FARM PLANNING METHODS
IN THE EUROPEAN COMMON MARKET

by

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Signatures have been redacted for privacy

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I. INTRODUCTION AND OBJECTIVES

Although the six countries of the European Common Market\(^1\) have attained somewhat different levels of economic development, shifts are taking place within agriculture which are similar in each country. Under economic growth, the labor input in agriculture has declined greatly in response to the price of labor which became high relative to that of capital, and also in response to substitution rates which, under changing technology, have grown to favor capital. Through the use of more capital and less labor, the subsistence farms have disappeared and a much larger portion of the agricultural production goes to the market.

This transition is taking place and will continue in the future. Through this development, emphasis must turn to "an economic planning framework." The production techniques have reached such a level that, in order to improve farm income, the interest of farmers and farm advisory workers has to be directed more towards the organization of the farm as an economic unit. It becomes evident that the efficiency of most farms can better be improved by providing guidance on the optimal allocation of the resources among all possible alternatives, than by trying to eliminate the technical inefficiencies for each crop or livestock enterprise separately. A well-balanced farm plan becomes increasingly important.

Several farm planning methods are used by farmers, farm advisory workers and research workers in each country. These methods differ only in the technique used, since most procedures are based on the same as-

\(^1\)Belgium, France, West Germany, Italy, Luxembourg and The Netherlands.
sumptions. They mostly need the same basic information and have the same general objective, namely the selection of the most efficient or at least "a better" farm plan. Nevertheless, the techniques used to attain this general objective are quite different. The methods vary from just "thinking through" to the most refined programming procedures.

The objective of a farm plan can be used as a basis for comparing the methods and for determining what kind of problems can be solved by each method. A farm plan must yield a maximum net income over a period of years. Hopkins (20, pp. 104-106) breaks this general objective down into several elements which are closely related to each other:

1) Provide for an adequate size of business
2) Full use of resources
3) Balanced combination of resources
4) Avoid excessive risks
5) Provide flexibility
6) Utilize the farmer's training and experience
7) Take account of price prospects
8) Take account of local climate, soil and topography
9) Give consideration to marketing facilities
10) Provide for the use of up-to-date methods

Implicit in these 10 points are the economic conditions of the theory of the firm. The following conditions must be fulfilled for profit maximization:

1) The use of variable resources for each enterprise must be expanded along the production function till the marginal product equals the marginal cost.
2) When a firm produces more than one product, the marginal rate of substitution between any two products along the production possibility curve, must be equal to their price ratio.

These principles are reflected in the 10 elements stated earlier. The production function and the production possibility curve are affected by the operator, local circumstances, production methods, etc. The market conditions determine the price ratios.

Aside from the objective of the farm plan as a criterion for comparing the different techniques, we need another more practical basis to derive the merits of the respective methods. The models must be workable by extension personnel, without too much trouble, for applications on the individual farm. Associated costs, time and other means are relevant factors in this context.

Based on the principles of the equilibrium theory of the firm, and with the practical conditions in mind which are stated above, the model must provide an answer to the three following questions:

1) What to produce
2) How much to produce
3) Which production methods to use

This study has a threefold objective:

1) Discuss the influence of the agricultural structure on the planning environment in the European Economic Community. The use of economic models for farm planning by farmers, advisory workers and research workers will be discussed for each country separately (Chapter II).

2) Demonstrate the usefulness of linear programming and associated techniques for individual farm planning through a practical application.
The advantages together with the limitations for a quick development of this method in the advisory services will be pointed out (Chapter III).

3) Explain the economic models which are actually used for farm planning. Attention will be given to the following methods:

a) Budgeting
b) Programme planning
c) Direct comparison
d) Farm slide rule method

Their relative advantages and shortcomings as compared to linear programming will be discussed (Chapter IV).

In recent years, strong efforts have been made in trying to improve farm planning by using linear programming methods. The availability of electronic computers has certainly influenced this development. This has raised the question whether linear programming can replace the models actually used or different methods have to be used at the same time. This study intends to indicate for what kind of problems and under which circumstances each method is most adequate.
II. SITUATION IN THE COMMON MARKET

A. General Structure of Agriculture

Before considering the situation in farm planning in each country separately, we will have a look at some general data about the structure of agriculture in the European Economic Community.

The indicated similarities and dissimilarities might be helpful for a better understanding of the specific farm planning problems facing the Common Market countries in general and each country in particular. These data can also be useful to understand the actual development and use of farm planning methods in the E.E.C.

Table 1. Farm size

<table>
<thead>
<tr>
<th></th>
<th>W. Germany</th>
<th>Belgium</th>
<th>France</th>
<th>Italy</th>
<th>Luxemburg</th>
<th>Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner-operated</td>
<td>88</td>
<td>32</td>
<td>55</td>
<td>48</td>
<td>73</td>
<td>47</td>
</tr>
<tr>
<td>Number of farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5 ha</td>
<td>48</td>
<td>59</td>
<td>30</td>
<td>85</td>
<td>32</td>
<td>39</td>
</tr>
<tr>
<td>5 - 10 ha</td>
<td>25</td>
<td>23</td>
<td>22</td>
<td>8</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>10 - 20 ha</td>
<td>18</td>
<td>15</td>
<td>25</td>
<td>5</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>20 - 50 ha</td>
<td>8</td>
<td>4</td>
<td>18</td>
<td>1</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 50 ha</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Average size</td>
<td>8.8</td>
<td>6.8</td>
<td>15.1</td>
<td>4.4</td>
<td>12.0</td>
<td>9.8</td>
</tr>
</tbody>
</table>


The intervals for Italy are: 0.5-5 ha; 5-10 ha; 10-25 ha; 25-50 ha; >50 ha.

1 ha = 2.47 acres.
These data show that, though there are significant differences among the countries, the average size is very small. More than 70 per cent of the farms cover less than 10 ha. The small farm raises questions of the efficiency of more sophisticated and complex planning procedures.

Table 2. Agricultural population

<table>
<thead>
<tr>
<th></th>
<th>W. Germany</th>
<th>Belgium</th>
<th>France</th>
<th>Italy</th>
<th>Luxemburg</th>
<th>Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agr. population (%)</td>
<td>18</td>
<td>10</td>
<td>27</td>
<td>40</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td>Number of farm workers per 100 ha</td>
<td>29</td>
<td>20</td>
<td>14</td>
<td>30</td>
<td>23</td>
<td>20</td>
</tr>
</tbody>
</table>

*Source: E.E.C. (13).*

The agricultural population in per cent of the total population, a rough indicator for the level of economic development, varies widely from 40 per cent in rural Italy to less than 10 per cent in Belgium. The number of farm workers per 100 ha is closely related to the average farm size.

Table 3. Physical productivity

<table>
<thead>
<tr>
<th></th>
<th>W. Germany</th>
<th>Belgium</th>
<th>France</th>
<th>Italy</th>
<th>Luxemburg</th>
<th>Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat/ha (100 kg)*</td>
<td>28.3</td>
<td>35.3</td>
<td>20.8</td>
<td>20.3</td>
<td>19.0</td>
<td>36.2</td>
</tr>
<tr>
<td>Milk/cow/year (kg)</td>
<td>3,293</td>
<td>3,760</td>
<td>2,273</td>
<td>2,057</td>
<td>(3,300)</td>
<td>4,100</td>
</tr>
<tr>
<td>Eggs/hen/year</td>
<td>134</td>
<td>170</td>
<td>110</td>
<td>89</td>
<td>125</td>
<td>200</td>
</tr>
</tbody>
</table>

*Source: E.E.C. (13).*

*b1 kg = 2.30 lbs.*
Table 3 shows that most countries have reached high yields per hectare and per animal. The high physical productivity indicates that in farm advisory work special emphasis must be given to the organization of the farm as a whole as a means to improve net farm income.

Table 4. Composition of gross products (1958)\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>N. Germany</th>
<th>Belgium</th>
<th>France</th>
<th>Italy</th>
<th>Luxemburg</th>
<th>Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Wheat</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>17</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Other cereals</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Vegetables</td>
<td>8</td>
<td>15</td>
<td>12</td>
<td>20</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Viniculture</td>
<td>2</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Other crops</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Total crops</td>
<td>29</td>
<td>38</td>
<td>40</td>
<td>66</td>
<td>22</td>
<td>34</td>
</tr>
<tr>
<td>Cattle</td>
<td>16</td>
<td>15</td>
<td>16</td>
<td>9</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Hogs</td>
<td>24</td>
<td>12</td>
<td>11</td>
<td>4</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Poultry</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Eggs</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Dairy</td>
<td>24</td>
<td>22</td>
<td>20</td>
<td>12</td>
<td>33</td>
<td>24</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total livestock</td>
<td>71</td>
<td>62</td>
<td>60</td>
<td>34</td>
<td>78</td>
<td>66</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Source: E.E.C. (13).

Table 4 gives the composition of the gross products in 1958 of the major farm products in percentage of the total gross products in agriculture. Livestock makes up almost two-thirds of the gross products. Since by far most farms have both crops and livestock, this does not make farm planning easier.
B. Situation in Each Country

Both in agricultural research and extension services, increasing attention is being given to farm planning problems. In each country, budgets have been developed for several decades to improve farm organization.

The use of more refined methods in recent years has developed in a different way in each country. The agricultural economists in Germany and The Netherlands have much basic information at their disposal. Consequently, they are ahead of the other countries. In France, Italy, and Belgium farm planning is much more restricted, largely due to a lack of data from the individual farms.

In general, however, the more refined methods have only found very few applications in the extension services.

1. Belgium

Although the extension service of the Ministry of Agriculture was established as early as 1885, it took a long time before special attention was given to the micro-economic aspects of agriculture. The foundation of the Research Station for Agricultural Economics at the State Agricultural University in Ghent in 1950 was an important step in the right direction. Much information has been assembled from farm accounts. Nevertheless, the comparisons between the accounts of different farms are seldom used for individual farm planning.

Actually, most advisory work on planning is done by the extension service. However, some professional organizations, especially the "Boerenbond" are also active for advice on farm management.

Most agricultural extension workers are not specially trained in
economics, and mostly only technical advice is given to the farmers. This also explains the fact that up until now budgeting is nearly the only method used for practical purposes. Special forms are available which facilitate the farm analysis and the setup of a new plan.

Since 1953, a strong effort has been made to use Wirtschaftsrahmen, a method developed in Germany which makes it possible to compare a large number of budgets in a short time (34, p. 133). However, this approach is not used on a large scale. Since 1962, a special service of the Ministry of Agriculture is charged with the study of farm planning methods.

Only very recently, a first study has been made on the possibilities of linear programming in farm management in Belgium (26). Actually, this method is under further study, but no other practical applications are known.

Also during the last few years much attention has been given to the development of standards for labor in agriculture and horticulture in several regions (35). This information can become very helpful for the application of more refined planning methods. The Agricultural Economics Institute, established two years ago by the Ministry of Agriculture, also provides hopeful prospects.

2. France

Organized record keeping in agriculture started shortly before the second World War. In 1937 the "Union des Offices de Comptabilité et de Statistiques Agricoles" was founded in Paris and organized 13 different record-keeping services (34, pp. 52-54).

In 1947 the "Confédération Générale de l'Agriculture" established a
"Division de la Rentabilité." Later this became the "Centre National de Comptabilité Agricole et d'Economie Rurale" (C.N.C.R.R.), which played an important part in the development of agricultural economics in France.

In recent years, several new centers for agricultural economics and management were created. In 1955 the "Union Nationale des Offices de Comptabilité et des Centres d'Economie Rurale" was established. In 1958 this organization grouped 50 centers. Actually, 85 centers are established all over the country.

Since 1955 the National Institute for Research in Agriculture is charged with research in economics, and laboratories are established at the chairs for economics from the various Agricultural Institutes. Especially the laboratories at Grignon and Rennes have contributed to farm planning (10).

Notwithstanding these strong efforts during the last decade, only few original studies in farm planning have been accomplished. The economic models developed in other countries are used.

Two different groups of budgeting models are used frequently and are kept simple for practical reasons. One group is based on the maximization of the total net revenue without making any distinction between variable and fixed costs. This, of course, is a theoretical weakness of the method. With the help of this technique, economic models for small regions are constructed. In the other group, the difference between gross revenue and variable costs is maximized.

For individual planning, however, more use is made of the method of comparison. The results from farm accounts are compared with standards or with the results of other farms operating under similar conditions.
Up until now the more refined methods have found only a very limited number of practical applications. Programme planning models have been worked out by Poitevin at Grignon (43). Since 1961 a few applications of linear programming are published, but this method has not yet penetrated into the extension services. Greater coordination is desirable between research and extension services and also between public and professional services.

3. Germany

The use of economic models is not at all a new idea in the German agriculture. As early as 1826 von Thünen published "Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationaalkonomie" in which he analyzed the influence of the factor space on the organization of agricultural firms in an isolated state.

The first practical use of planning in agriculture originated during the agricultural crisis of 1930 (34, pp. 71-94). "Osthilfe" (help to the East) was organized, and advice on individual farm planning was given especially in East Germany. Also before World War II budgeting models have been used for typical farms in several regions (46).

But especially after the second World War, economic models have been introduced. More and more budgets are developed by using data taken from accounts. The farmers show great interest and professional organizations for farm planning have been formed especially in some Länder in the northern part of the country.

However, data taken from individual records quickly showed several shortcomings and it has been tried to use information from research.
Standards have been developed to be used in economic models. During the last decade great progress has been made in applying these models in the field of research, individual applications and agricultural policy. Germany’s "Green Plan" is also involved in planning on a large scale (37).

Among others, especially the following two methods have been developed (3):

1) "Wirtschaftsrahmen" with the economic slide rule of Blechstein. This technique is also known as the "method of Kreuznach" because it has been developed at the "Max-Planck Institut für Landarbeit und Landtechnik" (Institute Max Planck for labor and technique in agriculture) at Bad Kreuznach in 1947.

2) The "Method of Völkenrode" has been developed at the "Institute für Betriebswirtschaft" (Institute for Business Economics) at Braunschweig-Völkenrode between 1952 and 1955 and has continuously been improved later on.

There exist also a certain number of variations and intermediate solutions which are used in other institutes. The "Institut für Wirtschaftslehre des Landbaues" (Agricultural Economics Institute) at Stuttgart-Hohenheim has combined both methods. The institutes at the University of Bonn and at the University of Kiel have applied a variation of the method of Völkenrode. These methods will be analyzed in a later section.

The direct comparison method is also used for individual planning and for the construction of regional models (48).

Occasionally programme planning in an adapted form has found a few applications (53). "Agrarwirtschaft," a German periodical for agricultural economics, regularly publishes articles describing the use of these
methods.

On a small scale, and more by way of trial, a few studies on linear programming have been made (47), particularly in the following institutes:

1) Institut für Betriebswirtschaft der Forschungsanstalt für Landwirtschaft. Braunschweig-Völkenrode.

2) Institut für landwirtschaftliche Betriebs und Landarbeitslehre. Kiel.

3) Institut für Wirtschaftslehre des Landbaues. München.


5) Forschungsstelle für bauerlichen Familienwirtschaft. Frankfurt.

Summarizing, it can be stated that in Germany much work has been done in farm planning, both in research and in extension services.

4. Italy

The use of economic models in Italy is more restricted than in any other country of the European Economic Community (2). There are several causes for this situation. Before World War II there were many subsistence farmers and little emphasis was given to agricultural economics in general and farm planning in particular. Even now very few farmers keep records. Lack of information limits the possibilities of farm planning.

In the past budgeting was the only method used to any extent. Budgeting has found two different fields of application in Italian agriculture. It has been used for regional analysis and predictions concerning the future units of production in the selected "regions of improvement and irrigation" to determine the size of the farms, given certain restrictions on capital and labor. On the other hand, budgeting is also useful for the
planning of the individual farm businesses.

Recently a few attempts have been made to apply more refined methods. Studies on programme planning are made at the Universities of Naples and Bologna.

While linear programming has found important applications in the Italian industry, the applications in agriculture are restricted to studies having the value of an example (29, 33).

Actually, the following institutes are doing research on economic models in Italian agriculture:


2) Centro di Specializzazione e Ricerche Economico-Agrarie per il Mezzogiorno (Center for Specialisation and Agricultural Economics Research for Mezzogiorno). University of Naples.


4) Istituto di Economia Agraria (Institute for Agricultural Economics). University of Bologna.

The main difficulty for further development remains the lack of basic information and sufficient personnel with the necessary preparation. Electronic computers are not available, so that it will not be possible to apply linear programming on a large scale in the near future.

