CHAPTER 4: PROGRAMMING IN AGRICULTURAL PRODUCTION

4. PROGRAMMING IN AGRICULTURAL PRODUCTION

INTRODUCTION

This unit presents the basic concepts and principles of programming in agricultural production as well as its main methods of application. Particular emphasis is placed on the method of mathematical (linear) programming which is the most widespread in its various versions.

KEY CONCEPTS

Programming, Linear programming

TERMS

Marginal cost: the increase of the total cost produced from the increase of production by one unit

Marginal product: the increase to the size of production with the addition of an extra production factor

UNIT GOALS:

After completing this unit, the trainees:

⇒ Will recognize the significance of programming in agricultural production

⇒ Will know about production factors and understand the meaning of their scarcity

⇒ Will understand the process of modelling of the problem of scarce resources

⇒ Will have general knowledge about how the linear programming method works

4 .1 CONCEPTS AND PRINCIPLES OF AGRICULTURAL PRODUCTION PROGRAMMING

Agricultural production programming is any systematic method which makes it possible to find the perfect economic combination of the available production factors available each time through plant and animal production sector. This combination through plant and animal production sectors achieves maximum possible profit or minimum cost during a specific period of time.

The need for programming in agricultural production arises from the fact that each farmer has restricted quantities of available production factors. Thus, if the farmer wishes to achieve the maximum net income he must find the best ratio between production factors and allocate the factors to the most efficient production sectors.

Agricultural production programming should be based on three principles:

1. when production factor quantities change, then the maximum net income is achieved at that level of production, where the marginal product is equated with the marginal cost;

2. when production factor quantities are fixed, then the maximum net income is achieved by allocating them in a manner that produces equal net marginal product in all production sectors; and

3. when the quantities of some production factors are fixed, then the maximum net income is achieved by allocating them in a manner that any change from one production sector to another does not add net income. At this point it is clarified that before maximum total net income we see a descending ratio of net marginal product.

The implementation of these principles requires knowledge of the cost increase ratio when the total product increases. This knowledge however is not available at the level of the personal operation, and for this reason it appears that these economic principles cannot, on their own, be adequate instruments for achieving maximum net income production programs for operations. If there are no reliable measurements of the marginal cost change ratio in each personal operation, then it may be assumed that it does not change. This hypothesis is considered reasonable within specific limits of net proceeds of an operation, which means that the above economic principles may be used basically in production programs of operations for achieving maximum net income. However, the contribution of economic principles to the solution of personal operation production problems is very small. And this is not due to an error of the economic theory, but to the lack of overall knowledge that allows direct implementation of marginal analysis.

Maximum net income, through marginal analysis, is the result of three relationships:

⇒ the relationship between factors used in production (factor to factor relationship);

⇒ the relationship between factors and product in each production sector (factor to product relationship); and

⇒ the relationship between products (product to product relationship).

The implementation of programming in agricultural production is linked with three fundamental components:

1) an objective;

2) production factors in restricted quantities; and

3) production sectors and production methods for these products, which shall use the restricted factors for achieving the objective. The objective refers either to maximising net income or minimizing cost. Income maximization is effected by selecting those production factors that perform better per unit of restricted factor, because if they perform to the maximum with these factors it is apparent that they will perform to the maximum with all the factors that compose the

agricultural operation. So, if labour is the most restricted factor then the production plan will consist mostly of production sectors that perform more per labour unit. Something similar applies in the case of a limited quantity of land or capital. Cost minimisation is achieved by selecting the animal feed (concentrated and forage) that provides more nutrients (dry matter, digestible protein, starch equivalent, amino acids, vitamins, etc) per monetary unit, in comparison with the required quantities of a nutrient for each category of animals.

4 .2 AGRICULTURAL PRODUCTION PROGRAMMING METHODS

Before World War II, programming methods in agricultural production were limited to estimating the economic result and suggesting general and frequently empirical methods for improving the economy of agricultural operations. Fundamental in this direction were Agricultural Accounting, Agricultural Product Costing, Simple and Multiple Co-variation and Correlation and Agricultural Budget.

