ACTA FORESTALIA FENNICA

234

JOUKO HÄMÄLÄINEN & MARKKU KUULA

AN INTEGRATED PLANNING MODEL FOR A FARM WITH AN ADJOINING WOODLOT

METSÄÄ OMISTAVAN MAATILAN KOMBINOITU SUUNNITTELUMALLI

THE SOCIETY OF FORESTRY IN FINLAND
THE FINNISH FOREST RESEARCH INSTITUTE

ACTA FORESTALIA FENNICA

Acta Forestalia Fennica was established in 1913 by the Society of Forestry in Finland. It was published by the Society alone until 1989, when it was merged with Communicationes Instituti Forestalis Fenniae, started in 1919 by the Finnish Forest Research Institute. In the merger, the Society and Forest Research Institute became co-publishers of Acta Forestalia Fennica.

Prior to the merger, 204 volumes had appeared in Acta Forestalia Fennica, and 145 volumes in Communicationes.

PUBLISHERS – JULKAISIJAT

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Subscriptions and orders for back issues should be addressed to Academic Bookstore, P.O.Box 128, SF-00101 Helsinki, Finland. Subscription price is FIM 70 per issue. Exchange inquiries should be addressed to the Society of Forestry in Finland.

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AN INTEGRATED PLANNING MODEL FOR A FARM WITH AN ADJOINING WOODLOT

Metsää omistavan maatilan kombinoitu suunnittelumalli

Jouko Hämäläinen & Markku Kuula

Approved on 28.12.1992

The Society of Forestry in Finland – The Finnish Forest Research Institute
Helsinki 1992

Hämäläinen, J. & Kuula, M. 1992. An integrated planning model for a farm with an adjoining woodlot. Tiivistelmä: Metsää omistavan maatilan kombinoitu suunnittelumalli. Acta Forestalia Fennica 234. 34 p.

The study deals with medium-term economic planning for a multi-branched farm enterprise on which agriculture and forestry plus associated livelihoods are practiced. A personal enterprise consisting of the earning economy sphere of an individual person or family is found to provide a suitable point of departure and framework for farm enterprise planning. In this case, the consumer economy cash withdrawals of the entrepreneur and members of his family are linked to the planning model. In a combined planning model of this type serving the management of the agricultural entrepreneur's entire economy, the problems of both the real process (chiefly pertaining to agriculture and forestry) and the financial process are solved simultaneously and optimally with regard to the goal function, taking into consideration the model's production factor, financing, taxation and other such constraints. The model also takes into account the possibility of investing money in financial targets (e.g. government bonds and stocks).

The study consists of constructing a multi-periodic, combined planning model in the form required by linear optimization and the technique for solving it. The model is applied to the economic planning of a farm and its adjoining woodlot located in south-western Finland. In order to simplify the presentation of the matter, the case calculation is made to apply to a planning period only two years; the time span in the formulae used in the model is actually ten years. For the same reason, the number of treatment alternatives for the stands in the woodlot may appear to be unrealistically small.

Within the planning period the model does not require the use of the calculation rate of interest typical of partial models; instead, it itself provides the solution to where to invest and what the financing costs will be. In connection with this point, an essential feature of the model is that the plan for the entire farm is not compiled by adapting to one another the plans made separately for farming, forestry, etc., and financing; instead, the entire real process and financial process plan are obtained as the solution for the model.

Key words: integrated planning, farms, woodlots.
FDC 641+264

Tutkimuksessa käsitellään monitoimisen, maa- ja metsätaloutta sekä niiden liitännäis- ja sivuelinkeinoja harjoittavan yksityisen maatilan keskipitkän aikavälin taloudellista suunnittelua. Yksittäisen henkilön tai perheen ansaintataloudellisen piirin käsittävä henkilönyritys todetaan hyväksi lähtökohdaksi ja kehykseksi maatilayrityksen suunnittelulle. Tällöin myös maatilatalouden harjoittajan ja hänen perheensä kulutustalouden rahaotot kytketään suunnittelumalliin. Tällaisessa maatilayrittäjän koko talouden johtamista palvelevassa kombinoidussa suunnittelumallissa sekä reaaliprosessin (lähinnä maa- ja metsätalous) että rahaprosessin ongelmat ratkeavat saman aikaisesti tavoitefunktion kannalta optimaalisesti mallin tuotannontekijä-, rahoitus-, verotus-, yms. rajoitteet huomioon ottaen. Malli ottaa huomioon myös rahan sijoitusmahdollisuudet finanssikohteisiin, esim. valtion obligaatioihin tai osakkeisiin.