5. Luxembourg

Up until 1950 there was no special advisory service for the farmers in Luxemburg, but the State Agricultural School did some advisory work
(33, pp. 33-34). Now an extension service is organized which also gives advice on farm management problems.

Since there is no institute for higher agricultural education in the country, students have to complete their training abroad. There is no research institute in Luxemburg. Therefore, the advisors have to keep in close touch with research in other countries.

6. The Netherlands

The "Landbouw-Economisch Instituut" (Agricultural Economics Institute), established since 1940 at The Hague, has an important influence on the development of farm planning in The Netherlands. Farm accounts extended fast and by now nearly 90 per cent of the farms larger than 10 ha keep records (34, pp. 55-69). This is largely due to the fact that tax accounts are required. Most accounting societies are organized in the "Vereniging van Landbouwboekhoudbureaus" (Federation of Farm Account Bureaus), and have agreed to use a uniform system. At the Agricultural Economics Institute, the results of each farm are ranked according to size and region which makes direct comparison between farms possible.

Because of the large flow of information from these records, it became possible to construct models for each region. Originally, each "typebedrijf" (31) or typical farm was the average farm for each particular region. Initially, they were used to compute the official production costs for price policy. For heterogeneous regions, however, this typical farm did not correspond with any real farm. Therefore, now the typical farm is the most frequent concrete farm (mode) in the considered region. Actually, these models are no longer used to calculate the official production costs.
Though these models are purely descriptive, they are frequently used as starting point for individual budgets. Farm management advisors have been offered training in budgeting since 1952.

As far as the use of linear programming is concerned, The Netherlands are far ahead of their partners in the Common Market. Most work with programming has been done at the Agricultural Economics Institute and also, but to a smaller extent, at the Agricultural College of Wageningen and by other organizations.

Though a certain number of programming models have been computed for individual farms (21), most models are used for larger groups of farms (32, 51).

An especially interesting study is made by Louwes and De Veer on the planning of future farms of different size in the new Polders of the Zuiderzee (23, 24).

In some provinces, the "Rijkslandbouwvoorlichtingsdienst" (National Advisory Service) has shown interest in linear programming for the solution of a series of farm planning problems. A department for applied farm management research has been established within the Central Advisory Institute at Wageningen to strengthen the economic element in advisory work and to improve the contacts between the research specialists and the advisory workers (39, p. 42).

The study of linear programming has also improved the existing budgeting techniques because of a better understanding of the planning problem.
III. LINEAR PROGRAMMING

As is pointed out in the previous chapter, in recent years attempts have been made in each country of the Common Market to use the linear programming technique for the planning of the individual farm business. Up until now, however, the study and the use of this method mostly remains restricted to Research Stations and has only very exceptionally penetrated into the agricultural extension services.

The objective of this chapter is to demonstrate the usefulness of linear programming methods for individual farm planning by advisory workers. The more specific objectives are:

1) To determine the optimum resource allocation for an individual farm by using data unique to this particular farm.
2) To specify the effect on the optimal plan of possible changes in the amount of available resources.
3) To indicate the stability of the optimal program for possible price changes and to compute the effect of different prices for livestock on resource allocation.
4) To discuss the possibilities of other programming techniques to solve more specific problems.
5) To discuss the advantages and shortcomings of linear programming for the planning of individual farms.

This study does not intend to give a full explanation of the principles and technique of this method. Detailed studies of linear programming in general (12) and more particular in agriculture (17) can be found elsewhere. Just a brief statement of the problem is given below.
We wish to maximize a linear function of $X$ (i.e., maximize profits):

(a) Maximize $f(X) = CS$

$C$ is a vector of net prices for enterprises and $X$ is a vector of activity levels. This function must be maximized, subject to the restrictions (b) and (c)

(b) $AX \leq S$

(c) $X \geq 0$

where $A$ is the matrix of input-output coefficients and $S$ is the matrix of the available resource supplies.

In the next part of this chapter, the problem will be handled in the same way as it occurs in practice when extension workers are asked to give advice on the planning of a specific farm.

A. Case Farm Situation

The farm selected for this programming analysis is located in central Belgium on loamy soil. The farm consists of 90.68 ha, which are spread over 28 parcels and allocated as follows (Figure 1):

- cultivated: 74.55 ha (parcels 1 to 20)
- permanent pasture: 14.67 ha (parcels 21 to 25)
- woods: 0.38 ha (parcel 26)
- farmstead: 0.90 ha (parcel 27)
- garden: 0.19 ha (parcel 28)
- total: 90.69 ha

The useful size is 89.22 ha since the permanent pasture can become cultivated land. Most parcels are adjoining and the greatest distance from the farmstead is less than one mile. The entire farm is rented from
Figure 1. Plan of the parcels
one landlord. The records are used from the period 1959-1969.

1. **Description of enterprises**

The enterprises considered in this study include 8 cash-crop enterprises, 1 livestock enterprise and 1 feed-crop enterprise. For each crop only one technique and one fertilizer level is considered according to the current situation on this farm.

   (a) **Crops**  Five different activities must be taken into consideration for grain-crops:
      a) Winter-wheat
      b) Winter-barley
      c) Summer-wheat
      d) Summer-barley
      e) Oats

For these crops, all the labor is furnished by the operator and three hired men and all the machinery used is owned by the operator.

Flax can be raised as a contract-crop. The gross profits are fixed in advance and the operator must furnish only labor and land, but no machinery. Peas are also raised as a contract-crop, although the gross profits are not fixed. The packing company furnishes the machinery to harvest the crop.

Sugar-beets are limited by the marketing quota of the farmer. Seasonal workers can be hired for singling the plants during spring and the harvest is partly done by custom work.

Alfalfa is raised as a two-year crop and no hay is sold. It is only used to meet the feed requirements of the livestock.

   (b) **Livestock**  Hogs. Building space is available, but the operator is
not interested in feeding hogs. Since the program is set up for an individual farm business, this activity is not included.

Poultry. Over 100 hens are kept, but this enterprise does not compete with other enterprises for the use of resources. As poultry is of minor importance and supplementary for labor requirements, it is not included in the program.

Cattle. Yearling feeder steers are purchased at a weight averaging between 400 and 425 kg. throughout the year. Nine to ten months later, they are sold at an average weight of 590 kg. During summer the steers are fed in permanent pasture and do not receive any additional feed. During winter additional silage, hay and supplement is fed. Three and seven-tenths steers can be fed per hectare of pasture. Resource requirements and returns are calculated per hectare of permanent pasture.

2. Prices, yields and gross revenue

Since this study is designed to use programming techniques within an individual farmer's planning framework, it is essential that prices as well as other coefficients be those determined by the farm operator from the actual farm (22, p. 960). Yields and prices are not average values for the region or research data but reflect the real situation on this farm.

Gross revenue for steers:

Average selling weight 594 kg.
Price per kg 29.81 BF
Gross revenue per steer 17,710.00 BF
Gross revenue per ha pasture 87,311.00 BF
Table 5. Gross revenue for crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield kg/ha</th>
<th>Price BF/100 kg</th>
<th>Gross revenue BF/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>5,000</td>
<td>470</td>
<td>23,500</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>4,600</td>
<td>360</td>
<td>16,560</td>
</tr>
<tr>
<td>Summer-wheat</td>
<td>4,700</td>
<td>475</td>
<td>22,325</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>4,500</td>
<td>390</td>
<td>17,550</td>
</tr>
<tr>
<td>Cattle</td>
<td>5,000</td>
<td>380</td>
<td>19,000</td>
</tr>
<tr>
<td>Flax</td>
<td>-</td>
<td>-</td>
<td>10,500</td>
</tr>
<tr>
<td>Peas</td>
<td>-</td>
<td>-</td>
<td>17,841</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>48,000</td>
<td>67</td>
<td>32,160</td>
</tr>
<tr>
<td>Pulp</td>
<td>28,500</td>
<td>10</td>
<td>2,850</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>9,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alfalfa silage</td>
<td>3,000</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*BF = $0.02.

3. Variable costs and net revenue

(a) Crops The variable costs for crops are composed of seeds, fertilizer, chemicals, hired labor and machinery, variable costs of tractor and combine and 4.5 per cent interest on operating capital. Table 6 gives the variable costs and net revenue.

A weighted average wage rate has been calculated for the variable labor expenses because different wage rates are paid. The weighted average is 20.16 BF per hour.

The same has been done for the variable tractor expenses. Three
Table 6. Variable costs and net revenue for crops (BF/ha)

<table>
<thead>
<tr>
<th></th>
<th>Winter wheat</th>
<th>Winter barley</th>
<th>Summer wheat</th>
<th>Summer barley</th>
<th>Oats</th>
<th>Flax</th>
<th>Peas</th>
<th>Sugar beets</th>
<th>Alfalfa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
<td>997.50</td>
<td>1,040.00</td>
<td>1,150.00</td>
<td>1,182.50</td>
<td>1,650.00</td>
<td>234.00</td>
<td>3,000.00</td>
<td>1,433.75</td>
<td>1,190.00</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>2,073.50</td>
<td>2,073.50</td>
<td>2,073.50</td>
<td>2,590.00</td>
<td>2,073.50</td>
<td>0.00</td>
<td>2,100.00</td>
<td>5,724.00</td>
<td>1,360.00</td>
</tr>
<tr>
<td>Chemicals</td>
<td>260.00</td>
<td>260.00</td>
<td>208.00</td>
<td>340.00</td>
<td>208.00</td>
<td>0.00</td>
<td>522.00</td>
<td>302.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Labor</td>
<td>490.65</td>
<td>490.65</td>
<td>497.30</td>
<td>497.30</td>
<td>497.30</td>
<td>557.60</td>
<td>436.80</td>
<td>1,831.70</td>
<td>1,502.30</td>
</tr>
<tr>
<td>Tractor</td>
<td>247.95</td>
<td>247.95</td>
<td>252.25</td>
<td>252.25</td>
<td>252.25</td>
<td>239.20</td>
<td>245.70</td>
<td>903.70</td>
<td>141.35</td>
</tr>
<tr>
<td>Combine</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Seasonal workers</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>3,637.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Custom work</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>2,000.00</td>
<td>3,025.00</td>
</tr>
<tr>
<td>Interest</td>
<td>167.55</td>
<td>169.50</td>
<td>172.30</td>
<td>202.95</td>
<td>194.60</td>
<td>28.45</td>
<td>268.35</td>
<td>524.05</td>
<td>337.70</td>
</tr>
</tbody>
</table>

Variable costs 4,283.15 4,327.60 4,399.35 5,111.00 4,916.65 1,659.25 2,936.85 572.85 16,356.20 7,556.35

Net revenue 19,216.85 12,232.40 17,925.65 12,439.00 14,083.35 9,440.75 11,268.15 18,653.80 -7,556.35
tractors with different power are used on this farm and the weighted average for gasoline and oil expenses is 16.95 BF per hour of tractor work.

(b) Livestock  The variable costs are average values taken from the records of the last three years.

Variable costs per steer:

<table>
<thead>
<tr>
<th>BF/steer</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase value</td>
<td>12,764</td>
</tr>
<tr>
<td>Supplement</td>
<td>1,075</td>
</tr>
<tr>
<td>Silage</td>
<td>355</td>
</tr>
<tr>
<td>Veterinary</td>
<td>30</td>
</tr>
<tr>
<td>Marketing expenses</td>
<td>450</td>
</tr>
<tr>
<td>Labor</td>
<td>235</td>
</tr>
<tr>
<td>Tractor</td>
<td>314</td>
</tr>
<tr>
<td>Interest</td>
<td>467</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15,390</td>
</tr>
</tbody>
</table>

Variable costs for pasture:

<table>
<thead>
<tr>
<th>BF/ha</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>1,650.00</td>
</tr>
<tr>
<td>Labor</td>
<td>39.15</td>
</tr>
<tr>
<td>Tractor</td>
<td>60.50</td>
</tr>
<tr>
<td>Interest</td>
<td>76.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,826.15</td>
</tr>
</tbody>
</table>

Total variable costs per ha pasture: 77,698 BF

Net revenue per ha pasture: 9,613 BF

4. Resource restrictions

(a) Available and required labor  The operator keeps daily records because his hired men are paid by the hour. Data are available for the labor requirements of each enterprise.

Much time of the operator is taken for marketing his products and for managerial decisions. Only four hours a day are available for work on crops or livestock.

Two hired men are on the farm up to nine hours a day. However, one
hour of their labor is used on jobs not identifiable with any particular enterprise (service labor). So, only eight hours of each hired man can be accounted for the enterprises. A third hired man is only available part time: three hours can be accounted for each day.

Together, the operator can have 23 labor hours per day at his disposal throughout the year. In addition, during the period that the sugar beets must be singled, three seasonal workers can be hired for about three weeks.

It is not necessary to set up labor restrictions for each month. Four periods can be distinguished during which more labor is required than during the rest of the year:

1) seeding of the summer-crops (March-April)
2) singling of the sugar-beets (May-June)
3) harvest of the grain-crops (July-August)
4) harvest of the sugar-beets (October-November)

Nevertheless, the periods 2 and 3 do not have to be taken in the program. Sufficient seasonal workers can be hired during period 2 and the harvest of grain-crops is highly mechanized, so that labor cannot become a limiting factor.

It is not convenient to express the labor restrictions 1 and 4 on a monthly basis because the peaks of labor requirements should be leveled off.

The summer-crops must be seeded between March 15 and April 10 including 20 week days or 460 hours. However, only 440 hours are entered into the program since for each day one hour must be subtracted for bad weather conditions which do not allow seeding.
The beginning of period 4 is determined by the opening of the sugar-manufactory on September 25. Beets can be delivered until November 30. This period includes 50 week days or 1150 hours. During this period 25 hours a day are available since sugar-beets can be harvested under bad weather conditions.

Table 7. Labor requirements per ha (hours/ha)

<table>
<thead>
<tr>
<th></th>
<th>March 15- April 10</th>
<th>Sept. 25- Nov. 50</th>
<th>Total man labor</th>
<th>Total tractor labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-grains</td>
<td>2.35</td>
<td>11.00</td>
<td>24.33</td>
<td>19.00</td>
</tr>
<tr>
<td>Summer-grains</td>
<td>9.33</td>
<td>0.00</td>
<td>24.66</td>
<td>19.33</td>
</tr>
<tr>
<td>Flax</td>
<td>9.33</td>
<td>0.00</td>
<td>27.66</td>
<td>18.33</td>
</tr>
<tr>
<td>Pea</td>
<td>9.33</td>
<td>0.00</td>
<td>21.66</td>
<td>18.83</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>9.33</td>
<td>51.00</td>
<td>90.83</td>
<td>69.25</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.00</td>
<td>30.00</td>
<td>74.50</td>
<td>10.83</td>
</tr>
<tr>
<td>Livestock</td>
<td>3.75</td>
<td>5.10</td>
<td>59.33</td>
<td>4.66</td>
</tr>
</tbody>
</table>

Only part of the labor requirements for livestock during the two restrictive periods must be taken into account. The other part is supplementary labor for two reasons:

1) Some work can be done in the morning or late in the evening before or after the labor for the crops.

2) It is possible to take care of the livestock under bad weather conditions when it is impossible to work outside.

(b) Capital situation The operator is not a beginning farmer. He has
a sufficient amount of capital at his disposal for producing purposes. No capital restriction must be brought into the program.

(c) **Land use**  The farmer does not follow a fixed rotation and no specific crop rotations are included in the program. However, all crops are restricted to a certain percentage of the arable land. Grain-crops cannot be raised on more than 60 per cent of the cropland. Wheat is limited to one-third, while peas can only be grown on one-seventh of the cropland. Flax must always be seeded after wheat and is restricted to 50 per cent of the wheat acreage.

Sugar-beets always follow after barley and cannot be raised on the same parcel more than once every four years. However, this last restraint is dominated by the limited marketing quota of the farmer. For average yields, the production of only 14 ha sugar-beets can be delivered to the manufactory.

(d) **Land restraint**  About 89.22 ha of equally fertile land are available for crops and pasture. From this, a small acreage must be subtracted to meet the feed requirements of the horse that is used for minor jobs. For this reason, 0.30 ha pasture and 0.17 ha alfalfa are taken out of the program, which brings the land restriction to 88.75 ha.

(e) **Other restraints**  Building space limits the cattle to 60 units. During the winter season, 409.5 kg. alfalfa hay must be available for each steer. In the program, the livestock activity is expressed per ha of pasture. With 3.7 steers per ha, 1515.15 kg. alfalfa hay are required per ha of pasture.

