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A REPRESENTATIVE FARM PLANNING MODEL FOR LIBERIA

Francis M. Epplin and Joseph G. Musah

Department of Agricultural Economics
Oklahoma State University
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Representative farm planning mathematical programming models are useful tools by which agricultural resource allocation problems can be addressed and analyzed. In this paper we report on efforts to develop a mathematical programming model for a representative Liberian farm and present results of the model.

Resource Base of Representative Farm

The modeled resource constraints for the representative farm include labor by month by sex, land, family (internal) operating capital, and government credit restrictions. A farm family of three adults and four children is assumed to be able to provide 50 days of male labor and 50 days of female labor per month for agricultural production and marketing. Labor requirements for household production activities are not included in the model. In addition, labor activity is not adjusted for the impact of weather on days available for field work. Activities are included which permit the purchase of male labor for each month. Each unit of purchased male labor costs $2.50 per day.

Ten acres of land are available for the production of annual crops and tree crops. Land is not differentiated by quality. Thus an implicit assumption included in the model is that land availability is not a major limitation or determinant of farm family production in the region.

The typical farm family is assumed to have an annual operating capital base of $170. An additional $1,000 can be borrowed from

government sources at an annual interest rate of 15 percent. An unlimited quantity of operating capital can be borrowed from private sources at an annual interest rate of 30 percent.

Family Subsistence Requirements

Annual family consumption demands are included for rice (1,880 pounds), cassava (270 pounds), okra (96 pounds), pepper (128 pounds), bitter balls (96 pounds), sugar cane juice (20 gallons), and palm oil (24 gallons). The model is structured such that all of these demands with the exception of rice, must be met by production on the farm. Rice can be purchased off the farm at a price of $0.30 per pound. No additional family consumption requirements are included in the model. In addition, alternative uses of family resources are not included. For example, off-farm employment of labor and other resources is not considered.

Farm Production Activities

Production activities are included in the model for rice, okra, peppers, bitter balls, cassava, cocoa, coffee, sugar cane, rubber, cultivated palm, and indigenous palm. One activity is included for single cropped rice. In addition, rice can be produced by intercropping with okra, peppers, bitter balls, or cassava, or rice can be produced in a two year rotation with rice and cassava in the first year followed by a one year crop of sugar cane.

As noted, okra, peppers, bitter balls, cassava, and sugar cane

can be produced in combination with rice. In addition, activities are included which will permit the production of these five crops independently.

Activities are also included for the production of cocoa, coffee, rubber, and cultivated palm. Resource requirements and production for these crops are annualized over the expected life of the plant. In other words, resource requirements for establishment, including brush cutting, burning, and clearing, are incorporated into the activities.

The indigenous palm activities depend upon the collection of fruits from indigenous trees. Indigenous palm production activities are included for each month. Each activity requires one hour of male labor, and one hour of female labor, and generates 2.5 gallons of palm oil.

Resource Requirements, Yields, and Prices

Table 1 includes estimates of the variable "cash" production costs, the labor requirements by month and the annual operating capital requirements for each of the production activities. These data were acquired from various sources by Mr. J. G. Musah. Crop yields and prices used in the model are included in Table 2.

Production and Sales Restrictions

Sales of palm oil are restricted to seven gallons per year. In addition, off-farm sales of cassava are restricted to 81 pounds per year. These levels were based upon the assumption that neither of these commodities could be exported in commercial quantities.

Table 1. Production Costs and Labor and Annual Operating Capital Requirements for the Production Activities Per Acre

