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The Application of Linear Programming Models in Planning the Diversification Strategy for Antigua and Barbuda

INTRODUCTION

This paper reviews the application of a Linear Programming (LP) model to the agricultural sector of Antigua and Barbuda. The general methodology used is explained and the results obtained in terms of resource use, and policy implications are summarised.

Linear programming models have been widely used in solving individual farm management problems. However, the use of LP models to facilitate planning and policy choices in the agricultural sector at the national level is less frequent. Prominent among the exponents of such national agricultural sector models was the U.S. economist, Earl O. Heady. He used these models to analyze land requirements for meeting the U.S. food and fiber needs (Heady and Timmons) as well as to evaluate alternative environment policies on farm prices (Campbell and Heady).

One major difficulty with the national LP models concerns the level of aggregation which must occur. Resources and farm technologies have to be grouped into manageable sizes thus creating the tendency for overestimation of efficiency relative to the existing situation. Nevertheless, these models provide a wide variety of insights for national decision-making which otherwise would have not been easily discerned.

A strong case can be made that such models are more applicable to small countries, such as those in the Eastern Caribbean, where resources for agriculture are extremely limiting. In such countries, good agricultural land is less than 5% of total land resources, while in certain territories up to 70% of the land is unsuitable for agriculture (Rojas and Meganck). Furthermore, the pressures of human settlements for land and the trend in the movement of labour away from agriculture also serve to reduce land and labour resources for the sector. The need to diversify the agricultural sector and to make radical changes in certain cases also strengthens the desire for such LP models which can give insights with respect to the rationalization of agricultural production.

Antigua and Barbuda can be classified as a dry country with an annual average rainfall of 40.95 inches. Prior to the 1960s, the agriculture sector was comprised mainly of two crops: sugar and cotton. During the 1970s, massive investment in tourism occurred and this combined with the fall in sugar prices among other factors led to the rapid decline of the agricultural sector. Agriculture contribution to GDP fell from 10.96% in 1977 to 3.67% in 1986. On the other hand, the contribution of hotels and restaurants increased from 11.65% to 16.67% for the same period.

Today, sugar cane is extinct and cotton has declined substantially. This has led to a large quantity of idle agricultural land (approximately 60% owned by Government), and the growth of the landless livestock farmer. Food imports have continued to increase and with the rapid growth of the tourism industry (now approximately 60% of GDP), these imports are due not only to the increased incomes of residents and the rapid movement away from the land. Antigua and Barbuda, therefore, represents a prime candidate where the use of a national LP model can facilitate decision-making in agriculture given its demand for food, its declining agricultural labour resources, limited water supply, and the fact that Government controls a large portion of the land base.

MODEL METHODOLOGY

Basically, the methodology for the national agricultural sector LP models involves matching the planned or anticipated demands for agricultural outputs (crops, livestock, forestry) with the ability of the sector as reflected in its available resources and by its production technology. Costs and available resources determine whether the desired demands on the agricultural sector are met by local production or imports.

Figure 1 illustrates the workings of the model. It shows that the objective is to minimize cost of local production and imports. The production technology is separated into three parts, namely: the variable cost of local production, inputs required and outputs generated. The inputs used must not exceed the national resources, while outputs produced together with imports must meet the national demands.

Data requirements of the model are fairly obvious from Figure 1. These include an assessment of natural resources and other resources available for agriculture; forecasts of the demands for agricultural commodities, and identification of costs and the technologies of production.

For the Antigua and Barbuda agriculture sector model, 22 commodities (crops and livestock) were identified as the most potentially significant enterprises. These enterprises were considered directly within the model thus the resources, demands, technology had to be defined. The estimation of the data needs for the model occurred as follows:

a. *Resources Estimates*

The resources which were considered critical to the agricultural sector of Antigua and Barbuda were land, agricultural labour and irrigation water. The data for the model were generated mainly by the Natural Resources Assessment for Agricultural Development (NRAD) Project developed under the technical cooperation agreement between the Government of Antigua and Barbuda and the Organization of American States (OAS).

In the case of land, the model considered only land capability Classes II to IV which are the best land for agriculture in the nation. Livestock may also be produced on Classes V and VI, but these were not allowed in the model. In obtaining the available land resources, the land capability and land use maps of Antigua and Barbuda (Ahmad, 1984 and 1985), were used to identify capability Classes II to IV land and to exclude from such areas all lands which were already under or prone to permanent non-agricultural uses. Hence, areas which were in capability Classes II to IV, but had human settlements, or were rapidly expanding tourist, industrial and commercial sites were eliminated.

