 TA 591 11 december 1970

Instituut voor Cultuurtechniek en Waterhuishouding
Wageningen

LINEAR PROGRAMMING AS A MEANS IN PROJECT EVALUATION, AN APPLICATION TO THE ALPU PROJECT IN TURKEY

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This paper was part of the study requirements.

INTRODUCTION

The study dealt with in this paper is a reconnaissance of the possibilities of applying the linear programming techniques to farm models and that for two purposes. Firstly, as a means in Cost-Benefit analysis and secondly as a source of information for the extension service and promotion of regional development in general.

The study is a partial application of the method proposed by LOCHT (1969). It has been carried out at the Institute for Land and Water Management Research (I.C.W.) in Wageningen with the aid of the IBM 1130 computer. The data stem from a survey carried out in Turkey (BENLI, 1968).

After presenting some information about the region and the project involved (par. 1) and the linear programming technique in general (par. 2) the application will be dealt with in par. 3 and par. 4. Our opinion on the usefulness of this method for the purposes mentioned will be summed up in par. 5.

1. REGION AND PROJECT

The project area covers 232.000 decares* in an area with a typical continental climate. Seasonal distribution of rainfall is uneven; average annual rainfall is 368 mm, of which only 154 mm fall during the growing period. Yearly avrage of relative humidity is about 68%, frost free days are generally from middle of May till the end of September. With respect to irrigability land classification, 0,95% of the project area is class I, 69.70% class II, 12.41% class III, 8.15% class V and 8.79% class VI. Total area of class I-IV lands where efficient irrigation seems to be possible is about 192, 700 decares and covers 83% of the project area.

* a decare = 10 ares = 0,1 hectare

The soils of the project area are of alluvial character and usually have deep profiles. Soil texture is heavy and lime content is generally greater than 15%; pH values are about 7.5 - 8.0. As far as irrigation is concerned, hydrailic conductivity is average. Salt content varies between 0.2 and 3.0%; in bottom lands salinity and alkalinity problems are observed.

In the project area 65.3% of the farmers operate on their own land only, 29% rent land and/or share crops in addition to their own land and 5.3% are renters or share-croppers solely. The average farm size is 121.6 decares. The average number of parcels is 4.8 for holdings less than 100 decares of land. 8.5 for holdings of 100-250 decares, and 11.4 on the holdings of more than 250 decares.

Most of the farmers in the project area irrigate only a part of their land due to the scattered parcels and unsuitable parcel shapes.

The main farming activity in the project area is crop growing. Arable lan covers 95.83% of the whole area; 39.61% of the arable lands are devoted to cereals, 10.73% to sugar beets, 0.6% to potatoes, 0.18% to beans, 0.6% to water-melons, 1.01% to alfalfa, 0.97% to vegetables, 0.20% to orchards; 46.51% is fallow. The most common crop rotation is cereals-sugar beets and cereals.

The total maximum canal capacity in the project area is now 16.1 m^3/sec. (0.0834 lt/sec/Dec). By lining up it can be increased to 20 m^3/sec.

2. LINEAR PROGRAMMING TECHNIQUE

Linear programming is a mathematical optimizing technique dealt with in general e.g. by HEADY and CHANDLER (1958). It is applicable to a class of problems having certain characteristics in common. Basic to this technique is that a mathematical model of formulation of the problem can be stated, using relationships which are linear. The complete mathematical statement of a L.P. problem includes a set of simultaneous linear equations which represent the condition of the problem and a linear function which expresses the objective of the problem. More specifically, there are required sets of equations, including clearly defined physical constraints, alternative activities, physical input-output coefficients and per unit costs. The linear combination of the variables must be optimized by the selected solution. The added condition of of optimization makes it possible to select a single solution that satisfies all the conditions of the problem and yields the unique optimum value of the function.

The technique could also be used for sensitivity analysis of any selected input coefficients, including those with large uncertainties.

Our L.P. problem is defined by the following three statements:

1) The production possibilities matrix, symbolically

$$a_{11}x_1 + a_{12}x_2 \ \ldots\ldots + a_{1n}x_n \quad b_1$$

$$a_{21}x_1 + a_{22}x_2 \ \ldots\ldots + a_{2n}x_n \quad b_2$$

....

$$a_{m1}x_1 + a_{m2}x_2 \ \ldots\ldots + a_{mn}x_n \quad b_n$$

where:

- b_i are the available quantities of various resources which are considered, such land, labour and water.
- a_j are the input requirements for these resources.
- x_i represents the kevel at which each activity will be carried on.

Then the columns contain the coefficients for each activity, the rows the coefficients for each resource.