The 11 restrictions are listed below:

\[
P_{11}: \text{total size} \leq 88.75 \text{ ha}
\]
$P_{12}$: grain-crops \quad \text{≤} \quad \frac{3}{5} \text{ of cropland}

$P_{13}$: wheat \quad \text{≤} \quad \frac{1}{3} \text{ of cropland}

$P_{14}$: peas \quad \text{≤} \quad \frac{1}{7} \text{ of cropland}

$P_{15}$: flax \quad \text{≤} \quad \frac{1}{2} \text{ of wheatland}

$P_{16}$: sugar-beets \quad \text{≤} \quad \text{barley}

$P_{17}$: sugar-beets quota \quad \text{≤} \quad 14.00 \text{ ha}

$P_{18}$: spring labor \quad \text{≤} \quad 440 \text{ hours}

$P_{19}$: fall labor \quad \text{≤} \quad 1150 \text{ hours}

$P_{20}$: pasture \quad \text{≤} \quad 5.94 \text{ alfalfa}

$P_{21}$: building space \quad \text{≤} \quad 60 \text{ steers}

These resource restrictions are used for the main analysis of the study. However, some variations of the restraints $P_{11}$, $P_{18}$ and $P_{19}$ will be considered.

The initial matrix (Table 8) contains 10 real activities which are listed below:

$P_1$ : winter-wheat

$P_2$ : winter-barley

$P_3$ : summer-wheat

$P_4$ : summer-barley

$P_5$ : oats

$P_6$ : flax

$P_7$ : peas

$P_8$ : sugar-beets

$P_9$ : pasture

$P_{10}$ : alfalfa

All computations have been done with a small desk calculator. The
optimal solution, presented with rounded numbers in Table 9, has been obtained after 11 iterations.

B. Optimal Farm Plan

1. Combination of enterprises

The optimal plan, together with the actual plan, is given in Table 10. A comparison of the return over fixed costs cannot be made here because the actual farm plan is only for 82.89 ha. The optimal plan has been computed for 89.21 ha because some land will be added to the farm next year.

Table 10. Actual and optimal farm plan (ha)

<table>
<thead>
<tr>
<th></th>
<th>Actual plan</th>
<th>Optimal plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>18.45</td>
<td>28.64</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>6.30</td>
<td>22.91</td>
</tr>
<tr>
<td>Summer-wheat</td>
<td>5.60</td>
<td>0.00</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>8.80</td>
<td>0.00</td>
</tr>
<tr>
<td>Peas</td>
<td>4.30</td>
<td>12.27</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>16.00</td>
<td>11.31</td>
</tr>
<tr>
<td>Flax</td>
<td>7.59</td>
<td>10.31</td>
</tr>
<tr>
<td>Pasture</td>
<td>13.75</td>
<td>3.13</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>2.10</td>
<td>0.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82.89</strong></td>
<td><strong>89.21</strong></td>
</tr>
</tbody>
</table>

The returns, before the fixed costs are subtracted, are 1,300,810 BF.
How much the actual plan deviates from the optimal resource allocation will be discussed in the section of variable resource programming.

The optimal plan (Figure 3) consists of fewer activities than the actual plan (Figure 2) since no summer-grains must be taken in the program. The necessary adjustments are:

1) A considerable decrease in pastureland from 16.59 per cent in the actual plan to 3.51 per cent or 3.15 ha in the optimal solution. This means a decrease in the number of feeder steers from 43 to 10 or 11.

2) A decrease in the acreage of sugar-beets from 19.30 per cent to 12.67 per cent or 11.31 ha. It seems surprising that the program indicates less than the marketing quota. However, this is entirely reasonable because of the high labor requirements during October and November.

3) An increase in the acreage of grain-crops. In both the actual and optimal plan grain-crops are raised on 60 per cent of the cropland. Because of a decrease in pastureland, the grain-crops can be expanded from 47.33 per cent to 57.80 per cent of the total acreage.

4) Flax and peas must also be expanded.

2. Allocation of the resources

Four restrictions are free resources. They do not limit production in the optimal plan and their marginal value product is zero.

1) Flax does not cover half of the wheatland.

2) The acreage of sugar-beets is smaller than the acreage of barley.

3) The marketing quota for sugar-beets is not fully used.

4) Building space for 49 steers remains unused.

The seven other restraints are scarce resources. The values in the
Figure 2. Actual farm plan

Figure 3. Optimal farm plan
Z-C row of the disposal activities in the final matrix (Table 9) indicate the marginal value products or shadowprices of these scarce resources. These marginal value products are important for managerial decisions since they indicate possible changes in the total net revenue through the purchase of additional resources.

Little meaning can be attached to the shadowprices of the crop restrictions (rotations) since changes in these restraints should also bring about changes in yields and other input-output coefficients.

Most important is the marginal value productivity of land. The value 6,769 BF/ha exceeds by far the rent. This indicates that the operator can profitably rent more land if it is possible to do so. The marginal value product of land remains unchanged when the size of the farm is decreased to 86 ha or increased to 103 ha. The vector \( P_{11} \) (Table 9) shows the necessary changes for the plan when one ha is added to the farm. Especially the pastureland must be expanded.

The shadowprice of labor between March 15 and April 10 is very high: 1,189 BF/hour. Additional labor can profitably be used during this period which makes it possible to raise more summer-crops instead of pasture. The marginal value product of labor during fall is 181 BF/hour which is also higher than the going wage rate.

**C. Variable Resource Programming**

The high marginal value productivity of land and labor indicates the importance of analyzing the effect of variations in the amount of land and labor on the composition of the optimal plan. This analysis can provide an answer for the following questions which face the farm operator:
1) To what extent is it profitable to change (increase or decrease) the amount of land and hired labor?

2) How must the farm plan be adapted to get the maximum out of these proposed changes?

1. **Influence of variable land resource**

   Through continuous programming, the six plans of Table 11 were obtained.

Table 11. Optimal plans for increasing farm size (ha)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>17.50</td>
<td>18.15</td>
<td>20.95</td>
<td>25.62</td>
<td>28.57</td>
<td>28.96</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>14.00</td>
<td>22.86</td>
<td>23.17</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Oats</td>
<td>0.00</td>
<td>0.52</td>
<td>2.76</td>
<td>6.50</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Flax</td>
<td>0.00</td>
<td>0.00</td>
<td>2.16</td>
<td>5.76</td>
<td>10.58</td>
<td>9.01</td>
</tr>
<tr>
<td>Peas</td>
<td>7.00</td>
<td>7.77</td>
<td>8.98</td>
<td>10.98</td>
<td>12.24</td>
<td>12.41</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>11.46</td>
<td>10.60</td>
</tr>
<tr>
<td>Pasture</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>16.22</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>2.73</td>
</tr>
<tr>
<td><strong>Total size</strong></td>
<td>52.50</td>
<td>54.44</td>
<td>62.86</td>
<td>76.86</td>
<td>85.71</td>
<td>103.10</td>
</tr>
</tbody>
</table>

The graphical presentation of Figure 4 makes it possible to derive all optimal plans when the total acreage increases from 52.50 ha and 103.10 ha. With only 52 ha, labor is not a restricting resource, and only the crops with the highest net revenue per ha are taken in the program. Sugar-beets
Figure 4. Optimal plans with increasing farm size
are raised to the limit of the marketing quota. Above 63 ha spring labor becomes limiting. The summer-grains are partly replaced by winter-barley though last activity has a lower net revenue per ha.

When the farm size increases further, fall labor also restricts the plan so that less sugar-beets must be raised. Once the size exceeds 86 ha, labor becomes even more restrictive and a part of the farm must remain in permanent pasture. When the total size reaches 103 ha, building space also becomes a limiting factor and additional land can no longer be used.

In general terms, it can be said that when the farm size increases and the labor remains unchanged, the crops with the highest net revenue per ha are gradually replaced by activities with the highest net revenue per hour of labor.

Table 12. Net revenue and marginal value products of land and labor with increasing size (BF)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total net revenue</td>
<td>850,471</td>
<td>878,993</td>
<td>998,441</td>
<td>1,194,328</td>
<td>1,280,260</td>
<td>1,397,975</td>
</tr>
<tr>
<td>Net revenue/ha</td>
<td>16,199</td>
<td>16,145</td>
<td>15,884</td>
<td>15,539</td>
<td>14,937</td>
<td>13,559</td>
</tr>
<tr>
<td>MVP of land/ha</td>
<td>14,668</td>
<td>14,194</td>
<td>13,993</td>
<td>9,703</td>
<td>6,769</td>
<td>0</td>
</tr>
<tr>
<td>MVP of spring labor/hour</td>
<td>0</td>
<td>0</td>
<td>2,028</td>
<td>1,587</td>
<td>2,438</td>
<td>2,438</td>
</tr>
<tr>
<td>MVP of fall labor/hour</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>842</td>
<td>181</td>
<td>181</td>
</tr>
</tbody>
</table>
By continuous programming, the total net revenue and the marginal value products for land and labor at different sizes can also be obtained (Table 12).

Figure 5 and Figure 6 give, respectively, the total net revenue and the marginal value productivity of land with increasing size. The shadow-price of land drops below the level of the rent at 103.10 ha, which indicates that, other resources remaining unchanged, it is not profitable to rent additional land. On the other hand, the marginal value product of labor increases gradually from 0 to 2,438 BF for spring labor and from 0 to 181 BF for fall labor.

Continuous programming enables us to compute how far the actual plan deviates from the optimal solution. We can compare the net revenue of the optimal plan for 82.89 ha with the net revenue for the actual plan.

Total net revenue

optimal plan: 1,252,995 BF
actual plan : 1,176,342 BF
difference : 76,653 BF

In reality, the difference will even be greater because in the actual plan, sugar-beets exceed the marketing quota and must be sold at a lower price.

Such a comparison is very important for extension workers. They are helpful to gain the confidence of the operator and to convince him of the advantages of the proposed plan.

2. Influence of the available labor

The farmer is interested to know how his income can be affected by
Figure 5. Total net revenue with increasing farm size

Figure 6. Marginal productivity of land with increasing farm size
possible changes in the labor restrictions. Will the net revenue increase with unlimited labor? How must the plan be changed when the third hired man is no longer available? To answer these questions, three plans for different discrete labor levels are compared:

1) Without the part-time hired man.
   March 15 - April 10: 360 hours
   September 25 - November 30: 1000 hours

2) Actual situation.
   March 15 - April 10: 440 hours
   September 25 - November 30: 1150 hours

3) Unlimited labor.
   The two labor restrictions are dropped from the program.

Table 13. Optimal plans and net revenue for different labor restrictions

<table>
<thead>
<tr>
<th></th>
<th>Limited labor</th>
<th>Actual situation</th>
<th>Unlimited labor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha</td>
<td>ha</td>
<td>ha</td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>25.01</td>
<td>28.64</td>
<td>29.58</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>20.00</td>
<td>22.91</td>
<td>0.00</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>0.00</td>
<td>0.00</td>
<td>14.00</td>
</tr>
<tr>
<td>Oats</td>
<td>0.00</td>
<td>0.00</td>
<td>9.67</td>
</tr>
<tr>
<td>Flax</td>
<td>7.67</td>
<td>10.51</td>
<td>8.82</td>
</tr>
<tr>
<td>Peas</td>
<td>10.72</td>
<td>12.27</td>
<td>12.68</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>9.31</td>
<td>11.31</td>
<td>14.00</td>
</tr>
<tr>
<td>Pasture</td>
<td>13.75</td>
<td>2.83</td>
<td>0.00</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>2.31</td>
<td>0.48</td>
<td>0.00</td>
</tr>
<tr>
<td>Total net revenue (BF)</td>
<td>1,206,584</td>
<td>1,300,810</td>
<td>1,366,082</td>
</tr>
</tbody>
</table>
Figure 7. Optimal plans for different labor restrictions
It is striking that with increasing labor supply the plan must be changed in the same direction as with decreasing land supply. The activities with the highest net revenue per hour are replaced by activities with the highest net revenue per ha when more labor is available (Figure 7).

D. Programming with Variable Prices

1. Stability of the program

Will the computed plan still be optimal if the real prices deviate from the price expectations which were used to set up the program? The optimal plan is only affected when changes in the price-ratios occur.

The final matrix (Table 9) enables us to derive by how much the net revenue of each activity may change before the computed plan becomes sub-optimal. Table 14 indicates the upper and lower limits within which the net-revenue of each enterprise may change without affecting the optimal solution.

It is very unlikely that the price-variations of the crops will exceed the upper or lower limits. All prices may change by more than 10 per cent. The smallest range exists for a price decrease of peas, only 11 per cent, but even this is quite improbable since peas are a contract-crop.

The program is much more sensitive for changes in the net revenue of livestock. The net revenue per ha of pasture can change between 5,747 BF and 12,753 BF without any effect on the optimal plan. Nevertheless, this is only a small range per steer. The net revenue per steer can only decrease by 784 BF or increase by 637 BF before a change becomes necessary.

If we assume that the costs of production remain constant, the range
Table 14. Stability of the optimal solution (BF/ha)

<table>
<thead>
<tr>
<th></th>
<th>A net revenue</th>
<th>B maximum decrease</th>
<th>A - B lower limit</th>
<th>C maximum increase</th>
<th>A + C upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>19,216</td>
<td>5,018</td>
<td>14,198</td>
<td>11,655</td>
<td>30,872</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>12,232</td>
<td>2,982</td>
<td>9,250</td>
<td>6,984</td>
<td>19,216</td>
</tr>
<tr>
<td>Summer-wheat</td>
<td>17,925</td>
<td>unlimited</td>
<td>unlimited</td>
<td>7,135</td>
<td>25,061</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>12,439</td>
<td>unlimited</td>
<td>unlimited</td>
<td>5,637</td>
<td>18,076</td>
</tr>
<tr>
<td>Oats</td>
<td>14,883</td>
<td>unlimited</td>
<td>unlimited</td>
<td>3,993</td>
<td>18,076</td>
</tr>
<tr>
<td>Flax</td>
<td>9,440</td>
<td>4,607</td>
<td>4,832</td>
<td>1,827</td>
<td>11,268</td>
</tr>
<tr>
<td>Peas</td>
<td>11,268</td>
<td>1,827</td>
<td>9,440</td>
<td>39,967</td>
<td>51,235</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>18,653</td>
<td>9,212</td>
<td>9,441</td>
<td>12,272</td>
<td>30,926</td>
</tr>
<tr>
<td>Pasture</td>
<td>9,613</td>
<td>3,865</td>
<td>5,747</td>
<td>3,140</td>
<td>12,753</td>
</tr>
</tbody>
</table>

of the selling price is only from 28.49 BF/kg to 30.88 BF/kg. This means that an adaptation of the plan is necessary if the average selling price decreases by more than 1.32 BF/kg or increases by more than 1.07 BF/kg.

2. Programming with variable livestock prices

In reality, the prices for steers often fluctuate beyond the stability range indicated above. It is important to know how the plan ought to be adapted outside this range.

The selling price is made variable between 28.49 BF/kg below which it is not profitable to feed steers and 32.28 BF/kg when livestock reaches the maximum possible level for the available building space. Five different plans are optimal within this range (Table 15).
Table 15. Evolution of the optimal plan with increasing selling prices for steers (ha)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>29.58</td>
<td>28.64</td>
<td>25.68</td>
<td>25.13</td>
<td>24.18</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>23.67</td>
<td>22.91</td>
<td>13.38</td>
<td>11.83</td>
<td>8.82</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>2.17</td>
<td>5.18</td>
</tr>
<tr>
<td>Oats</td>
<td>0.00</td>
<td>0.00</td>
<td>7.97</td>
<td>6.11</td>
<td>5.34</td>
</tr>
<tr>
<td>Flax</td>
<td>10.09</td>
<td>10.31</td>
<td>4.27</td>
<td>3.14</td>
<td>1.92</td>
</tr>
<tr>
<td>Peas</td>
<td>12.68</td>
<td>12.27</td>
<td>11.01</td>
<td>10.77</td>
<td>10.36</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>11.06</td>
<td>11.31</td>
<td>13.38</td>
<td>14.00</td>
<td>14.00</td>
</tr>
<tr>
<td>Pasture</td>
<td>0.00</td>
<td>2.83</td>
<td>11.69</td>
<td>13.55</td>
<td>16.22</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>1.67</td>
<td>0.48</td>
<td>1.97</td>
<td>2.25</td>
<td>2.73</td>
</tr>
<tr>
<td>Total cropland</td>
<td>88.75</td>
<td>85.92</td>
<td>77.06</td>
<td>75.40</td>
<td>72.53</td>
</tr>
<tr>
<td>Number of steers</td>
<td>0</td>
<td>10.48</td>
<td>43.28</td>
<td>49.40</td>
<td>60.00</td>
</tr>
</tbody>
</table>

By feeding more steers with increasing selling prices, more labor becomes available. This makes it also possible to raise more sugar-beets. In plan IV we have nearly the same ratio between cropland and pasture as in the actual plan. This means that the actual plan should be near the optimum if the average selling price of steers increases from 29.81 BF/kg. to 31.62 BF/kg. or more.

