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Economic planning of the farm forest operating unit

Ekonomisk planering av det kombinerade skogs- och jordbruksföretaget

by

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ABSTRACT

A method for long-term, comprehensive planning of farm operating units, primarily the forestry part, is described. The method is based on gross margin calculations, linear programming technique, and the use of high speed electronic computers. The capital value at period-end is used as efficiency criterion linked with a restriction guaranteeing an annual minimum amount of liquid funds. In principle the method is an investment model simultaneously treating all possible investments, their financing, and the need for liquid funds. The method should lend itself to both research and survey purposes as practical planning of forest operating units, either separately or in combination with other economic activity.

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PREFACE

The present paper is a summary of a study which has formed part of the research programme on the economics of farming sponsored by the Swedish Agricultural Research Institute, and which was presented as a doctoral dissertation at the Royal College of Forestry in the spring of 1967 (v. Malmborg, 1967). An abbreviated version was published as a bulletin from the institute (v. Malmborg, 1968).

The project was initiated during a stay as research assistant at the University of California School of Forestry, where I devoted the greater part of my time to a study on the economic planning of the farm forest enterprise. The results of this work have been set forth in a report (VON MALMBORG, 1962). My faculty advisor was Professor John A. Zivnuska, to whom I am greatly indebted.

Further work on the project has proceeded in continuous consultation with an advisory group consisting of Professor Gerhard Larsson at the Royal Institute of Technology, Department of Land Surveying; Professor Ulf Renborg, the Royal Agricultural College, Department of Agricultural Economics; and Professor Einar Stridsberg, Royal College of Forestry, Department of Forestry Economics.

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I wish to express my thanks to the executives of the Agricultural Research Institute for giving me the opportunity to carry out this work. The valuable cooperation within the advisory group, as well as the financial support from the different funds and from the National Office for Administrative Rationalization and Economy are hereby also acknowledged. It is impossible to enumerate all the others who have rendered valuable assistance towards completion of the project. However, I cannot forbear from naming my closest associates: Mr. Olle Ericson, a forester with rare collaborative gifts, and Miss Christina Hallberg, our speedy and capable typist.

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1. Introduction

1.1 Background

Economic planning is one of the most urgent problems in Swedish farming at the present time. In this study, farming is understood to refer to farm operation units, i.e. enterprises in which agriculture and forestry are pursued as a combined business and resources, for example labor and capital are utilized jointly—at least in part. Forestry and agriculture are both undergoing rapid transformation, which accentuates the need for planning to attain a more effective utilization of resources. At the same time planning methodology has developed apace, mainly on account of the advances that have taken place in data processing. These advances permit a fuller use of mathematical aids, which in turn makes it possible to take up planning problems that were beyond the scope of earlier methods and aids.

Inasmuch as agriculture has benefited to a greater extent than forestry from sophisticated techniques of management planning, it is natural that the majority of unsolved problems should be found on the forestry side. For that reason a study of the farm unit and its planning must deal not only with the problems of combination as such but also with a number of pure forestry problems, whereas the agricultural side should essentially lend itself to treatment in connection with existing methodology. The project can therefore also be classified as a study in forestry planning, with principal reference to private operation.

1.2. Objectives

Generally speaking, this study has aimed at the formulation of methods for the planning of farm operating units in terms of business economics. Since many tasks, some of them quite disparate, are involved in the economic planning of whole enterprises, there may be justification for working with different planning methods, depending on the situation in hand. The actual basis for the formulation of planning methods is the same, however, and the *first objective* of this study has been to analyze the fundamental factors.

With the preliminary analysis of problems as a guide, a method for the comprehensive long-term planning of farm forest operating units has been worked out; this may be defined as a *second objective*. Included here is a demonstration of the method as applied to a model farm and an analysis of the results obtained. For present purposes, long-term planning is understood as extending beyond the period of ten years that is commonly used in forestry. A duration of particular relevance in this context is that in which an individual functions as an active entrepreneur, which in farming is customarily given as from 25 to 30 years.

Proceeding from the model farm presented in Chapter 4, the analysis penetrates in some depth to show how changes of different factors affect the plan design, the aim being to ascertain which of these factors ought primarily to be considered for exhaustive research. Another aspect of the analysis is to shed light on the scope which the method offers for a more dynamic formulation than that represented by the static model in Chapter 4. This analysis as a *third objective* of the study. The analyses pertaining to the first and third objectives are not presented in this summary account.

1.3. Earlier research

The exposition under this heading is mainly confined to the literature which deals with the economic planning of farm units and of self-contained forest units. The review is limited to those works which have been deemed most important. Bibliographical references are likewise limited to the literature which is directly cited in this summary of the dissertation. For full details of source materials refer to the unabridged edition.

In the course of reviewing earlier research in the field it has been necessary to employ terms which are not defined until later in this study. This is particularly true of different planning methods, which are discussed at greater length in Chapter 3.

The first example of economic planning in relation to farm units is set forth by BARRACLOUGH-GOULD (1955). Their subject matter comprises nine farms in New England, for one of which the planning procedure is explained step by step on the basis of conventional budget accounting. The chief value of this study lies in its fundamental analysis of essential factors in the economic planning of farm operating units, which were greatly neglected in the past, with particular attention given to the forestry aspects. It is for that reason that the study can be regarded as pioneering.

A method of planning farm units with reference to linear programming technique has been introduced by COUTU-ELLERTSEN (1960). The forestry enterprises are made up of a few relatively large stands. The matrix which has been devised includes only one activity for each stand, and in the cases where this was common to several stands these have been amalgamated. In that way five forestry activities are included for each of the two farms described. Of the different problems associated with the integration of forestry in a plan common to the entire unit, special attention is given to the difficulties of making fair comparisons between the annual yields from agriculture with the periodical yields from forestry. The problem has been solved by resorting to a discounted annual value, equivalent to the annual interest earned on the discounted present value of future periodic receipts from the forests. This procedure has several drawbacks, one of them being that no idea of the cash position is conveyed. Further, all calculations pertain only to the first rotation, which varies somewhat with the species. Moreover, the planning period is not clearly specified and it must therefore be assumed to run for ten years.

COUTU and ELLERTSEN also touch on the lack of production data for forestry, as well as the difficulties of forecasting price movements, technological trends and the like. In this connection they stress the need for studying how changes in employed data affect the plan's design, so as to give an idea of its stability, as well as of those factors which are of special importance in that respect. Thus in order to investigate the stability of the results obtained, prices, interest rate, available capital, etc., have been varied. The results indicate relatively good stability in the optimal plans, especially where the small holding is concerned.

A study by VON MALMBORG (1962) deals with the economic planning of farm forests. Its purported object is to work out a method for the long-term planning of the forest operation with due allowance for the farms agricultural segment, and also to apply the method to a model unit. A major portion of the study is devoted to clarifying the organizational, productive and economic relationships which must constitute the basis of all planning. The study should therefore be regarded as seminal, which explains why substantial parts of it have been drawn upon for purposes of the present paper. The method is based on what agricultural planners generally refer to as programme planning (CLARKE, 1962), i.e. gross margin[1] calculations for separate activities which are combined into a management plan according to a certain procedure, with no use of linear programming. Alternative plans have been devised for agriculture and forestry, with the former primarily based in their turn on a special program planning method known as HUV (JOHNSON-RENBORG-SÄFVESTAD, 1959), whereas conventional budgeting has been used for the latter. The forestry alternatives are based in principle on variations in the volume of growing stock.

LEDJE (1963) has carried out model studies of farms in an area of Uppland Province in Central Sweden. Forestry is treated as one activity of the unit,

[1] Gross margin is defined as the surplus of income over variable costs which is obtained from an activity. Gross margin thus may refer to one unit of an activity or to the activity as a whole.

the point of reference being a "normal forest" model, i.e. unvarying annual income from timber crops is assumed. Of special interest in this study is a concise account of multiperiodic linear programming.

Throughout the 1960's the formulation of planning methods of direct practical application has been the focus of interest in Norway, and more recently in Sweden as well. The problem has been taken up by THORMODSÆTER-ELSTRAND (1960), though their main emphasis is on an analysis of collected accounting data, while one chapter is devoted to management planning, which is based on conventional budgeting. BJORÅ (1962) has, in his three planning examples, also relied upon conventional budgeting to present his findings, which relate to a planning period of ten years. In this work, however, the actual planning and its preconditions are considered more searchingly; the treatment of forestry is particularly detailed. Of special interest are his stress on the complexity of objectives and the possibilities of adapting forestry to the owner's current needs.

Latter-day research in Sweden offers several examples of synthesized planning of farm forest enterprises. Mention can be made of ÅGE (1964), VON MALMBORG (1965) and the National Board of Agriculture (1966). Common to all these studies is their use of gross margin calculations and a planning period of ten years. A similar method has been presented by the National Board of Private Forestry (1966). The cited examples can be summarized by saying that they represent different variants of one method rather than different methods, even though the arrangement of details diverges in several respects.

A few examples of economic planning in farm forestry are also worth mentioning in this context. Although they do not directly pertain to synthesized planning of the combined agricultural and forestry enterprise, conceptual allowance is made for this in the drafting of forestry plans. The first attempts in this sector commenced in the early 1950's in Norway, where Dyring was particularly significant in breaking new ground; his work can be regarded as seminal for the later research reported above. An account of the planning method he devised is given by STRIDSBERG (1956).

The method is characterized by its attention to objectives for the operations of the individual unit, as well as by its actual relationship to agriculture. The planning builds upon forest valuation data and only one plan is projected. No guarantee of its being optimal is given, but since the work is based on economic conditions of relevance for the unit, it should be possible to assume that the plan is "good" from the owner's point of view.

Lastly, mention will be made of a few works which relate exclusively to economic planning of the forest enterprise, with use made of operations research. Even though these studies do not take synthesized planning into account—indeed, they are not at all concerned with private forestry—they are of great interest since they represent the first more consistently pursued attempts in this field.

McConnen (1965) describes a current project in this field at the Pacific Southwest Forest and Range Experiment Station at Berkeley, California. Emphasis is on the presentation of two schematic examples in which linear programming is used. Both are purely technical problems: the object of one is to maximize the remaining stock of growing timber, of the other to attain an even age-class distribution over one rotation period. In both cases, moreover, a specified felling schedule must be met. The first case relates to two subperiods, whereas the second is divided into thirteen subperiods with durations varying from five 1-year subperiods at the beginning to three 20-year subperiods at the end. In his discussion of the period length, the author underlines the necessity of taking into account the whole transition period, which in this case is 100 years, even when the plan chiefly aims at obtaining a detailed management plan running for only one year. At the same time he points out that the long-term plan should be no more than a review. The solution is presented solely for the short-term problem, with the duration of planning divided into ten 1-year subperiods. It emerges from this and from the related discussion that the attempt to arrive at a directly usable management plan was not entirely successful, one reason being that the technical problems of felling were not fully comprehended. Further planning is therefore necessary. The result points up the difficulties of incorporating a detailed short-term action program as a direct element in longer-term planning, though this is deemed a necessary prerequisite of the detail plan.

In a chapter devoted to sensitivity analysis McConnen stresses the importance of this and also gives examples of ways of making such an analysis, e.g. by varying the assumptions with respect to entering factors. Reference is also made in this connection to shadow prices[1] as an aid to sensitivity analysis. Another chapter deals with the formulation of objectives and the design of an objective function. The objectives, he contends, are diffuse and complex, which makes them difficult to express in unambiguous terms. McConnen therefore recommends that the objectives be considered by way of an objective function, as well as by way of special restrictions similar to those given in his examples.

Wardle (1965) decribes how linear programming has been used to make a 10-year felling estimate for a forest management unit. Another study (1966 a) takes up a more special problem: the optimal organization of the

[1] This and most of the other terms in linear programming are defined in Chapter 5.

supply of wood to a pulp mill with due account taken of the losses incurred by different forest management units in the supply area owing to curtailed opportunities for disposing of other assortments or selling to other markets. In a Special Paper read before the Sixth World Forestry Congress, WARDLE (1966 b) discourses not only on his own work but also on that of other researchers and their experiences of linear programming. The presentation concludes with a survey of various applications where, according to the author, linear programming or more elaborate versions of it can render valuable service. Among the applications cited are machine-utilization schedules and the integration of plans at different levels, e.g. central and local plans within a forest operating unit.