2) The assumed objective for the enterprise being maximum profit, which can be written as:

$$\text{Optimize } f(x) = \sum_{i=1}^{n} C_i x_i$$

where:

- C_i are net revenues above variable costs per unit for the i^{th} activity.

3) The non-negativity constraint, being:

$$x_1,\ x_2 \ \ldots\ldots\ x_n \quad 0$$

In this study we used a special variant of L.P. being the Simplex Method available for the 1130 as : 'Linear Programming Mathematical Optimalization System; Manual nr H20 - 0345 - 0. This program, be it with a more complex input matrix, is often used for L.P. in the context of agricultural projects e.g. HARTMAN and WHITTELSEY (undated), RIGHOLT (1967), MARTENS (1968) and VAN OOSTROM (1969).

By-products of the simplex procedure are the marginal unit value of any resource considered, that is the reduction that would occur in the $C_i x_i$ from reducing that resource by one unit, with all other conditions constant.

The principles of L.P. are illustrated by several authors by a graphical presentation, usually with two activities. We present such on illustration in fig. 1 for one of the models in this study, being the case II.2 as discussed below. As is seen in this figure, the graphical solution were drawn by taking into account the maximum irrigation water requirements. In this solution, we can see the 'volume of production possibilities'. The income lines, which are tangents to surface of prism (ABCDEB), give the optimum points of solution. By means of the perpendiculars from this point to the x_1, x_2, x_3 axis, is deduced how many decares have to be cultivated from each crop to get the optimum income.

3. THE PROGRAMS RUN AND THEIR INPUT

For benefit-cost (B/C) analysis conclusions of L.P. studies have to be regionalized. Therefore it did seem necessary to differentiate between types of holdings. From the survey study mentioned earlier it was derived that as far as size of holdings is considered the region can be represented broadly by two types of holdings, having an area of about 50 decares and 200 decares. There are only a few cases of still larger farms.

For regionalisation of L.P. conclusions differentation after management, including the efficiency in production and after labour and capital availabilities an necessairy as well. In the content of this study data viz. these aspects where only available as means not as distributions. Therefore these differations had to be by passed which was not harmful in educating the methods.

It goes without argument that for B/C analysis a program has to be run for 'with the project' (this will be called strategy I) and a program for 'without the project' (this will be called strategy 0). For several reasons we evaluate also an alternative project possibility being an enlarged water supply of about 20% (which will be called strategy II).

As a consequence of one and the other, programs have to be run for three strategies, each with two types of holdings. A scheme of this is presented below.

Programs run	without project (strategy 0)	size of holding 50 dec. (0.1)
		size of holding 200 dec. (0.2)
	with actual project (strategy I)	size 50 dec. (I.1)
		size 200 dec. (I.2)
	with add. water supply; (strategy II)	size 50 dec. (II.1)
		size 200 dec. (II.2)

The input data are represented in the tables 1, 2, 3 and 4. They comprise the usual data for the more simple L.P. studies in this field. Table 1 presents efficient expenditure (costs) and the efficient returns for each possible activity is operated. Production is defined here as yield times price. Gross-income is defined here as production minus the costs mentioned in this table, therefore it is income for total land, total labour and the farmers' own capital. For sheep only gross-income was given. Table 2 presents the standard use of manpower and irrigation water for each possible activity. The water use mentioned is the monthly consumptive use determined by the Blaney Criddle method; irrigation water demand at diversion points have been taken in consideration of the irrigation efficiency. The next input table stipulates the supposed technical restrictions in the use of production resources and the supposed technical restrictions to the area for each crop. The restriction on land was discussed above. The availability of family labour was set at 100 mondays a month in conformity with the 4 to 5 workers established as an average in the survey. No restrictions are inputed to the number of wage-workers available at a price of 15 TL/day, as seems realistic for the regioninvalue in the near future. Capital was supposed to be unrestricted as well: Machines are hired from a cooperative without limitations and private capital requirement was assumed to be small and complementairy. In table 4 the same data are provided but none in the standard form of the Simplex Method.

4. THE OUTPUT

From the input, the L.P. computerroutine provides:

a. The optimal cropping pattern.
b. The matching farmers gross-income, being income for total land and the farmer's own labour and own capital.
c. The matching use of resources and the current costs

4.1. The optimal cropping pattern is found to be independent of the holding size. This is connected with the low wages involved (15 TL/day) and the facts that the co-operative provides machinery. As a consequence the farmers gross-income differs only by the wages paid, leaving gross-income for land and total labour at 145 TL/dec (strategy 0), 407 TL/dec (strategy I) and 427 TL/dec (strategy II) for the small farms as well as for the larger ones. This implies:

1e The computation for regionalisation in B/C analysis reduces to a simple multiplication of the per decare values with the matching areas in the region (holdingsize distribution being irrelevant.

