https://doi.org/10.29321/MAJ.10.A03506

Optimum Resource Allocation for Maximising Farm Income

by

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Introduction: Increasing agricultural production is crucial for overall economic development of India. Agriculture received high priorities in the Five Year Plans and efforts were not lacking in organising a big push in Agriculture. Various schemes both technological and institutional have been implemented. However, shortages in supply of farm products exist and a major section of farms remain inefficient. Of the many causes attributed, the inefficient allocation of scarce resources of the farms among competing enterprises needs careful examination. It is reckoned that farmers can reach higher levels of efficiency in production even with present resources and technology by careful farm planning. The farm planning approach endeavours to put each resource of the farmer to the best use.

Objective: Income is plausibly a measure of efficiency of operating a farm and maximising the profit is the goal. Hence the objective of the study was set to determine through linear programming the optimum farm plan that would maximise farm income with the existing resource and technology. The working hypothesis assumed was that farmers of the region under study could reach higher levels of efficiency in production even with present resources and technology.

Methodology: The study was conducted in Sarkar-Samakulam Block, Coimbatore Taluk, Tamil Nadu since it formed a homogenous area with regard to soil type, resource availability and cropping pattern. For the purpose of the field investigations a two stage random sampling procedure was adopted. First eight villages were selected at random from among the thirteen villages in the Block, then from the selected villages sixty four farmers were selected at random under small and large size-groups.

Of the three familiar methods of analysis, *viz.* the marginal analysis, budgeting, and the technique of linear programming the last one was used since it could be used with better advantage for handling problems of large dimensions having many resource constraints and alternate enterprises.

The data for input matrix resource restrictions and supplies and prices were collected from the selected farms by survey method. The study was made under synthetic farm situation formed by taking average of 32 farms in each size-group.

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By examining the resource requirements and resource supply for different seasons the resources were classified as follows:

Land: (i) July–October land (P_{13}), (ii) November–February land (P_{14}), (iii) March–June land (P_{15}) and (iv) Dry land (P_{16}).

Labour: (i) August or July labour (P_{17}), (ii) November or December labour (P_{18}) and (iii) March labour (P_{19}).

Irrigation: (i) September Irrigation (P_{20}), (ii) December irrigation (P_{21}) and (iii) May irrigation (P_{22}).

The above resources were decided to be most limiting resources deciding the enterprise combinations.

Keeping in mind their technical feasibility and product acceptance twelve processes or enterprises were selected for programming after running several trial programmes. For input matrix the resource requirements per unit of enterprise were estimated. The net value product (per acre) of each of the enterprises was calculated from the cost of production and market price of the commodity.

With (1) resource availability, (2) input matrix and (3) net value product a linear programming problem for maximising the income of the farms was formulated.

$$Zo = \sum_{i=1}^{n} x_i v_i$$

Where Zo = Income level of the farm

x_i = activity level

v_i = net value product of the unit activity

Subjected to:

$$\sum_{ij} a_{ij} x_i \leq B_j ; \quad \begin{matrix} i = 1, 2, 3, \ \ldots \ M \\ j = 1, 2, 3, \ \ldots \ m \end{matrix} \qquad (1)$$

Where a = resource requirement for an activity

B = total resource available in the farms

and

$$x_i \geq 0 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

Results and Discussion: The problem was solved by the 'Simplex Method'. The initial tableau and final tableau with optimal solutions for small and large farms are given in Appendix I. The optimal crop-mix, as can be seen increased the farm income by 5.71 per cent for small farms and 21.12 per cent for large farms and were more efficient when judged with farming efficiency measures. The present crop plan of the farmer and the optimum crop plan derived by linear programming are given in Appendix II.

APPENDIX I (a)

Technological Matrix and Simplex solution for programming (small farm)

INITIAL MATRIX

	Notation	Resource availability	C_j	2923	1226	1756	356	281	942	703	651	374	942	511	555
				Real Activities											
				P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
July–October Garden land	P_{13}	5.60		1.00	1.00	1.00	1.00								
November–February Garden land	P_{14}	5.60		1.00	1.00	1.00	1.00	1.00	1 00						
March–June Garden land	P_{15}	5.60		1.00						1.00	1.00	1.00	1.00		
Dry land	P_{16}	0.66												1.00	1.00
August Mandays	P_{17}	53.00		3.70	17.97	4.13	1.12							0.86	0.56
December Mandays	P_{18}	53.00		4.50	9.86	4.56		1.00	4.00					1.43	1.50
March Mandays	P_{19}	53.00		4.96		0.85				7.40	2.98	4.00	4.00		
September Irrigation	P_{20}	11.15		3.00	8.00										
December Irrigation	P_{21}	11.55		3.00	8.00	2.00			2 00						
May Irrigation	P_{22}	10.00		3.00						3.00	2 00	2.00	3.00		
$Z_j - C_j$				−2923	−1226	−1756	−356	−281	−942	−703	−651	−374	−942	−511	−55