GOULD and O'REGAN (1965) present a simulation model designed to test different management programs for their effect on timber yields and economic results. Although this model is presumably not primarily concerned with the economic management planning of individual forest units, but rather with more general considerations relating to the shaping of forest management programs, it does open up interesting perspectives for that type of planning as well.

2. Forest production

The exposition in this chapter seeks to illustrate the internal relationships of forest production and to define enterprises and activities against this background.

"Production process" is a term that nowadays has two main usages in the economic sphere. In production theory it designates the conversion of an input flow into an output flow, without any closer specification of the relations between inputs and outputs or between the input of production resources and the output of products (CARLSSON, 1939). This sense presumably reflects the generally accepted meaning of the term.

A narrower meaning is applied to the term in linear programming, where it signifies that two processes are identical provided only that they employ the same resources in the same proportions to make an identical product, also in the same proportion. As thus defined, the production process embraces only one alternative among the infinite number comprised by the term as understood in production theory. As a catch-all name for all the processes by which a certain product, say wheat, can be made, linear programming employs the concept, enterprise (HEADY-CANDLER, 1958, page 11). The term *activity* is also used synonymously with production process. In this paper *production process* will hereafter be used in its production-theory sense, whereas *activity* will be used in connection with linear programming.

A process may cover one or more stages of production. Hence the cultivation of wheat may be regarded either as a single process or as one part of a process ranging over an entire crop sequence, which is usually regarded as a *combined process*. Another example of a combined process is the production of fodder and livestock. These combinations clearly lend themselves to many permutations, and a clear-cut distinction between simple and combined processes can hardly be drawn. The same naturally applies to activities.

2.1. Timber production

A traditional concern of production research has been to study the influence of different thinning programs on output, rather than that of the growing stock in existence at any one time, which has been obtained instead as a result of the thinning programme in force. Available yield tables are therefore far from ideal as illuminators of the production role played by volume of standing stock. However, an attempt to illustrate the relationship between stock and yield has been made in Fig. 2.1. It is based on certain of PETTERSON's (1955) tables for naturally regenerated pines in northern Sweden, yield class $h_{100} = 20$. For this class Petterson presents a series of tables with successively increasing degree of heaviness of thinning, but with other conditions constant. The standing volumes of stock shown in the figure refer to averages for a normal forest, whereas average output is directly obtained from each source table for the optimal rotation periods relating to maximum timber output. The thinning interval is ten years and the same thinning percentage is imposed in principle on the volume of growing stock in existence on each thinning occasion. Depending on the thinning program in force, these proportions range from about 12 percent to more than 42 percent, as shown by the compilation of selected data from the figure in Table 2.1.

Table 2.1. Thinning, standing volume of stock and yield according to selected yield tables by Petterson

Source: PETTERSON (1955)

Yield table	Degree of thinning in percent of volume	Average volume of growing stock		Average yield		Optimal rotation period
		M^3ub	Percent of P 7	M^3ub	Percent of P 7	
P 7	11.6—12.6	137	100	3.3	100	158
P 8	18.6—19.5	87	64	3.0	91	128
P 13	26.9—27.7	60	44	2.8	85	108
P 19	34.8—35.5	46	34	2.7	82	98
P 20	42.3—42.9	37	27	2.5	76	88

The solid line in the figure connects the points obtained from the yield tables, while the broken line indicates the approximate trend that can be expected if the curve is extrapolated. Production in the latter instance is assumed to drop quickly towards zero as the volume of growing stock diminishes below the values indicated by yield table P 20, and will hold at the same level if the volume increases above that shown in table P 7. A thinning program so slight that it barely anticipates natural thinning is thus assumed to result in a maximum timber yield. The results of a program without active thinning, as presented in table P 95, suggests that this is the case. A program of this kind, however, is of limited interest as a practical action alternative. On the other hand, the rate of thinning in the program which underlies P 8 bears a great resemblance to the thinning standards which were formerly applied in practical forestry; this is illustrated, for

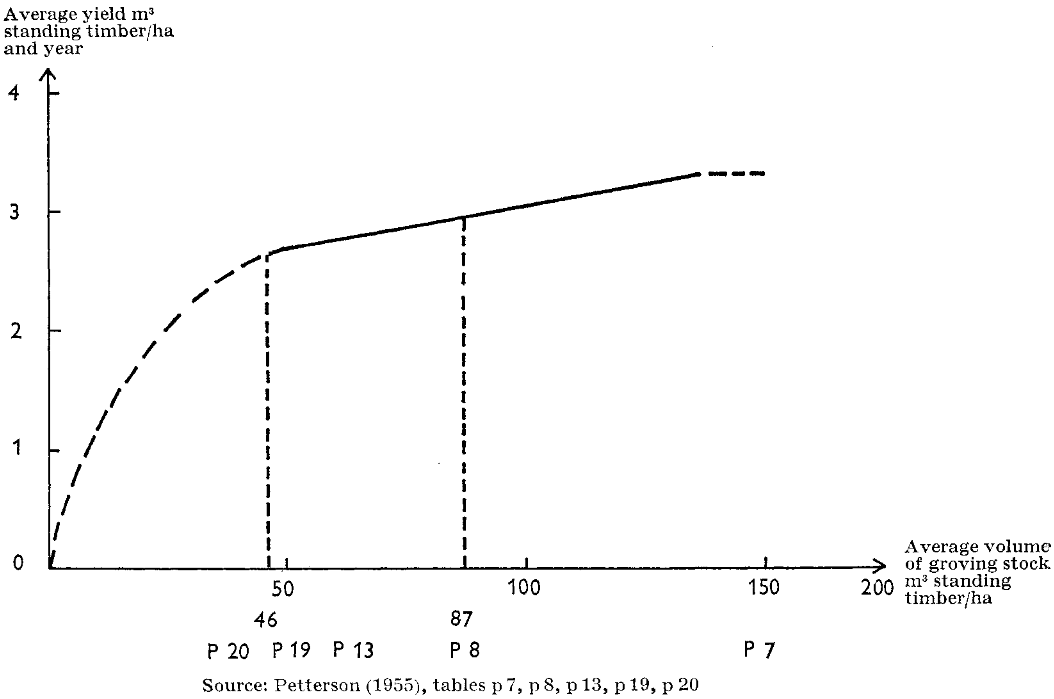

Fig. 2.1. Dependence of timber yield on volume of growing stock according to certain of Petterson's yield tables, applied to normal forest conditions

example, by the similarity of this program to the tables for the "better half" in "Yield Tables from the National Forest Survey" (NILSSON, 1961).

Since the output curve in Fig. 2.1 pertains to a single species of tree in a specific location, no generality for it can be assumed. Even so, it forms a suitable point of departure for a discussion of how timber output depends on the size of the productive growing stock. Our knowledge in this field is still relatively limited, but in recent years a number of yield tables have been published in Sweden. The Swedish results conclusively point in the direction indicated by Fig. 2.1, i.e. the highest output comes from a rate of thinning so low that it just about anticipates natural thinning (CARBONNIER, 1964). This finding also agrees with the data published by ASSMAN (1961).

2.2. Enterprises

The whole production sequence in a forest stand from establishment to felling may be regarded as a *combined process* composed of the three *production phases,* regeneration, timber production and felling. These in turn may be regarded as combined processes composed of the productive operations which enter into them; these operations constitute the simple processes of which the combined processes are structured.

If the timber which reaches a place of delivery is to be regarded as a result of one and the same *activity*, it must meet the definition of identicality, i.e. constitute a given selection of assortments and, further, it must have been obtained by inputs of identical production resources in exactly the same proportions. Insofar as there is change in any of these respects, the timber has been produced by another activity. This whole series of (combined) activities, through which a certain kind of timber can be produced for delivery, is designated, in accordance with previously given definitions, as an enterprise. In common with activities, it is clearly justified to speak of enterprises which are simple and combined.

The timber producing phase consists of a series (theoretically infinite) of simple enterprises, each like the others except that the factor input in the form of growing stock varies with age and choice of management program and that the productivity of timber capital diminishes with rising age. Hence the differences of technique which occur are linked to differences of volume and age in the growing stock input. Some additional operations may be performed during the timber-producing phase, such as pruning or other timber stand improvement.

Each of the different operations in regeneration and felling is viewed as a simple enterprise line composed of series of simple activities, which differ from one another not only as regards the employed technique in the ordinary sense, e.g. the use of horses instead of tractors for extraction, but also as regards the component raw material. In harvesting, this consists of different species, dimensions and grades of trees, and, like the finished product, must be treated as a specifically composed mixture of species, dimensions, grades, etc., obtaining in each special planning situation.

In principle, two approaches can be applied towards bringing simple enterprises into combination. The one approach draws on the interrelationships of the different working operations. It is exemplified by the three production phases at a lower combination level and by combinations of these into a development sequence at a higher level.

Under the second approach these interrelationships are disregarded and attention is focused instead on the operations taking place during a certain time period, regardless of the production phase to which they belong. The resulting combination of enterprises is exemplified by 10-year age classes. These too can be joined in a combined line of a higher order, e.g. the whole rotation period; in other words, the same combined lines are obtained as when the different production phases are linked.

3. Planning methods

3.1. Method description

General. Management planning has been traditionally based on budgeting income and costs for a limited number of production alternatives, for the whole unit or enterprise, after which the economic results of different production programs are compared. This type of planning is therefore usually referred to as the *budget method* or conventional budget method. It is characterized by the use of a few, generally two to four, predetermined production plans embracing all operations of the enterprise. The combination of production lines in the different alternatives is subjective, on the basis of the planner's general proficiency and experience.

Another method of management planning, increasingly used in recent years, is based on gross margin calculations of discrete activities. Under this method the gross margin, representing the excess of income over variable costs, is computed for one unit of each activity. For simplicity, the performance of this task makes it necessary to assume linear correlations, i.e. that two units of one activity will result in twice the inputs of production resources and twice the yield as one unit. Curvilinear correlations can also be handled, but these give rise to complications which will not be taken up here. Given the gross margin calculations the next step is to combine the activities in such a way as to maximize the aggregate gross margin. The main differences by comparison with the budget method are that one proceeds from the different activities, which are used as building blocks to construct the management plan, and that the activities can be combined objectively with reference to their economic results.

The reason why gross margin calculations has become so widely disseminated as to completely dominate the management planning of agricultural enterprises nowadays has to do with its relative flexibility, plus the fact that the utilization of machine aids is made easier by the availability of certain standard programs. Various techniques are employed for planning by means of gross margin calculations. One of these is *linear programming*, which Baumol (1961) defines as a mathematical technique for the processing of economic and other information.

The serviceability of linear programming for management planning is restricted by it being applicable in its conventional form only under static conditions, as for average-year calculations during a specified period, whereas all planning by its nature must respond dynamically to altered assumptions over time. Problems of this type can be solved with the help of multi-periodic linear programming, which represents a further advance on the conventional form. The multi-periodic version makes it possible to plan for an operating unit over a longer time span, with due allowance made for changes arising during one period and their repercussion on the planning of other periods.

Certain other techniques used in planning based on gross margin calculations can be subsumed under the common label of program planning. They are primarily intended for the practical planning of individual estates. In all these methods the different activities are combined systematically, but without the mathematical apparatus which characterizes linear programming. A general presentation of program planning is given by CLARKE (1962).

The different activities may also be combined quite randomly by simulated computations such as the Monte Carlo method. An essential practical difference between Monte Carlo and programme planning is that the usefulness of the former is confined to computer processing, since the whole method is based on working out a large number of alternative combinations, amounting to several thousand. The use of Monte Carlo for economic management planning of agricultural enterprises is discussed by CARLSSON-LINDGREN (1965). As in linear programming, the estimates proceed from a series of activities, but whereas linear programming systematically works toward a solution which maximizes the criterion, activities under the Monte Carlo method are randomly combined a great number of times to provide a whole series of plans. In that respect Monte Carlo recalls the budget method, although it produces a tremendously greater number of plans. Therefore, in common with the budget method, Monte Carlo does not impose the same compulsive need as linear programming for carefully defined and explicit objectives; and for each plan "a theoretically unlimited number of criterion functions can be calculated".