After World War II, the main object of agricultural production programming was that combination of agricultural production factors and sectors that aims at achieving the greatest possible economic result. Thus, at this stage of programming development, the methodology of the past provides on the one hand the necessary technical or physical and economic data for the combination of the production factors and sectors, on the other hand, the measure of comparison of the current economic status with the status resulting from the economic combination of production factors and sectors. Many methods contribute in determining the most economic combination of production factors and agricultural production sectors. Among the most important ones are the method for calculating the total production cost, the total and partial agricultural budget, simplified programming, and lastly mathematical programming. Only the short presentation of mathematical programming, and in particular linear programming, was considered necessary due to its extensive application in agricultural production.

> Linear programming is the method which determines the maximum or minimum quantity, taking into account certain conditions and restrictions.

4.3 LINEAR PROGRAMMING

This quantity may be expressed either in physical or monetary units, depending on the problem posed. More specifically, linear programming is **that method which can select the optimum possible between many combinations of existing production factors and sectors**, i.e. the one that ensures maximum total or per unit of restricted factor proceeds or the minimum possible cost for the production of this product. In practice, linear programming is used for the organization of new and the restructuring of old agricultural operations, with the ultimate goal of helping farmers achieve the largest possible income or the lowest cost, with a better use of the existing factors.

The above lead to the conclusion that the implementation of linear programming is linked:

⇒ to the existence of **an objective** (maximum income or minimum cost);

⇒ the existence **of more than one methods** for achieving this objective (many production sectors, various production methods for the same product); and

⇒ with the existence of **production factors** in restricted quantities (land, labour, capital).

From the various forms of proceeds and income used in agricultural economics, the most common method for comparing the various production sectors during the implementation of linear programming is gross profit or gross margin, i.e. the remaining balance from the gross proceeds after deducting variable cost.

4.3.1 Production sectors and their gross profit

Production sectors fall under two large categories, i.e. plant product production sectors and animal product production sectors. From the aspect of linear programming, the interesting information for each production sector is on the one hand their proceeds and on the other hand their requirements for production factors. The comparison of the various production sectors, for selecting them in the optimum production plan for the operation, is based on their gross profit compared to their requirements in fixed production factors, i.e. their gross profit per unit of restricted quantities of production factors. The criterion for selecting gross profit and not another economic result for linear programming is based on the capability of comparing the various production sectors at fixed cost, i.e. at the existing fixed production factors. Variable cost, as special cost, that refers to each specific production sector, is not preferred as a measure of comparison. In other words, the purpose of linear programming is to make available the existing fixed production factors to those production sectors that ensure the maximum possible gross profit.

4.3.2 Production factors and imposed restrictions

When production factors are not in limited quantities then there is no problem for linear programming to resolve, because the proposed plan will simply include the production sector with the largest gross profit per unit. Such a plan however would not be realistic, because in practice production factors are present in restricted quantities and because several other restrictions of a technical or economic nature exist in farming. These restrictions refer to the size of the operation and the size of each production sector, the available family labour and the existing variable and fixed capital.

a) Land: The surface that is cultivated or that may be agriculturally utilized is a restriction for selecting the optimum production plan for the operation. In other words, the sum of the requirements for land by production sectors, which constitute the proposed production plan, must not exceed the land available for use. Thus if e.g. the size of the operation is 50 stremmas[1] and x_1, x_2, x_3, … , x_v –represent the crops that may use this land, then the following equation must apply:

$50 \geq 1x_1 + 1x_2 + 1x_3 + \cdots + 1x_v$

Similarly, if there are 5 stremmas of irrigated land which may be utilized by three crops, the following equation also applies:

$5 \geq 1x_1 + 1x_3 + 1x_5$

Example:

We have an operation

In our example we will investigate the land production factor and define the restrictions in its use in the specific operation.

The producer has 5 irrigated stremmas and wants to cultivate tomatoes, peppers and eggplants.

The following table presents the various combinations for the 3 crops.