2e studies of this type (without capital restraint) in low wage regions ca be limited to one holding size only.

4.2. Another striking point is that the cropping patterns decived for the match 0_1 and 0_2 differs widley from the actual one: Instead of cereals it includes the maximum areas of table 3 for sugarbeets, potatoes and melon; the rest of the area would be assigned to cattle breeding instead of having it fallow. These differences account for a difference in gross-income of over 70 TL and 30 TL per decare respectively. We suppose that these differences are connected with:

A. In the L.P. computations yield coefficients are used which apply to the avarage rainfall, being 154 mm during the growing period. Rainfall being 154 mm, growing potatoes and melons might be warranted indeed, but in fact rainfall is varying between years. Because potatoes and melons are more sensitive to drought in the period involved than cereals, avarage yield depression will be larger than for cereals. Besides the farmers will weight the bad chances heavily because they may involve dropping below subsistence level or more general: an increasing marginal utility of income.

B. In the L.P. computations no constraint is applied to private capital and the cost of capital are not substracted and that because the amount of private capital involved was assumed to be small: the machinery beeing available in the co-operative. The deduced way of farming however implies private capital for cattle breeding on a rather large scale and financing of current cort at a level of about three times the actual level; (about 7000 TL and 30.000 TL per holding). Partly this may be available from the co-operative but as a whole the required private capital is not available and/or it may be that the activities are not warranted if the opportunity costs of private capital are introduced: values in alternative use such as housing will be high.

C. In the L.P. costs of marketing are not included. Market facilities for vegetables are still poor in the region, thus private costs for marketing are high.

These explanations - which have to be checked in further research - implie:

1e The procedure proposed by Locht (1969) to use L.P. results - after a correction - as an entey to benefit-costs analysis is not applicable to these findings. An L.P. program has to be used with:

- seperate runs for at least a few different rainfall types for the 'without' conditions;
- taking at least account of opportunity costs of private capital as is done in the study of Hartman and Whittelsey. For a full drawn application of the procedure however available private capital has to be surveyed and used as a constraint;
- including private costs of marketing as well for conditions with a poorly organised market as for future market conditions.

2e Regional promotion in regions like Alpu - without irrigation can in principle increase income considerably by introducing a system of insurance against bad harvest combined with shaping an efficient market organisation and providing capital for current costs. This would about treble income as well as costs, involving a considerable multiplies.

4.3. The effect of irrigation as it is provided on the cropping pattern is mainly an increase in the area cultivated: wheat is substituted for cattle breeding. The accounted gross-income is increased from about 150 TL/decare to about 400 TL/decare, current costs increasing only from 127 TL to 153 TL. Also in this case the optimum does include the maximum area for beets, potatoes and vegetables (melon).

For illustrative purposes it is assumed that in new L.P. computations it will be deduced that the optimal cropping pattern will include fallow instead of sheep, but will be the same in other respects. The accounted income would be TL 115 for model 0 and TL 397 for model I the increase being 282 TL/dec. This has to be compared in a prevent value computation after considering

- the laps of time in which the farmers adapt to the new possibilities;
- the economic growth in the farm and elsewhere sterney from the increase in income and costs;
- the question whether or not the attainable income level of about TL 4000 per manyear is sufficient as such is view of the goals set in national planning.

4.4. Land would be used fully in each of the optimal farming systems. The decived marginal internal values of land with models 0 and I an about 3 times actual rents. This is a consequence of the implied absence of a real constraint in labour and capital. After implimentation of strategy II also water would not beany more an important constraint either and marginal internal values of land would even approach total income. This implies that the farmers are prepared to hand over much of their revenus rent in an increased to the landowners.

This study therefore suggests that regional promotions in Alpu and not only then, has to be complemented with some provisions against increasing rents.

4.5. The use of labour is illustrated in the graphs of fig. 2. Holdings with an area of 50 decares do not need any foreign labour neither without nor with water supply: available family labour is larger than labour demand.

For regional promotion this implies that even after implimentation of strategy II the employment problem is not solved. Alternative employment opportunities are therefore of utmost importance. Another conclusion is that further mechanisation of agriculture in the near future is not warranted.

4.6. Water use is illustrated in fig. 3. After realising the optimum farming system of model I the farmers would use all the irrigation water available for them in June and July which is 0,0834 l/sec/dec and 7,2 mm/day. Say the relevant period is 4 months than the use is 864 mm additional to 154 mm rainfall, which amounts to 1018 mm in total.