	Rice Okra	Rice/ Peppers	Rice/ Bitter Balls	Rice/ Cassava	Rice	Cassava	Cocoa	Coffee	Sugar Cane	Okra	Peppers	Bitter Balls	Rubber	Rice/ Cassava/ Sugar Cane	Palm
Production Costs ($)	57.50	57.50	57.50	57.50	45.61	8.65	21.11	22.10	144.58	3.85	4.01	3.41	62.00	101.04	27.00
Male Labor (days)															
JAN	6.00	6.00	6.00	6.00	3.00	:	1.36	1.36	:	:	:	:	5.05	3.0	:
FEB	8.00	8.00	8.00	8.00	:	8.00	.80	1.20	10.00	:	:	:	6.18	4.00	:
MAR	5.00	5.00	5.00	5.00	10.00	12.00	.44	.44	18.00	:	:	:	5.24	10.50	5.60
APR	11.00	11.00	11.00	11.00	4.00	5.00	2.00	2.04	20.00	:	:	:	5.16	12.00	.50
MAY	10.00	10.00	10.00	10.00	7.00	:	.80	.60	20.00	:	:	:	6.38	12.50	5.40
JUN	10.00	10.00	10.00	10.00	5.00	:	1.24	1.24	4.00	:	:	:	7.29	5.00	1.50
JUL	:	:	:	:	3.50	:	.56	.40	:	:	:	:	5.19	:	2.40
AUG	:	:	:	:	2.00	:	.68	.28	:	:	:	:	4.91	:	:
SEP	1.00	1.00	1.00	1.00	:	:	1.00	1.20	:	:	:	:	6.16	.50	1.50
OCT	2.00	2.00	2.00	2.00	:	:	.60	.52	:	:	:	:	4.91	1.00	1.00
NOV	2.00	2.00	2.00	2.00	2.00	:	1.04	1.60	:	:	:	:	8.41	1.00	5.50
DEC	:	:	:	:	5.00	2.00	.40	.28	3.00	:	:	:	5.19	1.50	:
Female Labor (days)															
JAN	2.00	2.00	2.00	2.00	7.00	:	:	:	:	7.50	7.50	7.50	:	1.00	:
FEB	:	:	:	:	5.00	:	:	:	:	:	:	:	:	:	:
APR	5.00	5.00	5.00	5.00	:	:	:	:	:	10.00	10.00	10.00	:	2.50	:
MAY	4.00	4.00	4.00	4.00	:	:	:	:	:	10.00	10.00	10.00	:	2.00	:
JUN	3.00	3.00	3.00	3.00	3.00	10.00	:	:	:	:	:	:	:	1.50	:
JUL	7.00	7.00	7.00	7.00	3.00	6.00	:	:	:	:	:	:	:	3.50	:
AUG	6.00	6.00	6.00	6.00	4.00	4.00	:	:	:	:	:	:	:	3.00	:
SEP	2.00	2.00	2.00	2.00	8.00	:	.60	:	:	8.00	8.00	8.00	:	1.00	:
OCT	8.00	8.00	8.00	8.00	4.00	:	.80	.20	:	20.00	20.00	20.00	:	4.00	:
NOV	6.00	6.00	6.00	6.00	6.00	:	.80	.80	:	:	:	:	:	3.00	:
DEC	6.00	6.00	6.00	6.00	10.00	:	.48	.20	:	:	:	:	:	3.0	:
Annual Operating Capital($)	28.75	28.75	28.75	28.75	26.60	6.49	10.55	11.05	10.31	.96	2.00	.85	22.00	19.53	:

Table 2. Estimated Yields (per acre) and Product Prices.

Activity	Yield	Price($)
Rice/	960 lbs.	.12/lb.
Okra	100 lbs.	.11/lb.
Rice/	960 lbs.	.12/lb.
Peppers	150 lbs.	.10/lb.
Rice/	960 lbs.	.12/lb.
Bitter Balls	100 lbs.	.10/lb.
Rice/	960 lbs.	.12/lb.
Cassava	3,000 lbs.	.05/lb.
Rice	1,100 lbs.	.12/lb.
Cassava	6,000 lbs.	.05/lb.
Cocoa	400 lbs.	.45/lb.
Coffee	450 lbs.	.55/lb.
Sugar Cane	80 gals.	5.00/gal.
Okra	800 lbs.	.11/lb.
Peppers	800 lbs.	.10/lb.
Bitter Balls	800 lbs.	.10/lb.
Rubber	985 gals.	.32/gal.
Rice/	480 lbs.	.12/lb.
Cassava/	1,500 lbs.	.05/lb.
Sugar Cane	40 gals.	5.00/gal.
Palm	5.5 tons	30.00/ton

Mathematical Programming Model

The objective function of the model is to maximize annual returns to family labor, land, and family capital, subject to the family consumption demands. A pictorial description of the model is included in Table 3. It includes 46 rows and 60 real activities. The model includes 15 crop production activities and 12 activities for the production of oil from indigenous palm. Eleven selling activities permit off-farm sales of the commodities. Male labor purchase activities are included for each month. Two capital acquisition activities permit the borrowing of government or private operating capital. One activity is included to enable the purchase of rice to meet family demands in excess of production, and seven activities are included to facilitate the transfer of commodities from production activities to family demands.