Tutkimuksessa rakennetaan moniperiodinen kombinoitu suunnittelumalli lineaarisen optimoinnin ja sen ratkaisutekniikan edellyttämään muotoon. Mallia sovelletaan metsää omistavan, Lounais-Suomessa sijaitsevan maatilan talouden suunnitteluun. Esimerkkilaskelma tehdään asian esittelyn lyhentämiseksi vain kahden vuoden suunnitteluperiodille, vaikka aikajänne mallin kaavoissa onkin kymmenen vuotta. Samasta syystä metsälön metsiköiden käsittelyvaihtoehtojen lukumäärä on ehkä epätodellisen pieni.

Mallissa ei suunnitteluperiodin aikana tarvita partiaalimalleille ominaista laskentakorkokantaa, vaan siitä itsestään ratkeaa, mihin raha sijoitetaan ja mitkä ovat rahoituksen kustannukset. Tähän liittyen on myös olennaista, ettei koko maatilan suunnitelmaa koosteta yhteensovittamalla maatalouden, metsätalouden yms. toimialojen sekä rahoituksen erikseen tehdyt suunnitelmat, vaan koko reaali- ja rahaprosessin suunnitelma saadaan mallin ratkaisuna.

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ISBN 951-40-1273-9
ISSN 0001-5636

Tampere 1992. Tammer-Paino Oy

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1 A farm enterprise as the object of planning

1.1 Special features of agriculture and forestry

Agriculture and forestry are based on biological factors. The climate and the soil are of decisive importance. This applies especially to crop farming and timber production, but less so to animal husbandry. Despite the biological constraints, there is still quite a range of alternatives as to the lines of production and their combinations in agriculture in Finland, especially in the southern parts of the country.

In agriculture, too, the time required to produce a commodity is long in comparison to most industrial processes, but forestry is truly time consuming and for the crop there is no indisputable age of maturity based on biological factors. If the final death of a stand resulting from age is taken to be this age, then maturity is no longer rationally defined as far as economics is concerned. This means that the moment of harvesting a timber crop, and to an extent the volume of the crop within fairly long time intervals, is flexibly dependent on the decisions made by the entrepreneur. Adapting felling decisions to business cycles, for instance, is easier than is generally the case with regulation of production in other lines of activity. Thus, the line separating timber to be removed in thinnings and that to be allowed to keep on growing can vary (at least in Finland within the framework provided by regulations); the same applies to the time of the final cut.

Both agriculture and forestry generally possess features typical of joint production and combined production. Joint production means that the entrepreneur is simultaneously carrying on more than one line of production; in agriculture, for example, this might consist of cereal crop production, sugar beet production, animal husbandry, etc., and in forestry it may involve timber production, other forest uses, etc. Combined production, on the other hand, refers to a situation where a certain product cannot be produced unless a certain other or more than one other products are obtained. Examples of the latter are dairy farming, which in the end produces meat, and raising of beef cattle, which also produces hides. In the case of saw timber, the entrepreneur is able to gather seed before felling them and after felling he obtains a range of different timber assortments.

In forestry, one is confronted by an almost innumerable range of options differing from one another in their particulars. Agriculture, however, and at least in the southern parts of Finland, embodies a greater range of real, significantly different production line alternatives. In principle, agriculture and forestry can compete with one another on certain types of soil. Wooded areas can be cleared for agricultural needs and agricultural lands can be afforested. Especially the traction and loading equipment on farms lends itself to be used for both agricultural and forestry purposes. Similarly, the members of the farming family are generally able and willing to participate in work both in agriculture and forestry. Combined planning would appear to provide a means of improving the economic efficacy of the utilization of this labour force. Financing, too, on the farm is in principle a common and scarce factor for both agriculture and forestry and their supplementary income and associated means of livelihood. On the other hand, there are numerous government supported financing arrangements in both agriculture and forestry and these are granted only for either agricultural or forestry targets. When compared to many other small and medium-size enterprises, agricultural enterprises in Finland enjoy a special status in that the government, at least for the main part, ensures a certain price level and market for agricultural products. In forestry, this is not the case, but the price level of the roundwood markets has, nevertheless, provided circumstances sufficient to attract entrepreneurs to the sector.

1.2 The farm — a personal enterprise

The farm as an enterprise in Finland comprises two central business units; the agricultural side (fields, livestock etc.) and the forest holding on the part of forestry. The agriculture and forestry practiced on the farms are more or less interconnected. As a rule, the Finnish farm is owned by an individual person or a family. This is why it is

best to carry out the entrepreneurial examination of the practicing of agriculture and private forestry in Finland within the framework of a so-called personal enterprise. When this is done, the term enterprise can be taken to refer to the entire earnings economy sphere of activity of an individual person, family or other such uniform group of people (see Schneider 1970 and Hämäläinen 1973).