0	0	0	0	0	0	0	0	0	0		
Disposal Activities											
P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}		
1.00											
	1.00										
		1.00									
			1.00								
				1.00							
					1.00						
						1.00					
							1.00				
								1.00			
									1,00		

APPENDIX I (a) *Contd.*

FINAL SOLUTION

	Notation	Resource availability	C_j	2923	1226	1756	356	281	942	703	651	374	942	511	555
				Real Activities											
				P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
July–October Garden land	P_{13}							-1.00	-1.00						
Chithirai Cholam	P_8	4.48			-9.00		3.00	3.00		1.50	1.00	1.00	1.50		
March–June Garden land	P_{15}	0.77			3.00		-1.00	-1.00		0.50			-0.50		
Cholam + Redgram	P_{12}	0.67												1.00	1.0
August Mandays	P_{17}	29.65			16.42		-3.87	-4.99	-4.13					0.30	
December Mandays	P_{18}	26.49			5.66		-4.68	-3.68	-0 56					-0.70	
March Mandays	P_{19}	33.47			1.31		-1.57	-1.57	-0.85	2 93		1.02	-0.47		
September Irrigation	P_{20}	4.85			-5 00		3.00	3.00	-1.00						
Cotton MCU 1	P_9	5.25			-5.00	1.00	3 00	3.00	1.00						
Sugarcane	P_1	0.35	1.00		6.00		-2.00	-2.00							
$Z_j - C_j$		13521.55			1673.05		1018.98	1093.98	814.00	273.49		277.00	34.47	44.00	

0	0	0	0	0	0	0	0	0	0
Disposal Activities									
P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}
1.00	-1.00								
	3.00							-1.50	0.50
	-1.00	1.00						0.50	-0.50
			1.00						
	-4.99		-0.56	1.00				0.43	
	-4.68		-1.50		1.00			0.06	
	-1.57					1.00		0 36	-1.49
	3 00						1 03	-2.00	
	3.00							-1 00	
	-2 00							1.00	
	1374.98		555.00					190.51	325.49

NOTE: P_1 = Sugarcane, P_2 = Paddy, P_3 = Cotton, P_4 = Dry cholam, P_5 = Bengal gram P_6 = Maize II season, P_7 = Ragi, P_8 = Chithirai cholam. P_9 = Cumbu, P_{10} = Maize III season. P_{11} = Cholam + Green gram + Mochai, P_{12} = Cholam + Green gram + Red gram.
Blanks in co-ordinate columns indicate zeros; all figures are corrected up to two decimals.

APPENDIX I (b)

Technological Matrix and Simplex Solution for Programming (Big Farms)

INITIAL MATRIX

	Notation	Resource availability	C_j	3074	1252	2058	380	978	332	743	647	843	961	692	738
				Real Activities											
				P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
July-October Garden land	P_{13}	14.71		1.00	1.00	1.00	1.00								
November-February Garden land	P_{14}	14.71		1.00	1.00	1.00	1.00	1.00	1.00						
March-June Garden land	P_{15}	14.71		1.00						1.00	1.00	1.00	1.00		
Dry land	P_{16}	5.34												1.00	1.00
July Mandays	P_{17}	94.00		2.77	5.28	3.47	1.85							0.63	1.42
November Mandays	P_{18}	90.00		3.82	9.03	3.96		3.00	3.24						
March Mandays	P_{19}	94.00		3.57		1.91	2.00	0.83		7.25	7.24	7.00	4.67	0.80	1.78
September Irrigation	P_{20}	25.55		3.00	8.00	1.00									
December Irrigation	P_{21}	26.46		3.00	8,00	2.00		2.00							
May Irrigation	P_{22}	23.82		3.00						3.00	2.00	3.00	3.00		
$Z_j - C_j$				-3074	-1252	-2058	-380	-978	-332	-743	-647	-843	-861	-692	-738

0	0	0	0	0	0	0	0	0	0
Disposal Activities									
P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}
1.00									
	1.00								
		1.00							
			1.00						
				1.00					
					1.00				
						1.00			
							1.00		
								1.00	
									1.00