Crops	A	B	C
Tomatoes	1	2	2
Peppers	2	1	2
Eggplants	2	2	1
Total	5	5	5

We see some combinations of the three crops in the above table

The restrictions in place are:

The total stremmas for the 3 crops cannot be equal or less than 5 stremmas

$5 \geq 1x_1 + 1x_3 + 1x_5$

Where X_1 X_2 X_3 are the three crops

b) Labour: There are similar restrictions for the available family labour. The participation of each production sector of the operation depends on its requirements for labour compared with the requirements of other production sectors and the available family labour. Since the requirements of the various crops for labour are not evenly distributed over the year, we must not take into account their annual needs in hours related of course with the corresponding available hours, but the monthly needs. Therefore, if e.g. the available labour for the month of July is 818 labour hours

[1] A surface measurement used in Greece , corresponding to 10 Are (1,000 square meters).

and the requirements for labour for the same month are 9,3, 12,6, 82,5,..., 8,8 labour hours per stremma for crops x_1, x_2, $x_{3, ...}$ x_v then the following equation applies:

$818 \geq 9,3x_1 + 12,6x_2 + 82,5x_3 + ... + 8,8x_v$

Example

There are 1000 available labour hours for the month of July in an agricultural operation, for the following crops

Crops	Hours per stremma	Total labour hours per crop A	Total labour hours per crop B	Total labour hours per crop C
Wheat	2	2x120=240	2x200=400	3x140=280
Tomatoes	180	180x2=360	180x2=360	180x1=180
Corn	8	8x50=400	8x30=240	8x55=440
Total hours		1000	1000	1000

We see in the table that we can increase the stremmas but we have to maintain labour at 1000 or less hours a month. We have made 3 combinations, and we can make many more with labour being the only restricted factor.

c) Capital: This falls under variable capital, capable of covering current expenses (seeds, fertilizers, pesticides, lease of labour and machinery, etc) of the various production sectors, and fixed capital (land improvements, agricultural constructions, all types of mechanical equipment, labour animals, etc) which is not directly linked with the production sectors that are included in the final production plan of the operation. The following equation may apply for the variable capital:

$6,365 \geq l67x_1 + 70x_2 + 46x_3 + ... + 362X_v$

where the 6,365 drachmas represented the available variable capital and the 167, 70, 46 and 362 drachmas represent the demands per stremma in variable capital of production sectors x_1 , x_2, x_3 ,...,x_v (the numbers are random). In practice, the requirements for variable capital of the various production sectors are allocated evenly or irregularly during the year.

Example:

A producer has a capital of 6365 euros and has no restriction on the labour and land factors.

Crops	Variable expenses per stremma (euros)	Total expenses per crop A	Total expenses per crop B	Total expenses per crop C
Wheat	8	8x120=960	8x500=4000	8x140=1120
Tomatoes	950	950x2=1900	950x2=1900	950x3=2850
Corn	18	18x195=3505	18x26=465	18x133=2395
Total hours		6365	6365	6365

We see in the table various increases and decreases in the stremmas of the various crops. Total expenses do not exceed the amount of 6365 euros which is the available capital.

4.3.3 Implementation and results of linear programming in agricultural production

As aforementioned, linear programming is the best method for determining the optimum agricultural production plan, and therefore the maximum income or minimum production cost, with many production sectors that can claim a place in the optimum production plan and numerous possible restrictions. In practice, there are many combinations between production sectors and set restrictions, to a greater or lesser extent.

4.3.4 Multiple production sectors and one restricted factor

The simplest form is when there are 10, 20, 30 or even 50 possible production sectors, but only one production factor in restricted quantities (e.g. land). In this case it is certain that the optimum production plan will include only one production sector, the one with the largest gross profit per unit of land surface. It is self-evident that in the aforementioned simple form, the optimum production plan may be easier to determine by simple arithmetic instead of linear programming.

4.3.5 Two production sectors and multiple restricted factors

If there are two production sectors and more than one production factors in restricted quantities, the solution to the problem (maximum possible income) may be given with a simple chart. Let us assume that we have a 50 stremma operation and crops of barley and maize. Crops with maize or crops with barley, or any combination of these two crops may be grown. Provided of course that there are no other restrictions, except for land, whether maize or barley are exclusively grown or any combination thereof will depend on the gross profit of each production sector per stremma.

In practice however both labour and capital are of restricted quantities. In this case there is change to the original optimum production plan of the operation. Restriction examples are the following: the available labour from February is 70 labour hours and the labour requirements for maize and for barley for that month are 2 labour hours per stremma respectively or the available labour of July is 18 labour hours and the labour requirements of barley and maize for the same month are 0.6 and 0 labour hours per stremma respectively. Furthermore, if the available variable capital amounts to 22,000 drachmas and the requirements for barley and maize consumables are 550 and 352 drachmas per stremma respectively.