A labor row is included for each month for both male and female labor. One row is included to constrain land use to ten acres. One constraint restricts annual operating capital use. Eleven transfer rows facilitate the transfer of commodities from the production activities to uses. Seven rows are included to force the model to meet the family consumption requirements for rice, okra, peppers, bitter balls, cassava, sugar cane juice, and palm oil.

Results of Base Model

Production levels for the optimal farm plan are included in Table 4. The plan generates a return to the family resources of $1,761. Production levels for rice (1.724 acres), sugar cane (0.25 acres),

a'le 3. Historial Description of Iberian Farm Model

		RICEOK	RICEPE	RIBLPS	RSWPSA	CAOCIV	COFAAE	SOCFEA	OKRA	PEPARL	BABLSR	RUBSC	RICSLM	PPOAJN	PPOEBR	PPOAFR	PPOMAY	PPOAMN	PPOJUB	PPOJUL	PPOUGP	PPOAST	PPOOTV	PPOOCL	PIEEEL	ROEEEL	PKEEEL	PPLEEL	BSEEEL	CLEEEL	CFEEEL	OOEEEL	PCEEEL	BUEEEL	PAEEEL	PPSEEL	OLSEEL	OMSEEL	JMMELL	FMMELL	RMMELL	AMMELL	YMMELL	JMMELL	JMMELL	LMMELL	GMMELL	SMMELL	OMMELL	NMMELL	DMMELL	VTMCBA	OTRCYP	RIRECW	OIRECR	OKTCT	PECTR	BCTTR	CVTTR	SCTTR	PCTRR	B
	N	-B	-B	-B	-B	-B	-A	-B	-B	-C	-A	-A	-A	-3	-C	-B	-T	-T	-T	-T	-T	-T	-T	-T	-T	-T	-T	-T	T	T	U	U	U	T	T	A	T	B	A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-T	-T	-T							
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STR	L				-D		-D								-D															1																												
OATR	L							-C																							1																											
FETR	L								-C																							1																									
NETR	L									-B					-B																		1																								
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Table 4. Production Levels for Optimal Farm Plan.

Production Activity	Acres	Quantity Produced	Family Consumption	Sales
Swamp Rice	1.607	1880.000 lbs.	1880.00	
Coffee	2.582	1161.857 lbs.		1161.857
Sugar Cane	.133	10.64 gals.	10.64	
Okra	.12	96.00 lbs.	96.00	
Pepper	.16	128.00 lbs.	128.00	
Bitter Balls	.12	96.00 lbs.	96.00	
Rubber	5.044	4968.451 lbs.		4968.451
Rice/	.117	112.32 lbs.	112.32	
Cassava-		351.00 lbs.	270.00	81.000
Sugar Cane	.117	9.36 gals.	9.36	
Palm Oil	Gallons			
April	17.022	17.022 gals.	10.022	7.000
September	13.978	13.978 gals.	13.978	

okra (0.12 acres), peppers (0.16 acres), and bitter balls (0.12 acres) are at the minimum quantities to fulfill family consumption requirements. Production of cassava (0.117 acres intercropped with rice) and palm oil (from indigenous palm) is restricted to the maximum permissable levels. Production in excess of 351 pounds of cassava and 31 gallons of palm oil is not permitted. The remaining acreage is planted to coffee and rubber. The optimal plan includes 2.582 acres of coffee and 5.044 acres of rubber.

A summary of labor and capital utilization is included in Table 5. All fifty days of male family labor are utilized in the months of April, May, and November. However, hired male labor is utilized in only the month of April and only 0.56 of one day is hired. The optimal plan indicates that if fifty days of female labor are available in each month (and the weather does not limit field days) for the farm production activities, female labor is not a constraining resource. In fact, during the month of September, female labor requirements peak at 21.88 days per month. Again we note that the model does not include any household labor requirements and does not have provisions for capturing the influence of weather on days available for field work.