Figure 8 shows the total net revenue for the five plans. Table 16 gives the marginal value products for land and labor. The marginal value product of labor decreases with increasing livestock prices because the
Figure 8. Total net revenue with increasing livestock prices
livestock enterprise does not require much labor.

Table 16. Total net revenue and marginal value products of land and labor with increasing livestock prices (SF)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total net revenue</td>
<td>1,289,865</td>
<td>1,289,865</td>
<td>1,309,700</td>
<td>1,334,874</td>
<td>1,360,734</td>
</tr>
<tr>
<td>MVP of land/ha</td>
<td>3,164</td>
<td>3,164</td>
<td>9,698</td>
<td>11,815</td>
<td>13,991</td>
</tr>
<tr>
<td>MVP of spring</td>
<td>1,821</td>
<td>1,821</td>
<td>548</td>
<td>268</td>
<td>29</td>
</tr>
<tr>
<td>labor/hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVP of fall</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>0</td>
</tr>
<tr>
<td>labor/hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

E. Other Programming Techniques

In this section a short review is given of other programming techniques which have been developed more recently. They are either further applications of the simplex method or other procedures developed to solve special problems.

Programming with one variable price can be extended to two or more variable prices (17, pp. 283-307). Important in this context is the analysis of the effect of simultaneous variations in feed prices and livestock prices, on the equilibrium between livestock, feed used on the farm and feed raised for the market. Price maps can be constructed which show the optimal plans for each price combination. Programming with variable prices makes it also possible to derive aggregate normative supply functions for agricultural products from homogeneous regions.

Programming with two or more variable resource restrictions can be
equally important in farm planning. Contour maps can be drawn by finding first the ridge lines and then completing the plans within these lines (17, pp. 243-264). It is also possible to analyze the effect of changes in the input coefficients.

All programming solutions in the preceding sections give the optimal plans for a single period in general for one year. The development of dynamic programming (22) made it possible to provide sequences of optimal plans over time. This is especially important when capital is a restricting resource. In such cases, the optimal plan of one year is dependent on the optimal plans of the previous years or periods. The additional amount of capital made available each year "ties together" the plans of succeeding years. Spending for the household in one period competes directly with the capital available for the farm during next period. With dynamic programming, the present value of future income from several years is maximized.

Because of the assumption of divisibility, the variables in the final solution can take on non-integer values. This does not necessarily disturb the results for crops since often the field layout can be adapted. For livestock, however, we need integer numbers. This problem can be solved with mixed integer programming (7). This procedure deals with problems in which some of the variables are integers or which have a nonconvex character or both (8). With this technique, the following problems can also be handled:

1) Initial investment or set-up cost
2) Economies of scale
3) Long term investments in capital goods
The simplex procedure cannot handle these problems because they violate basic assumptions such as divisibility, continuity and convexity.

First an ordinary linear programming solution is computed, ignoring the integer restraints (25). If some unknowns fail to take on integer values, cutting planes can be constructed, and the problem can be solved for a new optimal solution.

An example taken from the Belgian farm analyzed above will illustrate this method. In the final matrix (Table 9), the variable $p_{21}$, indicating the ample building space, takes on the non-integer value 49.53. This means that 10.47 steers must be fed to maximize profits which obviously is impossible.

The addition of a new row vector $S$, forming a cutting plane, and a corresponding slack variable, makes it possible to find an integer solution. The additional restraint takes the form:

$$ S = -0.53 - 0.71(-p_3) + 0.71(-p_4) - 0.71(-p_5) - 3.898(-p_{11}) - 0.94(-p_{12}) - 0.67(-p_{18}) - 0.00079(-p_{20}) $$

Because of the penalty imposed on the new disposal activity, some of the Z-C values become negative and the problem must be remaximized.

Table 17 shows that only minor shifts between the enterprises have taken place. Exactly 10 steers can be fed on the 2.71 ha pasture. The optimal Z-C value for the mixed integer solution is 1,300,506 BF which is only 304 BF less than for the continuous solution.

The minor changes indicate that in such a case it is not worth while to compute the mixed integer solution where more than three iterations were necessary. Rounding can give nearly as good a solution. However, for the handling of economies of scale and investment costs, integer pro-
Table 17. Continuous and mixed integer solution (ha)

<table>
<thead>
<tr>
<th>Item</th>
<th>Continuous plan</th>
<th>Mixed integer plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>28.64</td>
<td>28.68</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>22.91</td>
<td>22.95</td>
</tr>
<tr>
<td>Peas</td>
<td>12.27</td>
<td>12.29</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>11.31</td>
<td>11.30</td>
</tr>
<tr>
<td>Flax</td>
<td>10.31</td>
<td>10.30</td>
</tr>
<tr>
<td>Pasture</td>
<td>2.83</td>
<td>2.71</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.48</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Programming can help to solve important problems.

The assumption of linearity still is one of the major restrictions on the possibilities of programming solutions in farm planning. Further study on non-linear and quadratic programming is desirable.

All methods discussed above have been based on the implicit assumption of resource supplies, input coefficients and prices which are known with certainty. However, all these coefficients are subject to variability. Stochastic programming handles this problem (17, pp. 554-588). Here the objective is not merely to maximize profits since the decision-maker can be willing to sacrifice expected income to achieve greater income stability (4, p. 17).

An E-V (expected income versus income variance) indifference system must be constructed. A series of preferred plans can be obtained which minimize the variance associated with each expected income. If only the
variability in the objective function (yield and price variability) is recognized, and in practice the major errors occur in the objective function, the problem can be handled without too much trouble.

This discussion of different programming techniques cannot be finished without giving attention to the wide opportunities of linear programming for studies on regional adjustments. Which regional adjustments ought to come about once the six countries of the E.E.C. form one economic unit? Very interesting work can be done in this field, but further discussion of these possibilities is beyond the objective of our present study.

F. Possibilities and Limitations

The previous sections have made obvious that a broad range of possibilities of linear programming exist for the planning of the individual farm business. Let us consider now, before we draw any conclusions about the practical usefulness, some shortcomings and limitations which are attributed, rightly or wrongly, to this technique. It will turn out that many objections either are without foundation or are not peculiar to programming methods since the same can be argued against other farm planning procedures.

Sometimes it is argued that linear programming requires too many and very precise data (55, pp. 169-171) which usually cannot be obtained on most farms. Indeed, collecting data is the most laborious task in setting up a program. However, it is also true that a plan cannot be more precise than the information used to compute it. This does not restrict linear programming by more than some other planning techniques, since they mostly require the same data. In any case, farm accounts and other sources of
information are very helpful, if not necessary.

The computational burden can also be considered as a limitation for the practical use of this procedure (34, p. 93). We have to be careful with this objection. It is true that linear programming does require many computations. However, if we wish to attain the same accuracy with other methods, even more computations can be involved if the number of variables is large. The computations can be done by clerical workers, whereas this possibility is excluded with budgeting techniques because too much personal judgment is involved.

High speed computers, if they are available, can solve large problems in a much faster and probably cheaper way. This can facilitate the job of extension workers who are involved in farm planning since the computational facilities make it possible to centralize the planning over larger areas. Actually, the use of an electronic computer can cost less than budgeting by hand.

It can also be argued that the assumptions underlying the method do not always correspond with the real world situation.

1. Linearity

The functional input-output relationships must be homogeneous of degree one. Other methods, even conventional budgeting, are also based on the very same assumption. The name of the method which explicitly underlines this assumption has marked this criticism from outsiders more strongly.

The concept of diminishing returns can be included by breaking down the production function into linear segments (56). With increasing returns,
more difficulties are involved, but mixed integer programming helps us to handle this problem. However, budgeting can be more suited to handle some of these cases.

2. **Homogeneity**

Deviations make the program more complicated but can be handled in the same way as non-linearity.

3. **Finiteness**

The number of possible alternatives must be finite. In an agricultural firm, the possible variations in the production technique are almost unlimited, but many possible variations need not be considered if we are planning in the short run. Nevertheless, with linear programming many more variables can be handled than with any other planning method.

4. **Certainty**

The assumption of perfect knowledge in our world of uncertainty of course is a serious restriction. Once more, the same is true for any other technique. Stochastic programming shows hopeful prospects but does not yet reach the field of practical applications.

5. **Divisibility**

Mixed integer programming permits us to treat problems which do not satisfy this condition. However, problems of indivisibility in crop production are ignored in the literature since it is assumed that the layout of the fields can be adapted to the computed program. Nevertheless, especially under Western European conditions, indivisibility in crop production can become troublesome. Therefore, more attention is given to this
situation here.

Many farms are divided into several small parcels of irregular shape. The map of Figure 1 is a rather favorable example. In addition, the parcels are often scattered over a wide area which makes it impossible for the individual operator to improve this situation. This means that the farmer is obliged to set up his plan in conformity with the layout of his fields and not vice versa.

The size of each activity must take on a specific non-integer value, corresponding with one of all possible combinations of the parcels. Theoretically, it is not impossible to take this into account in setting up the initial matrix. In practice, however, this should over-complicate the programming.

Ignoring these restraints, the practical execution of the computed plan will not allow the operator to achieve the highest possible net revenue. However, it will mostly be possible to combine the parcels in such a way that the practical solution is near the optimum and that it is not worth while to consider the size of the parcels as restraints.

It must be noted that linear programming is not a panacea which gives an answer to all possible management problems with which the operator is faced. Of the three management questions,

1) What to produce
2) How much to produce
3) How to produce it

a programming solution can easily supply an answer to the first two questions. However, an answer to the third problem is not always obtained with programming. Nevertheless, several activities representing different pro-
duction methods for each crop or livestock enterprise can be included in the program. Some decisions which affect only a part of the farm business or which have a more or less technical character are not likely to be solved with the programming techniques.

Let us return to the farm analyzed above for two illustrations. The question whether the farmer should go on with harvesting the sugar-beets with hired machinery or buy his own equipment can easily be answered with partial budgeting but becomes very troublesome if included in a programming model.

It can also be argued for the same farm that it is not necessary to decrease the acreage of pasture as is indicated by the optimal program, but that the real problem is to make the pasture more productive. Indeed, the data used are peculiar to this farm and no comparison is made with the production potential of the soil. This means that first the purely technical inefficiencies must be eliminated before the optimal combination of enterprises is computed. If this is neglected, the final solution will not be optimal.

Sometimes, lack of flexibility is indicated as a disadvantage of the programming techniques. It is hard to find any real foundation in this objection. All kinds of possibilities can be included, but of course they make the model more complicated.

Some shortcomings are due to the programmers themselves, rather than to the method. In many programs, the labor restrictions are set up in monthly periods. However, in reality the labor peaks do not always coincide with these monthly periods. The eventuality that some labor restrictions are overlooked that way is not imaginary. The personal judgment of the
programmer in the setup of the initial matrix and in defining the coefficients is decisive for the optimality of the final solution.

Summarizing, we are able to state that many so-called shortcomings are not peculiar to linear programming or can be prevented by a careful formulation of the problem. The shortcomings are more in terms of a comparison with the "ideal method" than with the other existing approaches.

Whether or not linear programming will become the most appropriate farm planning procedure for extension services largely depends on the costs which are associated with the preparation of an individual plan. Becker (49) cites the following figures for the United States:

1) Two full weeks of a person experienced both in linear programming and the agricultural production of the area.

2) Approximately $60 of computer time.

The last value seems to overestimate the computer expenses.

Planning a small farm is nearly as expensive as planning a larger operation. This makes it doubtful whether or not the benefits will be sufficiently large to exceed the costs for the planning of the small farms which make up the majority in the E.E.C. Though there are numerous publications on linear programming, only a limited number of practical applications is known.

Many extension workers in Europe question the practical usefulness of linear programming. Typical for this view are the conclusions of the seminar on farm business planning methods held at Oslo in 1960 (39, p. 7).

"Detailed consideration of this technique (LP) was not made as the technique was considered to be primarily appropriate for research workers rather than farm advisers."
Nevertheless, they recognize the benefit of linear programming if a great mass of data must be handled (39, p. 35):

"Theoretically, however, linear programming is the best farm planning method, since it permits comparison of a larger number of alternatives in the farm organization than can be handled by traditional budgeting."

Actually, most farm advisory workers in the countries of the European Economic Community are more familiar with technical than with economic problems. Advice on farm management problems is only a small part of their advisory work. Under such circumstances, linear programming cannot be considered as being of immediate practical utility. It would be a great progress if a staff of agricultural economists could release these extension workers from their work on farm planning. This would make it possible to centralize the planning over larger areas and would also justify the use of electronic computers for the elaboration of linear programming models.

Wide prospects are open for the use of linear programming in individual farm planning. The method is ideally preferable to the other existing planning devices for the solution of most management problems. However, certain limitations of a rather temporary and material nature prevent a fast development in the use of this technique.
IV. OTHER FARM PLANNING METHODS

A. Budgeting

1. Definition

Before going into detail, it is necessary to specify exactly what is meant by budgets and budgeting. The literature is very confusing in the use of the meaning of these terms.

In its most general sense, a budget is a plan for "future using or spending" (19). Evidently, in this meaning budgeting cannot be considered as a farm planning method because its objective is not to obtain the optimal or a better production plan. Such a budget is purely descriptive.

Up until ten years ago and sometimes also in more recent publications farm budgeting has been used in the same meaning as farm planning. This is not surprising since budgeting has long been the only method used for farm planning. In this sense must Hopkins' definition of budgeting be interpreted (20, p. 109):

"... the practical method of checking over farm plans and perhaps developing new ones."

This definition covers any farm planning method.

In still other publications (40, pp. 59-64) budgeting is only considered as the final stage for each planning method. In this sense it is only a systematic way to measure the financial gain or loss for farm plans obtained by other methods. Its objective is only to show the relative advantage of a particular organization.

In this study the word budgeting will be used in a more specific way to indicate the method of substitution. This method consists of trying
out, at least on paper, the effect of substituting a new enterprise in place of an old one or of changing relative sizes of present enterprises (20, pp. 445-447). It is an informal trial and error process leading to an improved farm plan. Starting from the existing organization, the effect of alternative solutions is measured.

During the last decade relatively less attention has been paid to budgeting at least in the literature than during earlier years. This is largely due to the development of more refined techniques. Nevertheless, budgeting has not lost its usefulness. We will consider the possibilities which are still open to this approach.

2. Methods

We can distinguish partial and complete budgeting. Complete budgeting refers to making out a plan for the farm as a whole. In most countries special budget forms are available to make easier the collection of the required input-output data. They are arranged so that the person making computations is less likely to make mistakes in calculating costs or returns. An assessment of costs and returns for different farm plans is made and the final selection is based on the comparison of such alternative plans.

Complete budgeting is more nearly parallel with linear programming than is likely to be revealed at the first glance. The same restrictions have to be taken into account. The tables used for budgeting can be very similar to the initial matrix for linear programming. Linearity is also assumed. Only the variable costs of each enterprise must be taken into consideration.

Partial budgeting has become more important relative to complete budgeting through the development of other techniques for planning the farm
as a whole. Partial budgeting refers to estimating the returns for a small part of the farm business. It can be used to estimate the effect of using additional resources or of replacing one activity by another.

The formula for partial budgeting is quite simple (40, p. 60):

\[
\begin{align*}
\text{extra costs} : A & & \text{costs saved: C} \\
\text{sales foregone: B} & & \text{extra sales: D} \\
\text{advantage : E} & & \\
\hline
A + B + E & = & C + D
\end{align*}
\]

Some advisory workers point out that the preparation of a complete farm plan, though ideally desirable, has practical disadvantages (41, p. 12). Many operators are unwilling to undertake a complete reorganization of their farms. Thus, it is advisable to proceed gradually by making improvements in specific aspects of the farm economy. In Germany, models have been constructed consisting of a sequence of changes over three years (46). Partial budgeting is essential for such problems.

