the tractor would cost a total of $JM80,000 without the duty concession. With the duty concession the Stamp Duty would be $JM24,000, thereby lowering the total cost of the tractor to $JM74,000.

[6] The 20% overstates the likely increase in tractor service cost (which would be approximately 8%) but a larger value (20%) was used to provide a significant change in machinery costs.

[7] If the price of a bottle of pesticide was $JM500 and the CET was 80% of the price of the pesticide, the total cost of the bottle would be $JM900. If the CET were lowered by 11.25% then the tariff charged to the bottle of pesticide would be 71% of $JM500. The lower CET would result in the bottle of pesticide costing $JM855, a reduction of 5%.

paid by farmers for imported inputs as a result of less Jamaican dollars purchasing more US dollars. The appreciation in the real exchange rate would also reduce the price received by farmers for exports because exporters would be forced to lower the price of exported crops to compensate for the stronger Jamaican dollar. Table 3.9 shows the parameter changes in the itemized and total costs for machinery services. The changes in the cost of chemicals and the export prices received by farmers are shown in Table 3.8.

The model was used to evaluate a 5% appreciation in the real exchange rate. Between March 1997 and March 1998, the real exchange rate rose from $JM5.4:$US1 to $JM5.3:$US1, which is equivalent to a 2% appreciation. The real exchange rate change in the model was a much larger shift of 5% to emphasize the effects. A 5% change would appreciate the real exchange rate from $JM5.4:$US1 to $JM5.13:$US1. Bank of Jamaica officials (Brown, 1998) concurred that a 5% appreciation in the real exchange rate was reasonable and would coincide with current Bank of Jamaica fiscal policies.

<u>Credit Subsidy</u>: Policy changes to the subsidized interest rate received by farmers were modeled by eliminating the activity which allowed borrowing at the subsidized real interest rate of 3% in the model. Without the credit subsidy, farmers could borrow money only at the real market interest rate of 25.51%.

<u>Real Interest Rate</u>: In the model, farmers could borrow money at a subsidized real interest rate of 3% and a market rate of 25.51%. A limit of $JM100,000 was placed on loans with the subsidized rate. The director in Office of the Managing Director reported that the farmers have a maximum limit of borrowing of $JM100,000 (Williams, 1998). A farmer could, however, borrow as much money as needed at the unsubsidized rate.

Because the model is static there is no accounting for inflation and a real interest rate is used. As an approximation the inflation rate could simply be subtracted from the nominal rate to calculate the real interest rate. In 1997, the annual average inflation rate was 10%. The nominal subsidized and market interest rates were 13% and 35.52%, respectively. Therefore, in the model, the subsidized real interest rate was 3% and the real market interest rate was 25.52%.

From March 1997 to March of 1998, the real interest rate has dropped almost 25%. Both the real market interest rate and the real subsidized interest rate incorporated into the model were dropped by 25% to evaluate effects of interest costs on IPM profitability. The new real subsidized interest rate was 2.25% and the new real market interest rate was 19.13%. Officials with the ACB (Williams, 1998) and the Bank of Jamaica (Brown, 1998) agreed that a 25% drop in the real interest rate was possible.

Preclearance: Preclearance affected three areas of production: quantity of labor required for production, price received for exported goods and quantity exported. The parameter changes are supported by interviews with officials from the Ministry of Agriculture (Thomas, 1998), APHIS (Lawrence, 1998a), and the Jamaican Exporters Association (Reid, Charles, 1998).

The quantity of labor increases because farmers must first inspect their own goods before shipping them to the preclearance station. If the goods are found to be infected, the farmer's next few shipments will be inspected automatically. To prevent these subsequent inspections, farmers will check their own goods prior to the transport to the preclearance stations. Labor requirements during harvest season were increased by 25% in the model to simulate farmers' self inspection.

If farmers chose to inspect their harvest, they also received a higher export price. The higher price reflects the assumption that the exporters who purchase from the farmer will have more confidence that the farmer's goods will pass inspection. The exporter can rely on the farmer and will be willing to pay a higher price for the farmer's goods. The premium price was 2.5% higher than the regular export price. The premium price was supported by interviews with government officials (Thomas, 1998) (Reid, Charles, 1998).

Quicker access to US markets through preclearance allows the farmer to export a larger quantity of the harvest. Because farmers inspected their crops before the preclearance station, the crops moved through the station more quickly than non-farmer inspected crops. The farmers were able to export more of their harvest because less of the crop spoiled in the wait to be inspected at the preclearance station and because less of the crop is rejected by the station. In addition, before a farmer self inspected his crops, an infected box would result in all of the shipment being rejected. With self inspection, a farmer might ship less to the preclearance station in total pounds, but a higher percentage of the shipment will be exported. The increase in exported harvest was 10% on all crops eligible for the preclearance program: hot pepper, pumpkin, sweet potato, callaloo, and cassava (Thomas, 1998) (Reid, Charles, 1998). The assumed yield for these crops was raised by 10% in the model.

<u>Water Rates</u>: The representative farmer had two sources of water from which to choose. He could use a pump in the river and pay for fuel and repairs on the pump for a total cost of $JM19.39 per hour[8] or he could purchase water from the NIC for a subsidized rate of $JM8 per hour. Evaluation of the water rates was accomplished by the elimination of the option for farmers to purchase water from the NIC at a reduced cost but instead farmers could only buy water at the market rate as reflected by the

[8] Calculations for the per hour pumping costs are shown in Appendix D and supported by literature from the Virginia Cooperative Extension (Virginia Cooperative Extension, 1997).

cost of pumping water from the river. Farmers interviewed did not purchase water from the NIC because of preconceived notions about the NIC for unreliability.

VI. Summary

The conceptual framework used to evaluate the effect of policies on IPM adoption was a mathematical programming model. The objective function of the model was to maximize the returns to fixed assets for the farmer. Data on the model came from interviews with farmers in Ebony Park, Clarendon, government officials, and CARDI scientists working on the IPM-CRSP grant. The representative farm model could produce: hot pepper, pumpkin, sweet potato, callaloo, sugar cane, and cassava. In addition, the farmer could produce hot pepper, sweet potato and callaloo using conventional or the IPM technologies. Callaloo could be planted three times throughout the year. The IPM systems incorporated into the model represented the best available technologies as developed by the CARDI scientists. Seven policies were included in the model through the addition of new and elimination or modification of existing parameters. The following chapter will analyze and evaluate the results from the empirical model.