Agriculture. Although the budget method has been traditionally employed in agriculture, recent years have witnessed the advent of linear programming for the management planning of agricultural units. The latter method, however, has found its most widespread use in research work, whereas a programme planning method is generally used for the practical management planning of single farms, e.g. by the county agricultural boards. RENBORG (1957) has been particularly active in developing Swedish applications for linear programming.

Forestry. Planning in forestry has been traditionally linked to each production phase, and as such divided into two stages which have not borne much relationship to one another. Felling plans have directly aimed at optimizing the economic results of operations on the basis of given assumptions about felling volume, physical location and the like. Nor are any of the economic principles employed at variance with those of management planning in general. The exposition under this head will accordingly focus on the planning of timber output. Naturally, such planning has been mainly rooted in economic considerations, but these have been diffuse for two reasons: first, because they have not been clearly defined; and second, because they comprise aspects not only of purely business economy but also of broader public economy. An additional factor that has characterized conventional forestry planning is that the technical pattern for timber production has been largely taken as given, so that alternative operating patterns have been virtually precluded. This conception may have been motivated on technical grounds, i.e. it has not been considered technically possible to produce timber other than with a certain, more or less fixed, combination of production resources. Economic motives may also have entered in, i.e. a certain technical combination has been thought to confer the best economic result. The reasons have presumably been both technical and economic, but no penetrating analysis of these problems has been made, though they have been considered to some extent by DICKSON (1956). It appears likely, however, that considerations of public interest have played a major role in forestry planning as well as in forest operation generally (HERMANSEN, 1961). The result has been to shape the traditional forestry plan as a purely technical production plan, where one of the most important objectives has been to create an even distribution of age classes, i.e. to equalize yield over the long run, and another to attain a high timber yield with a certain distribution between assortments. A revealing commentary on this state of affairs is the traditional use of the words skogsindelningsplan—literally "forest division plan"—to designate a forestry management plan, where the word indelning evidently alludes to a division into action areas. The German term, from which the Swedish presumably derives, is *Forsteinrichtung*, which more strongly emphasizes an orientation to the goals involved, though it must be said that the German foresters do not appear to have analyzed their goals any more closely, either.

The traditional forestry plan is rooted in a more or less detailed recording of present conditions. Its central element is a plan which indicates the felling volume and its distribution in space and time. A plan of the silvicultural measures to be taken is usually included and, occasionally, a plan relating to other measures such as roadbuilding and drainage. A forestry plan normally runs for a 10-year period, but other durations are in force depending on the intensity of forest management. It is thus typical for a plan to focus on the purely technical aspects and to limit itself to one of the two traditional production processes in forestry. This type of plan therefore cannot be regarded as an economic management plan in the ordinary sense, since it lacks some of the elements which are essential for such a plan. One of the most important of these deficiencies is that the goal is neither clearly defined nor stated in economic terms. Another is that the economic outcome of the resulting plan can admittedly be estimated, but is not permitted to influence the design of the plan, whereas in economic management planning the final plan is, in principle, obtained as an outcome of economic considerations.

Forestry plans used to be drawn up individually for single estates, and it was also customary to collect the data for each estate separately. More recently, in Kopparberg County and elsewhere, efforts have been made to rationalize the work by comprising larger areas in surveying the data being subsequently processed separately for each estate. The use of computers has also achieved major savings in the data processing, making it possible to cut down the time spent on planning work. Strictly speaking, however, not even these cases represent true economic management planning.

As was pointed out by way of introduction, the growing latter-day interest in economic management planning for farm-forests is largely a response to the rapid advance of management planning in agriculture. For that reason most of the methods devised for such planning in forestry aim at the production of plans which lend themselves to joint planning of the whole operating unit. By and large, the methods of *forest management planning* have been based on the budget method, but certain attempts have been made in the past few years to use gross margin calculations. Programs have also been devised for the computer processing of plans pursuant to the budget method (e.g. GOTAAS, 1967). Gross margin calculations has commonly been used in Sweden to plan whole agricultural enterprises, with forestry regarded as an enterprise and the finalized economic forestry plans used as gross margin calculations. In other cases no formal plan common to agriculture and forestry has been set up, but these have been coordinated by allowing for the complementary activity in the preparation of separate plans for each sector. Analogous circumstances have obtained in Norway. In the United States, on the other hand, there have been some attempts to subject the whole farm enterprise to more integrated joint planning. A summary of the research carried out in these fields was given in Chapter 1.

3.2. Method recommendation

If a method is to be useful for research purposes, it must satisfy one main criterion: the ability to handle a multitude of activities under varying assumptions. Not only is the budget method overly cumbersome from that aspect, it does not either lend itself with the same ease to computer processing unless systems work is done on a large scale. By contrast, the gross margin method is flexible and better suited to computers. Besides, machine programs have been devised for the use of linear programming in the formulation of plans. Other techniques, e.g. Monte Carlo, should also be feasible, but in view of the limited experience of them to date, linear programming would appear to be preferable.

The choice of method for the practical planning of a particular farm is less restricted, principally because the requirement for an exhaustive enumeration of all or at least many theoretically conceivable activities and data is not as strict. However, the force of events in recent years has favoured the use of gross margin calculations in these cases, too, and the greater facility they offer for standardizing the calculations is a compelling reason for this method. Even the formulation of methods for practical planning should therefore be based primarily on gross margin calculations.

Given the arguments presented above, it has been thought justified to focus subsequent interest on methods based on gross margin calculations, linear programming and the use of electronic computers.

4. General method formulation

4.1. Planning situation

Goals etc. It is presumed that planning will take place at the request of a private owner, who is also the decision maker, and with due consideration to the circumstances which hold true for him. The goal assumed for the owner is to maintain a certain living standard during the planning period, combined with a desire to obtain maximum value for his enterprise as a going concern at the end of the period. The requirement of disposable income for consumption can be held constant over the period or vary according to the owner's wishes, but this does not affect the method formulation in either case.

The objective function includes only certain capital values at period-end, whereas the gross margin from activities during the actual planning period enters only into the restriction that has been set up for current income during each subperiod.

The planning period, which is assumed to run for 25—30 years or longer, is divided into subperiods. Post-planning time is taken into account by the evaluation of relevant activities and is dealt with in principle as a period embracing the infinite future.

Resources. Basically it is assumed that conventional means of estimating existing resources are employed for both agriculture and forestry. For every stand there must be information on mean diameter corrected for basal area and corresponding mean height, which form the basis for pricing and the felling labor requirements. Account may also be taken of the possibilities of augmenting resources by acquisitions of supplementary land or by other means.

Production data for timber yield are based on material from national forest surveys (NILSSON, 1961) and Petterson's tables (PETTERSON, 1955).

The restriction which guarantees a certain average level of current income during each subperiod is of special interest, since it enters as one of the elements in the formulation of goals—indeed for this type of planning it may well be the most important element. It has been devised as a disparity, but amounts in excess of the minimum level specified in the restriction are carried over to disposable capital in the next period. In other words, the specified level cannot be exceeded.

Prices. As a general point of reference for the determination of product prices, use is made of the prices obtained by the private farmer for deliveries via marketing cooperatives. Provision is made in these prices for post-sale proceeds, if any. By the same token, production resource costs should relate to the market prices which generally hold for farmers. Thus the wages of forest workers should be established with reference to existing collective agreements.

The prices for different dimensions are computed in accordance with a method used of the National Land Survey Board for valuation purposes. This method was originally devised in connection with the formulation of proposals for a new method of assessing real estate. The Board has used it to estimate standing-timber values based on the mean diameter of stands, corrected for basal area.

Evaluation. The evaluation at period-end pertains only to those parts of the enterprise which are affected by planning, namely the growing stock, buildings and disposable capital, whereas other parts of the enterprise are regarded as holding a constant value irrespective of planning alternatives. The values sought are market values, which in respect of growing stocks are approximated by a special evaluation which draws on the so-called table method. An account of this method and its use in land surveys is given by the National Land Survey Board in a bulletin of advice and instructions (1966).

4.2. Activities

Agriculture. Activities in agriculture are defined in the usual agricultural management planning nomenclature. The reconditioning and/or construction of outbuildings are treated as separate activities and are not combined with the activity concerned in livestock production; the main reason for this is the multi-period division of planning.

Forestry. Enterprises and activities in forestry are defined with reference to the viewpoints presented in Chapter 2. Every 10-year age class is defined as an enterprise, whereas component activities are defined with the aid of:

a) Volume of growing stock
b) Harvesting technique
c) Regeneration method

The significance of the foregoing for timber output is that activities are defined with reference to both ingoing and outgoing growing stock at the beginning and end of a 10-year period. At the outset of the first period the ingoing volume and its distribution by age classes agrees with circumstances on the farm concerned. For subsequent subperiods the ingoing volume agrees with the outgoing value of the prior period, and several ingoing values are then possible. In principle, the model permits a very large number of activities, i.e. combinations of ingoing and outgoing volumes of growing stock, and from that aspect can be regarded as general. But for various reasons, among them practical considerations in data processing the number of activities must be limited in any one planning situation. The example here presented proceeds from an upper and lower limit on the volume of growing stock at each age.

An attempt has been made in Fig. 4.1 to present the defined activities and clarify their interrelationships for a planning period consisting of three subperiods. The upper and lower limits as regards growing stock are represented by levels 2 and 4, while 0 signifies the current condition at the start of the planning period. Level 3 represents that which is attainable over a 10-year period if one whishes to go from the lower towards the higher level. The increment over a 10-year period is thus presupposed to be inadequate for the step from lower to higher level to be taken directly. Level 3 accordingly represents the final stage of a subperiod during which there has been no cutting. For that matter, cutting is not "allowed", and one cannot go from level 3 at the end of one period to level 3 at the end of the next. Nor is it possible to proceed to level 3 from any other level than 4. Level 1, lastly, represents a standard program for age classes 1—4, ranging from zero to 40 years, which means that in these classes there is only one level. Level 1 is also applicable here to clear-cutting woodland, when a stand is carried over from level 2, 3 or 4 to level 1.

Key to the symbols:

The detailed definitions in brackets refer to the model presented in chapter 5.

Level 0. Actual level at beginning of the planning period.

Level 1. Standard level: (this is to be found in stands younger than 40 years, i.e. age classes 1—4, in which no alternative levels are possible. This means that the standard level must always be used after clear-cutting).

Level 2. Upper limit corresponding to a large volume of growing stock, relatively speaking. (The "better half", Nilsson, 1961, in age class 5 and older classes).

Level 3. Lower limit plus increment during a 10-year period, i.e. no cutting is done during the period. (This level can be found only in stands which have been cut to level 4 in the previous period).

Level 4. Lower limit (corresponding to 70 percent of volume of the "better half". Can be used in age class 5 and older classes).

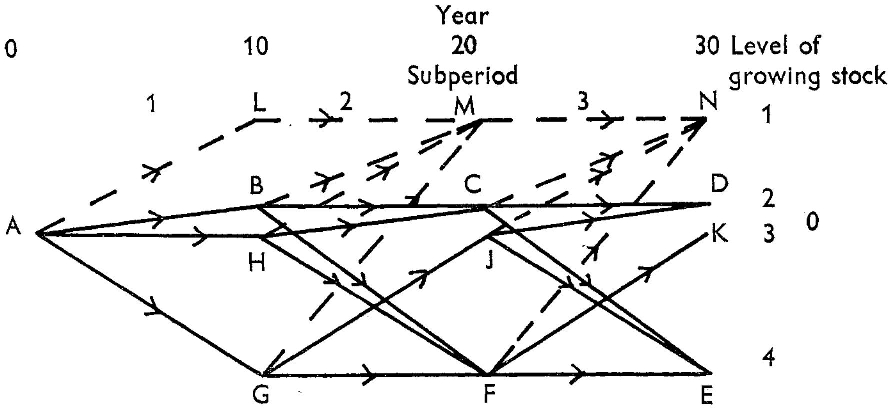

Fig. 4.1. Diagram showing possible activities during a planning period of 30 years

Woodland in age class 4, i.e. 35 years old, can be cut so that the volume of growing stock at period-end agrees with levels 2 or 4. This means that a certain part can be kept at level 2 and another part at level 4. On the other hand, no intermediate positions are permitted, unless volume at the start of the period is so low that level 2 is unattainable, i.e. level 3 has to suffice instead.