The capability Class II to IV were further sub-divided into a total of eight land types based on cropping suitability. Land was also sub-divided by ownership (Government and private sector), and it was assumed that 80% of Government owned and 75% of privately owned agricultural lands could be utilized by the model. Private lands were further divided depending on the scale of farm owning the resources: small scale – up to 5 acres, large scale – more than 5 acres. The model had internal flexibility to allocate Government land among the two farm scales.

The labour resources used 90% of the available household and hired labour identified in the 1984/85 agricultural census and survey (Campbell, 1986, and Campbell and de Freitas, 1986). Hired labour was transferable between the farm scales but labour was assumed immobile among the four regions of production which were defined.

Water resources for the model were restricted to available irrigation water resources, thus planned constructions of additional dams were not considered. The water resources data were based on July 1987 data, obtained from the Ministry of Agriculture. Limited distribution of water was allowed so that irrigation was confined to areas in the vicinity of the water sources as currently exist.

b. *Demand*

The demands for the 22 commodities were estimated for the year 1997. This time period was chosen so that there would be a long enough gestation period for the agricultural sector to adjust to the optimal production path.

Time series data on local consumption and imports were used to obtain the estimates based on a 1997 population of 83,800 residents, tourist arrivals of 370,000 persons, and a projected GDP/capita of EC$ 3,528. Two quality standards of products were identified, namely: for the local market, and for tourist and exports. Three periods of consumption were defined reflecting the tourist season, the dry and rainy seasons. Export demand was assumed to be maintained at current levels. The demand estimates were in general fairly conservative.

c. *Technology*

The technology assumed was that of the more progressive farmers as developed by Strachan. The model, therefore, did not re-

FIGURE 1: A Schematic Showing the Basic Components of an LP Model Framework.

OBJECTIVE: Minimize Variable Cost of Local Production	Imports
SUBJECT TO: Inputs Required by the Production Technology	<= Resources available for agric.
Outputs Produced by the Production Technology	Import possibilities >= National demand for agric. commodities

flect· the average farmer in Antigua and Barbuda, but looked at future potential using technology which was actually being applied on farms in the nation presently.

In general, two farm size groups were defined except in the case of tree crops, which were specified only for large-scale farms. Irrigation and rainfed options were allowed for vegetables but not for root and tree crops.

d. *Imports*

The model allowed for the importation of all the 22 commodities. Imports would occur in order to satisfy demand if the domestic cost of production was above the existing retail price of an import less a percentage retail mark up, or if local resources were insufficient.

THE RESULTS

The results presented are based on the estimated demand for the 22 commodities for the year 1997. However, prior to a discussion of the 1997 outlook, it seems useful to review the 1985 demand for the same commodities and to compare this with the actual production and the optimal production as generated by the model.

Because of the lack of data it was difficult to make detailed regional comparison; however, Tables 1 and 2 show that the potential value of the 1985 demand was EC$23.1 million evaluated at 1985 wholesale prices. Actual production, however, was valued at EC$10.8 million. The effective gap between the actual path and the optimal path being greater than EC$8.5 million/year reflects a sector working at 58.1% (10.8 X 100%/18.6) of its potential capacity. If the sector were allowed to continue at this rate, the value of its production in 1997 would be EC$16.9 million/year and imports of these commodities alone would have risen from EC$13.0 millions in 1985 to EC$20.8 million/year in comparable dollars (excluding inflation) in 1997.

Both Tables 1 and 2 show that the optimal production path does not mean elimination of imports; however, imports can be substantially reduced if the farm sector moves towards the optimal path. This is the challenge for the agricultural sector: from the policy-makers to the farmers in the field.