A distinction can also be made between long-run and short-run budgets. While the former are set up for a period of several years into the future, short-run budgets are applicable for the individual year. A frequent mistake in long-run budgets is the fact that future returns are not always properly discounted (14, p. 402).

Let us consider the budgeting procedure more closely to analyze the underlying principles. Heady points out what happens when a small change is made in the quantity of resources (19, pp. 67-72):

... the analyst has in mind the concept of a value production function where capital, labor and other technical complements are measured on the horizontal axis, while the value returns are measured on the vertical axis of a two-dimensional graph. Ordinarily, no attempt is made to estimate the curve, but only to determine two or three points on it.
Partial budgeting can also be used to estimate the effect of reducing the amount of resources for one activity and increasing it for another activity:

In this case, the analyst has in mind two simple value production functions . . . He also has in mind a production possibility curve or iso-resource curve and examines, in effect, two points on the iso-resource curves, to determine which crop or livestock system is consistent with the highest revenue.

This comparison can be between two points on a production possibility curve where all resources used are shifted from one to another enterprise. More often only a part of the resources are shifted to another enterprise.

3. Example

These principles can be illustrated graphically with an example of the farm analyzed above with linear programming. We consider the optimal combination of sugar-beets and pasture (Figure 9). It is not possible to handle more than two variables at once with this method.

The broken line ABC is the production possibility curve for sugar-beets and pasture. This curve is composed of iso-resource curves for labor and land. The other activities are assumed to be fixed. Each iso-resource curve indicates the amount of resources available for sugar-beets and (or) pasture, left over after subtraction of the resources required by the fixed activities. RR is the highest iso-revenue curve which can be attained without violating the imposed restrictions. The point R indicates the optimal combination of pasture and sugar-beets for which land and labor are fully utilized.

The combination of 10.22 ha sugar-beets and 3.92 ha pasture is identical with the optimal combination obtained by linear programming. This is
Figure 9. Optimal combination of pasture and sugar-beets

Figure 10. Combination of pasture and sugar-beets with changed labor restrictions
so only because the fixed activities were already in an optimal combination.

The same result is obtained by solving the two following equations:

iso - land: \[ x_1 + x_2 = 14.14 \]

iso - labor: \[ 9.33 x_1 + 1.20 x_2 = 108.92 \]

Through substitution we obtain:

sugar-beets: \[ x_1 = 11.31 \text{ ha} \]

pasture: \[ x_2 = 2.83 \text{ ha} \]

The substitution method can also be used to estimate the change in profits associated with reducing (or increasing) the quantity of resources (Figure 10). The effect of a reduction in labor force is considered for the same farm and for the same pair of activities. Labor I is reduced from 440 to 380 hours and labor II from 1,150 to 1,000 hours. Again, we assume that the level of all but two activities remains unchanged. The two iso-labor curves are shifted to the left and the new production possibility curve is \( A'B'C' \).

In \( B' \), the iso-revenue curve \( R'R' \) reaches its maximum level for a combination of 3.92 ha sugar-beets and 10.22 ha pasture. Again, the same result can be obtained by solving the equations:

\[ x_1' + x_2' = 14.14 \]

\[ 9.33 x_1' + 1.20 x_2' = 48.92 \]

A comparison of these results with the combination obtained by linear programming (Table 13) indicates that \( B' \) does not give the real optimum, but only a shift in the right direction. The reason is clear: a change in the labor restrictions does not only affect the combination of sugar-beets and pasture, but the organization of the whole farm. More alfalfa must be
raised because the livestock program is expanded and the area of grain-crops must decrease since they cannot exceed 60 per cent of the cropland. It is necessary to consider several pairs of activities before the optimum can be reached.

4. Evaluation

The example has shown that conventional budgeting is based on the same assumptions as linear programming, but it gives the optimal solution only if not more than two activities with several restrictions or two restrictions for several activities need to be considered.

If more activities are involved, we can consider several pairs of activities and proceed towards an optimal or an improved solution via a trial and error process. The problem becomes especially difficult if we want to establish the equilibrium between livestock and crops since this equilibrium cannot be presented in a two-dimensional graph. Only by small chance, a person might hit the optimum.

It is true that, in setting up a budget, all these curves are seldom drawn upon paper, but they show the substitution rates which really must be taken into account when one activity is substituted by another.

In practice, the following procedure is often used. A production plan is composed based on the highest net revenue per hectare, disregarding the other restrictions. If it turns out that the plan is not feasible, the necessary adaptations are made. Though this rough approach can give satisfactory results for rather poorly organized farms, it becomes much less appropriate for the planning of above-average farms. In practice, however, it frequently is the most advanced operators who ask for advice on farm organization.
Nevertheless, it is not to be denied that budgeting has some definite advantages over the more sophisticated and more formal farm planning techniques. Up until now, budgeting has contributed more to the improvement of farm organization than any other planning method.

Some problems which affect only a part of the farm business can more easily be solved with budgeting than with programming. Initial investment costs which influence one single enterprise are a typical example. When the operator prefers a sequence of partial improvements above a complete reorganization of the farm, simple partial budgets can prove to be useful.

Another advantage is related to the actual farm planners. As mentioned earlier, many extension workers in the countries of the E.E.C. are not specially trained in economics and mathematics. Their broad practical experience is more suited to budgeting than to mathematical procedures. They have in mind many real farm plans for the region in which they are working which enables them to combine budgeting in an intuitive process with the method of comparison.

A third advantage also finds its origin in the simplicity of budgeting. We can expect that in the future more farmers will use paper and pencil to figure out the best organization. However, we cannot expect that they will use complex methods. Budgeting is the most appropriate method to be used by the operator.

Budgeting is not going to be completely replaced or out-moded through the development of refined techniques. However, the budgets must be kept simple since other methods are available where high precision is required. Too much subjective judgment is required to reach the optimal solution with the budgeting approach.
B. Programme Planning

1. Development

There is a growing tendency to use the term "programme planning" to describe all farm planning methods which fall between traditional budgeting and linear programming. These programme planning methods are more formal than budgeting through the use of a systematic process for the selection of the enterprises, but they are less formal than linear programming methods because the mathematical elegance of matrix algebra in the simplex approach is relaxed.

The general idea of programme planning is to avoid the difficult mathematical procedures but also to eliminate the strong trial and error element of budgeting (39).

Programme planning was originally developed by Hartmans at the University of Minnesota (40, pp. 46-58). Later, a similar technique has been developed in Sweden (27) and the United Kingdom (9). In both these countries programme planning is used in the advisory services. Actually, the same approach has been applied in Norway, France and Italy. A slightly different procedure has been developed in Germany (53). Linear programming is the underlying basis of all programme planning methods.

2. Methods

The preparatory stage of programme planning is identical with the preparation for the setup of the initial matrix for a linear programming solution. The very same activities and restrictions must be defined. The input-output coefficients are the same for both methods and they use identical objective functions. Both methods depend on the difference between
gross revenue and variable costs per enterprise for the selection of profitable enterprises.

While matrix algebra must be used for linear programming, to solve a set of simultaneous equations and to obtain the optimal solution, programme planning tries to get around the computational burden through a simplified approach. Though there exist slight differences according to the country where the method is used, in general the same work sequence is followed.

In the Swedish work sequence (54), which has been taken over by some countries in the E.E.C., consecutively four different forms are used.

Form I is used for the collection of all necessary information on the farm.

Form II, "summary of the contribution calculations," is very similar to the matrix for the simplex solution. All possible activities are listed with their resource requirements, gross revenue and variable costs.

Form III, "choice key" (Table 18), simplifies the computations and is used to choose the activities which have to enter in the program by priority.

Three operations are necessary to complete this form:

1) The amount of available resources is divided by the amount of resources required per unit (ha) for each enterprise. The smallest of these ratios for each enterprise indicates the maximum possible size of the enterprises within the framework of available resources. The risk element can be taken into account by including stronger restrictions.

2) The contributions per unit of the various resources for each enterprise are computed: net revenue per ha; net revenue per hour in period I; net revenue per hour in period II, etc. These values are obtained by dividing the net revenue per ha, for each enterprise, by the amount of each resource required per ha.
3) For each resource restriction, the various enterprises are ranked according to the net revenue (gross revenue minus variable costs) per unit of that resource. This is similar to what must be done for continuous programming with variable resources.

Form IV (Table 19) is used for the determination of alternative production plans. Several steps are involved in the computation of a new plan:

1) One resource is chosen which is expected to be the most limiting according to the experience of the advisor. The planning situation is simplified in the sense that only a one row matrix is considered for the selection of the enterprises. However, the other resources are also kept in mind so that they are not exceeded.

2) The enterprise which yields the highest net revenue per unit of the resource investigated is first inserted in the program with the maximum possible number of units allowed by the restrictions. The quantity of the remaining resources is obtained by subtraction.

3) Step 2 is repeated for other enterprises in descending order of profitability for the resource investigated. This process is repeated until all of one resource is used up.

4) When a resource is exhausted, other enterprises can be included which do not require the used resource. The production plan is found if an improvement is no longer possible.

5) Steps 1 to 4 are repeated by choosing arbitrarily and intuitively other resources to be considered most limiting to obtain alternative programs. Usually, not more than 2 or 3 limiting resources have to be considered.

5) The total net revenue for each plan is compared and the best program
is selected.

The formal rule, described above, can be relaxed. A certain degree of judgment and trial and error can be employed by including processes that seem to combine well with respect to the utilization of the limiting resources. This is similar to conventional budgeting. However, instead of choosing a complete plan by intuition after considering the relative contribution of each enterprise, the benefits of intuition and experience are introduced not piecemeal, but in a controlled manner at intermediate stages in the planning procedure (27). This gives the intuitive process a better chance. However, from this procedure results also that with the same information, different planners can obtain different results.

Programme planning is based on the practical principle that where the quantities of resources are fixed, maximum profit will be obtained by allocating them so that no shift from one product to another could add to profit. If the fixed resource which relatively is in shortest supply and thus first limits profit can be determined, and if an enterprise selection is made which yields the highest profit which that scarcest resource in its present combination of fixed resources can earn, the profit will be at a maximum for all the resources in that combination (39, pp. 77-80).

The approach described above just as linear programming, starts from a zero solution. Weinschenck, in Germany, uses nearly the same procedure, but he tackles the optimal solution from a point other than the zero solution (39, pp. 137-163). He starts from the existing farm organization. He also distinguishes three stages: a short-run solution giving the optimal combination of enterprises which have already been undertaken on the farm; a medium-term optimum in which the introduction of activities not yet
carried out on the farm is tried; and a long-run optimum for which labor and capital is made variable.

3. Example

The programme planning procedure will be used for the planning of the Belgian farm which has been analyzed earlier with linear programming. The same activities and restrictions are used as in the initial matrix (Table 8) for linear programming, but the activities pasture and alfalfa have been combined into one enterprise: steers. This combined activity has a net revenue of 7,143.40 BF/ha, requires 1 ha of land for 0.856 ha pasture and 0.144 ha alfalfa, 1.03 hours spring labor, 1.88 hours fall labor and 3.17 units of building space.

The "choice key" (Table 18) indicates the 9 activities, together with the 3 restraints which will respectively be used as the most restricting resources: 88.75 ha land, 440 hours spring labor (labor I) and 1,150 hours fall labor (labor II). The columns 1, 3 and 5, respectively, give the net revenue for each enterprise per ha, per hour of labor I and per hour of labor II. The numbers in brackets indicate the ranking of the enterprises according to the net revenue per unit of each of the 3 resources.

The columns 2, 4 and 6 show the maximum number of hectares of each enterprise which are possible for each restraint. The quantities in column 2 are determined by the rotation, the marketing quota or the available building space. The quantities in the column 4 and 6 have been obtained by dividing the available labor into the labor requirements. The underlined figures are the absolute limits.

Again, the last operation is similar to what has to be done after the
Table 18. Choice key

<table>
<thead>
<tr>
<th>Activities</th>
<th>Land Net revenue maximum</th>
<th>Labor I Net revenue maximum</th>
<th>Labor II Net revenue maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BF/ha</td>
<td>BF/hour</td>
<td>BF/hour</td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>19,217</td>
<td>8,248</td>
<td>1,747</td>
</tr>
<tr>
<td></td>
<td>29.58</td>
<td>440/2.33</td>
<td>1,150/11</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>12,232</td>
<td>5,250</td>
<td>1,112</td>
</tr>
<tr>
<td></td>
<td>23.67</td>
<td>440/2.33</td>
<td>1,150/11</td>
</tr>
<tr>
<td>Summer-wheat</td>
<td>17,925</td>
<td>1,921</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>29.58</td>
<td>440/9.33</td>
<td>-</td>
</tr>
<tr>
<td>Summer-barley</td>
<td>12,439</td>
<td>1,333</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>23.67</td>
<td>440/9.33</td>
<td>-</td>
</tr>
<tr>
<td>Oats</td>
<td>14,083</td>
<td>1,509</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>23.67</td>
<td>440/9.33</td>
<td>-</td>
</tr>
<tr>
<td>Flax</td>
<td>9,440</td>
<td>1,012</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>14.79</td>
<td>440/9.33</td>
<td>-</td>
</tr>
<tr>
<td>Peas</td>
<td>11,268</td>
<td>1,218</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>12.68</td>
<td>440/9.33</td>
<td>-</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>18,653</td>
<td>1,998</td>
<td>336</td>
</tr>
<tr>
<td></td>
<td>14.00</td>
<td>440/9.33</td>
<td>1,150/51</td>
</tr>
<tr>
<td>Steers</td>
<td>7,143</td>
<td>6,035</td>
<td>3,799</td>
</tr>
<tr>
<td></td>
<td>18.95</td>
<td>440/1.05</td>
<td>1,150/1.88</td>
</tr>
</tbody>
</table>

Available 88.75 ha 440 hours 1,150 hours

outgoing column in a linear programming problem has been selected to determine the maximum size of the incoming activity.

For the first program, land has been chosen as the most limiting resource (Table 19). Winter-wheat has the highest net revenue per ha and can be introduced on one-third of the total area. Sugar-beets rank second
Table 19. Combination of activities with land as limiting factor

<table>
<thead>
<tr>
<th></th>
<th>Farm plan ha</th>
<th>Net revenue per ha BF</th>
<th>Total BF</th>
<th>Land Required per ha</th>
<th>Total &amp; rest ha</th>
<th>Labor I Required per ha hours</th>
<th>Total &amp; rest hours</th>
<th>Labor II Required per ha hours</th>
<th>Total &amp; rest hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>29.58</td>
<td>19.217</td>
<td>568.434</td>
<td>1</td>
<td>88.75</td>
<td>2.33</td>
<td>440.00</td>
<td>11</td>
<td>1,150.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-29.58</td>
<td>39.17</td>
<td></td>
<td>11</td>
<td>-76.82</td>
<td>362.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>14.00</td>
<td>18.654</td>
<td>261.153</td>
<td>1</td>
<td>-14.00</td>
<td>9.33</td>
<td>-130.62</td>
<td>51</td>
<td>-714.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.17</td>
<td></td>
<td></td>
<td>51</td>
<td>-824.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer-barley</td>
<td>14.00</td>
<td>12.439</td>
<td>174.146</td>
<td>1</td>
<td>-14.00</td>
<td>9.33</td>
<td>-130.62</td>
<td>100.94</td>
<td>-110.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.17</td>
<td></td>
<td></td>
<td>110.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.50</td>
<td></td>
<td></td>
<td>110.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>1.15</td>
<td>11.268</td>
<td>12.958</td>
<td>1</td>
<td>-1.15</td>
<td>9.33</td>
<td>-10.72</td>
<td>0</td>
<td>-110.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.35</td>
<td></td>
<td></td>
<td>110.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total net revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,152.878</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in profitability and cannot exceed 14 ha. Since sugar-beets have to follow
after barley in the rotation, also 14 ha summer-barley must be included.
Third in profitability are oats which can be raised on the remaining
9.67 ha of the 60 per cent of the cropland available for grain-crops.
Finally, only 1.15 ha peas can be included because labor I is exhausted.
The total net revenue for this production plan is 1,152,878 BF but 20.35 ha
land and 110.62 hours of labor II remain unused.