In other words, this period is marked by two activities in the age class, represented by the lines AG and AB, or possibly AH. For the second subperiod, therefore, there will be two starting positions, G and B (possibly H), and three final positions, F, I and C, whereas the activities, four in number, are represented by the lines GF, GI, BC and BF (possibly HC and HF). The third and last subperiod takes in six activities, represented by the lines FE, FK, ID, IE, CD and CE.

If age class 7, where the starting age is 65 years, is selected instead, there comes the added alternative of clear-cutting already in the first period—an activity that is represented by the line AL. This entails an obligation to adhere to the standard program for young stands in the following periods, and only activities LM and MN can occur in each period. Hence in this age class the performance of an additional activity is possible in each period as compared with age class 4.

Under the assumptions given here, forests in age class 10 or higher, i.e. 95 years or older, can be treated only in accordance with the standard alternative, i.e. clear-cutting activity AL and thereafter activities LM and MN.

Lastly in respect of age class 3, i.e. forests where the starting age is 25, the first period permits only one standard activity, which is represented by the line AL. In subsequent periods, on the other hand, both levels 2 and 4 can occur.

Apart from the level at the outset of each subperiod, the activities within different subperiods do not relate to one another, making it feasible to cut heavily during one subperiod and lightly in the subsequent periods or vice versa. The patterning of production lines and activities thus permits the adaptation of harvesting to widely diverging planning situations.

The enterprises and activities as defined above should be practicable in all types of planning situations that are of primary interest for purposes of farm forests, and should also lend themselves to the planning of separate forestry units on units integrated with other kinds of economic activity.

Definitions of activities have here been discussed exclusively with reference to the technical pattern of timber production. None the less, the application of varying techniques is conceivable for the conduct of regeneration and logging work, which would lead to an increase in the number of activities. Fundamentally, no difficulties are posed by defining activities in consideration of these factors or by incorporating them in a linear programming system. However, the basis for such a differentiation is weak owing to the lack of production data.

Other activities. Activities for hired labor are quite conventional. Under the head of capital, activities relating to different kinds of loans have been augmented by other activities for transfers to the next period of capital and of the surplus accumulated during a particular period.

Activities in the final period, which comprises the infinite future, absorb in the objective function the value of relevant resources. These resources chiefly comprise growing stocks in the different age classes, but also buildings which are not more than 20 years old and any disposal capital.

Special activities of different kinds may also be incorporated. Examples are purchases of land, which may be of particular interest in certain planning situations.

4.3. Gross margin calculations

General. The distinguishing features of the general calculation situation which are of greatest importance for the working out of gross margin calculations are bound up with the efficiency criterion and with the length and division of the planning period into subperiods. Traditional planning usually employs the concepts of income and cost, this being justified because the planning pertains to a specified period, with no regard taken of the value changes that may arise. Special calculations must be performed to take account of the investments necessary for the optimal management plan and their financing. When planning is for a longer period and pertains to the whole enterprise, as in this case, it must acquire a partially different alignment. The object is to make a total appraisal of production policy together with the attendant investments and their financing. Such planning can still be regarded as management planning, it is true, but fundamentally it boils down to investment planning with the special assumptions which apply to it. One consequence of this is the replacement of income-and-cost concepts by "payments in and out".

The pay-outs which must be covered by current receipts during a particular subperiod consist of (1) living expenses and (2) other joint payments. Subsumed under the latter are:

(a) Interest and amortization on borrowed capital
(b) Maintenance and renewal of machinery and maintenance of buildings
(c) General expenses
(d) Wages of permanently employed labor
(e) Subscriptions to marketing cooperatives
(f) Taxes

The capital referred to under item a) is that originally invested at time of purchase, and as such will involve certain payouts irrespective of the production policy.

The amount of capital in machinery is assumed as constant irrespective of production policy and is renewable every tenth year, i.e. written off at ten percent per annum.

Items c) and d) are self-explanatory. Subscriptions to marketing cooperatives are assumed to be a constant sum per year irrespective of production policy, either during the whole planning period or—which is more realistic—during a part of it.

Under f), only income tax is considered, and its basic amount is calculated with reference to the estimated need for current taxable receipts, including the value of benefits in kind. Certain assumptions are also made in regard to tax rates and the like. The tax on excess taxable income is computed with the aid of an approximate marginal rate. All interest and amortization payments are calculated according to the annuity principle, i.e. with payouts constant throughout the borrowing period, the amortization portion rising continuously while the interest portion dwindles by a corresponding amount. This assumption has also been applied to the design of capital activities. Under this method the need for current income is partly shifted from the beginning to the end of the planning period, as contrasted with repayments comprising constant amortization.

Working capital is assumed to enter at a certain constant amount, which is included as a portion of the capital invested in the operating unit, in conformity with the philosophy adopted as regards machinery, etc. There is accordingly no need to make special provision for working capital to deal with every single activity.

All gross margins are counted as annual averages for the period, and any surplus is assumed to earn the rate of interest appropriate to the particular owner.

Agriculture. The gross margin calculations adhere in principle to the method commonly used in agricultural management planning, with such modifications as are dictated by changes in the calculation situation. The main differences are twofold: income-and-cost concepts have been replayed by payments in and out; and no attempt has been made to distribute the pay-outs for capital allocations. To some extent this also applies to pay-outs for maintenance, for machinery and tools, and for existing buildings.

In addition to agricultural activities proper, activities relating to the reconditioning and construction of barns are included under different alternatives. These cases cover normal pay-outs for repairs as separate payments in all subperiods, whereas depreciation is accounted for in the final value of buildings.

Forestry. Pay-ins, or receipts, consist of gross prices at place of delivery, while capital changes are allowed for by the evaluation performed at period-end. The category of variable pay-outs is confined to direct payments for fuel and repairs of tools, inclusive of the extra outlays that may arise from use of the tools in forestry, e.g. increased wear and tear and repair charges for farm tractors. In addition there are variable pay-outs for seedlings, as well as for jobs which are assumed to be contracted out, e.g. scarifying. Receipts may also pertain to stumpage prices, which will facilitate the calculating.

Capital. As mentioned earlier, the activities are of two kinds, the one pertaining to loans, the other to transfers of capital. Pay-outs for loan activities consist of the annually payable instalments, which may be limited to one subperiod or embrace several, depending on the nature of the loan. To the extent a loan is not completely repaid during the planning period, the remainder will figure as a deductible item when disposable capital is calculated at period-end.

4.4. Matrix

The matrix is sparse, which is mainly due to division of the planning period into subperiods. A matrix model is shown in Fig. 4.2; though greatly simplified, it sets forth the essential relationships.

Resources and current income are indicated in the matrix by capital letters. The corresponding lower-case letters designate the resources needed by activities and the gross margin they earn.

Period	Enterprises and activities / Resources and restrictions	Unit	B	S Agri-culture SPML	S Agri-culture ANIM	S For-estry	S Lab HIRED	S Capi-tal TRI	S Capi-tal TRM	1 Agri-culture SPML	1 Agri-culture ANIM	1 Agri-culture BYGG	1 For-estry	1 Lab HIRED	1 Capi-tal LÅN	1 Capi-tal TRI	1 Capi-tal TRM	2 Agri-culture SPML	2 Agri-culture ANIM	2 Agri-culture BYGG	2 For-estry	2 Lab HIRED	2 Capi-tal LÅN	2 Capi-tal TRI	2 Capi-tal TRM	3 Agri-culture SPML	3 Agri-culture ANIM	3 Agri-culture BYGG	3 For-estry	3 Lab HIRED	3 Capi-tal LÅN	3 Capi-tal TRI	3 Capi-tal TRM	F Bldgs Per 2	F Bldgs Per 3	F For-estry	F FMHT
	Criterion		C																															c	c	c	c
S	Areas: Arable land	Ha	Å ≥	1	å																																
	" : Woodland	Ha	S =			1																															
	Bldgs: Existing	M^2	B ≥		b																																
	Labor: Own	M.h.	A ≥	a	a	a	-1																														
	" Hired (f For.)	M.h.	0 ≤			a	-1																														
	Capital: Disposable	SKr	K ≥		k			1																													
	Current income	SKr	I ≤	i	i	i	-i	i	-1																												
1	Areas: Arable land	Ha	Å ≥							1	å																										
	" : Woodland	Ha	0 =			-1							1																								
	Bldgs: Existing	M^2	B ≥									1																									
	" : Reconstructed	M^2	0 ≥								b	-1																									
	Labor: Own	M.h.	A ≥							a	a		a	-1																							
	" : Hired (f For.)	M.h.	0 ≤										a	-1																							
	Capital: Disposable	SKr	0 ≥		-k				-1		k	k			-1	1																					
	" : Borrowed	SKr	K ≥												1																						
	Current income	SKr	I ≤							i	i	-i	i	-i	-i	i	-1																				
2	Areas: Arable land	Ha	Å ≥															1	å																		
	" : Woodland	Ha	0 =										-1								1																
	Bldgs: Existing	M^2	B ≥									1								1																	
	" : Reconstructed	M^2	0 ≥									-1							b	-1																	
	Labor: Own	M.h.	A ≥															a	a		a	-1															
	" : Hired (f For.)	M.h.	0 ≤																		a	-1															
	Capital: Disposable	SKr	0 ≥								-k						-1		k	k			-1	1													
	" : Borrowed	SKr	K ≥																				1														
	Current income	SKr	I ≤									-i			-i			i	i	-i	i	-i	-i	i	-1												
3	Areas: Arable land	Ha	Å ≥																							1	å										
	" : Woodland	Ha	0 =																		-1								1								
	Bldgs: Existing	M^2	B ≥									1								1								1									
	" : Reconstructed	M^2	0 ≥									-1								-1							b	-1									
	Labor: Own	M.h.	A ≥																							a	a		a	-1							
	" : Hired (f For)	M.h.	0 ≤																										a	-1							
	Capital: Disposable	SKr	0 ≥																-k						-1		k	k			-1	1					
	" : Borrowed	SKr	K ≥																												1						
	Current income	SKr	I ≤									-i			-i					-i			-i			i	i	-i	i	-i	-i	i	-1				
F	Woodland	Ha	0 =																										-1							1	
	Bldgs: reconstructed in period 2	M^2	0 =																	-1														1			
	" : reconstructed in period 3	M^2	0 =																									-1							1		
	Capital	SKr	0 =																				k				-k				k		-1				1

Keys to abbreviations:

- SPML Grain production
- ANIM Dairy and meat production
- TRI Transfers within a period
- TRM Transfers between one period and the following
- FMHT Capital values of resources whose value depends on the plan
- LÅN Borrowed capital
- BYGG Buildings

Fig 4.2. Construction of the matrix

The treatment of arable land and the pattern of grain activity conforms with traditional treatment and is not influenced by the multi-periodicity or the linkage with forestry. Essentially the same applies to the livestock activities, but here the connection over the periods is noted by the capital rows; in principle this means that the livestock are sold at the end of each period, thereby releasing capital. The building activities imply that one can build in each of the three 10-year subperiods. A building project in period 1 is also carried over to periods 2 and 3.

The forested land is divided into age classes. Irrespective of whether or not action is taken, the stand will grow into a new age class. Consequently the resource, i.e. the area in each age class, must be entirely consumed by the different activities and be transferred as an asset to the next period. The coefficient for the resource will therefore be zero in all periods except the starting year. The value of growing stock at period-end results from the forestry program in force and must therefore enter into the objective function, as well as building projects during periods 2 and 3.

For forestry the availability of hired labor is assumed to be unlimited as seen by the individual entrepreneur, except that it cannot be used for other work. This resource must therefore not exceed the requirement, which is guaranteed by special restrictions. There is no connection between the different subperiods.

Available funds in the capital restriction refers to that portion which is disposable, e.g. the capital invested in livestock. During the course of a period this can be increased by different forms of borrowed capital, each with a certain restriction.

Other capital activities refer to transfers. According to the one TRI, transfers within a period, capital may be transferred from available funds to current income. The activity thus enables funds to be saved during a previous subperiod so as to meet the requirements of a coming subperiod. It is assumed that such capital is deposited in banks and successively withdrawn during the period.

The activity TRM permits the transfer of surplus from one period to the available funds of the next period. Among other things, capital transfers from the forest take place by way of this activity, which is the main connecting link between the different subperiods.