The results of the model indicate that operating capital is not a severe limitation to agricultural production. All $170 of family capital is used. However, only $18.72 is borrowed from government sources. Since the cost of borrowing from private sources exceeds the cost of borrowing from the government, all of the requirement for borrowed capital is met from government sources.

Table 5. Labor and Capital Summary of Optimal Farm Plan

	Male Labor (Days)			Female Labor (Days)	
	Used	Slack	Hired	Used	Slack
January	34.51	15.49		14.48	35.52
February	36.53	13.46		8.03	41.97
March	48.49	1.51		0.00	50.00
April	50.00	0.00	0.56	11.39	38.61
May	50.00	0.00		4.47	45.53
June	49.71	0.29		5.17	44.83
July	32.84	17.16		5.64	44.36
August	28.70	21.30		7.13	42.87
September	39.88	10.12		21.88	28.12
October	26.34	23.66		15.88	34.12
November	50.00	0.00		12.41	37.59
December	35.69	14.31		17.29	32.71

(Household production labor is not included in the model.)

Capital Summary

	Quantity($)	Rate
Provided by family	170.00	
Borrowed from government	18.72	15%
Borrowed elsewhere	0	30%

Sensitivity analysis for the results is included in Table 6. Ten acres of land are available for crop production. The shadow price of land is estimated to be $219.49 per acre. This price is valid over a range from 8.4 to 10.7 acres. This finding indicates that the model may not adequately represent the situation. Land availability was not assumed to be a major constraint to production.

Family demand requirements were included for seven commodities. Only two of the commodities (cassava and palm oil) would be produced on the farm if production had not been required. Thus production of five of the seven required commodities "penalizes" the value of the objective function. The income penalty associated with rice is $0.264 per pound and is valid over the range from 1,777 to 1,974 pounds. This finding suggests that if rice could be purchased off the farm at some price less than $0.26 per pound, the farm family would be better off purchasing rice and producing some other commodity. Of course, this is contingent upon the ability of the model to properly represent the situation.

Minimum okra production was set at 96 pounds. The income penalty of $0.279 per pound for okra is valid over the range from zero to 1,374 pounds. Similarly, income penalties for peppers ($0.28 per pound), bitter balls ($0.279 per pound), and sugar cane ($5.195 per gallon) range from zero to 1,406 pounds for peppers, zero to 1,374 pounds for bitter balls, and 18 to 26 gallons for sugar cane juice. Thus, the shadow prices for rice, okra, peppers, and bitter balls are more than double the farm gate market prices. The shadow price for sugar cane is only $5.195 per gallon compared with a farm gate market

Table 6. Range Analysis for Selected Resources and Activities

		Shadow Price	Range
Land	10 acres used	219.49	8.4 to 10.7

Family Requirements

		Income Penalty	
Rice	1880 lbs.	.264	1777 to 1974
Okra	96 lbs.	.279	0 to 1374
Pepper	128 lbs.	.28	0 to 1406
Bitter Balls	96 lbs.	.279	0 to 1374
Sugar Cane	20 gls.	5.195	18 to 26
Cassava	270 lbs.	0	
Palm Oil	24 gls.	0	

The income penalty is the cost per unit for the requirement. For example the requirement to produce 96 lbs. of okra penalizes (cost) the value of the objective function by 96 x $0.279 or $26.784.

Items not Produced in Excess of Family Requirements

	Market Price	Shadow Price
Rice	.12/lb.	.264
Okra	.11/lb.	.279
Pepper	.10/lb.	.28
Bitter Balls	.10/lb.	.279
Sugar Cane	5/gal.	5.195
Cocoa	.45/lb.	.615
Cultivated Palm	30/ton	48.99

These shadow prices indicate the market price level that would increase the production of these items such that some could be produced for commerical sales.

Items Produced for Sale

Cassava — Sales restricted to 81 pounds. Production limited to 351 pounds. Income penalty is $0.035/lb. over the range from 351 to 750 lbs., at a market price of $0.05/lb.

