LINEAR PROGRAMMING: THE APPLICATIONS IN AGRICULTURE

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Abstrak
'Linear programming' adalah teknik pemodelan matematika yang didisaln untuk mengop-timasikan penggunaan sumber-sumber yang terbatas; sifatnya deterministik yaitu dalam kondisi informasi data yang lengkap. Sebagai salah satu dari berbagai metoda kuantitatif dalam masalah optimasi, dapat diaplikasikan tidak hanya dalam sektor industri tetapi juga dalam sektor pertanian. Model matematika 'linear programming' bagi masalah pertanian yang diambil dari contoh kasus di Tanzania, variabelnya adalah luas area yang ditanami, batasan-batasannya seperti ketersediaan lahan, ketersediaan tenaga kerja, kebutuhan akan makanan, dan batasan non-negatif. Fungsi tujuannya, merupakan salah satu dari beberapa kemungkinan fungsi tujuan, yaitu memaksimumkan penerimaan tahunan bersih.

Introduction

Linear programming is one of many tools in Quantitative Methods that can be used by decision maker in processing decision-making. According to Decision Methodology, Quantitative Methods are classified as degree of certainty on information availability, with respect to decision variable and possible outcomes. The degree of certainty furthermore is classified as certainty, risk, and uncertainty. The figure 1 shows the existing Quantitative Methods [Monks J.G: p.41].

Linear Programming is one of Operations Research Techniques that used widely and is the basis for development of solution of other (more complex) types of operations research models, including integer programming, non-linear programming, and stochastic programming. **Linear Programming is a mathematical modeling technique that designed to optimize the usage of limited resources** [Taha : p.11]. It is used under complete information condition. So, it is deterministic.

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Degree of Certainty

Certainty
(Complete Information)

Algebra :
- Break-Even Analysis
- Benefit/Cost

Mathematical Programming:
- Linear
- Integer
- Dynamic
- Goal
- Nonlinear

Risk
(Some Information)

Statistical Analysis :
- Probabilitas
- Estimation and Test Hypothesis
- Decision Theory
- Correlation and Regression
- Analysis of Variance
- Non-Parametric Methods
- Queuing Theory
- Simulation
- Heuristic Methods
- Network Analysis Technique:
- Decision Tree
- PERT and CPM
- Utility Theory

UNCERTAINTY
(No Information)

- Game Theory

Figure1 : Existing Quantitative Methods.

Heritage of Linear Programming

Actually the basic idea of Linear Programming have been acknowledged by Russian Mathematician L.V. Kantorivich in 1939. Because of no opportunity to develop in Russian, so West taking over, using and developing it. First, ir was applied for military, American Navy (USAF), to arrange second war strategies and logistic problems. After war, American mathematician named George B. Dantzig develop and publish his work called Simplex Method in 1947. George B. Dantzig and then was well-known as 'The Father of Linear Programming'. Later on Linear Programming is being applied in any other areas.

Linear Programming Applications

Succesful applications of Linear Programming exist first in military, and then in various of industry sectors especially for economics problems in the areas of production mix, shipping and transportation, inventory, labor scheduling including manufacturing applications, media selections and marketing research including marketing appilcations as well as its applications in health for ingredient blending problems [Taha:]

Because of its history, then almost every body that ever study about operations research in generally and linear programming in particular will have a perception that linear programming can only be adopted in industry sector. However, this is not only the case since recently it has been introduction in agriculture area.

In this paper the writer will present the application of linear programming in agriculture.

Linear Programming in Agriculture : A case of Tanzania[2]

Linear Programming Method may contribute to formulate, analyze, and even solve agricultural daily life problems especially growing in developing countries, such as in Tanzania.

Elements of the model

There are at least four elements in agriculture that have to be considered namely: what is grown, when to grown, how to grown, and how much is grown.

a. What is grown
It depends on many things like the character of soil, climate, availability of water, ets.

b. When to grown
It was given by the growing valendar, the time to start planting or harvesting, and also by the different stages of the growth like clearing, ploughing, sowing, weeding, fertilizing, and harvesting.

c. How to grown
It is in part will be a matter of research.

d. How much is grown
It is a subject of research.

Variables of the model
X_j is area where the crop j is grown for one season; j = 1,2,3,...... n
Remark : in one year there is only one grawing season.
For example : j = 1 for 'maize' then X_1 is the area where maize is grown.
X_1 is divided into four sub-areas called 'parcel', where for instant;
Parcel 1 :where rice is grown, herbicides are used, and ploughing is done with an ox drawn plough.
Parcel 2 :where rice is grown, herbicides are used, and ploughing is done with the hoe.
Parcel 3 :where rice is grown, no herbicides are used, and ploughing is done with an ox-drawn plough.
Parcel 4 :where rice is grown, no herbicides are used, and ploughing is done with the hoe.
The size of a parcel depends on the availability of land, labour, and capital.