For the second farm plan the enterprises are introduced in descending
order of their net revenue per hour of labor I (Table 20). Since steers
rank second, they are introduced to the limit of the building space. Then
winter-wheat and winter-barley are introduced to the limit of two-thirds
of the remaining cropland. Next, sugar-beets can only be raised on 12.44
ha since this uses up all labor II. Nevertheless, peas and flax can still
be raised on the remaining acreage since they do not require fall labor.
The total net revenue for the second plan is 1,218,250 BF and 73.78 hours
of labor I remain unused.

Finally, labor II has been considered as the most limiting resource
(Table 21). Steers rank sixth with respect to profitability per hour. This
activity is included to half of the building capacity. Summer-crops rank
highest in profitability because they do not require labor II. However,
since the summer-grains would completely exhaust spring labor, only oats
are included. Sugar-beets are introduced as far as the rotation allows.
The remaining labor I is exhausted through peas and flax. The total net
revenue is 1,192,398 BF and 6.18 ha remain idle.

Three quite different production plans have been obtained and the
highest total net revenue over fixed expenses has been obtained through
Table 20. Combination of activities with labor I as limiting factor (a)

<table>
<thead>
<tr>
<th>Farm plan ha</th>
<th>Per hour of labor I BF</th>
<th>Total BF</th>
<th>Land Required per ha</th>
<th>Total &amp; rest ha</th>
<th>Labor I Required per ha hours</th>
<th>Total &amp; rest hours</th>
<th>Labor II Required per ha hours</th>
<th>Total &amp; rest hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td>18.95</td>
<td>6,935</td>
<td>135,367</td>
<td>1</td>
<td>88.75</td>
<td>1.03</td>
<td>440.00</td>
<td>1.88</td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>24.18</td>
<td>8,248</td>
<td>464,663</td>
<td>1</td>
<td>-24.18</td>
<td>2.53</td>
<td>-56.34</td>
<td>11</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>19.34</td>
<td>5,250</td>
<td>236,575</td>
<td>1</td>
<td>-19.34</td>
<td>2.53</td>
<td>-45.06</td>
<td>11</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>12.44</td>
<td>1,998</td>
<td>232,053</td>
<td>1</td>
<td>-12.44</td>
<td>9.33</td>
<td>-116.07</td>
<td>51</td>
</tr>
<tr>
<td>Peas</td>
<td>10.36</td>
<td>1,218</td>
<td>116,738</td>
<td>1</td>
<td>-10.36</td>
<td>9.33</td>
<td>-96.66</td>
<td>106.35</td>
</tr>
<tr>
<td>Flax</td>
<td>3.48</td>
<td>1,012</td>
<td>32,854</td>
<td>1</td>
<td>-3.48</td>
<td>9.33</td>
<td>-32.47</td>
<td>72.88</td>
</tr>
</tbody>
</table>

Total net revenue: 1,218,250
Table 21. Combination of activities with labor II as limiting factor

<table>
<thead>
<tr>
<th>Farm plan ha</th>
<th>Net revenue</th>
<th>Land</th>
<th>Labor I</th>
<th>Labor II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per hour of labor II</td>
<td>Total BF</td>
<td>Required per ha</td>
<td>Total &amp; rest ha</td>
</tr>
<tr>
<td>Steers</td>
<td>9.48</td>
<td>3,799</td>
<td>67,719</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>26.87</td>
<td>1,747</td>
<td>516,357</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>13.49</td>
<td>-</td>
<td>189,984</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter-barley</td>
<td>8.00</td>
<td>1,112</td>
<td>97,859</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>8.00</td>
<td>366</td>
<td>149,230</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>11.52</td>
<td>-</td>
<td>129,807</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flax</td>
<td>4.39</td>
<td>-</td>
<td>41,442</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Total net revenue: 1,192,398
considering spring labor (Table 20) as the most limiting resource. This is not surprising since in the linear programming solution, spring labor has shown up with the highest marginal value productivity.

Mostly, the experienced advisory workers will be able to pick out immediately the most limiting resource, so that much time can be saved. On many Western European farms, land can be considered as the most limiting factor since labor is often underemployed.

However, the plan obtained in Table 20 is not yet the optimum solution. Still 73.88 hours of spring labor remain unused. A closer consideration of the marginal substitution rates is necessary to determine the optimal plan. Though steers have only the second highest net revenue per hour (Figure 11), they have been introduced to the limit.

A quite arbitrary reduction in the number of steers from 60 to 20 units (Table 22), makes land and labor available for raising more winter-grain-crops. Again, sugar-beets are included in the program until the labor II is exhausted. Peas and flax can be raised on the remaining acreage, since these crops do not require fall labor. Through this change, the total net revenue has been increased from 1,218,250 BF to 1,284,930 BF, while only 14.42 hours of labor I remain unused.

A comparison of Table 20 and Table 22 enables us to determine the plan which makes full use of the available resources. A reduction of the livestock by 40 units causes a reduction of the unused spring labor from 73.88 to 14.42 hours which means that for the replacement of one steer by crops, 1.5 hours additional labor are needed. So the 14.42 hours unused labor allow for a reduction of the livestock to 10 units (Table 23). The crops can be expanded until all resources are fully exhausted. It must be noted
Figure 11. Net revenue per hour of labor I
Table 22. Combination of activities with labor I as limiting factor (b)

<table>
<thead>
<tr>
<th></th>
<th>Farm plan ha</th>
<th>Net revenue Per hour of labor I BF</th>
<th>Total BR</th>
<th>Land Required per ha</th>
<th>Total &amp; rest ha</th>
<th>Labor I Required per ha hours</th>
<th>Total &amp; rest hours</th>
<th>Labor II Required per ha hours</th>
<th>Total &amp; rest hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td>6.32</td>
<td>6,935</td>
<td>45,146</td>
<td>1</td>
<td>88.75</td>
<td>1.03</td>
<td>440.00</td>
<td>1.88</td>
<td>1,150.00</td>
</tr>
<tr>
<td>Winterwheat</td>
<td>27.78</td>
<td>8,248</td>
<td>533,844</td>
<td>1</td>
<td>-27.78</td>
<td>2.33</td>
<td>-64.75</td>
<td>11</td>
<td>-305.58</td>
</tr>
<tr>
<td>Winterbarley</td>
<td>22.22</td>
<td>5,250</td>
<td>271,804</td>
<td>1</td>
<td>-22.22</td>
<td>2.33</td>
<td>-51.77</td>
<td>11</td>
<td>-244.42</td>
</tr>
<tr>
<td>Peas</td>
<td>11.90</td>
<td>1,218</td>
<td>134,091</td>
<td>1</td>
<td>-11.90</td>
<td>9.33</td>
<td>-111.03</td>
<td>-1</td>
<td>-0</td>
</tr>
<tr>
<td>Flax</td>
<td>9.00</td>
<td>1,012</td>
<td>84,967</td>
<td>1</td>
<td>-9.00</td>
<td>9.33</td>
<td>-83.97</td>
<td>-19.39</td>
<td>-0</td>
</tr>
</tbody>
</table>

Total net revenue: 1,284,930
Table 23. Combination of activities with labor I as limiting factor (c)

<table>
<thead>
<tr>
<th>Farm plan</th>
<th>Net revenue</th>
<th>Labor I</th>
<th>Labor II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per hour of labor I</td>
<td>Total</td>
<td>Required</td>
</tr>
<tr>
<td>ha</td>
<td>BF</td>
<td>BF</td>
<td>per ha</td>
</tr>
<tr>
<td>Steers</td>
<td>3.16</td>
<td>6,935</td>
<td>22,573</td>
</tr>
<tr>
<td>Winterwheat</td>
<td>28.68</td>
<td>8,248</td>
<td>551,139</td>
</tr>
<tr>
<td>Winterbarley</td>
<td>22.95</td>
<td>5,250</td>
<td>280,734</td>
</tr>
<tr>
<td>Sugarbeets</td>
<td>11.30</td>
<td>1,998</td>
<td>210,779</td>
</tr>
<tr>
<td>Peas</td>
<td>12.29</td>
<td>1,218</td>
<td>138,486</td>
</tr>
<tr>
<td>Flax</td>
<td>10.37</td>
<td>1,012</td>
<td>97,900</td>
</tr>
<tr>
<td>Total net revenue:</td>
<td>1,301,611</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
that programme planning allows for a slight over-exhaustion of some resources. This possibility is excluded in linear programming.

The optimal program obtained with programme planning yields a total net revenue of 1,301,611 BF, which is nearly equal to the net revenue of the plan obtained through linear programming. If we compare the programme planning solution with the optimal plan computed with the simplex procedure, we find that the two plans are nearly identical (Table 24).

Table 24. Linear programming and programme planning solution (ha)

<table>
<thead>
<tr>
<th></th>
<th>Linear programming</th>
<th>Programme planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter-wheat</td>
<td>28.64</td>
<td>28.68</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>22.91</td>
<td>22.95</td>
</tr>
<tr>
<td>Peas</td>
<td>12.27</td>
<td>12.29</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>11.31</td>
<td>11.30</td>
</tr>
<tr>
<td>Flax</td>
<td>10.31</td>
<td>10.37</td>
</tr>
<tr>
<td>Pasture</td>
<td>3.13</td>
<td>2.71</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.64</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Moreover, programme planning immediately provides an integer solution for the livestock activity.

In this case it is evident that the programme planning approach must be preferred, if we are only interested in the optimal plan. Only a few computations were necessary, and the same results have been obtained as with linear programming.
It must be noted that a plan has been obtained which makes full util-
ization of the available resources. However, this does not ensure that the
optimal solution has been attained. Contrary to linear programming, the
planner does not have any assurance that he has found the optimum.

The programme planning technique also allows to consider the effect
of changes in the resource supply. We can compute the optimal plans for
unlimited or more limited labor, just as has been done with linear program-
mong. With unlimited labor, the two labor restrictions in Table 19 must
be relaxed. We reach an identical production plan as with linear program-
mong by introducing the enterprises in descending order of their net re-
venue per ha.

In the case of more limited labor, spring labor has been decreased
from 440 to 380 hours and fall labor from 1,150 to 1,000 hours. Here, spring
labor must be considered as the most limiting factor (Table 25). With 60
steers fed and winter-wheat and winter-barley introduced to the limit, only
9.52 ha sugar-beets can be raised before fall labor is used up. Peas and
flax can be grown on the remaining acreage. With this program, 13.89 hours
of spring labor are left unused. Earlier we have found that the replacement
of one steer required 1.5 hours. So nine steers can be replaced by crops
(Table 26). Again, the final solution is identical with the optimal linear
programming solution.

Of course, only two plans for discrete labor levels have been obtained.
The programme planning technique does not lend itself for continuous pro-
gramming.
Table 25. Combination of activities for limited labor (a)

<table>
<thead>
<tr>
<th>Farm plan ha</th>
<th>Per hour of labor I BF</th>
<th>Total BF</th>
<th>Net revenue</th>
<th>Land</th>
<th>Total &amp; rest ha</th>
<th>Labor I</th>
<th>Total &amp; rest hours</th>
<th>Labor II</th>
<th>Total &amp; rest hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td>18.95</td>
<td>6,935</td>
<td>135,367</td>
<td>1</td>
<td>28.75</td>
<td>1.03</td>
<td>380.00</td>
<td>1.85</td>
<td>1,000.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.95</td>
<td></td>
<td>19.52</td>
<td></td>
<td>35.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69.80</td>
<td></td>
<td>369.48</td>
<td></td>
<td>964.37</td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>24.18</td>
<td>8,248</td>
<td>464,663</td>
<td>1</td>
<td>-24.18</td>
<td>2.33</td>
<td>56.34</td>
<td>11</td>
<td>265.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45.62</td>
<td></td>
<td>304.14</td>
<td></td>
<td>698.37</td>
</tr>
<tr>
<td>Winter-barley</td>
<td>19.34</td>
<td>5,250</td>
<td>236,575</td>
<td>1</td>
<td>-19.34</td>
<td>2.33</td>
<td>45.06</td>
<td>11</td>
<td>212.74</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>26.28</td>
<td></td>
<td>259.08</td>
<td></td>
<td>485.65</td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>9.52</td>
<td>1,998</td>
<td>177,584</td>
<td>1</td>
<td>-9.52</td>
<td>9.33</td>
<td>88.82</td>
<td>11</td>
<td>485.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.26</td>
<td></td>
<td>170.28</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Peas</td>
<td>10.36</td>
<td>1,218</td>
<td>116,738</td>
<td>1</td>
<td>-10.36</td>
<td>9.33</td>
<td>96.66</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Flux</td>
<td>6.40</td>
<td>1,012</td>
<td>60,421</td>
<td>1</td>
<td>-6.40</td>
<td>9.33</td>
<td>59.71</td>
<td></td>
<td>15.89</td>
</tr>
</tbody>
</table>

Total net revenue: 1,191,348
Table 26. Combination of activities for limited labor (b)

<table>
<thead>
<tr>
<th>Farm plan ha</th>
<th>Net revenue Per hour</th>
<th>Land Required per ha</th>
<th>Total &amp; rest ha</th>
<th>Labor I Required per ha</th>
<th>Total &amp; rest hours</th>
<th>Labor II Required per ha</th>
<th>Total &amp; rest hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Steers</td>
<td>16.12</td>
<td>6,935</td>
<td>115,152</td>
<td>1</td>
<td>88.75</td>
<td>1.03</td>
<td>380.90</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter-wheat</td>
<td>24.98</td>
<td>8,248</td>
<td>480,037</td>
<td>1</td>
<td>-24.98</td>
<td>2.33</td>
<td>-58.20</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter-barley</td>
<td>19.98</td>
<td>5,250</td>
<td>244,033</td>
<td>1</td>
<td>-19.98</td>
<td>2.33</td>
<td>-46.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar-beets</td>
<td>9.51</td>
<td>1,998</td>
<td>177,398</td>
<td>1</td>
<td>-9.51</td>
<td>9.33</td>
<td>-88.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>10.70</td>
<td>1,218</td>
<td>120,569</td>
<td>1</td>
<td>-10.70</td>
<td>9.33</td>
<td>-99.63</td>
</tr>
<tr>
<td>Flax</td>
<td>7.46</td>
<td>1,012</td>
<td>70,428</td>
<td>1</td>
<td>-7.46</td>
<td>9.33</td>
<td>-69.60</td>
</tr>
</tbody>
</table>

Total net revenue: 1,207,617
4. Evaluation

The example above has surely shown that programme planning has some merits, even as compared to linear programming. For problems of limited size, programme planning can give as accurate a solution as linear programming, often with fewer computations. However, for more complex problems, its usefulness becomes questionable.

It is a simplified technique and simplification will almost inevitably result in some sacrifice of precision. The verdict on any proposal for simplification must be taken not solely on the basis of whether or not there is such a loss but rather on whether the loss is acceptable as the price of simplification. No simplification at all is likely to be acceptable to the research worker if any loss of precision occurs. However, for the individual farmers and advisors, the research technique may be impracticable, too complicated or too expensive (9). Here lies the answer for the use of programme planning. It is nothing more than a practical tool for the solution of farm management problems. This simpler approach with some loss in precision may be acceptable if this method makes it possible that more advisors can handle the technique and that more farmers can receive advice at a lower cost.

Programme planning is an attempt to introduce the economic principles in a systematic way into the enterprise selection of the budgeting technique. Though the approach is based on the same principles and assumptions, programme planning does not enter into the conceptual complexities and computations of linear programming which favors a quick application in extension work.

These advantages of programme planning are especially relevant where
no electronic computers at a reasonable cost are available or where the
personnel does not have the necessary preparation for the use of linear
programming.

Just as for linear programming, the relation between activities and
restrictions must be formulated explicitly. Contrary to traditional
budgeting, the analyst is forced to look for the technical and economic
relationships. However, the farmer is still able to follow and understand
the approach so that he is more likely to accept the proposed plan.

Some restrictions in programme planning are considered less rigid than
in linear programming. Indeed, the labor restrictions cannot be regarded
as absolutely fixed and never to be exceeded by as much as a minute. Most
operators are prepared to work some extra hours if their income is affected
accordingly.

Indivisibilities can easily be overcome by programme planning so that
an integer solution can be obtained if necessary. Economies of scale can
also be handled since the activities can be introduced at any size the
planner wants to within certain absolute limits. However, it is necessary
to consider linear segments along the production function.