The usefulness of the model is the clear delineation of the desired path in terms of location and amount of production. The main features of the result of the model using the 1997 demand can be summarized in terms of production, resource use, and farm prices and incomes.

a. *Production*

The model results show that the nation is generally capable of meeting the demand for vegetables and cash crops during the period October to May, with some glut situations occurring between January and May. Shortages for many of these crops

TABLE 1: *A Comparison of Actual Production in 1985 with the Optimal Production Estimated by the Model for the Same Year in (000) Units (lbs except if otherwise given)*

Commodities	Demand 1985	1985 Production		Gap[2]	
		Actual	Model	Actual	Model
Cabbage	337.5	258.0	337.5	79.5	0.0
Carrot	491.3	300.0	491.3	191.3	0.0
Cucumber Exp	1065.6	248.0	991.2	817.6	74.4
Cucumber Loc	855.1	723.0	666.3	132.1	188.8
Eggplant	286.7	286.7	240.5	0.0	46.2
H. Pepper Exp	400.0	12.6	313.4	387.4	86.6
H. Pepper Loc	39.0	19.8	39.0	19.2	0.0
Export Okra	300.1	0.0	300.1	300.1	0.0
Local Okra	187.8	131.9	147.0	55.9	40.8
Onion	300.0	50.0	236.0	250.0	64.0
S. Pepper	234.7	193.0	234.7	41.7	0.0
S. Potato Exp	400.0	0.0	400.0	400.0	0.0
S. Potato Loc	906.6	222.0	906.6	684.6	0.0
Tomato	1500.0	331.0	1039.0	1169.0	461.0
Cotton	150.0	182.7	150.0	32.7	0.0
Peanut	100.8	3.8	100.8	97.0	0.0
Fresh P. Apple	436.7	409.0	436.7	27.7	0.0
Beef Grade A	953.7	0.0	622.0	953.7	331.7
Beef (Low)	1181.7	1057.0	528.9	124.7	652.9
Goat Grade A	43.3	0.0	43.3	43.3	0.0
Goat (Low)	67.3	33.0	67.3	34.3	0.0
Sheep Grade	87.5	0.0	87.5	87.5	0.0
Sheep (Low)	57.5	30.0	57.5	27.5	0.0
Grapefruit	16.8	11.0	16.8	5.8	0.0
Limes	28.4	19.8	28.4	8.6	0.0
Orange (dz)	90.5	29.4	90.5	61.1	0.0
Avocado	81.4	22.4	81.4	59.0	0.0
Mango	2882.0	4016.0	2882.0	1134.0	0.0
Coconut (nut)	182.1	180.0	182.1	2.1	0.0
Value[1] $'000	23064.9	10770.3	18553.7	12959.6	4511.2

[1] Values evaluated at 1985 wholesale prices.

[2] Difference from 1985 Demand.

TABLE 2: *A Comparison of the Estimated Demand for 22 Agricultural Commodities in 1997 in (000) Units (lbs except if otherwise given) with the Optimal Production Estimated by the Model for the Same Year.*

	Demand 1997	Model Prodn. 1997	Prodn. Gap 1997
Cabbage	653.0	653.0	0.0
Carrot	945.0	945.0	0.0
Cucumber Exp	1407.1	1327.5	79.6
Cucumber Loc	1050.1	926.7	123.4
Eggplant	461.1	327.4	133.7
H. Pepper Exp	800.0	586.1	213.9
H. Pepper Loc	41.0	14.9	26.1
Export Okra	428.8	428.0	0.8
Local Okra	310.0	111.4	198.6
Onion	1069.0	236.0	833.0
S. Pepper	417.0	287.0	129.1
S. Potato Exp	800.0	800.0	0.0
S. Potato Loc	2000.0	2000.0	0.0
Tomato	2000.0	1448.2	551.8
Cotton	150.0	150.0	0.0
Peanut	121.0	121.0	0.0
Fresh P. Apple	913.0	913.0	0.0
Beef Grade A	1379.4	641.6	737.8
Beef (Low)	1709.2	507.1	1202.1
Goat Grade A	77.4	77.4	0.0
Goat (Low)	111.4	111.4	0.0
Sheep Grade	128.9	128.9	0.0
Sheep (Low)	84.7	84.7	0.0
Grapefruit	60.1	60.1	0.0
Limes	66.0	66.0	0.0
Orange (dz)	266.7	266.7	0.0
Avocado	146.0	120.0	26.0
Mango	4125.0	4125.0	0.0
Coconut (nut)	202.4	202.4	0.0
Value[1] ($'000)	37773.5	29048.6	8724.9

[1] Values estimated at 1985 wholesale prices.

occur during June to September, due to the unavailability of irrigation water and farm labour supplies. Most of the importation therefore will have to occur during this latter period.