Palm Oil — Sales restricted to 7 gallons. Production limited to 31 gallons. Income penalty is $3.74/gal. over the range from 31 to 56 gals., at a market price of $4.00/gal. This production is from indigenous palm.

Coffee	1161 lbs.	1140 to 1206
	$0.55/lb.	0.538 to 0.576
Rubber	4968 gals.	4872 to 5016

price of $5. The shadow price of cocoa is $0.165 per pound greater than the market price of $0.45 per pound. And, the shadow price of cultivated palm is $18.99 per ton greater than the market price of $30 per ton.

Family consumption requirements for cassava are set at 270 pounds. Off-farm sales are restricted to 81 pounds at $0.05 per pound. This restriction on off-farm sales penalizes the objective function $0.035 per pound over the range from 351 to 750 pounds.

Off-farm sales of indigenous palm oil is restricted to seven gallons at a farm gate market price of $4.00 per gallon. Family requirements are 24 gallons. Thus, production is restricted to 31 gallons. The income penalty associated with this restriction is $3.74 per gallon over the range from 31 to 56 gallons.

Results of Model with 25 days of Male and Female Labor per month

Experienced observers of typical Liberian farms contend that agricultural output is restricted by labor availability. The base model does not validate this contention. As noted, labor availability does not account for the influence of weather on available days for field work. To test the influence of a reduction in the number of available days, the model was solved with 25 (rather than 50) days of labor available from both sexes in each month. Table 7 includes a summary of labor use for the revised model. The 25 days of male labor is completely utilized in the months of January, March, April, May, and November. Additional male labor is hired in the months of March and April. The 25 days of female labor are not totally utilized in any month.

Table 7. Labor Summary of Optimal Farm Plan with 25 days of Male and Female Labor Per Month

	Male Labor (Days)			Female Labor (Days)	
	Used	Slack	Hired	Used	Slack
January	25.00	0.00		21.30	3.70
February	14.51	10.49		8.03	16.97
March	25.00	0.00	2.26	0.00	25.00
April	25.00	0.00	4.39	4.58	20.42
May	25.00	0.00		4.47	20.53
June	22.95	2.05		5.17	19.83
July	11.65	13.35		5.64	19.36
August	8.22	16.77		7.13	17.87
September	12.82	12.18		16.76	8.24
October	6.92	18.07		16.76	8.24
November	25.00	0.00		21.07	3.93
December	13.97	11.03		18.17	6.83

(Household production labor is not included in the model.)

Table 8 includes a summary of the optimal organization of the farm with 25 days of labor per month. Production levels for rice, sugar cane, okra, pepper, bitter balls, cassava, and indigenous palm oil are not different from those with 50 days of labor. When the labor availability is reduced, production of coffee increases by 4.4 acres and production of rubber decreases by 4.4 acres. Returns to the family resources decrease from $1,761 per year to $1,626 per year. The shadow price of rice increases from $0.264 to $0.281.

Results of Model with Unlimited Family Labor and Reservation Wage of $0.50 per Day

In the previous two models, available family labor is utilized up to the point were the marginal value of labor is zero. In other words, family labor is assumed to be a fixed resource with a short run marginal cost of zero, and would be utilized as a "free" resource. However, an individual's utility function depends upon leisure as well as the goods derived from work. If the utility derived from leisure is positive, family members would prefer leisure to work at some reservation wage. If the returns from work are less than the reservation wage, family members would not work. A reservation wage of $0.50 per day was incorporated into the model for both male and female labor. Quantity of family labor was not restricted.

Labor utilization for the model is presented in Table 9. The option to purchase male labor is not included in the model. However, this does not influence the results which show that 27 days of male labor would be utilized in April. However, requirements are less than

Table 8. Production Levels for Optimal Farm Plan with 25 days of Male and Female Labor per month.