Nevertheless, the method is not free of certain drawbacks. Most as-
sumptions for linear programming, such as linearity, homogeneity and certainty,
may not be overlooked in programme planning. The procedure still con-
tains an element of trial and error, since the mathematical elegance has
been lost through relaxing the simplex approach. The more complex the
problem, the smaller is the chance that the optimum will be found. The
planner is never sure that the optimum has been attained, especially in the
handling of transfer activities and variable resources such as hired labor.
The largest part of the planning job, namely the collection of data, is identical for linear programming and programme planning. If an electronic computer is available, it is reasonable to use the simplex approach to determine the optimum. Wallace (39) argues that the use of an electronic computer for farm planning "seems to be using a steam hammer to crack a nut." This argument is irrelevant: if a computer provides the solution in a cheaper way than a desk calculator, the former must be preferred, especially when the solution is likely to be more accurate.

Programme planning does not provide the by-products which linear programming provides. Only an approximative measure of the marginal value productivity of additional resources is available.

The method does not allow for a division of labor between the specialist on one side and the computer or clerical worker on the other side, as is the case with linear programming since personal judgment is involved at any stage. For research, linear programming must surely be preferred.

Programme planning does not have the power and rigor of linear programming, but it is a practical approach at the farm level. It must be preferred above conventional budgeting when the organization of the farm as a whole is involved. In some situations it can be more useful than linear programming. Under the present organization of the advisory services in the countries of the E.E.C., many advisors do not have the preparation nor the equipment to apply the simplex method. Moreover, the majority of the farms are small and land can immediately be chosen as the most limiting resource which limits the size of the problem and shortens the computations for programme planning.
C. Direct Comparison Method

1. Method

The direct comparison method or farm record analysis is quite different in concept from the economic models discussed above. This method is based on the comparison of several efficiency factors obtained from the records of different farms from a homogeneous group. Hence, this technique is an analysis of the existing situation, while the other methods are normative approaches.

Sometimes, a distinction is made between the "method of standards" and the "method of direct comparison" though there is no fundamental difference. The basic data for both methods are obtained from representative farms in a region by survey or from accounts. The method of standards is rather based on the development of standard efficiency factors for normal conditions, not particularly connected with a specific year. The direct comparison method consists of comparing the characteristics of each farm directly with averages for groups of actual farms (20, pp. 440-447). Occasionally, the name "farm business method" has also been used for the same approach (40, pp. 40-46).

For each agricultural region, it is usually necessary to establish several groups of farms since a single group is seldom representative for the whole region. Within each group, the farms must be similar in size, soil types, topography, crops grown, livestock products produced, and farm practices followed (11, pp. 117-124).

Within each group, the farms are grouped on the basis of net farm income or management return. This makes it possible to calculate three groups
of characteristics, respectively, for the farms with above average, average and below average results. The average efficiency factors of the farms with the highest profits represent the standard organization and performance which is put as the objective for the farms in the average and below average profits group. Charts are sometimes prepared to arrive at a more effective demonstration of the differences. In several countries, procedure sheets have been prepared to systematize the analysis.

The efficiency factors characterizing the high profits group represent the best allocation of resources actually realized in that particular region. In comparing the individual results with these standard efficiency factors, two questions can be raised (40, p. 43):

1) Does the profit achieved reflect a normal level of resources productivity?

If the answer is negative, a second question must be raised:

2) Is this due to the nature and size of the enterprises, or due to the yield obtained from them?

The comparison leads to consider the three main farm management decisions:

1) The nature of the enterprises
2) The size of the enterprises
3) The manner of carrying out the enterprises

2. Example

We will analyze an example from France, taken from the study of Chambart de Lauwe and Poitevin (6, pp. 140-166). The group of farms is situated in the Plain of Versailles, department Seine-et-Oise. Though the
region is very heterogeneous, it has been possible to select a more or less homogeneous group. From the 41 farms which have been analyzed, for reasons of homogeneity, a group of only 20 farms has been selected for the comparison.

It must be noted that the average management return for this group is considerably higher than the average for the region as a whole since especially the best operators were willing to participate in the study. This means that, from the assembled information, it is not possible to make any generalizations for the entire region. This is probably true for most farm record analyses. It is extremely difficult to obtain a random sample from all farms, especially when the sampling units have to be fairly homogeneous.

Though there are very small and very large farms in the analyzed region, for reasons of homogeneity, the survey has been limited to farms between 19 and 34 ha. Table 27 gives a summary of the most significant efficiency factors which have been calculated, together with many others. The above average group is composed of five farms with the highest management return per ha. The efficiency factors of this group of five farms are considered as the objective for the 15 average and below average farms.

Several significant differences can be detected by this comparison. Land and labor are under-employed in the below average group, since less root-crops are raised and more land is fallow. Less potatoes and more oats are grown in the below average group. On some farms, there are too many fodder-crops which cannot be transformed into livestock because capital is too limited to buy more livestock or because the building space is too limited. The above average farms have the highest physical productivity
Table 27. Efficiency factors

<table>
<thead>
<tr>
<th></th>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results (FF)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross profits/ha</td>
<td>1,277</td>
<td>983</td>
<td>636</td>
</tr>
<tr>
<td>Production costs/ha</td>
<td>1,056</td>
<td>1,002</td>
<td>906</td>
</tr>
<tr>
<td>Management return/ha</td>
<td>221</td>
<td>-19</td>
<td>-27</td>
</tr>
<tr>
<td>Net farm income</td>
<td>16,450</td>
<td>10,000</td>
<td>4,400</td>
</tr>
<tr>
<td><strong>Land utilization (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root crops</td>
<td>17.80</td>
<td>16.80</td>
<td>10.40</td>
</tr>
<tr>
<td>Fallow</td>
<td>0.60</td>
<td>2.60</td>
<td>7.10</td>
</tr>
<tr>
<td><strong>Organization (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>14.70</td>
<td>12.30</td>
<td>4.20</td>
</tr>
<tr>
<td>Oats</td>
<td>14.10</td>
<td>17.50</td>
<td>21.50</td>
</tr>
<tr>
<td><strong>Physical production</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat (kg)</td>
<td>4,130</td>
<td>3,660</td>
<td>2,590</td>
</tr>
<tr>
<td>Barley (kg)</td>
<td>3,460</td>
<td>3,110</td>
<td>2,380</td>
</tr>
<tr>
<td>Potatoes (kg)</td>
<td>27,200</td>
<td>23,100</td>
<td>14,800</td>
</tr>
<tr>
<td>Livestock/ha foddercrops</td>
<td>1,66</td>
<td>1.36</td>
<td>1.11</td>
</tr>
<tr>
<td>Milk production/cow (kg)</td>
<td>3,310</td>
<td>3,250</td>
<td>2,650</td>
</tr>
<tr>
<td>Gross profits/ha foddercrops (FF)</td>
<td>1,045</td>
<td>793</td>
<td>580</td>
</tr>
<tr>
<td><strong>Resource use</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ha/labor unit</td>
<td>13</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Ha root-crops/labor unit</td>
<td>2.30</td>
<td>2</td>
<td>1.10</td>
</tr>
<tr>
<td>Gross profits/labor unit (FF)</td>
<td>16,630</td>
<td>11,850</td>
<td>5,870</td>
</tr>
<tr>
<td>Operating capital/ha</td>
<td>5,780</td>
<td>5,080</td>
<td>3,550</td>
</tr>
<tr>
<td>Total capital/gross profits</td>
<td>1.12</td>
<td>1.30</td>
<td>1.79</td>
</tr>
<tr>
<td>Fertilizer/ha (FF)</td>
<td>123.70</td>
<td>99.20</td>
<td>40.80</td>
</tr>
</tbody>
</table>

aSource: Chombarde Lauwe, J. and Poitvin, J. (6, p. 165)

b1 FF = $0.20

for all enterprises. More fertilizer and selected seeds are used on these farms.

From these informations, several remedial steps have been proposed
They are in order of priority:

1) Utilization of operating capital. Use more fertilizer and selected seeds. Improve weed control. Better preparation of the land.

2) Organization. Use the fallow land and raise more potatoes, more barley and less oats. Raise less fodder-crops if they cannot be used on the farm.

3) Replace horses if possible.

4) Buy productive dairy cows if capital and building space allow to do so. Use more supplement.

It is remarkable that most emphasis has been given to technical improvements. Advice on the combination of crops and livestock enterprises is in very loose terms since only the direction of possible improvements is indicated, but not how far to go. The same is true for the technical advice: more fertilizer must be used, but it is not possible to say how much. The conclusions of this example provide an excellent illustration for the evaluation of the direct comparison method.

3. Evaluation

The major theoretical weaknesses of group analysis as a farm planning method have to do with a lack of homogeneity. The group of farms from which the efficiency factors are calculated must be "as homogeneous as possible." However, in practice it becomes impossible to exclude a certain amount of heterogeneity. Often, the operators have different quantities and qualities of resources. Especially the managerial ability is a major source of variability within a group.

A common source of defect is the use of management return as a measure-
ment of the effectiveness of resource allocation on a farm. Management return is a "residual," computed by subtracting from net farm income, a charge for all resources except management. Heady (14, pp. 404-414) points out that this type of measurement is only acceptable if the elasticity of production is equal to one and if the market prices used actually represent the marginal productivities of the resources. This need not be true in the short run and can lead to erroneous conclusions. Knowledge of the marginal productivity coefficients is required to compute useful residual indices.

When factor prices are lower than their actual productivity, the residual does not only represent the renumeration for management, but contains a portion which is dependent upon the quantity of resources used. The result is that practices found on farms with a large quantity of resources appear too profitable when compared to practices on farms with a smaller quantity of resources. The reverse is true when the factor prices are higher than the marginal productivity (19, pp. 152-153). Hence, direct comparison is not free of the assumption of linearity.

This discussion points out the importance of comparing farms with equal amounts of resources. Whereas it can be possible to form groups of farms with nearly equal acreages, it becomes more difficult to have comparable quantities of labor and capital within these groups.

A related problem is the classification of family farms with excess labor. Underemployment causes the profits to be negative, even if all other efficiency factors fall in the above average group. If the excess labor is not removable, the existing organization and performance can be optimal although the negative management return indicates that the manage-
ment is below average.

It may also happen that a farm falls purely accidentally in the above average group. It is necessary to normalize the results of a particular year so that only the farms with durable profits are selected.

A second general source of defect lies in the attempt to get at the "level of output problem" by relating profits to the index of crop yields or the rate of livestock production (15). The group analysis from the Plain of Versailles illustrates this very well. The index "yield of potatoes/ha" can be related to the index "fertilizer expenses/ha."

Table 28. Yield of potatoes and fertilizer expenses

<table>
<thead>
<tr>
<th></th>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of potatoes/ha (kg)</td>
<td>27,200</td>
<td>23,100</td>
<td>14,800</td>
</tr>
<tr>
<td>Fertilizer expenses/ha (FF)</td>
<td>123.7</td>
<td>99.2</td>
<td>40.8</td>
</tr>
</tbody>
</table>

These data suggest increasing returns without economic limit to the level of output per unit of fertilizer input (Figure 12). The "hybrid" production function III overestimates the productivity of resource inputs throughout. It is quite probable that operators from the below average group end up with the yield a instead of c, when they increase the fertilizer expenses from A to C. The three groups are probably working along different production functions I, II and III, due to such factors as soil fertility, selected seeds, etc. Nevertheless, it can still be profitable to expand fertilizer expenses to C, but the comparison does not allow to
determine this with certainty.

The comparison shows only the existing differences. However, the data mostly do not provide the basis for action by the individual farmers. We cannot answer the question how to get in the above average group, or how far to go in imitating this group.

Another shortcoming is due to the fact that the standard efficiency factors are based on the past performance of actual farms. The use of such standards is little more than "the erection of monuments to past folly" (40, p. 45). New developments in organization or technique will not be found in operation on farms. The method of record analysis cannot be used for such problems and must wait until a sufficient number of operators have provided their own guidance and have adopted the new organization or practice. This shortcoming becomes especially relevant in less developed regions, where even the above average group produces under inefficient conditions.

The method is inadequate to give advice to operators in the above average group, though the latter are most interested in an improved organization. Also, one group comparison does not allow to make a diagnosis for a whole region. Several groups must be composed according to farm size and differences in the production system.

The record analysis method has no formal logical procedure for selecting between enterprises and deciding on their size in a way which can be claimed to result in maximum profit for a given combination of resources. Strictly speaking, direct comparison is not a planning method. It can indicate what is wrong, but not what to do about it. The method of direct comparison is a diagnostic technique, since it allows to identify the
Figure 12. Relationship between yield of potatoes and fertilizer expenses.
aspects of a farm's activities which could be altered to increase profit. This is contrary to the other methods discussed, which are of a remedial nature: the action necessary to obtain a profit increase is identified.

Nevertheless, the method of direct comparison has also its merits and has proved to be a useful technique for extension work. Farmers are very sensitive to see that their results compare unfavorably with those of a neighbor. They easily understand the procedure and are more willing to accept the proposed changes. They are more ready to believe in combinations which have proved to be good than in purely theoretical organizations. Perhaps the findings with the limitations outlined above (hybrid production functions), have been of value as "persuaders."

Some technical inefficiencies of the performance, which are often overlooked with budgeting or programming, can be pointed out. It might be useful first to detect these inefficiencies by direct comparison before an optimal combination is computed with another method.

The proposed changes are likely to be adapted to the regional conditions. Especially when a period of several years has been considered, the proposed improvements can be an excellent precaution against uncertainty. Alchian (1) cites variability of environment as a motive to imitate patterns of observed successful firms.

The usefulness of comparative analysis as a farm planning method is largely a statistical problem of proper sampling and deduction. Only a highly experienced analyst can use records effectively. The recommendations must remain restricted in conformity with the homogeneity or lack of homogeneity of the group. The influence of the most variable factor, managerial ability, cannot be ignored.
Even with extreme caution, the technique does not allow to do much more than locating a defect and to indicate the direction of a desirable change. Too much subjective judgment is required to obtain a well-defined program. The direct comparison method is not much more than an introductory analytical stage to provide basic information for farm planning and to indicate possible lines of improvement (39, p. 5).

D. Farm Slide Rule Method

1. Development

No discussion of farm planning methods in the European Economic Community can be complete without including the technique developed at the "Max-Planck Institut für Landarbeits und Landtechnik" at Bad Kreuznach in Germany. In Germany and Belgium, this technique is generally known under the name "Wirtschaftsrahmen," which can be translated by "economic frame." The names "Method of Kreuznach," according to the city where the technique originated, and "Method of Dr. Freuschen," according to the director of the institute, are also commonly used to indicate the same procedure. Finally, the technique has also been named "farm slide rule method," referring to the use of a special slide rule (27).

After a long experience with farm budgeting, research workers at Bad Kreuznach felt that many identical computations came back regularly, and that a limited number of relations adjusts the different enterprises of a farm into one economic unit (44, pp. 7-12). Based on these relationships, all necessary computations for a large number of farms have been done once. So the method of Kreuznach allows a great number of different combinations of the production factors and still automatically obtains a harmonic
organization.

Initially as early as 1947, practical research data about the relations between different activities were grouped systematically in tables and graphics (3). This technique has been named the geometric planning method. The tables and graphics made it possible for different natural and economic conditions to derive the desirable production plans.

As these graphics were difficult to handle, in 1954 a logarithmic slide rule "Wirtschaftsrechenstab" has been constructed by Blechstein which made it possible to do many calculations in a short time. Actually, the method is used in this form.

2. Method

(a) Indices Basically for all calculations is the conceptual division of the farm into three areas:

1) Protein fodder area (grass, clover, alfalfa)
2) Roots area (potatoes, beets, vegetables)
3) Cereals area (including legumes, grass seeds and oil seeds)

This division allows us to reduce all possible characteristics of a farm into two important indices which can be used for comparison. Since the symbols used in the formulas to derive these indices are the initials of German terms, the underlying relations will not be given here.

These two indices are the following:

\[ e = \frac{\text{protein fodder area}}{\text{total acreage of arable land}} \]

The "protein part" e indicates the acreage of the fodder crops as a percentage of the arable land.
\[
\frac{h}{\text{remaining acreage}} = \frac{\text{roots area}}{\text{arable land}}
\]

h gives the root crops as a percentage of the difference between the total acreage of arable land and the acreage of fodder crops.

It can be necessary for some farms to use one or two additional indices:

\[
\frac{z}{\text{total acreage of arable land}} = \frac{\text{sugar-beets area}}{\text{arable land}}
\]

\[
\frac{zw}{\text{total acreage of arable land}} = \frac{\text{after-growth area}}{\text{arable land}}
\]

According to these indices, the procedure has also been given the name "shz-method" (28, pp. 217-276).