In addition to the property that produces income, a personal enterprise consists of the use of the labour input of the person or family owning it; this labour input is used either within the enterprise or in the service of an external employer. A personal enterprise, therefore, comprises all the measures carried out by the individual or the family working together for the purpose of achieving earnings. The owner's consumption decisions decide how much capital is left over to be used within the enterprise. In other words, these decisions have to be made in awareness of the effect that the consumption expenses have on the personal enterprise's capacity to function and they are included in the personal enterprise's planning model. From the point of view of the owners, one of the most essential differences between a personal enterprise and a company-type enterprise, especially one with several owners (usually a limited liability company), is that the person or family is able to more flexibly regulate the sums of money or commodities withdrawn from the personal enterprise for consumption purposes than is the case if the person or family were to be one of the many shareholders in a company. Thus, the farmer or his family is in a position to withdraw money for consumption from the common cash, cut large volumes of timber when necessary, buy new fields, take out loans, buy or sell shares, etc. In any case, an individual shareholder with a few shares in a firm, on the other hand, has no practical means of influencing the firm's investment, financing and profit distribution policy to benefit him personally; i.e. he has no influence on the sums of money that the firm is willing to permanently hand over to its owners to be used for consumption purposes or investments mainly outside the firm.

2 Enterprise planning models

The purpose of the enterprise planning models is to describe, explain or predict the functioning of entire enterprises. The models provide a means of examining the inter-relations between an enterprise's financing, marketing and production functions by means of mathematical and logical correlations (cf. Naylor 1979). Nowadays, enterprises have access to models that have names such as enterprise planning models, factory models, budget models and medium-term economic planning models. Behind this variety of models there are generally model systems that can be considered to be at least close to the content of the above defined enterprise model concept (Kivijärvi 1985).

2.1 Distinctive characteristics of the enterprise planning models

The distinguishing features of the enterprise planning models may be depicted by the following factors:

1. The relationship to time
2. The structure of the model
3. The initial data used

Enterprise planning models usually describe the development of the enterprise as a function of time. The aim is to use them for clarifying the influence of various measures during several consecutive periods. The models may, for instance, be used to examine the effect of various depreciation programs on taxation and thereby on the profitability of the enterprise.

Usually, the enterprise planning models are simultaneous models in which all equations and inequations need to be solved simultaneously. In other words, the equations cannot be solved one at a time in a certain order. Special techniques have been developed for the purpose of solving such groups of equations (e.g. Simplex-algorithm for linear optimization). Another structural feature is that enterprise planning models often contain both definition and behaviour equations.

The initial data in enterprise planning models consists of either quantitative or qualitative material. Most of the quantitative material used in enterprise planning models originates from the enterprise's data systems. Foremost internal sources of information used by enterprise planning models, especially in the case of small enterprises such as farms, are the enterprise's book-keeping records[1] and the information included on tax forms. In addition to internal information, enterprise planning models make quite a lot of use information provided by various research organizations, textbook information based on statistics and practical experience, etc.

2.2 The classification of enterprise planning models

According to Rosencrantz (1979), there are three basic types of enterprise planning models or they can be used for three different purposes. Firstly, there are models that are used as a means of obtaining answers to the question "What has happened earlier?". The second group consists of models that are used to obtain answers to the question "What if...?". The third group consists of models that are used to obtain answers to the question "What should be done so that..?"

The models in the first group are not used to examine the influence of the actual decision factors on the functioning of the enterprise; instead, they are used to describe the enterprise as a system. In doing so, the intention is to learn from the past and to understand the events that have occurred in the enterprise and its environment. In other words, the idea is to define the enterprise's weak and strong points, and to examine the enterprise's ability to respond to the challenges imposed by the environment.

The "What if...? " models are used to examine how the enterprise behaves or what will happen from the point of view of the enterprise if a certain measure is executed in it or what will happen if changes take place in the enterprise's environment (i.e. in the environmental or non-controlled variables).

Models of this type could, for instance, be used to examine how a rise in the price of a certain raw material or some other production factor might affect the enterprise's finances or profitability. These models can also be used to examine the uncertainty connected to the demand for products.

The "What should be done so that" models are used as a means of achieving a goal defined by a decision maker. Linear optimization models are typical examples of this type. These models can be used to maximize or minimize, within certain constraints, an enterprise's annual after-tax returns, for instance, or to minimize the taxes to be paid by the enterprise.