APPENDIX 1 (b) *Contd.*

FINAL SOLUTION

	Notation	Resource availability	C_j	3074	1252	2058	380	978	332	743	647	843	961	692	738
				Real Activities											
				P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
July-October Garden land	P_{13}							−1.00	−1.00						
Dry Cholam	P_4	1.48		−0.50	−3.00		1.00		1.00						
March-June Garden land	P_{15}	5.22		0.24	0.13			0.09	0.16	−0.21		−0.19		0.08	
Cholam + Red gram	P_{12}	5.34												1.00	1.00
July Mandays	P_{17}	37.75		−1.51	−3.06			−3.47	−1.85					0.80	
November Mandays	P_{18}	37.60		−2.12	−6.81			0.96	3.24						
Chithirai Cholam	P_8	4.65		−7.20	−0.40			−0.26	−0.48	0.63	1.00	0.57		−0.24	
September Irrigation	P_{20}	12.32		1.50	4.00			−1.00							
Cotton MCU 1	P_3	13.23		1.50	4.00	1.00		1.00							
Maize III Season	P_{10}	4.84		1.48	0.27			0.17	0.32	0.58		0.62	1.00	0.16	
$Z_j - C_j$		39391.24		779.45	5837.46			1078.34	44.94	221.95		114.43		44.51	

0	0	0	0	0	0	0	0	0	0		
Disposal Activities											
P_{13}	P_{14}	P_{16}	P_{19}	P_{17}	P_{18}	P_{15}	P_{20}	P_{21}	P_{22}		
1.00	−1.00										
	1.00							−0.50			
	0.16	1.00	0.14			−0.08		−0.00	−0.21		
			1.00								
	−1.85		−1.42	1.00				−0.81	0.00		
					1.00			−1.98	0.00		
	−0.48		−0.43			0.24		0.01	−0.38		
							1.00	−0.50	0.00		
								0.50			
	0.32		0.29			−0.16		−0.01	0.58		
	376.94		735.27					839.07	317.94		

NOTE: P_1 = Sugarcane, P_2 = Paddy, P_3 = Cotton, P_4 = Dry cholam, P_5 = Maize II, P_6 = Bengal gram, P_7 = Ragi, P_8 = Chithirai cholam, P_9 = Cumbu, P_{10} = Maize III, P_{11} = Cholam + Green gram + Mochai, P_{12} = Cholam + Green gram + Red gram.
Blanks in co-ordinate columns indicate zeros; all figures are correlated up to two decimals.

APPENDIX II

Comparison of present and optimum plan

Crop enterprise	Present cropping plan				Optimum cropping plan			
	I season	II season	III season	Dry land	I season	II season	III season	Dry land
SMALL FARM:								
Garden land								
Sugarcane	1.02	1.02	1 02	—	0.35	0.35	0.35	—
Cotton MCU. 1	3.05	3.05	—	—	5.25	5.25	—	—
Paddy	0.11	0.11	—	—	—	—	—	—
Vegetables	0.12	0.12	0.13	—	—	—	—	—
Dry cholam	0.48	0.48	—	—	—	—	—	—
Chithirai cholam	—	—	2.88	—	—	—	4.48	—
Ragi	—	—	0.69	—	—	—	—	—
Maize	—	0.30	—	—	—	—	—	—
Other irrigated crops	0 14	0.32	—	—	—	—	—	—
Dry land								
Cholam+red gram	—	—	—	0.30	—	—	—	0.67
Cholam+mochai	—	—	—	0.37	—	—	—	—
Fallow	0.68	0.20	0.88	—	—	—	0.77	—
Total	5.60	5.60	5.60	0.67	5.60	5.60	5.60	0.67
BIG FARM:								
Garden land								
Sugarcane	3 57	3.57	3.57	—	—	—	—	—
Cotton MCU. 1	6.38	6.38	—	—	13.23	13.23	—	—
Paddy	0.27	0.27	—	—	—	—	—	—
Vegetables	0.31	0.31	0.37	—	—	—	—	—
Dry cholam	1.56	1.56	—	—	1.48	1.48	—	—
Maize	—	0.35	0.21	—	—	—	4.84	—
Bengal gram	—	0.28	—	—	—	—	—	—
Chithirai cholam	—	—	7.37	—	—	—	4.65	—
Ragi	—	—	1.66	—	—	—	—	—
Other irrigated crops	0.51	0.51	0.45	—	—	—	—	—
Dry land								
Cholam+red gram	—	—	—	2.67	—	—	—	5.34
Cholam+mochai	—	—	—	1.60	—	—	—	—
Cotton (dry)	—	—	—	1.07	—	—	—	—
Fallow	2.11	1.48	1.08	—	—	—	5.22	—
Total	14.71	14.71	14.71	5.34	14.71	14.71	14.71	5.34

In the small farms, where land was limited and availability of water per unit area of the farms was relatively high, a combination of (1) sugarcane, (2) cotton in the main season (July-February) followed by chithirai cholam or maize in March–June season and (3) dry cholam* in the main season were most profitable in the garden lands. In dry lands growing of cholam mixed with green gram and red gram was profitable.

In the large farms, where land area was more and availability of water per unit area of the farm was comparatively less, sugarcane was not profitable. A combination of (1) cotton in the main season followed by maize or chithirai cholam in the March–June season and (2) dry cholam* in the main season was most profitable in garden land. In dry land growing of cholam mixed with green gram and red gram was profitable.