Production Activity	Acres	Quantity Produced	Family Consumption	Sales
Swamp Rice	1.607	1880.000 lbs.	1880.00	
Coffee	7.005	3152.170 lbs.		3152.170
Sugar Cane	.133	10.64 gals.	10.64	
Okra	.12	96.00 lbs.	96.00	
Pepper	.16	128.00 lbs.	128.00	
Bitter Balls	.12	96.00 lbs.	96.00	
Rubber	0.621	611.879 lbs.		611.879
Rice/	.117	112.32 lbs.	112.32	
Cassava-		351.00 lbs.	270.00	81.000
Sugar Cane	.117	9.36 gals.	9.36	
Palm Oil	Gallons			
January	17.034	17.034 gals.	10.034	7.000
September	1.166	1.166 gals.	1.166	
November	12.800	12.800 gals.	12.800	

Table 9. Labor Summary for Optimal Farm Plan for Unlimited Family Labor with Reservation Wage of $0.50 per day and 10 acres of land.

	Male Labor (Days) Used	Female Labor (Days) Used
January	15.89	14.48
February	23.82	20.43
March	24.27	0.00
April	27.45	4.58
May	21.41	4.47
June	19.19	5.17
July	8.67	5.64
August	5.35	7.13
September	9.27	16.29
October	4.20	16.89
November	15.65	16.44
December	10.92	18.30

(Household production labor is not included in the model.)

25 days in all of the other months. Maximum female labor requirements occur in February when 20 days are utilized.

Production levels for the cropping activities are included in Table 10. The results are almost identical with those of Table 8 which include results when no reservation wage is imposed on the family labor. The imposition of the reservation wage reduces the production of rubber from 0.62 to zero acres and increases the production of coffee by the same acreage. Rubber production is more labor intensive than coffee production, and is not economical with the reservation wage of $0.50 per day.

The model indicates that with a reservation wage, coffee is the most economical tree crop alternative. The market price of coffee is $0.55 per pound. The model results would not change if the price of coffee fell to $0.548 or rose to $0.593. If the price of coffee fell to $0.45 per pound coffee production would drop only slightly from 7.63 to 7.09 acres. Interestingly, if the price of coffee declines to $0.45 per pound, rice production would decline and cultivated palm production would enter the optimal plan. If the coffee price were decreased to $0.40 per pound, cocoa (at $0.45 per pound) would replace coffee in the optimal farm plan, but rice production would still be less than that required for family consumption. If the price of coffee was $0.40 (compared to the original budgeted price of $0.55) and the price of cocoa was $0.30 per pound (versus the original budgeted price of $0.45), coffee would still be the preferred crop and some of the rice consumption demand would be fulfilled with off-farm purchases at $0.30 per pound for rice.

Table 10. Production Levels for Optimal Farm Plan with Unlimited Family Labor with Reservation Wage of $0.50 per day and 10 acres of land.

Production Activity	Acres	Quantity Produced	Family Consumption	Sales
Swamp Rice	1.607	1880.000 lbs.	1880.00	
Coffee	7.626	3152.170 lbs.		3431.708
Sugar Cane	.133	10.64 gals.	10.64	
Okra	.12	96.00 lbs.	96.00	
Pepper	.16	128.00 lbs.	128.00	
Bitter Balls	.12	96.00 lbs.	96.00	
Rice/	.117	112.32 lbs.	112.32	
Cassava-		351.00 lbs.	270.00	81.000
Sugar Cane	.117	9.36 gals.	9.36	
Palm Oil	Gallons			
January	31.0	31.0 gals.	24.00	7.000

Results of Model with Unlimited Land, Reservation Wage of $0.50 per day, and 25 days of Male and Female Labor per Month

In the three previous models land resources were restricted to ten acres. In this model the limit on land is lifted. In addition, male and female labor is restricted to 25 days each per month and the reservation wage is maintained at $0.50 per day. Labor utilization for the model is included in Table 11. All 25 days of male labor is utilized in the months of April, September, and November. Female labor is totally utilized only in the month of October.

Optimal cropping for the model is included in Table 12. The optimal farm plan requires 12.48 acres of land. Given the resources and limits on labor, additional land would not add to the income of the family. Virtually all of the rice required for family consumption is purchased from off-farm sources at $0.30 per pound. The 1.6 acres utilized in all three previous models for the production of rice is diverted to other crops. Coffee production is increased to 9.2 acres. However, the major difference between this model and the previous models is that 1.8 acres are allocated to the production of cultivated palm. In previous models cultivated palm was not included in the optimal farm plan.