3 Overall planning of a combined agricultural and forestry enterprise

3.1 Decision making and its premises

The old truth is that the practicing of both production and consumption requires choosing between alternatives; i.e. one is faced by an economic selection problem. In an enterprise, this consists largely of having to provide an answer to the question "What should be done so that such-and-such could be achieved?" as mentioned in Section 2.2. In order to solve this problem successfully, the economic subject is forced to make decisions involving the future. The formulation of decision making is affected, amongst other things, by the type of decision maker involved, what the operational motives, objectives and goals of the decision maker are, and by the extent to which and by what means that decision maker obtains and processes the information used as the basis of decision making.

The great majority of economic decisions made in practical life would appear, at least ostensibly, to take place without any previous preparation; i.e. by "rule of thumb". This may go so far that no individual decision concerning the matter can be distinguished; either the decision maker does not consider such preparation worth his while or the problem is a routine one recurring frequently in much the same form.

[1] Even though, according to the Finnish Act relating to the keeping of books of account, the farming enterprise is not accountable, nevertheless according to the Act concerning farm taxation, it must keep a record of all purchases and sales on cash basis.

So-called genuine decisions often require detailed preparations as their basis. Such preparations and the actual making of the decision, its implementation and adapting to the generally continuous changes in the environment and the enterprise's resources constitute the decision making process. Prior to the selection of the alternative, a number of initial data concerning the alternatives are combined and transformed into new information better serving the decision to be made. A characteristic of the decision making process is that the picture created of the alternatives becomes more precise as the "main lines" begin to take shape. It is often appropriate to return to earlier phases, perhaps because a new piece of information has been obtained.

Thus, the economic decision making process that leads to genuine decisions can be viewed as a dynamic series of events, with the next decision linked to the result of the one preceding it. There is good reason for likening the decision making process to even such a wide concept as the managing of a unit of operation such as an enterprise (Simon 1977). The decision making stages preceding the implementation, steering and monitoring of the selected alternatives can also be accommodated within the broadly defined concept of planning. There is, however, a whole range of versions in the literature as to the factual contents of planning.

3.2 The basic idea behind the combined planning model

A characteristic of situations appropriate for planning models in place of simple process control models and decision models is that so-called environmental changes take place with time (e.g. Starr 1971). New environmental states appear and old ones disappear constantly among the states affecting an enterprise (e.g. because of the agricultural policy, forestry policy, price policy, etc.). The labour resource represented by the farming family is also subject to changes, etc. Thus, the enterprise must develop new operational alternatives among its existing ones, or in place of them, and then select the most advantageous ones according to the situation on hand.

The decision maker's and the planner's knowledge concerning the coming operational alternatives and the states of the environment in the future declines of a necessity as a function of time. However, if the developing environmental conditions of the planning models are to be forecast with at least "some degree" of probability, predictions do supply material for alternative plans. Of course planning means not only adaptation to new, more or less probable and given environmental conditions; it is also an active effort to form the future of the decision unit. The ultimate purpose of planning, therefore, is to find means by which the decision maker can achieve his goal in spite of unstable environmental conditions, that at least in part are unknown in advance. In their extreme forms, planning models may, either formally or perhaps even owing to the nature of the object of planning, be more or less deterministic or, on the contrary, stochastic. Enterprises have based their plans mostly on the assumption that the system to be planned is deterministic, regardless of whether this is the case or not.

The idea is to form an optimum combination of separate partial action alternatives of a personal enterprise with respect to the enterprise's goals (Schneider 1970). The principle in optimization planning of this type is, therefore, to combine a limited number of production, investment, financing and other alternatives until the optimum is achieved for the most central goal and the partial goals (e.g. financing and labour force constraints) are fulfilled. Mathematical programming techniques (e.g. multi-periodic, annually segmented linear programming as in this study) may be used as tools in arriving at the optimum. The model gives, for example, an optimum program for a 10-year planning period within these constraints. It gives for every year of the planning period simultaneous solutions for such things as the use of the various financial sources, real investments to be made (e.g. reforestation), production programmes (e.g. various ways of thinning or cereal crop areas), and the investing of annual cash balances in a way that will ensure liquidity. And all this in such a way that the optimum value of the goal is achieved.

Thus, the combined model enables the user to take into account the interdependence between the various alternatives for the acquisition and use of money and the different ways of combining them with the enterprise's already existing resources of a permanent nature. It is possible to distinguish the interdependencies and possible ways of combining the altervatives separately for each year of the planning period and secondly between the planning period's individual years.