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2 C. Schweigman, Operations Research Problems in Agriculture in Developing Countries, Tanzania Publishing House. Dar es Salaam, Tanzania, 1985.

Restrictions :

The avilability of land

If a farm have a land with size A, then

$X_1 + X_2 + X_3 + ... + X_{11} \leq A$ (land constraint)

The availability of labour

The number of labour required in farming activies depends on the stages of the growth Then

$$\sum_{j=1}^{n} l_{tj} X_j \leq L_t \quad , \quad t = 1, 2, 3, ..., 12 \quad \text{(labour constraint)}$$

l_{tj} : work time (averaged working time) which is required in month t per ha of parcel j.

t : month of the year (t = 1,2,3,........., 12)

j : per ha of parcel j

L_t : the total number of available working hours in month t.

Remark : 1. The value of Lt can vary form month to month.

2. adults are productive labourers rather than children or elderly people.

L_t can express as $L_t + L_t^{11}$, then

$$\sum_{j=1}^{n} l_{tj} X_j \leq L_t^{11} \quad , \quad t = 1, 2, 3, ..., 12 \quad \text{(labour constraint)}$$

L_t : the number of available hours of e.g. relatives (being assumed to be known).

L_t^{11} : the number of working-hours of hired labourers in the month t (being assumed to be unknown variables).

Similar equation can be build for ox-drawn plough constrain:

$$\sum_{j=1}^{n} p_{tj} X_j \leq P_t \quad , \quad t = 1, 2, 3, ..., 12$$

p_{tj} : the number of hours an ox-drawn plough is used is used in ploughing one ha of parcel j in month t.

P_t : the number of hours available for ox-drawn ploughs in month t.

The avilability of capital

On private farm, the land belongs to the farmer and all work are done by hand, so no money will be needed for agricultural activities. In many cases, however, production cost comes from hiring oxen or tractors, buying fertilizer or

pesticides that will be paid from last year's proceeds or from the current year's through loans.
If there are no loans, then

$$\sum_{j=1}^{n} K_j \; X_j \leq C \qquad \text{(capital constraint)}$$

K_j : the operating production costs per ha for parcel j.
C : the amount of money at our disposal for these production costs obtained from last year's proceeds.

Remark : 1. The money not for capital expenditure as purchase of equipment.

If the farm have no labourers then the operating production cost only for purchasing materials, maintenance, and rental of machines. But if the farm have hired labourers that receive wages include family labour than the operating productions cost include annual costs of cultivating one ha with crop j.

Then
$$\sum_{j=1}^{n} K_j X_j + \sum_{t=1}^{12} V_t L_t^{11} \leq C \qquad \text{(capital constraint)}$$

L_t^{11}: the number of working-hours of hired labourers in month t
V_t : the wage per working-hour in month t

If the money C coming from the previous year is the variable, then relation between C and proceeds should be included, for example :

$$C = \sum_{j=1}^{n} C_j X_j - Z_0 \qquad \text{(capital constraint)}$$

C_j : the net revenue per ha where crop j is grown
Z_0 : required minimum income to be spent on salt, sugar, extra food, household utensils, etc.

Food Requirement
In general, food requirement is written as :

$$\sum_{j=1}^{n} Y_{fj} X_j \geq r_f \,, \qquad f = 1, 2, 3, \ldots\ldots, m \qquad \text{(food requirement)}$$

f : the kind of food crops
m : the total number of food crops to be considered
r_f : the annual amount of food crop f to be harvested
Y_{fj} : the amount of food crop f harvested per ha on parcel j

The practical problems : $X_j \geq 0$, $j = 1, 2, 3, \ldots n$ (non-negativity constraint)

Objective Function

The objective function is to maximize the net annual revenue, then

$$C_j = S_j Y_j - K_j - K_j^{11} \quad \text{(objective function)}$$

C_j : the net revenue per ha where crop j is grown
S_j : the farmgate selling price of 1 kg
Y_j : the yield per ha in kg
K_j : the variable production costs per ha of crop j
K_j^{11} : the annualized cost (depreciation) from investment in equipment for crop j.

Remarks

1. Linear programming has to be adjusted according to the situation.
2. Complicated situation require involving other knowledge like risk measurement and stochastic nature to reduce gap between on-paper result and the reality.

Conclusion

Linear Programming as one of the Quantitative Methods for optimization under complete information condition can be applied not only in industry sector but also in agriculture applications.

Application for linear programming in others area requires adjustment according to the situation in area itself.

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