5. Application of method to a model operating unit

5.1. Description of the farm

The model farm on which the method is demonstrated has been designed to keep complexities to a minimum but at the same time realistically portray a farm unit in all essential respects. Accordingly, the number of activities has been cut down wherever possible for both agriculture and forestry, while more detailed treatment is given to capital and labor. Although planning embraces the enterprise as a whole, no external activities are assumed to occur. A planning period of 31 years is provided for, consisting of one starting year and three 10-year subperiods.

It has been considered essential to present the model unit in fairly great detail for two reasons: to illustrate its realism, and to afford a necessary basis for the analysis of results. So as not to encumber the exposition under this head, the latter is fully presented in Appendix 1.

5.2. Result and analysis

Primal. This contains the solution to the formulated problem, i.e. the optimal combination of activities which form the production plan sought. The term "primal" will henceforth be used to designate the whole assembly of activities obtained in the solution, including activities at zero level. The terms *optimal production plan* or *optimal plan* will be used for activities in the primal, which ar at a level higher than zero.

The solution distinguishes between *disposal activities* and *real activities.* HEADY-CANDLER (1958) defines the former as "nonuse activities", whose object is to permit the utilization of a certain resource at less than 100 percent; the unutilized portion is then reported as a *slack variable.* Real activities are accordingly those which make use of existing resources.

A primal that contains one or more activities at zero level, i.e. where no production takes place, is called *degenerate.* As a general rule, the number of variables entering into a base—whether it is optimal or not—must match the number of restrictions. Should the number of activities at non-zero level then fall short of the number of restrictions, the difference will consist of activities at zero level. The framing of (say) forestry activities and their interrelationship over the subperiods will mean that one component variable pushes two or more variables towards zero. In the event of two different solutions there is then no guarantee that one and the same activity at zero level will leave the base. And in this case, as will have emerged from the foregoing account, the number of activities at zero level is relatively great. In mathematical terms, therefore, some of the restrictions are redundant. However, this is not to suggest that the restrictions are unnecessary. On the contrary, they are essential to keep the method flexible under varying conditions and to avoid manual calculating work.

Degeneration serves to make the *primal* unstable, which is to say that different runs of one and the same model may result in mutually dissimilar primals. The resulting optimal *plan* is stable, however, and does not change even if the primal is changed. From that point of view, degeneration makes no difference one way or the other. One of its consequences, however, is that the activities entering at zero level are missing among the *reduced costs*, for which reason this is incomplete in economic terms. According to the empirical data obtained in the present study, which also agree with the findings reported by WEINGARTNER (1962) on integer programming, this fact has no effect on the make-up of the optimal plan and its economic result; a primal, on the other hand, is subject to change because activities at zero level in a solution can be replaced by others in a parallel solution, which in its turn can react on shadow prices and reduced costs.

An outline of the optimal plan and non-used resources is presented and commented in Appendix 1. Codes for activities and restrictions are listed in Appendix 2.

Dual. Every linear programming problem has a *dual*, i.e. a problem where the optimal solution entails minimization of the costs if the primal problem's optimal solution entails maximization of profits or vice versa. The costs correspond to the *marginal values* of resources, which in cases where the resources are not fully utilized are equal to zero. These values, usually called *shadow prices*, are combined in the solution for all right-hand terms in the same way that activity levels are combined in primals. According to HEADY-CANDLER (1958), shadow prices are defined as marginal value products and not as marginal values; this is justified, since shadow prices generally do not reflect the value of a resource, but rather the value of yield from one item of that resource, i.e. the increment to profits obtainable when an additional item of the resource becomes available, or the loss incurred when one item of the resource is carried over to disposal activity.

Shadow prices of forest resources in a certain period, i.e. growing stock of a certain age and composition, consist not only of the yield for that period but also of the yields in following periods, including value at the end of the planning period. These values must therefore be subtracted if the intention is to get value products equivalent to those obtained for other resources.

They are of slight interest, however, since they indicate the maximum that could be paid for disposing over forest of a certain type, i.e. growing stock of a specific age and composition during the 10-year period in question. On the other hand, by transferring the shadow prices of forest resources to the beginning of a period, one can obtain an *approximate* expression of their marginal value, i.e. the price that can be paid for buying the stock which grows on one hectare of woodland.

Summing up, it can be said that the information given by duals is of greatly limited value. It is a general weakness of linear programming that the stated values pertain to marginal estimates, but that is not the only reason. In this case there are the added drawbacks that the analysis of duals is arduous and the resulting information difficult to interpret. That is due both to multiperiodicity as such and also to degeneration. A detailed account of result analysis and interpretation is given in Appendix 1.

Reduced cost is defined as the amount by which the cost must diminish so that the activity in question can enter into the optimal base. But in this study reduced cost specifies the need for *increases in contributions to current income.* Activities *not* included in the optimal plan thus have costs which exceed the gross margin by an amount equivalent to reduced costs for the activity in question. In respect of reduced cost the solution also tells whether the obtained optimal plan is unique or whether alternative optima exist, in which case reduced costs will contain one or more entries at zero level.

Interest in the derivation of reduced costs has focused on forestry, whereas agricultural activities have been treated less exhaustively, as have capital and labor activities, where the relationships are evident. The findings of analysis show that reduced costs can be made to give information on the losses incurred from choices of forestry alternatives other than those which enter into the plan. Should these losses turn out to be negligible, it means that considerable freedom is permitted in the choice of forest management program, which is of importance for the planning of (say) logging operations, especially in cases where these are carried out jointly for several properties. An analysis of this kind must be based on a program which extends over several subperiods and will be rather laborious to perform. One advantage, however, is that it can be directly based on the values of reduced costs, which are specified in the solution without conversion to each subperiod, inasmuch as the objects of search are relations. The analyses that have been made also suggest that the information given by reduced costs is of great practical value. A supplementary analysis is presented in Appendix 1.

5.3. Conclusions and recommendations

The planning methods herein described boil down to investment estimates which embrace the whole operating unit with all possible investments, their financing and the need for liquid funds treated simultaneously. The comprehensive plan functions as a frame for the short-term detail planning of individual production lines. Such planning is thereby simplified without inviting the risk of suboptimization. *This means that the forestry section of the plan replaces the conventional forestry management plan.*

The method should lend itself to both research and survey purposes as practical planning. Its use is primarily recommended for model studies, either in direct research work or as a basis for practical planning. The difficulties of obtaining necessary data and the need for intensified work in this field should be underlined.

One application which exemplifies the principles involved concerns the total planning of individual farms in a "forestry area".[1] The result is an optimal plan for each holding which takes the actual situation of its owner into account. On the basis of these total plans it is then possible to set up annual plans for the total forestry area which chiefly prescribe the technical planning of such matters as the size and location of harvested volumes, roads, landings, allocation of machinery, etc.

Although the method has been devised with combined forests and agricultural units in mind, its applicability is not restricted to this special type of operation, the method being valid for the comprehensive planning of forest operations in general.

[1] A forestry area is a geographically defined tract having from 5,000 to 40,000 hectares of woodland (about 12,500 to 100,000 acres) divided between 50 to 200 owners who collaborate in timber production, especially in harvesting.

Summary

1. The study has admittedly aimed at formulating a method for long-term planning of farm operating units, but it is chiefly a study of comprehensive planning in forestry.

2. The term *production process* is used in the sense it has in investment theory, while the term *activity* is reserved for use in accordance with linear programming terminology. Enterprise is used as a common term for all activities producing a common product.

Interest is concentrated on timber output and its dependence primarily on the investment in terms of growing stock. Emphasis is put on the relatively slight decline in output when the volume is reduced from maximum to half.

3. In principle, management planning in agriculture employs two methods, or if one wishes two variants of one fundamentally common method: *traditional budget method* and *gross margin calculating method.* A review of the problems which arise, among them uncertainties in estimates of output and prices, results in a recommendation that the planning of farm operating units ought to be based on gross margin calculations which because of its greater flexibility is held to be superior in the planning situations which are deemed most relevant.

4. The method is demonstrated on a model operating unit. A planning period of 31 years is chosen, consisting of a one-year change-over period at the beginning followed by three 10-year subperiods. The efficiency criterion is based on the capital value at period-end of those resources which vary with the production program. The requirement of maximum capital value is linked to a restriction guaranteeing a certain annual minimum amount to meet the need of liquid funds for current payouts, including those for private consumption.

Forest activities are defined with reference to site quality, age class, growing stock and the technical and organizational pattern of logging and regeneration work. The number of alternatives relating to growing stock have been confined to upper and lower limits. Capital activities are of special interest as a connecting link between forestry and agriculture, and also between subperiods. They embrace loan activities as well as transfers from one period to the next; these have great fundamental interest in terms of methodology.

The concepts of income and cost commonly used in traditional planning are replaced in the long-term total plan by pay-in and pay-out flows. That is because this type of plan, by contrast with the traditional management plan, is in principle an investment estimate embracing the whole enterprise.

5. The solution obtained is *degenerate*, i.e. it also includes activities at zero level. That is a consequence of the method's conceptual structure, above all its linkage between activities in different periods. The *optimal plan*, which is composed of activities that are not at zero level, is not affected and from that aspect degeneration becomes of no consequence.

Included in the solution are data on marginal value products—in certain cases values—of resources and restrictions, so-called *shadow prices*. The conclusion is that the information obtained by way of shadow prices is of greatly limited value in this method owing to their multi-periodicity and degeneration of the solution.

Activities not included in primals are to be found among *reduced costs*, with specification of the increase in marginal income that is required to enable them to enter into the base. Analysis of reduced costs permits losses to be evaluated on the strength of variance from a specified forestry program within the optimal plan. This has particular value for considering modifications which may be warranted for various reasons, such as the technique of logging operations. The analysis, moreover, can be useful to help test stability of the plan.

6. Planning in accordance with the method described boils down to an investment estimate embracing the whole farm operating unit with simultaneous treatment accorded to all possible investments, their financing, and the need for liquid funds.

The method should lend itself to both research and survey purposes as practical planning of forest operating units, either separately or in combination with other economic activity.

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ABBREVIATIONS USED

Acta Forestalia Fennica	AFF
Studia Forestalia Suecica	SFS
Nordic Agricultural Research Workers' Association	NJF
Periodical publ. by the Forestry Association of Northern Sweden	NST
Periodical publ. by the Swedish Forestry Association	SST
The Swedish Agricultural Research Institute	JU
The Forest Research Institute of Sweden	SFI
The Royal Agricultural College	LHS
The Royal College of Forestry	SHS
Government Official Investigations	SOU

Sammanfattning

Ekonomisk planering av det kombinerade skogs- och jordbruksföretaget

1. Studiens mål är visserligen att utforma en metod för långsiktig planering av lantbruksföretag, men den är främst en studie i översiktlig planering inom skogsbruket.

2. Termen *produktionsprocess* används i investeringsteoretisk betydelse, medan termen *aktivitet* reserveras för användning enligt lineär programmeringsterminologi. *Produktionsgren* används som en gemensam beteckning för alla de aktiviteter, vilka producerar en gemensam produkt.

Intresset koncentreras till virkesproduktionen och dennas beroende av framför allt det investerade virkesförrådets storlek. Den relativt ringa nedgången i produktion vid sänkning av förrådet från maximal volym till hälften eller en tredjedel betonas.

3. Vid driftsplanering inom lantbruket är det i princip två metoder, eller om man så vill två varianter av en i grunden gemensam metod, som används, *traditionell budgetmetod* resp *bidragsmetod.* En redovisning av de problem, som föreligger, bl a osäkerheten vid uppskattning av produktion och priser, resulterar i en rekommendation, att planering av lantbruksföretag bör grundas på bidragsmetoden, vilken på grund av dess större smidighet anses överlägsen i de planeringssituationer, som bedöms vara av störst intresse.

4. Metoden demonstreras på ett modellföretag. Planeringsperioden är 31 år uppdelad på en 1-årig omställningsperiod i början och därefter tre 10-åriga delperioder. Effektivitetskriteriet baseras på kapitalvärdet vid planeringsperiodens slut av de resurser, som varierar med produktionsprogrammet. Kravet på maximalt kapitalvärde är kopplat med en restriktion garanterande ett visst årligt minimibelopp för att möta behovet av likvida medel för löpande utbetalningar inklusive för privat konsumtion.