The marginal value would be very high (table 5). On account of this result, water supply to the farm has to be enlarged as soon as and for those farms where optimum farming system is approached.

After implimentation of strategy II water supply would be about sufficient. Wether strategy II implies the optimum water supply has to be deduced from equating marginal costs of strategy II with the deduced marginal revenue.

5. CONCLUSIONS

This study has shown that for with data assembled in project studies in Turkey, linear programming of farm organisation is possible. The output of these L.P.'s can be considered as accounts of simulated farms and that for the conditions without the project and with two project alternatives.
The L.P.'s could have been run previous to the execution of the project, thus as an element of prospective cost-benefit calculation.
In the Netherlands practice is to applie a correction ratio to the output of the L.P.'s to deduce an estimate for actual farming to eleminate the point made for instance by PREST and TURVEY (1965) against the use of L.P. in the B/C context. In this study we formed however that the differences between simulated and actual farming are that large that such an application of a correction ratio would not yet be warranted.
For use in the B/C context for conditions as in Turkey therefore, we are of opinion that first L.P.'s would have to be run with additionally take in account

- constraints on private capital as these occur in fact and which therefore have to be surveyed;
- various rainfall intensities for the 'without' project conditions which have to be inserted in the L.P. input as a rainfall-yield table;
- marketing costs under actual conditions as well as after promotion.

In the fully drawn B/C analysis introduced by Locht, the accounts of simultated farms are used to derive a table of all differences in cost, resources and products and a Cobb-Douglas production function. This function with other relations are foundated in a regional growth model from which development in the course of time is deduced.
Essential features are the growth of capital deduced from the growth of income and saving and the growth of the labour force which is also related to the growth of income. This procedure did seem to be irrelevant in the project region whilst capital and labour were not operating as constraints in the L.P.'s run.
Now that it seems that in fact - as stated above - private capital does be a constraint Lochts' growth model might be usefull.

The by-products of L.P.'s run in this educational context, the optimal crop pattern send marginal values of resources have limited vality: Such aspects as differences in risk, which are very important indeed for the low income farmers involved, are not taken into account in this application. However they may still be guiding points the extension service.

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Table 1. Efficient expenditures (costs) and returns per unit for non-irrigated (0) and irrigated conditions (I, II)

Crops		Costs in TL per decare per year							Yield Kg/Dec		Price TL/Kg		Production TL/Dec		Gross-income TL/Dec
		Seed	Fertilizer	Insecticide	Land	Machines	Irrigation	Total	Grain	Straw	Grain	Straw	Grain	Straw	
Wheat	0	20	36	0	60	10	5	131	250	300	0.92	0.10	230.0	30.0	129
	I,II	20	16	0	40	10	0	86	120	135	0.92	0.10	110.4	13.5	37.9
Barley	0	19.5	25	0	61	10	5	119.5	250	400	0.75	0.10	187.5	40.0	108
	I,II	19.5	16	0	40	10	0	85.5	150	175	0.75	0.10	112.5	17.5	44.5
Sugarbeets	0	00	56	0	75	5	10	146	3500	2000	0.15	0.05	525.0	100.0	479
	I,II	0	31	0	40	5	0	76	1500	800	0.15	0.05	225.0	40.0	189
Oats	0	12.8	20	0	60	10	5	107.8	250	200	0.66	0.10	159.0	20.0	71.2
	I,II	12.8	0	0	40	10	0	62.8	100	150	0.66	0.10	66.0	15.0	18.2
Potatoes	0	112	63	10	75	5	8	273	1500		0.55		825		552
	I,II	76	23	8	40	5	0	152	500		0.55		275		123
Alfa-alfa	0	10	50	0	60	5	8	133	950		0.41		392.0		259
	I,II	5	0	0	40	5	0	50	200		0.41		82.0		32
Sunflowers	0	1.8	62	0	60	5	8	136.8	150		1.80		270.0		133.2
	I,II	1.8	18	0	40	5	0	64.8	80		1.80		144.0		79.2
W.Melon	0	2.3	40	7	75	5	8	137.3	2000		0.68		1360		1223
Melon	I,II	2.3	15	5	40	5	0	78	750		0.68		510		432
Beans	0	17.5	0	7	60	5	8	97.5	120		2.0		240		142
	I,II	9.5	0	4	40	5	0	58.5	60		2.0		120		61
Maize	0	2.5	40	0	60	5	8	115.5	1250		0.83		207.5		92.0
	I,II	2.5	-	0	40	5	0	47.5	130		0.83		107.9		60.4
Cucumbers + tomatoes	I	120	75	15	75	5	8	298	2000		0.75		1500		1202
Sheep	•	•	•	•	•	•	•	•	•		•		•		68