It is precisely the latter temporal dependence that brings dynamics into the relatively long-term planning. This kind of model provides the solution, at least in principle, to the problem of deciding, for example, when during a 10-year planning period certain, as such profitable investments in forestry should be implemented, taking into account various aspects (dependencies).

3.3 Central concepts of the combined planning model

An important concept connected to enterprise planning is the enterprise's activity period. In the case of personal enterprises, this refers to the future time span over which the enterprise's owner individual expects to be probably making economic decisions affecting his sphere of property. When a 40-year old person makes his plans, he may extend at least some kind of outlines perhaps to the age of 65 when, for natural reasons, he intends finally to end or at least radically diminish his money-earning activities. It is necessary to point out that the activity alternatives implemented in personal enterprises are often different at different ages of the person in question. In the case of farms, this may make itself evident, for example, in timber sales being abundant during the early stages of the person's activity period (see Järveläinen 1981). Money may be spent on the acquisition of durable consumer commodities, on building, on paying off sibling shares following the distribution of an estate and often on intensifying of agriculture.

The planning period of a personal enterprise refers to a period for which a plan is formulated in a particular planning situation. It covers the time which can be spanned by "adequately" detailed plans for the enterprise. Thus, an important factor limiting the length of the planning period is the uncertainty which increases as the period is extended. The terminal point of the planning period of a personal enterprise is the planning horizon. This coincides with the future date beyond which the entrepreneur or the planner no longer finds it meaningful to plan in the relatively great detail required by the combined model, since information is increasingly incomplete or for other reasons, too.

The connection between the available activity alternatives and the goal being optimized, as well as the available production factors and the financing alternatives, are described mathematically by the model's goal function, constraint equations and inequations.

A personal entrepreneur may have at least the following financial objectives at his disposal (see Schneider 1970):

1. The value of the assets at the end of the planning period is maximized. Certain sums of "money received" (cash withdrawals), often in varying amounts, are taken annually from the enterprise for consumption.
2. The desired value of the assets at the end of the planning period is pre-determined, and so is the relative distribution of cash withdrawals in the different years. The annual cash withdrawals from the enterprise are maximized.
3. Several goals are maximized simultaneously (Steuer 1986). This might, for instance, mean that the entrepreneur aims to achieve both rising cash withdrawals as well as augmenting of his assets during the planning period.

The objectives have been derived from Fisher's (1930) theories on capital and income presented already early in the 20th century. To him, the terms "money received" and "money income" correspond to the cash withdrawals or money takings spent on consumption and payment of taxes.

The above objectives of a personal enterprise may, with good reason, be the objectives of an individual agricultural and forestry entrepreneur, too. It is necessary to emphasize that such a combined planning model as this, is, in principle, independent of how the economic activity has been organized and what kinds of subsidiary goals (which act as constraints) the entrepreneur may set for his activities. He may, for instance, use the model's constraints to take into account the possibility of obtaining a maximum loan, the steering of the woodlot's age class distribution, a minimum timber volume for the woodlot, the maximum annual self-executed timber extraction volume, his desire to raise a particular crop of plants on a part of his fields, etc.

Whether the entrepreneur strives to achieve the maximal value of his assets or a certain amount of assets at the end of the planning period, those assets must, in terms of both physical volume and composition, be such that they will enable entrepreneurial activity to be continued beyond the planning horizon. In other words, the entrepreneur must already in the planning situation try more or less to outline, what he or his successor will with considerable probability do after the planning horizon. The influence of this

on the forestry side becomes evident, for instance, in the significance that, perhaps, is given to endeavours to achieve an even age class distribution during the planning period.

The formulation of an operational goal requires definition of the economic content of one or more goal variables or that of limited (subsidiary) goals expressed as constraints in the form of so-called definition equations. Definition equations express the goal variables as functions of the decision variables affecting them; i.e. as functions of the different factors of the various activity alternatives. The goal formulation of the planning model (i.e. the converting of the activity motives into economic goal variables and the verifying of their dependence on the partial factors of the activity alternatives) is, therefore, a central economic problem. At this stage, if not before, one is forced to bring the goals of the enterprise's various lines of activities into operational harmony.

Special questions can be raised concerning the true goals in the decision making of each economic unit. Even when working for economic gain, people do not always "feel like" acting as the pure profit-maximizing *homo economicus* of the classical economic theory.