Table 1 exhibits the efficiency of the optimum plan derived by the linear programming technique.

TABLE 1

Particulars	Present plan		Optimum plan		Percentage increase over present plan	
	Small farms	Large farms	Small farms	Large farms	Small farms	Large farms
Net income in rupees	12,795	32,525	13,525	39,391	5.71	21.12
Cropping intensity (per cent)	143.93	142.79	171.45	147.33	15.63	4.54
Labour utilization (Mandays)	237	580	245	598	3.37	3.10

The table indicates that there is scope for increasing the income of the farms by rational use of farm resources.

Table 2 gives the cost and returns of the present and optimum plans.

The study revealed that by rational allocation of resources available in the farm through careful decisions on farm planning the return to capital, return to labour and management and return to man work day may be increased considerably. The increase was substantial in large farms while it was only marginal in small farms which indicated that small farmers are more rational than the large farmers.

The linear programming technique provides Marginal Value Products (MVP) of the resources and shadow prices of the activities. The $Z_j - C_j$ row (vide Appendix I) of the final solution gives the MVP of the resources at the disposal activities side and shadow prices of the activities (crops) at the real activities side. The MVP of the resources are very useful for making decision

* Due to water limitations dry cholam is entering as an activity in garden lands.

TABLE 2. *Cost and returns of present and optimum plans*

Particulars	Small farm			Large farm		
	Present plan	Optimum plan	Per cent increase over present plan	Present plan	Optimum plan	Per cent increase over present plan
1. Net value of produce from crop enterprises of the farm	12,795	13,525	5.71	32,525	39,391	21.12
2. Cash expenditure for crops	5,097	5,194	1.90	14,051	16,394	16.67
Total (1+2)	17,892	18,719		46,576	55,785	
3. Return to capital per Rs. 100.00 invested	351.03	360.40	2.67	319.54	340.28	6.49
4. Cost including operation cost						
a) Rent	24	24		100	100	
b) Depreciation	415	415		918	918	
c) Interest on Fixed capital	1089	1089		3289	3289	
(a+b+c)	1528	1528		4307	4307	
5. Return to labour and management (1−4)	11267	11997	6.68	28218	35084	24.33
6. No. of man work days used for operation	936	979	4.59	2408	2781	15.49
7. Net return per man work day (5÷6)	12.03	12.25	1.83	11.72	12.62	7.68

on the selection and combination of activities since they indicate the potentiality of each of the resources. It serves as a guide to hiring and purchasing of farm resources. All the zero MVP values of the farm resources indicate that these resource are surplus in supply. Positive MVPs indicate that resources may be hired or purchased, but should not cost more than the MVPs of the respective resources.

The implication of MVPs in each of the programming situations solved and given in Appendix I can be explained as follows:

Small farms: MVP of the garden land indicated that if the land available was decreased by one acre the income of the farm would decrease by Rs. 1374.98 or alternatively put, it would be profitable to rent land at a value not exceeding Rs. 1374.98. Renting of additional acre of dry land would increcase the farm income by Rs. 555.00. By augmenting an acre of irrigation water it was possible to increase the income of the farm by Rs. 516.00. The zero values of MVPs for permanent labour and September irrigation suggested that they were in surplus.

Large farms: An additional acre of garden land and dry land rented would increase the income of the farm by Rs. 376 94 and Rs. 735.27 respectively.

Permanent labour was available in surplus during November–February and March–June seasons. An acre of addition of irrigation water will bring at increased income of Rs. 1,157.01 for the farm.

The high MVP of irrigation water seems to explain and indicate the economic rationale for digging wells under Coimbatore conditions at a cost of Rs. 40,000.00 or more and/or incurring an expenditure to a tune of 4,000.00 every year for deepening the wells.

Summary and Conclusion: The study revealed that there exist a great scope for increasing the income of the farmers by reorganising the existing resources with the present level of technical know-how. In the region where the study was conducted the permanent men labour and irrigation water were the limiting factors (as indicated by the MVPs) which influence the cropping plan in a farmer's holding. The allocation of resources by the farmers was not optimum and therefore, they have to be educated on better farm management decisions. The market price alone was not the criterion for allocation of area among different crop enterprises and it should be considered in conjunction with resource constraints for deciding enterprise combinations.

The method of programming as applied in the study is essentially a static concept since the resource level and technolgy are assumed to remain constant and when changes occur in the above parameters one should think of relaxing the assumption and dynamise the programming model.

Acknowledgement: The authors' thanks are due to the University of Madras for kindly granting permission to publish the above work which formed part of the dissertation of the first author submitted for the award of M,Sc.(Ag.) degree in Agricultural Economics.

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