Coffee production would be included in the optimal plan at the same level (9.2 acres) over a price range of $0.45 to $0.59 per pound. In other words, if land is not a limiting resource, and if family labor is restricted to 25 days each of male and female labor per month with a reservation wage of $0.50 per day, coffee production would be a preferred activity even if the price fell to $0.45 per

Table 11. Labor Summary of Optimal Farm Plan with 25 days of Male and Female Labor Per Month with Reservation Wage of $0.50 per day and Unlimited Land.

	Male Labor (Days)	Female Labor (Days)
January	13.02	8.60
February	14.60	1.27
March	19.13	0.00
April	25.00	11.67
May	20.91	11.58
June	15.68	0.27
July	8.09	0.63
August	2.57	0.54
September	25.00	20.29
October	6.79	25.00
November	25.00	7.88
December	3.32	2.38

(Household production labor is not included in the model.)

Table 12. Production Levels for Optimal Farm Plan with 25 days of Male and Female Labor per month with Reservation Wage of $0.50 per day and Unlimited Land.

Production Activity	Acres	Quantity Produced	Family Consumption	Sales
Coffee	9.176	4129.031 lbs.		4129.031
Sugar Cane	.160	12.80 gals.	12.80	
Okra	.842	673.60 lbs.	96.00	577.600
Pepper	.16	128.00 lbs.	128.00	
Bitter Balls	.12	96.00 lbs.	96.00	
Rice/	.090	86.40 lbs.	86.40	
Cassava-		270.00 lbs.	270.00	
Sugar Cane	.090	7.20 gals.	7.20	
Cultivated Palm	1.843	10.14 tons		10.14
Palm Oil	Gallons			
February	3.165	3.165 gals.	3.165	
September	27.835	27.835 gals.	20.835	7.000
Rice Purchased	Pounds		1793.60	

pound. (All other prices, yields, and input-output coefficients are assumed to be held constant.) On the other hand, the price of cocoa would have to be increased from the budgeted level of $0.45 per pound to $0.59 before production of cocoa would enter the optimal farm plan. Similarly, with labor limited, the price of rubber would have to increase from the budgeted level of $0.32 per pound to $0.72 before it would be a preferred alternative. Thus, the results of the model indicate that production of coffee is preferred to production of cocoa or rubber. Again we note that these results are derived from the relationships incorporated in the coefficients of the model. Changes in relative prices, yields, and input-output coefficients may alter the results and the conclusions drawn from the analysis. The importance of verifying the technical coefficients, especially for coffee production, can not be overemphasized.

Conclusions

A mathematical programming model was constructed to represent a typical Liberian family farm. Production activities were included for rice, okra, peppers, bitter balls, cassava, cocoa, coffee, sugar cane, rubber, cultivated palm, and indigenous palm. Family consumption requirements were included for rice, okra, peppers, bitter balls, sugar cane, cassava, and palm oil. The model was structured to permit purchases of rice from off-farm sources. However, all other family requirements are forced to be fulfilled from on-farm production. Family resources in excess of those required to meet family consumption demands were permitted to be allocated to the production of crops for sale.

Four alternative resource combinations were considered. For all situations analyzed, the production of rice, peppers, bitter balls, and sugar cane juice in excess of family requirements is not economical. Production of cassava, and palm oil from indigenous palm, was restricted to levels considered to be appropriate for domestic consumption. If family labor is plentiful (50 days of male and female labor per month) and land is limited to 10 acres, the production of coffee and rubber is indicated. However, if family labor is restricted to 25 days per month from each of the sexes, and a reservation wage of $0.50 per day is imposed, coffee production expands and rubber production ceases.

If land is not a limiting resource, the optimal farm plan would include more than 9 acres of coffee and almost 2 acres of cultivated palm. Most of the family rice requirements would be purchased from off-farm sources. The major conclusion to be drawn from the modelling effort is that production of tree crops, especially coffee, offer more potential for improving the economic well being of Liberian farm families, than rice production.

All results are contingent upon the reliability and validity of the data used in the model. In addition, the family decision makers are assumed to be risk neutral and to possess the technical skills necessary to produce the alternative crops. It is suggested that the coefficients in the model be refined by farm management workers in Liberia as additional information becomes available.