Unwillingness to accept the premise of maximization is the basis for the satisfaction theory derived by Simon (1957) from the psychological concept of satisfying the level of aspiration. According to this theory, the decision maker , in his bounded rationality, usually does not attempt to make an optimal choice but instead tries to find an alternative that meets his aspiration level. One may be inclined to agree with Starbuck (1963). According to him, from the angle of economic theory, "the conditions under which satisfying is more rational depend upon the specific assumptions which are made about the problem solver and his environment. However, two requirements seem clear: (1) the environment must be complex, and (2) the problem solver's perceptions must understate the complexity of the environment". "These conditions are necessary if satisficing is to appear more rational to an omniscient observer. Satisficing will be more rational from the viewpoint of the problem solver only if he recognizes the existence of these conditions". This must not be confused with another premise that has been used in opposing maximizing as the financial goal of enterprises. The proponents of this premise claim that maximizing is impossible, because we do not know all the activity alternatives. Nevertheless, optimization methods do enable one to determine the best from the known alternatives.

This being so, one is justified in claiming that the operational usefulness of the goal function for an individual personal enterprise that is largely based on the practising of agriculture and forestry, for instance, depends on the following factors.

1. The decision maker's or the group of decision makers' factual willingness to reach the goal (psychic factor).
2. The alternatives available for the achievement of the goal function and the attitudes of the decision maker's environment inside and outside of the enterprise on the goal function and the steps its realization requires.
3. The possibilities for predicting future developments of decision variables controlled by the entrepreneur and the environmental (non-controlled) variables, both of which influence the goal function.

In the above described multi-periodic planning model, it is appropriate to define the enterprise's incomes and expenditures, at least in the main, as cash flows based on transactions between the enterprise and the world outside. Since the purpose is to factually adhere to liquidity constraints, to the owner's cash withdrawals, and other such factors, it is necessary to estimate the transactions of the individual years of the planning period in terms of each year's probable money units, i.e. in nominal values. The same applies to the values of the final assets, loans and other liabilities at the planning horizon. This means, for example, that the real value of bank deposits and loans will usually fall year after year. After all, they are not subject to inflation- induced nominal price increases, whereas the rise (or fall) of the nominal values of real estates, shares and other such assets year after year in the model may correspond to developments in reality. It is not possible here to give a detailed account of the valuation premises of the final property at the end of the planning period. Nevertheless, it can be pointed out that there are sound reasons for using market values when evaluating various types of assets. On the part of the woodlot, the values corresponding to the planning period's activity alternatives of the forest stands are obtained, as discounted values (see the application example, Section 5.2).

4 The main features of the linear planning model

4.1 An overview of the model

In this connection, a multiperiod linear optimization model is used as a medium-term combined planning model. It is assumed that the theory of linear optimization is generally known. It should, however, be pointed out that the theory of linear optimization has been dealt with in the following works: Dantzig 1974, Gass 1985, Hadley 1962, Spivey & Thrall 1970, for example. The model developed in this study breaks down timewise into ten parts, each dealing with one year, and these are further divided into six components, according to the activities, as mentioned at the top of Fig. 1. The annual parts are linked to one another by means of variables that affect the enterprise's economy during two or more years. The model also contains certain constraints concerning the parts of property and these constraints are influenced by all the variables formed for a particular part of property, regardless, for instance, of the year during which they cause cash transactions during a 10-year planning period.

The goal of the personal entrepreneur in the linear model dealt with here is to maximize the value of his assets at the end of the planning period. The expenditures, incomes and financing events are taken into account as cash flows. The annual cash withdrawals (money received) for the entrepreneur's consumption are taken into account by constraints (Appendix 2).

The variables X_{ij} and TAX_{vj} are defined for the model. The variables X_{ij} are activity alternatives possibly implemented in the year j (j=1...10) and connected to agriculture, forestry, subsidiary and associated means of livelihoods, investments, loans, and/or financial investments. During the optimization process, the model selects alternatives for implementation. TAX_{vj} are technical variables that the model uses for calculating the post-taxation yearly income. Greatly simplified, the model may be presented in the form of the following optimization problem in which equation (1) is the goal function and equations (2)–(8) are the constraints.

$$(1)\quad \text{Maximize OBJ} = \sum_{i=1}^{M}\sum_{j=1}^{10} a_{ij}X_{ij}$$

on the conditions

$$(2)\quad \sum_{j'=1}^{j}\sum_{i=1}^{M} b_{ij'j}X_{ij'} - \sum_{v=1}^{12} TAX_{vj} = 0 \quad \text{for all } j$$

$$(3)\quad \sum_{j'=1}^{j}\sum_{i=1}^{M} c_{ij'j}X_{ij'} + \sum_{v=1}^{12} perc_{vj}TAX_{vj} \ge PRV_j \quad \text{for all } j$$

$$(4)\quad \sum_{j=1}^{10} X_{ij} = 1 \quad \text{for all } i \in K$$

$$(5)\quad \sum_{j'=1}^{j}\sum_{i=1}^{M} d_{ij'j}X_{ij'} \le WORK \quad \text{for all } j$$