De skogliga aktiviteterna definieras med utgångspunkt från bonitet, åldersklass, virkesförrådet samt avverknings- och föryngringsarbetets tekniska och organisatoriska utformning. Antalet alternativ med avseende på virkesförråd har begränsats till ett övre resp nedre gränsvärde. Kapitalaktiviteterna är av speciellt intresse som en sammanbindande länk mellan dels skogs- och jordbruk, dels delperioderna. De omfattar dels låneaktiviteter, dels transfereringsaktiviteter från en period till en följande, vilka är av stort principiellt intresse ur metodologisk synpunkt.

De i traditionell planering vanligen förekommande begreppen intäkter och kostnader ersätts i den långsiktiga totalplanen av in- och utbetalningsströmmar, då denna plantyp i motsats till den traditionella driftsplanen i princip är en hela företaget omfattande investeringskalkyl.

5. Den lösning, som erhålls är *degenererad*, dvs innefattar även aktiviteter på nollnivå. Detta sammanhänger med metodens principiella uppbyggnad, framför allt med bindningen mellan aktiviteter i olika perioder. *Den optimala*

planen, vilken är sammansatt av aktiviteter, som inte är på nollnivå, påverkas inte och ur den synpunkten är degenerationen alltså betydelselös.

I lösningen ingår även uppgifter om marginella värdeprodukter — i vissa fall värden — av resurser och restriktioner, s k *shadow prices*. Slutsatsen blir att den information, som erhålls via shadow prices är av mycket begränsat värde i denna metod beroende på dessas flerperiodicitet och lösningens degeneration.

Aktiviteter, som inte ingår i primal, återfinns bland *reduced costs* med angivande av vilken ökning i täckningsbidrag, som fordras, för att de skall ingå i basen. Analys av reduced costs ger möjlighet att bedöma förluster genom avvikelse från ett visst i den optimala planen ingående skogsbruksprogram. Detta är av speciellt värde vid överväganden rörande modifieringar motiverade av t ex avverkningstekniska skäl och överhuvudtaget som ett led vid en prövning av planens stabilitet.

6. Planering enligt den redovisade metoden är i princip en investeringskalkyl omfattande hela företaget, varvid samtliga möjliga investeringar, deras finansiering och behovet av likvida medel behandlas simultant.

Metoden bör kunna utnyttjas för såväl forsknings- och utredningsändamål som praktisk planering av skogsföretag, fristående eller i kombination med annan verksamhet.

Appendix 1

1. Description of enterprise

The model is worked out in line with that described in Chapter 4, but with two exceptions:

a) Contributions to cover the need for current income have been calculated at the average-year amounts for each single activity accumulated by the end of each 10-year period. Surpluses, if any, are transferred without correction for marginal tax to capital resources of the following period. However, the amortization part on loans taken up during the period are taxed.

b) All values in the goal function have been discounted to year 1.

Later models have been devised in full conformity with the guide lines, also given in Chapter 4, which are formulated with reference to the experiences gained from the original model cited herein. It should be noted, in particular, that surpluses are taxed at an approximately calculated marginal rate.

1.1. Planning situation

The annual pay-ins required during each period, allowing for certain variations between subperiods, amount to just under SKr 80,000. Included therein are the entries set forth under section 4.3.

The woodland amounts to 100 hectares. It is assumed that the forest satisfies the average conditions which hold for a specified region with reference to yield class, growing stock and age-class distribution. A mixture of tree species is assumed, consisting of 50 percent pine and 50 percent spruce in all age classes. The basal area corrected mean diameters in each age class, as well as data on growing stock, and timber yield are derived from national forest surveys (Nilsson, 1961) for mixed coniferous forests.

The farm has 40 hectares of arable land and a barn of 250 square meters which can be used "as is" during the starting year for dairy or meat production, but which must later be either rebuilt or replaced. In addition, the farm is equipped with other necessary outbuildings which can be used during the period. Both woodland and arable land are assumed to be homogeneous.

The permanently employed labor is assumed to be capable of working 5,000 man-hour per year, of which the owner puts in 2,400, family members 600 and hired labor 2,000 hours. It is also possible to hire labor for all forest work and a total of 600 hours for hay-making and harvesting. The performance of joint tasks is assumed to require 400 man-hours.

The amount of capital invested in the enterprise at the beginning of the period is assumed to be SKr 380,000, whereof the directly disposable portion amounts to SKr 26,000. Own capital totals SKr 65,000 but is presumed to increase to SKr 154,000 during the planning period by amortization in accordance with the conditions governing the distribution of borrowed capital by different types of loans, which form the basis for calculating the annual charges on fixed capital. Neither this increase in assets or that which follows from the accumulation of capital invested in marketing cooperatives is reported in the efficiency criterion, since this is assumed to be independent of operating policy.

1.2. Activities

The following enterprises and activities have been included under *agriculture:*

a) Grain cultivation, only one activity.
b) Dairy production. This is assumed to be feasible during starting year in existing buildings only, but during other periods in modernized or new buildings.
c) Meat production. During starting year in existing buildings, thereafter in modernized buildings.
d) Construction. It is assumed that the original barn can be rebuilt for dairy or meat production during any of the 10-year subperiods. In addition, the construction of a new building for dairy production is also assumed as feasible during any of these periods.

Activities in *forestry* are defined in accordance with the general presentation given in previous chapters. Data on timber production have been determined on the basis of yield surveys (Nilsson, 1961). The upper limit is set with reference to growing stock in the "better half", i.e. that half of the sample-plot material which shows the highest density. The lower limit is set at 70 percent of the stock as per the "better half", which roughly corresponds to stocks in the density class which fall immediately below the "better half".

Yield is assumed to follow the national forest surveys as regards the higher-class stock, while yield from the lower-stock alternative is assumed to follow the trend described by Petterson (1955) in his series for unplanted pine in northern Sweden. The reason for adopting Petterson in this case is that national forest survey data does not give a correct picture of the trend for a systematically managed stand of trees. On the other hand, diameter growth is assumed to follow the curve shown in national forest surveys. For clear cutting, the upper and lower limits are set at 100 and 70 years, respectively. For young stands, i.e. trees of 35 years or less, only one timber production alternative has been given.

Activities are not differentiated according to techniques of regeneration and logging; instead, only one technical level has been stated. The definition of activities is thus entirely based on dissimilarities in patterns of timber production, defined on the basis of volume of growing stock at different ages.

Capital activities are defined as described in previous sections:

a) Loan activities of two kinds, bank loans secured by the State and ordinary bank loans, occur in each of the three 10-year periods.
b) Transfers of capital from disposable capital to consumtion occur in all four periods.
c) Transfers of capital from one period to the next also occur in all four periods.

The activities for *hired labor* are:

a) Agriculture—activities in connection with haymaking and harvesting in each of the three 10-year periods.

b) Forestry—activities occur in each of the subperiods for certain specified operations.

The *evaluation* at period-end is done via special activities, which are assigned to period F, the time after the planning period ends. Growing stock is evaluated at the rate of 5 percent, which is expected to give a value level that ties in closely with the actual market level.

The total comes to about 260 activities and 200 restrictions, and 1,600 matrix elements, which illustrates the sparseness of the matrix.

1.3. Gross margin calculations

Agriculture. The gross margin calculations for agricultural activities proper are identical for all periods and pertain to an average year.

On the other hand, the calculations for buildings differ somewhat owing to outlays for maintenance, which arise not only in the period when a building is erected but also in subsequent periods. Further, buildings erected in the second and third 10-year periods have a certain residual value at the end of the planning period.

Table B.1. Gross margin calculation for age class 9 at ingoing level 4

Type of payment or resource	U of m	Alternative (In ⟶ outgoing level)								
		4 ⟶ 1			4 ⟶ 3			4 ⟶ 4		
		Quant.	unit price	Sum SKr	Quant.	unit price	Sum SKr	Quant.	unit price	Sum SKr
1. *Payment for cut timber*	M^3 dbr	164	46.7	7 659			0	36	45.4	1 634
	cm	24.0						22.8		
2. *Var. payments*										
Scarifying	hrs	5	25	125						
Seedlings	1 000	2.5	60	150						
Clearing saw	hrs	10	0.75	8						
Power saw	hrs	61	1.25	76				14	1.25	18
Tractor w. equipm.	hrs	82	3.25	267				18	3.25	59
Total:				626						77
3. *Receipts- var. payments SKr*				7 033						1 557
4. *Need of resources*										
Labor M.h.	hrs	10								
Clearing		25								
Planting										
Release										
Felling		121						28		
Haulage		82						18		
Joint logging work		115						25		
Total:		353						71		
5. *Standing volume of stock*	M^3	1			189			151		
at end of subperiod	dbr cm	—			23.9			24.5		

Table B.2. Estimate of felling volume 2. Ingoing stock corresponds to the "better half" (NILSSON, 1961). Mixed coniferous forest. Increment region IV. Site class IV

Age at beginning of period		Standing vol. of stock, m^3					Total increment m^3 at outgoing level				Total harvest at outgoing level				Average D.B.H., cm	
			Outgoing level													
Class	Year	Ing.	1	2	3	4	1	2	3	4	1	2	3	4	Standing stock	Thinning
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
			1													
							1	=		=	—	—		—	—	—
1	5	1	25	=		=										
							25	=		=	—	—		—	—	—
2	15	25	57	=		=										
							50	=		=	—	—		—	—	—
3	25	57	115	=		=										
							58	=		=	—	—		—	14.0	—
4	35	(115)	—	116		81									14.2	
							—	59		56	—	58		90	14.5	14.5
5	45	116	—	141		99									16.0	
							—	57		54	—	32		71	17.5	17.1
6	55	141	—	163		114									18.2	
							—	56		53	—	34		80	18.9	18.0
7	65	163	1	182		127									19.6	
							27	54		51	190	35		87	20.3	19.3
8	75	182	1	200		140									21.0	
							27	54		51	209	36		93	21.6	20.5
9	85	200	1	215		151									22.3	
							26	52		49	226	37		98	22.9	21.8
10	95	215	1	—		—									23.5	
							26	—		—	241	—		—	24.1	22.9

Forestry. Identical standard figures and prices are assumed to apply in all periods. An example of gross margin calculations for forestry is given in Table B.1, while an example of an estimate of felling volume is given in Table B.2. The volume of cut timber is obtained as the difference between ingoing stock plus period increment and outgoing stock. Hence for every ingoing level as many felling estimates are obtained as there are outgoing levels, in this example three alternatives.

Capital. The interest rate in capital activities is based in principle on the actual interest level without correction for any inflation. For bank loans secured by the State the rate is 6.5 percent, whereas 8 percent is used for other bank loans during the first and second 10-year periods and 6.5 percent during the third period (this because of the greater security that can be put up in the last period). Any surplus which arises during a subperiod is assumed investable at the rate of 6 percent.

2. Primal

The optimal plan is set forth in Table B.3 and the extent of unused resources in Table B.4. Codes for activities and restrictions are listed in Appendix 2.