Livestock production (beef, goat and sheep) is a fairly stable activity. The nation could meet its demands for goat and sheep, and production should be concentrated in the hands of large scale operators. Beef production, on the other hand, is suitable to both the large scale and small scale (improved landless) farmers. The production of beef, however, will fall far short of the desired demand, resulting in continual imports of both high grade and low quality cuts.

Some fruits seem to have an excellent potential. The model generally chose the best land classes for the tree crops, thus the potential is area specific.

b. *Resource use*

The model indicated that 20,317 acres of land (Classes II to IV) will be required. Of this total, 17,172 acres will be utilized for livestock; 936 acres for fruit crops, and the remainder 2,209 acres for vegetable and other cash crops. Much of this land, 58.6%, is Government owned, thus affording easier transformation. The rental value of land was estimated to be approximately EC$ 114/ acre/year. Comparison with the actual situation for 1985 reveals that on land Classes II to IV, livestock use accounted for 20,152 acres, fruit trees 435 acres and cash crops 3,322 acres. Land rents are currently EC$7.50/acre/year.

Farm labour for crop production was a serious limitation. This was particularly true for the large scale farmers who might be capable of paying a wage rate (EC$5.28/hr.) comparable to other sectors. Small scale farmers were not able to compete for hired help and must depend on household labour.

The model indicated that the availability of irrigation water was not uniformly critical among the regions of production. The East had sufficient irrigation water, but in the South and North, there were distinct shortages. The model showed that in the South and North, and during the dry period (April to July), farmers can pay a maximum of EC$3,800/acre ft./year, while in the East, the sum was negligible (less than EC$7.20/ acre ft./year).

c. *Farm Prices and Incomes*

The model generated the minimum prices (breakeven prices covering variable costs), farmers would need for their commodities. From these prices, it was evident that livestock, some fruit crops, okra, cucurbits, pineapples, sweet potatoes and other vegetables in certain periods had an excellent potential.

In calculating farm incomes there was a difficulty in determining the actual farm prices. Two alternative farm prices were used namely: (a) the breakeven farm price which is the lowest expected price, and (b) the 1985 wholesale price which is closer to actual farm price.

Using these two measures of farm prices, total farm incomes were estimated to be EC$11.1 million/year and EC$27.4 million/year, respectively. The revenues to small scale and large scale farmers were in the ratio of 31:69 using the breakeven prices, and 60:40 using the wholesale prices. This indicates that the model chose activities for small scale farmers with high gross margin (vegetables rather than tree crops and livestock).

SUMMARY AND IMPLICATIONS

It is evident that the results generated by the model have implications for many aspects of the agricultural sector of Antigua and Barbuda.

First, in the area of future projects, the case of an irrigation project is apparent in order to rationalize irrigation water distribution and facilitate greater supplies to the South and North regions of production. Modernization of the livestock sector and expansion in tree crop production are also areas for potential project development. Nurse has in fact detailed a number of other project profiles based on the results of the model.

For policy, the problem of irrigation water rationalization was already highlighted. In the case of land, one of the most glaring features was the disparity between actual land rents (EC$7.50/acre/year) and the value (above EC$100/acre/year) that the model predicted that farmers could pay. A policy of extremely cheap land may not be in the best interest of the agricultural sector and may lead to a sort of land "vagrancy."

Competitive rents will boost Government revenue directly; stimulate efficient land use; and diminish the pressure of other sectors for agricultural lands. However, restructuring of land rents should be linked with long term security of tenure, zoning, and farm price policies which strengthen the bond between the agriculture and tourism sectors.

The model indicated that labour was the most critical resource. The availability of farm labour in all likelihood would decrease over time, thus a policy to address increased labour productivity or availability will be needed in the future.

The model also provides an excellent starting point for zoning of lands to reduce competition in land use from other sectors. The model generated information on the specific land types and acreages required, and locations in the country which are best suited for agriculture by commodity. Such lands should be set aside for agriculture. In fact, the OAS-NRAD Project is currently preparing an "Optimal Agricultural Land Use" map for Antigua and Barbuda based on the results of the model.

Finally, one can look ahead to the development of such a model for the OECS territories or even the Caricom countries. This would help to plan the diversification strategy from a regional perspective, and may serve to lessen trade conflicts intra-regionally.

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