$$(6)\quad \sum_{j'=1}^{j}\sum_{i=1}^{M} e_{ij'j}X_{ij'} \le TRA \quad \text{for all } j$$

$$(7)\quad \sum_{j'=1}^{j}\sum_{i\in M_p} f_{ij'j}X_{ij'} \le CAP_p \quad \text{for all } j$$

$$(8)\quad TAX_{vj} \le LIMIT_{vj} \quad \text{for all } j$$

$X_{ij}, TAX_{vj} \ge 0$

$j = 1,...,j$
$j' = 1,...,j$
$i = 1,...,M$
$v = 1,...,12$
$p = 1,...,P$

in which

- a_{ij} = the effect on the enterprise's assets at the end of the planning period of activity alternative i to be implemented in year j
- $b_{ij'j}$ = the addition/reduction to the taxable income for year j caused by the implementation in year j' of the activity alternative i
- $c_{ij'j}$ = the addition/reduction to the enterprise's liquidity in year j caused by the implementation in year j' of the activity alternative i
- $d_{ij'j}$ = the effect on the available own labour force in year j caused by the implementation in year j' of the activity alternative i
- $e_{ij'j}$ = the effect on the available tractor capacity in year j caused by the implementation in year j' of the activity alternative i
- $f_{ij'j}$ = the effect on a certain line of activity's separate capacity in year j caused by the implementation in year j' of the activity alternative i
- $perc_{vj}$ = the proportion of income after taxes available to the enterprise in year j in tax category v
- M = the set of all possible activity alternatives
- P = the set of all examined lines of activities
- K = the set of stands
- M_p = the number of activity alternatives belonging to line of activities p
- PRV_j = money withdrawal (money received) from enterprise by entrepreneur for his own use during year j
- WORK = annual available number of man hours
- TRA = annual available number of tractor hours
- CAP_P = annual available amount of line specific capacity for line of activities p
- $LIMIT_{vj}$ = class interval in FIM of tax category v in the year j

The effect of the variables X_{ij} may appear in the form of resource use and/or non-use during several years of the planning period under the constraints (2)–(7). This is why the variable coefficients have two time-related indices. The first of these, j, defines which year's constraints are in question, while index j' (j'≤j) defines the previous year during which the possibly effecting activity i has been implemented.

The constraints (2) are used for calculating the enterprise's annual taxable incomes. The after-tax funds available to the personal entrepreneur are transferred to constraints (3) by means of the variables TAX_{vj}. The constraints (3) regulate the enterprise's liquidity and they are also used for reserving annually certain sums of money for the entrepreneur's money takings for consumption purposes.

The constraints (4) define that a particular stand can be treated no more than once during the planning period. In principle, the resources available to the enterprise are always scarce. Since it is possible to use them alternatively for production purposes in several different lines of activities, it is necessary to have constraints in the model to prevent these resources from being exceeded. Examples of these are the annual constraints (5) and (6) that apply to the number of hours of human labour and tractor use.

The constraints (7) determine the scarcities and preferences due to capacity, the market situation and production technique. The constraints (8) are used for entering the annual state income tax scales into the model (a total of 12 tax categories).

The model thus developed is used to draw up the plan by stages (Fig. 1). Stage 1 consists of collecting the initial data required for the optimization model from bookkeeping records, other written records, by making observations, by interviewing people or from research publications and textbooks. The correctness and adequacy of the data collected is of great significance. Erroneous and inadequate initial data are a hindrance to the construction of the model and lessen the applicability of the results obtained.

Stage 2 of the planning process consists of the pre-calculation routines (contribution calculations by different lines of activities, etc.) that have to be carried out individually for each activity. The collected enterprise-specific data are combined at this stage with the material from the data bank supporting the planning. The material thus obtained is made use of and fused in stage 3 when the linear optimization model is formed. This means that the final collection of constraints is defined and the goal variables to be maximized and/or minimized are chosen. The model is solved at stage 4 and a user-friendly and easy-to-read report is made of the results in stage 5.

The formulation of the plan is, by nature, an iterative process, which may later on cause for one reason or another, a return to one of the preceding stages; e.g. backwards from stage 3, if the initial data obtained turns out to be false.

4.2 The real processes of the various lines of activities

4.2.1 Forestry

The planning model in question is used to treat forestry as a part of the enterprise as a whole. The initial woodlot data required consist of observations made of each stand that can then be used to simulate the woodlot's future development. The simulator used here is based largely on the increment models of Nyyssönen & Mielikäinen (1978). It is used to create a number of different treatment alternatives for each stand. These alternatives are such that there are silvicultural and yield premises for their implementation during the planning period. The results of the simulation are then combined with the price and labour demand data and the results thus obtained are used as the planning model's coefficients.