The optimal plan for agriculture is based on dairy production. Capital in the starting year does not suffice for many head of cattle. Dairy production

Table B.3. Optimal management plan

Activity	Level	Activity	Level	Activity	Level	Activity	Level	Activity	Level
S		1		2		3		F	
Agriculture		Agriculture		Agriculture		Agriculture		Agriculture	
SPM Ha	28.6	J MOB Cows	41.7	J MOB Cows	41.7	J MOB Cows	41.7		
MUG Cows	14.4	J MNB ”	9.0	J MNB ”	9.0	J MNB ”	9.0		
		B OMJ M^2	250.0						
		B NMJ ”	53.8						
Forestry		Forestry		Forestry		Forestry		Forestry	
01 A1	5.2	01 11	5.2	02 11	5.2	03 11	5.2	04 1F	5.2
02 AB	4.8	02 B1	4.8	03 11	4.8	04 14	4.8	05 4F	4.8
03 AB	5.5	03 B1	5.5	04 12	4.9	05 24	4.9	06 4F	5.5
04 AB	6.1	04 B4	6.1	04 14	0.6	05 44	0.6		
05 A4	9.4	05 44	9.4	05 44	6.1	06 44	6.1	07 4F	6.1
06 A4	9.3	06 44	9.3	06 44	9.4	07 41	9.4		
07 A4	11.2	07 44	11.2	07 44	9.3	08 41	9.3		
08 A4	11.2	08 44	11.2	08 41	10.6	09 41	0.6	01 1F	19.3
09 A4	7.7	09 41	4.5	08 44	0.6	01 11	25.0	02 1F	25.0
10 AB	7.6	09 44	3.2	09 41	11.2	02 11	34.1	03 1F	34.1
16 A1	4.9	10 B1	7.6	10 41	3.2				
16 AB	2.9	16 B1	2.9	01 11	34.1				
17 A1	4.4	00 11	19.1						
18 A1	0.7								
KL A1	9.1								
Labor M.h.		Labor M.h.		Labor M.h.		Labor M.h.		Labor M.h.	
HU	1 962.5	PL	85.2	PL	62.5	PL	48.2		
IA	2 262.9	IA	181.5	IA	366.6	IA	99.2		
Capital SKr 1 000		Capital SKr 1 000		Capital SKr 1 000		Capital SKr 1 000		Capital SKr 1 000	
TPS	64.6	LBK	0.5	TLI	128.8	TLI	376.7		
		LGI	130.5	TPS	376.7	TPS	736.8	FMH	827.9
		TPS	128.8						

Table B.4. Nonused resources and other restrictions

Resource	Level	Resource	Level	Resource	Level	Resource	Level
S		1		2		3	
Agriculture		Agriculture		Agriculture		Agriculture	
Existing buildings	163.3						
Labor force M.h.		Labor force M.h.		Labor force M.h.		Labor force M.h.	
Own for:		Own for:		Own for:		Own for:	
haymaking	548.1	haymaking	321.2	haymaking	321.2	haymaking	321.2
harvesting	582.9	harvesting	428.3	harvesting	428.3	harvesting	428.3
Hired for:		Hired for:		Hired for:		Hired for:	
felling	691.6	haymaking	240.0	haymaking	240.0	haymaking	240.0
halulage	1 633.4	harvesting	360.0	harvesting	360.0	harvesting	360.0
		clearing	34.1	clearing	25.0	clearing	19.3
		release	7.3	release	47.7	release	35.0
		felling	372.0	felling	438.3	felling	357.5
		haulage	226.2	haulage	262.5	haulage	192.7
		joint logging work	133.9			joint logging work	169.0
		Capital SKr 1 000		Capital SKr 1 000		Capital SKr 1 000	
		Bank loan	49.5	Bank loan	50.0	Bank loan	50.0
Standing volume of stock M^3	8 036	Standing volume of stock M^3	7 029	Standing volume of stock M^3	5 285	Standing volume of stock M^3	4 815
						Clear cutting	5.7

(JMUG) is therefore limited to 14.4 units, which will require all available capital, 11.4 hectares of arable land and 87 square meters of building space. The remaining arable land, 28.6 hectares, is used for grain production, while the remaining building space of 173 square meters stays unused.

All available building space is reconditioned (BOMJ) at the beginning of period 1, augmented by 53.8 square meters of new construction (BNMJ). Altogether this provides space for 50 cows (JMOB and JMNB), which make full use of the available arable land. The reconditioning is completely financed by State-secured loan (KLGI), which is turned to full account, whereas remaining capital is chiefly obtained by heavy cuttings during the starting year. This is illustrated in part by the large amount of SKr 64,000 transferred from period S to period 1 (SKTPS) and in part by the sharp reduction of the standing stock (FORR) from 10,844 to 8,036 m^3. Consequently there is a large slack component for ordinary bank loan (KLBK) in this period, but none for State-secured loan. During the period, moreover, a considerable surplus arises; this is carried over to period 2 for retransfer—via 2KTLI—to the following period. These amounts are naturally stated in absolute quantities without corrections for time. In periods 2 and 3 dairy production continues in the buildings reconditioned and newly erected during period 1. No loans are taken up; on the contrary, there are large surpluses of capital.

The optimal plan for forestry, including the services of hired labor, shows that cuttings are consistently high. It should be noted, however, that cuttings would decline considerably if marginal tax were taken into account; this has been done in a further development of the model. Other work undertaken in the starting year includes, first, clear cutting of residual forest and left-over trees on cleared ground (SKLA1) and in age class 1 (SO1A1) plus age classes VI, VII and VIII (S16A1, S17A1 and S18A1) as long as the restriction for clear cutting permits, i.e. 10 hectares; and second, heavy thinning in all other age classes except 4 and 10, which is because no such activity has been included for these two age classes. This intensive felling program then continues into other periods except for age class 4 in period 2, the reason for that being the availability of manpower. In this period all planting and indirect logging tasks are performed by hired labor (2ALPL and 2ALIA). Since additional cutting would require the services of more-expensive fellers, part of the cutting is postponed to the next period, when labor is in better supply owing to the reduced volume of clear cutting, etc. The marginal price of hired labor is SKr 8.77, compared with the price of SKr 8.30 applicable to the first and third periods (Table B.5). All labor for planting is hired even during the other periods, as is most of the labor for indirect logging work. During the starting year, moreover, the greater part of felling labor is hired. The order in which hired labor is used depends entirely on its hourly rate. The cost of hired labor is SKr 6.25 for planting, 8.30 for indirect logging work and 10.30 for felling, while the costs for haulage and farm work are both much higher. Altered price relations would introduce other kinds of hired labor. There are restrictions which impede the use of forest workers for farm work, but hired forest workers can release the owner and his family for farm work. Period 3 has a slack of 5.7 hectares for the cleared land restriction (3KALG), the reason being that there are only 19.3 hectares of forest above 70 years of age and that trees below 70 may not be clear-cut pursuant to the restrictions which are assumed to apply when gross margin calculations are made.

Entries in the columns headed "Level" in Table B.4 relate in principle to quantities of nonused resources. They are not difficult to interpret when they specify the restrictions for a certain quantity of resources which must not be exceeded, as in respect of available arable land and building space and certain kinds of capital or labor.

In cases where the restrictions have been devised as for (say) hired labor in forestry, where the volume of hired labor for a certain activity must not exceed the actual work available, the slack corresponds to that part performed by the owner or his family; this of itself is a valuable piece of information. Similar information is obtainable for other restrictions which have been devised in a similar manner. For example, the proportion of investments, for which State-secured loans could be obtained but, which are financed by other means is indicated. Adding the slack to the real consumption gives the total labor requirement for the kind of work concerned, as well as the total capital requirement for that kind of investment, which in this case pertains to the reconditioning and construction of barns. Lastly, the slacks for the FORR rows indicate the standing volume of stock at the end of each subperiod.

3. Dual

Shadow prices refer to one and the same moment in time, i.e. in this case year 1. If relation of the values to respective periods is desired, they must be converted by an interest factor. Conversion to average-year values—marginal value products assigned to each period—for the different resources is done by dividing the product of the cumulative factor (the interest factor) by the shadow prices applicable in each period to the restriction on current income —the LINK row—which gives the marginal value of disposable capital at each period-end. In the starting year, of course, the LINK value is used by itself. This shadow price accordingly agrees with the shadow price for available funds—KEGT—in the following period. The values thus derived reflect the marginal value product of different resources with allowance for the actual marginal value of capital, which is obtained by way of the shadow prices on the LINK rows. A list of converted shadow prices is shown in Table B.5.

Table B.5. Marginal value products, agriculture, capital, labor

Label	Period					
	S	1	2	3	F	
JAUG	334	382	743	1 184	ASP1	1 424
JBUG	0	26	5	0	ASP2	850
JBOM	0	73	52	0	ASP3	161
JBNM	0	107	88	35	BOM2	57
JBOK	0	70	0	0	BOM3	121
KEGT	1 173	245	136	136	BNM2	138
KLNB	0	0	0	0	BNM3	270
KLNG	0	55	9	0	BOK2	34
AESR	0	0	0	0	BOK3	69
AESD	0	0	0	0	KEGT	999
ALSR	0	0	0	0		
ALSD	0	0	0	0		
AETT	1 030	8.30	8.77	8.29		
ALHR	0	0	0	0		
ALPG	0	2.05	2.52	2.05		
ALPJ	0	0	0	0		
ALHG	0	0	0	0		
ALKG	0	0	0	0		
ALIN	2.00	0	0.48	0		

According to the marginal cost estimates and the original matrix, contributions to current income in each period (LINK) are figured as the total at period-end of income earned over 10 years, with the interest rate set at 6 percent to give a cumulative factor of 13.182. The surplus arising in one period is assumed to be transferred to disposable capital in the next period, where it is spent either for production or consumption purposes or deposited in a bank. In the former instance the interest rate is unknown, in the latter it is 6 percent. Lastly, all values have been discounted at the rate of 6 percent to year 1.

The shadow prices specified in periods 1, 2 and 3 for the LINK restriction agree with the discounting factor for 10, 20 and 30 years at 6 percent. This means that if the surplus at every period-end were reduced by SKr 1,000, this reduction would be prolonged to the end of the planning period at 6 percent and would then be discounted back to year 1. Looking next at current income during the starting year (SLINK), it will be seen that this simple relation no longer applies, the reason being that money must be borrowed during period 1 for later repayment with taxed money. One aspect, particularly interesting in forestry terms, concerns the possibilities of employing shadow prices to find an expression for the marginal value of capital. The annual instalment comes to around SKr 145, whereof the amortization part amounts to about SKr 100. With a marginal tax of 50 percent the annual charge works out at about SKr 245. Should the surplus dwindle during starting year, corresponding amounts must be borrowed under these terms during period 1.

SLINK is obtained when the totalled value of these annual amounts during period 1, expressed in thousands of kronor, is prolonged to the end of the planning period and thereafter discounted to year 1, i.e. $0.245 \times 13.182 \times 1.06^{20} \times 1.06^{-30} = 1.8034$. The other LINK values can be similarly shown to consist of annual amounts totalled up with the factor 13.182. In these cases the annual amounts come to about SKr 136, which is the annual yield obtained if SKr 1,000 invested at 6 percent is consumed over a 10-year period. This is the same as if 1,000 SKr was borrowed at the beginning of the period and repaid during it.

As mentioned above, shadow prices for disposable capital agree with the LINK value of a previous period. Under the conditions assumed, these capital values are linked over the periods and so, of course, are the LINK values. Disposable capital at the beginning of period F, i.e. for the infinite future (FKEGT), is quite simply SKr 1,000 discounted at 6 percent to year 1, while 3KEGT and 2KEGT are discounted in 20 and 10 years, respectively. Dividing 2KEGT by 3KEGT or 3KEGT by FKEGT gives the factor 1.7908, i.e. the prolongation factor for 6 percent and 10 years. But 1KEGT divided by 2KEGT gives the factor 3.2366, which equals an interest rate of between 12 and 13 percent. However, the quotient 3.2366 is recognizable as the product of 0.245×13.182. This is also found in the matrix as the coefficient of bank loan activity in the LINK row. Because of the obligation to amortize and to pay marginal tax, the pay-out for the 8-percent loan thus works out at 12 to 13 percent. A similar calculation gives the interest rate on the pay-out for capital during the starting year, which amounts to 17 percent.

1LINK is not affected because it refers to the period-end, while the capital value refers to the period-beginning. This direct means of finding an expression for the marginal value of capital is one of the method's big advantages, as WEINGARTNER (1962) has pointed out. In this case, however, the value is limited by the fact that the result obtained is the interest rate for capital pay-outs.

Conversions with other capital factors, e.g. at a recurrent interest rate of 6 percent, produce downright erroneous values. This stands out most plainly from a conversion of shadow price for own work (AETT), e.g. in the starting year, which is given as SKr 18.60 in Dual. Since all amounts relate to the end of each period, conversion at 6 percent gives the same results (prolongation and discounting in 30 years). On the other hand, conversion with the LINK row's shadow price gives SKr 10.30, which is the marginal value product of the work and corresponds to the hourly rate earned by a feller.

Shadow prices for arable land and buildings during subperiods 1, 2 and 3 are determined by dairy production in newly erected buildings, since that is the activity which would increase if an additional hectare of such land could be used, or decrease if its area were reduced by one hectare. This becomes evident from the displacement of all other activities by dairy production; in the process advantage is taken first of all the possibilities for reconditioning, and expansion by means of new construction is resorted to thereafter until all arable land is brought into use. The values specified for arable land and buildings pertain to hectares and square meters, respectively, and can be converted into a cow unit, which shadow price equals the marginal value product for dairy production in new and reconditioned buildings. The difference between them stems from the difference in labor requirement and its marginal price. The relation between shadow prices for arable land and buildings is obviously governed by grain production, which determines the shadow price for arable land, after which the remaining part of the shadow price for dairy production is chargeable to buildings.