(b) Data Freuschen (39, p. 190) cites that the following information is necessary:

1) Acreage of the farm and crops
2) The livestock by type, age and intended produce
3) The yields of crops and livestock
4) The labor and machinery available
5) The local climatic conditions
6) Factor-product price relationships

This means that complete farm records are not required. An inventory of products and resources, together with the price relationships, is sufficient. In fact, the production costs are nearly ignored. For crops, only seed expenses are taken into account. For livestock, only the expenses for feed and the purchase of livestock are considered. Labor and tractor expenses are only taken into account in aggregate for the farm as a whole after a plan has been computed.

No attempt is made to estimate data which most operators are unable
to supply such as seasonal labor requirements for various activities. Standard labor coefficients are used which can be adjusted according to the layout of the farm, distance of the fields from the buildings, and type of machinery used.

(c) **Work sequence** The planning of a farm with the method of Kreuznach can be divided in several stages. First, a model is constructed which is free from all particularities of the individual farm. Only general information about the natural and economic conditions of the region in which the farm is situated, such as the conditions of soil and climate and the price relations, is required. The initial plan computed from these data will probably not be optimal for the region. However, it is possible to compute several alternatives without going into detail in a very short time. The comparison of these alternative solutions makes it possible to choose an optimal plan. This "regional plan" is characterized by the indices \( e_r \) and \( h_r \). This model is free of all particularities and can be used as an objective for all farms under the same natural and market conditions.

The second stage consists of the reduction of all characteristics of the individual farm into the indices \( e_n \) and \( h_n \). These indices characterize the actual farm plan which has to be improved. The computation of \( e_n \) and \( h_n \) requires only the knowledge of yields and the size of each enterprise.

In the next step a diagnosis is made of the actual plan through comparison with the regional model. This confrontation makes it possible to detect all the peculiarities of that particular farm. The influence of the factors labor, capital and entrepreneur becomes relevant. A distinc-
tion is made between the variable and fixed characteristics. The restrictive influence of the fixed factors must be determined which lead to certain upper and lower limits.

With these limits in mind, we reach the fourth and final stage. The regional plan is changed in such a way that it becomes consistent with the fixed factors of the individual farm. This leads to the construction of the optimal farm plan again characterized by the indices $e_0$ and $h_0$. The necessary adaptations can be ranked in order of priority.

Table 29 gives the results of these successive stages from a German study (34, p. 94). A few other characteristics, derived from $e$, $h$ and $z$, are also included.

Table 29. Results of farm planning with the farm slide rule method

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Regional plan</th>
<th>Actual plan</th>
<th>Limits</th>
<th>Optimal plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein fodder crops $(e)$</td>
<td>%</td>
<td>40</td>
<td>27</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Pasture</td>
<td>%</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Root crops $(h)$</td>
<td>%</td>
<td>40</td>
<td>18</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>Sugar-beets $(z)$</td>
<td>%</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Straw for livestock</td>
<td>kg/day/L.U. $^b$</td>
<td>1.5</td>
<td>7</td>
<td>3</td>
<td>5.5</td>
</tr>
<tr>
<td>Milk production</td>
<td>kg/cow</td>
<td>3,500</td>
<td>3,500</td>
<td>3,500</td>
<td>3,500</td>
</tr>
<tr>
<td>Total livestock units</td>
<td>L.U.</td>
<td>23.5</td>
<td>16.5</td>
<td>16.5</td>
<td>16.5</td>
</tr>
<tr>
<td>Total protein fodder crops</td>
<td>ha</td>
<td>10.3</td>
<td>4.3</td>
<td>-</td>
<td>7.3</td>
</tr>
<tr>
<td>Reduced gross profits</td>
<td>DM $^c$/ha</td>
<td>1,940</td>
<td>1,610</td>
<td>-</td>
<td>1,870</td>
</tr>
<tr>
<td>Labor expenses</td>
<td>DM $^c$/ha</td>
<td>-990</td>
<td>-980</td>
<td>-</td>
<td>-990</td>
</tr>
<tr>
<td>Net farm income</td>
<td>DM $^c$/ha</td>
<td>950</td>
<td>630</td>
<td>-</td>
<td>880</td>
</tr>
</tbody>
</table>

$^a$Source: Nationaal Congres over Landbouwbedryfsleiding (34).

$^b$1 L.U. = livestock unit = equivalent of a dairy cow weighing 500 kg and producing 3,000 kg milk per year.

$^c$1 DM = $0.25.$
In this example, the actual plan is quite different from the computed regional plan. An expansion of livestock and root crops is desirable. However, the fixed factors of the individual farm put limits on the possibilities of the operator. The building space is too limited to expand the livestock program, so that the regional plan must be adapted accordingly to be feasible on this farm.

(d) **Slide rule** With the help of the Blechstein slide rule, it is possible to complete all these steps within a few hours. In fact, this slide rule is only a tool which mechanizes the calculations which are involved. Special forms, "Betriebsmodell-Rechenbogen," are available which give directions for the successive stages.

The Blechstein slide rule is similar in structure to an engineer's slide rule and measures 12.5 inches by 5 inches. However, seven different scale-groups are involved for calculations on the following aspects of farm organization:

- **scale A**: the efficiency of labor organization.
- **scale B**: equilibrium of the farm; relations between livestock, fodder crops, rotations, straw and humus.
- **scale F**: relationship between livestock carried and the composition and acreage of the fodder requirements.
- **scale C**: the calculation of gross profits.
- **scale R**: the transformation of livestock numbers to livestock units and fodder requirements.
- **scale S**: the determination of substitution rates between tractors and horses.
- **scale U**: the calculations between yield class and fodder and feed
requirements.

For most calculations three numbers must be used to find a fourth value. The scale-groups have a separate scale for each of these numbers.

Since most farms for which the slide rule method is used are small, it is not surprising that such emphasis is put on livestock. A farm analysis frequently begins with the livestock enterprise. First it is necessary to assume, quite arbitrarily, either the number of animals kept or the size of the fodder acreage. Given the number of cows, calculations on scale R show the number of young cattle and calves necessary for the herd. The scales allow for various rates of cow depreciation, calving age, composition of age group, etc.

Once the number of livestock units has been calculated, the fodder acreage must be determined (scale F). It is possible to choose among seven different groups, each of which represents a given ration of hay, protein silage, carbohydrate fodder, straw and litter, and concentrates. The number of livestock unit rations required, depends on the yield class of the farm. From these selected rations, the acreage of each of the fodder crops can be determined.

All these calculations can be performed in the opposite direction. Given any two of the factors herd size, yield of fodder crops and acreage of fodder crops, the third can be calculated and checked against the reality.

Scale G allows the calculation of the gross profits from given prices and size of enterprises. The value of the output is reduced by the expenses for seeds and feed.

For the labor organization no distinction is made between different peak periods. Actual acreages are multiplied by standard labor requirements
to determine how many labor units are required for the farm. Given any two
of the three factors, namely farm size, labor available and type of farm
(determined by e and h), the amount required of the third can be found
and checked against the amount used. Scale A refers to total labor and has
been designed for farms using horses.

The scales S, A and B are generally used very little in practice.

3. Evaluation

Summarizing, it can be stated that the farm slide rule method is based
on the reduction of all characteristics of a farm in two indices, and the
substitution of these characteristics in a set of equations. It is an
original attempt to provide a tool which allows the kind of computations
required in farm analysis and planning to be carried out on the farm
"within a few hours."

In fact, the farm slide rule method is a budgeting technique, since
it is based on a trial and error process which leads to the choice of a
production plan through the comparison of alternative programs. A plan is
chosen, quite arbitrarily, and tested for profitability and feasibility in
respect of the various constraints imposed by the fixed resources.

No absolute optimum will be obtained, since there is no indication
whether or not a better plan is possible. However, within a couple of
hours it is possible to calculate and compare many more programs than with
traditional budgeting. Because of this, the final solution can be closer
to the real optimum. At the same time, the technique contains elements of
the comparison method since standard values are used to calculate a model
that is compared with the existing farm program.
An important advantage of this method is that the extension worker can prepare a few regional plans, typical for the area in which he is working. From these regional models, the individual plans can be derived very quickly. Because of this, more farmers can be reached.

The method is nearly equally useful for farms with or without accounts, which is a very valuable advantage, in Europe at least. Preuschen (44, p. 11) claims that the procedure can also be a useful instrument for research and agricultural policy. He also pretends that the use of this method is not restricted to a certain region or Germany, but that this technique can be used at least all over Europe. However, this statement is very questionable.

We must be aware of some severe shortcomings of the method of Kreuznach. The farm organization can be described only in a very broad manner, such as the proportion of acreage in cereals, root crops and fodder crops. It is evident that the combination of all characteristics into two or three indices contains several over-simplifications. No distinction is made between the different grain-crops. All livestock is combined in a common unit, and only seven feed rations can be considered.

Labor is considered as a simple restriction for the whole year. As seasonal labor would be a more effective restraint, it is difficult to attach a realistic meaning to the calculations on scale A. However, on many small farms in Western Europe, the labor restriction is not very significant.

The method nearly ignores the costs and allows only to obtain the plan with the highest gross profits after subtracting the variable expenses for labor, seeds and feed. This will correspond with the optimum only if the
assumption that all other production costs remain unchanged, holds true.
Linearity is also assumed just as for the methods discussed earlier.

It has also been argued that the method has gone too far in making

easier the job of extension workers (34, p. 79-80). The technique is so

artificial that it requires a great effort to handle the slide rule. Most
extension workers do not make a daily use of the slide rule, since farm
planning is only a small part of their job. Hence, each time the method

is used, it requires a new effort and the manipulation never becomes fully
automatic. The simplification can turn out to be a complication.

Despite these inadequacies, the method can be useful as a practical

partial and complete budgeting technique. It has also proved to be appro-

priate for the technical information of small farms. On the assumption of

the data fixed on the slide rule, the method can be applied with precision

and speed (39, p. 5).
V. CONCLUSIONS AND SUMMARY

A farm planning method must determine an improved or optimal production plan for a farm. The optimal plan is that program which serves best the goals of the operator. The ultimate goal is not necessarily profit maximization, but more generally, it can be stated as the maximization of welfare.

Five quite different models have been discussed in this study, each of which can be used to obtain an improved farm organization. All five methods can provide guidance to the individual farmers on the efficient allocation of resources.

A. Factors Affecting the Use of Farm Planning Methods

Which method has to be used in each particular case, largely depends on the following factors:

1. The problems to be solved

In general, three different but related questions must be answered:

1) Which crops and livestock enterprises to produce.
2) How much to produce of these selected enterprises.
3) Which production method to use for each enterprise.

All five methods can give at least some indication to answer the first question. The second question can be solved precisely with linear programming, and in many cases programme planning can provide a nearly as accurate answer, if not too many activities and restrictions are involved. The farm slide rule method can indicate the size of the activities, but only for broad groups of enterprises. For problems which affect only a part of the farm organization, even a simple budget can provide the answer. The method
of comparison fails to determine the size of the enterprises. It can only
indicate the direction of adjustment.

The third question, which production method to use, has a more tech-
nical nature. Through comparison, weak points can be detected, but the
possible improvement cannot always be determined. Again, partial budgeting
can be helpful, if only a part of the farm business is involved. The method
of Kreuznach can reveal some technical inefficiencies. Linear programming
and programme planning allow for determining the production method, but
only with linear programming can a large range of alternatives be handled.

Linear programming is always preferable, for each of these questions,
if a very precise answer is desirable and if information on the marginal
value productivity of the fixed resources is required. For reasons of
precision, the other approaches are less appropriate for research work.

Which method must be used for a certain problem, also depends on the
farm. On small farms with excess-labor, simplified methods can provide a
sufficient accurate answer. On farms where many restrictive factors are
relevant, or where the resource allocation is already highly efficient,
only the most refined methods, especially linear programming, can supply
a satisfactory solution.

2. Available data

The need of information depends basically on the problem to be solved
and not on the method used (39, p. 211). If for one method less data are
used than for another method, it will be because in the first case the
problem is simplified, and consequently the solution will be covering less
ground. The need of data therefore depends on the scope of the method used
and the comprehensiveness with which the problem is tackled.

For linear programming and programme planning exactly the same data are used. So the available information is not a criterion in deciding which of these two methods to use. Against these approaches it is often argued that they require too many and too precise data which cannot easily be obtained on most farms. However, if we want to obtain a solution with the same accuracy through budgeting, the very same information is required. For partial budgeting, of course, only data concerning a part of the farm are necessary.

Preuschon claims that the farm slide rule method requires only data which can be obtained on each farm. The computations are based on standard data, fixed on the rule. The plan obtained for a particular farm is only accurate if the standard data are realistic. However, based on the same standard data, linear programming can also provide a solution.

For the record analysis method, accounts from a group of comparable farms for a certain region must be available.

In general, the collection of data is the most difficult stage in farm planning and requires most sound judgment.

3. The planner and his means

The farmer himself is a factor which determines the method to be used. In the future, we can expect more operators to be using paper and pencil to make up their own farm plan. For this reason, it is important that simple budgeting techniques are demonstrated to the farmers. Even the use of programme planning is not excluded for this purpose. Also the comparison of farm records can be done by the operators, if they are
warned for the shortcomings of this procedure.

Where the agricultural advisory services are centralized over larger areas and specialists are charged with advice on farm planning, the use of linear programming must be preferred. Only then can high speed computers be used at a relatively low cost. For most programming problems, the utilization of an electronic computer is not merely a matter of choice, but it should be regarded as a "conditio sine qua non."

If no computer is available, if the planners do not have much of a mathematical training, or if the advisory services are not centralized, programme planning can become preferable as a practical approach. In some parts of Germany and Belgium the farm slide rule method has also proved to be useful in extension work.

In general, essentially the three following factors are restrictive for the further development in farm planning:

1) Lack of basic technical information. The knowledge of production functions is desirable for effective farm planning.

2) Unsatisfactory mathematical and economic training of the advisory workers charged with farm planning.

3) Unsatisfactory means, especially lack of electronic computers and not up-to-date organization of the advisory services.

B. Review of Each Method

1. Direct comparison method

This method is only an introductory analytical stage to provide basic information for farm planning. The technique is of a diagnostic nature since it can indicate possible lines of improvement. It is an approach
which is easily understood and accepted by farmers. However, the high amount of subjective judgment required to reach a planning solution and the difficulty to compose a homogeneous group are the main limitations. The approach has several theoretical weaknesses and is inadequate for the improvement of above average farms or for the introduction of new production techniques.

2. **Budgeting**

Traditional budgeting has not become superfluous through the development of other techniques. Especially partial budgeting can provide answers which cannot easily be obtained by other methods. In its simplest form, budgeting can be applied by the farmers themselves.

The method is less appropriate where high precision is required. Again, too much subjective judgment is required to reach a satisfactory solution for complex problems.

3. **Farm slide rule method**

The method of Kreuznach is a practical approach which provides a farm plan in broad terms. A minimum amount of information from the individual farm is required since the calculations are based on standard data fixed on the Blechstein slide rule. The precision of the results largely depends on these standards.

Though the method proceeds to an optimum via a trial and error process, a plan can be obtained within one or two hours. Possible technical faults can be detected. The speed of the method makes it possible that more farmers can be reached, but much practice is required for a quick manipulation of the slide rule.
4. Programme planning

Programme planning is a refined budgeting technique which makes use of the findings of linear programming in a simplified way. It has been developed to get around the computational burden and conceptual difficulties of linear programming. The real optimum can be approached very closely without too many calculations.

Under the present organization of advisory services the application of programme planning for individual farm planning seems to be very practical, especially on the small farms in Western Europe where the labor restriction is of minor importance. Nevertheless, the method requires the same data and does not have the power of linear programming.

5. Linear programming

This is the most scientific method and results in the optimal plan for available resources on the basis of the data used. The approach is ideally desirable above the other existing techniques, especially for research. However, the present organization, personnel and facilities of advisory services often do not allow for the practical application of linear programming.

If a great mass of data must be handled, it is the only method which can give satisfactory results. This approach must always be preferred where high precision is required.

In the recommendations of the seminar on farm business planning methods is stated (39, p. 8):

It was recommended that for rapid development and to contribute to efficiency in advisory work . . . all five techniques of management should be recognized. Each technique may then be used where and when it is most appropriate.
Methods are available for all needs so that the technique itself is not in the first place limiting in farm planning. The variability of the planning environment is most restrictive on the effectiveness of farm planning since mostly only single valued expectations are being used.
VI. LITERATURE CITED


41. Farm planning and budgeting services in farm management advisory work. Paris, author. 1955.


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