4.3.6 Multiple production sectors and multiple restricted factors

In practice however we rarely find an operation that is based only on two crops. There are usually multiple crops, in order to select their optimum combination. In this case the problem cannot be resolved by a chart, but through algebra. The algebra solution is produced through a method known as the simplex method or with the use of a desk calculator or an electronic computer. The more production sectors and the more restrictions set on the problem, the more necessary becomes the use of the computer. In advanced countries, where the problems to solved are complicated and the cost for using the computer is relatively small, the implementation of linear programming is closely linked with its use. This becomes more apparent when we take into account that the solution of a not very complicated linear programming problem requires a few days of work on a desktop calculator, whereas the solution of this problem with a computer requires only 1 to 2 minutes.

SELF-EVALUATION TEST

Answer True (T) or False (F) to the following questions:

1. Agricultural production programming is any systematic method which makes it possible to find the average economic result of the available production factors available each time through plant and animal production sectors.

a) True

b) <u>False</u>

2. The need for programming in agricultural production arises from the fact that there are unlimited quantities of each farmer's available production factors.

a) True

b) <u>False</u>

3. Linear programming is the method which determines the maximum or minimum quantity, taking into account certain conditions and restrictions.

a) <u>True</u>

b) False

Select the correct answer to the following questions:

1. According to the principles on which agricultural production programming is based, when the quantities of the production factors change:

A) <u>then the maximum net income is achieved in that production level, where the marginal product is equated with the marginal cost</u>

B) then the maximum net income is achieved in that production level, where the marginal product is equated with the average cost

C) then the maximum net income is achieved in that production level, where the marginal product is equated with the total cost

D) then the maximum net income is achieved in that production level, where the average product is equated with the marginal cost

2. According to the principles on which agricultural production programming is based, when the quantities of the production factors are fixed, then the maximum net income is achieved:

A) with their allocation in a way that the total product is equal in all production sectors

B) with their allocation in a way that the net average is equal in all production sectors

C) <u>with their allocation in a way that the net marginal product is equal in all production sectors</u>

D) with their allocation in a way that the net profit is equal in all production sectors

3. The most popular method for determining the economic combination of the production factors is:

A) the method of complete production cost

B) the method of partial and total agricultural budget

C) simplified programming

D) <u>linear programming</u>

4. In the case of many production sectors and only one restricted factor, the optimum production plan will include:

A) <u>only one production sector, the one with the largest gross profit per unit of land surface.</u>

B) unlimited production sectors

C) all production sectors with gross profit over the average

D) all production sectors regardless of profit result

5. In the case of two production sectors and more than one production factors in restricted quantities:

A) the solution of the problem (maximum possible income) requires a 3D chart

B) the solution of the problem (maximum possible income) may be given with the use of a PC and specialized software

C) there are infinite optimum solutions

D) <u>the solution of the problem (maximum possible income) may be given with a simple chart</u>

ACTIVITIES

1. Create the relationships that express the restricted resources and the maximization of the result (linear programming) in the following problem.

A farmer has 50 stremmas and wants to grow cotton (x_1) and wheat (x_2) in order to maximize the operation's gross profit. The gross profit per stremma of cotton is 3000 drachmas and of wheat 2000 drachmas. Also a stremma of cotton requires 4 labour hours daily and each stremma of wheat 7.8 labour hours. The total labour hours for the farmer daily are 78 labour hours.

Answer:

- $Zmax=3000\ x_1+2000\ x_2$

(maximization correlation)

- $x_1+x_2 \leq 50$

(land restriction)

- $4,0x_1+7,8x_2 \leq 78$

(labour restriction)

2. By using as data the entries in the agricultural accounts of your operation of the last 2 years, try to check whether there was any possibility to achieve a better economic result by applying linear programming. Use land as the restricted production factor.

ADDITIONAL SOURCES OF INFORMATION

1. Linear Programming

http://www.usna.edu/Users/weapsys/avramov/Compressed%20sensing%20tutorial/LP.pdf