Shadow prices for labor (AETT) are equivalent in periods 1 and 3 to the wages paid for joint logging work (ALIN), said wages being higher in period 2. That is because the plan calls for maximum use of hired labor to perform indirect logging work during this period, the price of such labor working out at the cheapest rate next to planting. The services of more expensive fellers must therefore be engaged if increased cutting volume is desired. Instead of doing that, a light cutting program is adopted in this period for the greater part of age class 4, i.e. trees between 30 and 40 years old. The reduction is made good in period 3 though at a certain loss, which is reflected in shadow prices for labor in period 2. Shadow prices for planting labor (ALPG) equal the difference between hourly rates for the total of own work (AETT), which in period 1 and 3 agree with the hourly rate of payment for indirect logging work, and planting.

Comparison with a solution for an identical model but with average-year amounts and undiscounted final capital value as criteria shows that first-period values accord fairly well, though not exactly (presumably due to errors in rounding), whereas the values for other periods differ markedly. It has not been possible to demonstrate an acceptable explanation of these variations based on economic factors; to all appearances, the variations have to do with the fact that the primal solution is degenerate, which results in the replacement of certain activities at zero level in the original solution by other activities in the alternative solution. That in turn has the consequence of making certain activities, which in the original solution lacked reduced cost because they entered into the primal, take on such costs in the later solution and vice versa. This problem will be discussed in detail in connection with the analysis of shadow prices for the forest resources. The optimal plan is not affected by the change in the criterion function, which of course is quite formal.

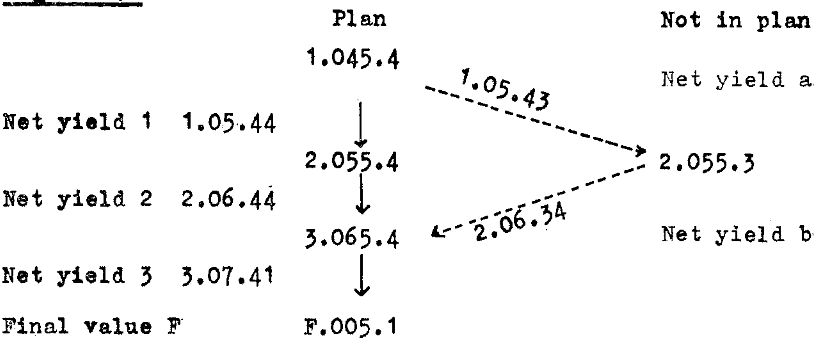
Shadow prices for forest activities may be derived in a manner similar to that already applied to other activities. It emerges that these are based on the interest rate which for each period is reflected in the LINK values. As was observed in the previous account, these are not necessarily identical with the values reflected in the same period's KEGT values, which of course relate to the period-beginning by contrast with the LINK values. If on the other hand woodland is to be bought, capital must be available at the beginning of the period, which means that the interest rate to be used in an evaluation of yield should be the one applicable to capital at each period-beginning.

The forest values derived from shadow prices for each period will evidently be somewhat on the high side, since they are based on the 6 percent which enters into the LINK coefficient except for the starting year. It can be said that the evaluation suffers from a phase displacement. In other words, it is not possible to work out the forest values other than by way of special estimates. Neither can these be directly based on a coefficient extracted from the machine computations, for which reason a fairly great deal of manual figure work is required if they are to be turned to useful account.

Shadow prices for forest resources to be used under the plan, i.e. by activities above zero level, thus equal the capitalized values resulting from a conventional yield evaluation based on the used gross margin calculations corrected for actual wages, i.e. shadow prices for hired labor. In respect of clear cutting, the shadow price under the cleared-land restriction must also be added to the shadow price for the relevant age class in order to produce the capitalized value. Further, the forestry program specified by the plan must be followed. The capitalized values worked out in this way correspond to the values obtained from a conversion of shadow prices with consideration for capital scarcity, i.e. with use of the LINK coefficient as conversion factor.

For resources not to be used under the plan, i.e. which either enter into the primal at zero level or are completely excluded from the primal, it is only in exceptional cases that shadow prices equal capitalized values in the same manner as for activities which enter into the plan. For example, the shadow prices for outgoing level 3 in a certain period are identical, when corrected to the same moment of time, with those for outgoing level 4 in the previous period with certain exceptions. The relations are illustrated in Fig. B.1, which gives an example for resource 2.055.3, i.e. a 55-year-old forest with growing stock equivalent to level 3 in period 2.

Figure B.1



A program which follows the continuous arrows, i.e. lies at level 4 throughout, gives the highest capitalized value, while a program adhering to level 3 in period 2 would give a lower capitalized value. Both values may be indicated as follows:

$S_{1/4\,max}$	$= 1+2+3+F$	(6: 1)
$S_{1/4\,via\,2/3}$	$= a+b+3+F$	(6: 2)
R	$= S_{1/4\,max} - S_{1/4\,via\,2/3}$	(6: 3)
$S_{1/4\,max}$	= Capitalized value in period 1 for ingoing stock at level 4, i.e. in accordance with the optimal alternative	
$S_{1/4\,via\,2/3}$	= Capitalized value in period 1 for ingoing stock at level 4, but an alternative management program based on level 3 in period 2	
a, b, 1, 2, 3, F	= Yield during each period assigned to common moment of time.	

R thus indicates how much the yield from those varied activities entering into the broken-line alternative need to increase so as to make the alternative competitive. This difference is defined as reduced cost and will be taken up in section 4 we limit ourselves here to its effect on shadow prices.

Hence $S_{1/4}$ may have two or more capitalized values depending on the forestry program chosen. Shadow prices, however, are based on capitalized value under the optimal program, which equals the marginal value in observance of the definition and also enters into the plan. The shadow price for resource 1.045.4 may also be expressed as:

$$S_{1/4\,max} = a + b + 3 + F + R \qquad (6:4)$$

i.e. $S_{1/4\,via\,2/3}$ plus reduced cost for the non-optimal program by way of stock level 3 in period 2. Since no cutting takes place in activity 1.05.43, $a = 0$. The activity also enters into the primal at zero level and therefore lacks reduced cost, which is offset by a corresponding increase of reduced cost in activity 2.06.34. These two activities are bound up with one another—or perhaps in some other combination—since they cannot appear separately. Inasmuch as reduced cost for activity 2.06.34 also compensates for non-optimality in activity 1.05.43, the shadow price for resource 2.055.3 will be the same—assigned to the same moment of time—as for resource 1.045.4. However, this shadow price—for 2.055.3—is evidently not a marginal value in the economic sense. When $a = 0$, (6: 4) can be written as

$$S_{1/4\,max} = b + 3 + F + R \qquad (6: 5)$$

which is the capitalized value of $S_{2/3}$

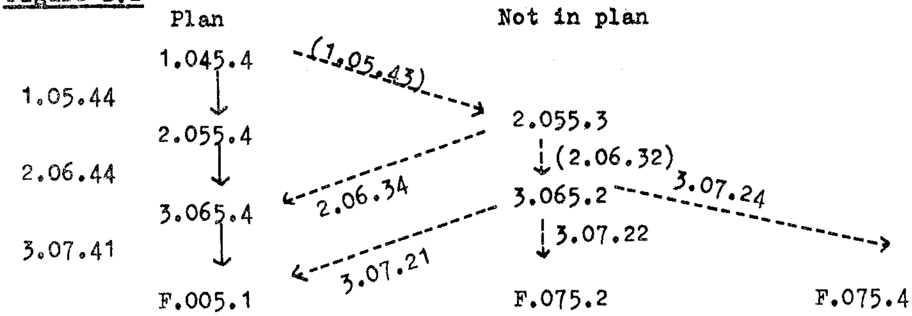
Another type of variations in shadow prices appears for such resources which are commonly used by one activity, e.g. arable land and building space. In that case the sum of shadow prices for resources used by the activity is stable, whereas its distribution by activities may vary. Here again degeneration is evidently responsible.

Each combination of figures between the arrows stands for a specific resource. For example, 1.045.4 identifies a 45-year-old forest at stock level 4 at the beginning of period 1. The combinations alongside the arrows stand for activities, e.g. 1.05.44 for age class 5 at the beginning of period 1 and stock level 4 at beginning and end of the period.

4. Reduced costs

The derivation described for forestry is geared to the corresponding example used in the analysis of shadow prices.

Figure B.2



Activities which are entered at zero level in the primal, and accordingly lack reduced costs, are put in parentheses. The reduced cost for activity 2.06.34 is obtained as the difference between net yields for activities 1.05.44 and 2.06.44 on the one hand, and the "detour" over activities 1.05.43 and 2.06.34 on the other, meaning that the whole difference is charged to activity 2.06.34, as was described in connection with the exposition on shadow prices.

Similarly, the reduced cost for activity 3.07.21 is obtained as the difference between the forestry program contained in the plan and the "detour" along the broken arrows, which in this case cover three subperiods. As shown by the figure, reduced costs are lacking for the first two stages of the "detour" and the whole difference is charged to activity 3.07.21. Reduced costs are similarly derived for other forest activities as well, i.e. as a difference between different programs extending over several periods, inasmuch as a change cannot relate to only one subperiod but has repercussions on one or more others. In the cases which have been investigated, it has proved impossible to isolate such a change even where the last subperiod is concerned.

In certain cases, however, the total difference between two forestry programs may be distributed between at least two links in the chain, the reason being that one of the links has been amenable to determination by another alternative program.

Appendix 2

Labels for activities and restrictions

	Label
1. GENERAL	
11. Period	S, 1, 2, 3, F
12. Agriculture	J
13. Capital	K
14. Labor	A
15. Forestry	No label
2. RESOURCES AND RESTRICTIONS	
21. Arable land	A
211. Existing	UG
212. Purchased during the period	TP
22. Building	B
221. Existing	UG
222. Reconstructed for milk	OM (OM2 and 3)*
223. Constructed for milk	NM (NM2 and 3)*
224. Reconstructed for meat	OK (OK2 and 3)*
23. Capital	
231. Disposable	EGT
232. Loan	LN
Bank loans not secured by the State	B
Bank loans secured by the State	G
24. Labor	
241. Own	E
Haymaking	SR
Harvesting	SD
Total per year	TT
242. Hired	L
Haymaking	SR
Harvesting	SD
Clearing	HR
Planting	PG
Release	PJ
Cutting	HG
Haulage	KG
Indirect logging work	IN
25. Forestry	
251. Age at beginning of period	005, 015 . . . 095 110 . . . 150, KAL, 000

	252. Ingoing level	A, B, 1, 2, 3, 4
	253. Clear cutting	KALG
	254. Standing of stock at end of each period	FORR
26.	Current income	LINK

3. ACTIVITIES

31.	Agriculture	
	311. Grain	SPM
	312. Milk production in	M
	original buildings	UG
	reconstructed buildings	OB
	new buildings	NB
	313. Meat production in	K
	original buildings	UG
	reconstructed buildings	OB
	314. Construction work for	B
	.1. milk	
	reconstruction	OMJ (OBM2 and 3)*
	new construction	NMJ (NBM2 and 3)*
	.2. meat	
	reconstruction	OKO (OBK2 and 3)*
32.	Capital	
	321. Loan	L
	Bank loans not sesured by the State	BK
	Bank loans secured by the state	GI
	322. Transfers to	T
	.1. current income from disposable income	LI
	.2. the following period from	
	disposable at beginning of period	PB
	surplus at end of period	PS
33.	Labor (hired)	
	Haymaking	LSL
	Harvesting	LSK
	Clearing	LHY
	Planting	LPL
	Release	LPR
	Cutting	LHU
	Haulage	LKO
	Joint logging work	LIA
34.	Forestry	
	341. Age class at beginning of period	01, 02 . . . 10 16, 17, 18, KL
	342. Ingoing and outgoing levels	A, B, 1, 2, 3, 4, F

* In period F the construction period has to be known in order to assess the value of the buildings.