* TL = Turkish pound = 0,25 Dutch guilders = 0,07 U.S. $

Table 2. Possible labour use in mandays/Dec and irrigation water use in lt/sec/10 Dec for non-irrigated (0) and irrigated (I,II) conditions

Crops		March-April		May		June		July		August		September		October-November		Total
		manpow.	irr.water	manpow.	irr.water	manpow.	irr.water	manpow.	irr.water	manpow.	irr.water	manpow.	irr.water	manpow.	irr.water	manpow.
Wheat	0	0.30	-	0.34	-	0.20	-	0.65	-	0.80	-	0.50	-	0.20	-	3.05
	I,II	0.50	0.62	0.35	0.77	0.20	0.91	0.66	0.20	0.80	0	0.50	0	0.20	0	3.26
Barley	0	0.30	-	0.20	-	0	-	1.30	-	0.10	-	0.50	-	0.20	-	2.60
	I,II	0.30	0.62	0.40	0.77	0	0.91	1.30	0.20	0.10	0	0.50	0	0.20	0	2.80
Sugarbeets	0	1.50	-	2.40	-	0.95	-	0.10	-	0.10	-	1.10	-	4.10	-	10.25
	I,II	1.71	0	3.30	0.34	0.95	0.95	0.20	1.64	0.20	1.55	1.25	0.41	6.12	0	13.73
Oats	0	0.30	-	0.20	-	0	-	0	-	1.40	-	0.50	-	0.20	-	2.60
	I,II	0.30	0.62	0.40	0.77	0	0.91	0	0.20	1.40	0	0.50	0	0.20	0	2.80
Potatoes	0	0	-	1.0	-	0	-	2.50	-	0	-	2.00	-	0.80	-	6.30
	I,II	0	0	1.20	0.08	0	1.27	4.50	1.14	0.10	0	2.70	0	0.80	0	9.30
Alfa-alfa	0	0	-	0.50	-	0.30	-	0.30	-	0.40	-	0	-	0	-	1.50
	I,II	0	0.18	0.74	0.44	0.74	0.80	0.75	1.19	0.75	1.15	0	0.62	0	0	2.98
Sunflowers	0	0.30	-	0.10	-	0.10	-	0	-	0.10	-	0	-	0.60	-	1.20
	I,II	0.50	0	0.25	0.60	0.25	1.18	0.30	1.48	0.20	0.27	0.20	0	0.60	0	2.30
Melon	0	0.25	-	0	-	0.10	-	0	-	0.05	-	0.30	-	0.30	-	1.00
W.Melon	I,II	0.95	0	0.45	0.22	0.45	0.68	0	0.99	0.20	0.43	0.50	0	0.30	0	2.85
Beans	0	0.35	-	0.60	-	0.30	-	0.10	-	0.10	-	1.00	-	1.80	-	4.25
	I,II	1.00	0	1.50	0.22	1.80	1.00	0.30	1.23	1.00	0.46	2.40	0	1.80	0	9.80
Maize	0	0.30	-	0.10	-	0.10	-	0	-	0.10	-	0.50	-	0	-	1.10
	I,II	0.50	0	0.40	0.12	0.35	0.76	0.50	1.43	0.60	1.27	0.50	0.21	0	0	2.85
Vegetables	0	0.30	-	2.00	-	2.00	-	0	-	0.30	-	0.10	-	0.30	0	5.00
	I,II	0.40	0	4.60	0	4.10	0.59	2.70	1.08	1.50	0.90	0.30	0.28	0.30	0	13.90
	0	0.96	-	0.48	-	0.48	-	0.48	-	0.08	-	0.12	-	0.10	-	2.70
	I,II	0.96	.	0.48	.	0.48	.	0.48	.	0.08	.	0.12	.	0.10	.	2.70

Table 3. Restrictions in resources and cropping patterns per holding

Restrictions	O_1	O_2	I_1	I_2	II_1	II_2
a. Land (decares)	50	200	50	200	50	200
b. Family labour (manday/month)	100	100	100	100	100	100
c. Irrigation water (lt/sec)	0.00	0.00	4.17	16.68	5.00	20.02
d. Max. area ratio available for each crop (crop rotations)		All models				
cereals		0,50				
sugar beets		0,25				
potatoes		0,20				
alfa-alfa		0,10				
sunflowers		0,25				
maize		0,33				
vegetables (melons, beans, cucumbers, tomatoes)		0,10				

[illegible]