The results of the optimization process include treatment instructions for each stand in the enterprise's woodlot for the duration of the planning period. The optimization also provides information on the annual income and expenditure

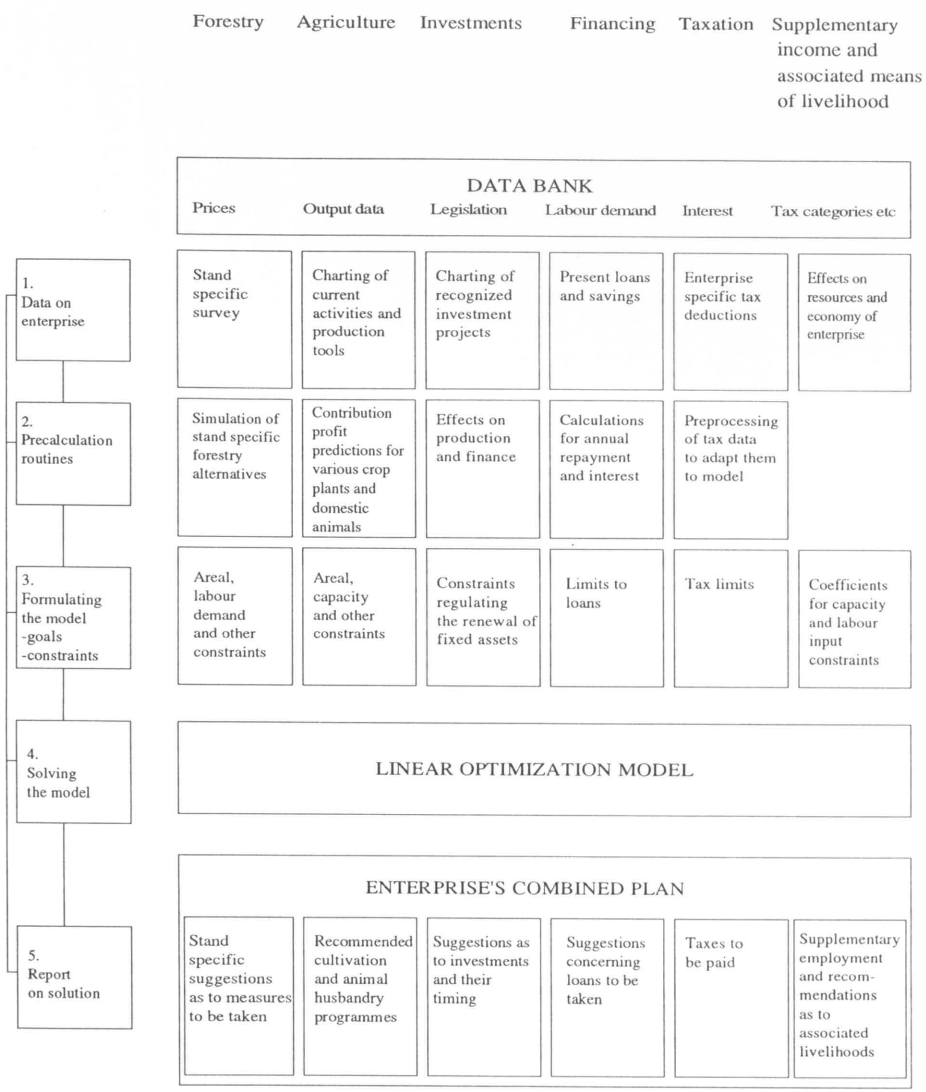

Figure 1. The planning method

brought about by the woodlot during the planning period. Furthermore, the solution of the model reveals the annual labour input requirements.

4.2.2 Agriculture

Agriculture includes two partly interdependent entities, open-field cultivation and animal husbandry. Firstly, the model provides the solution as to whether or not animal husbandry should be practiced on the farm. If so, then to what extent the existing production capacity (the livestock included) is utilized. The model also provides the solution to the fodder that should perhaps be produced on the farm and what should be acquired from outside. The planning problem on the part of open-field cultivation is how to divide the available arable land in the most advantageous way between not only fodder crops, but other crop plants as well. The minimum initial data required for the implementation of this planning model consists of the area of arable land plus any information (mainly biological) on possible plant species constraints, information on the available farm machinery and a description of the currently implemented system of animal husbandry.

Optimization results in the subdivision of the arable land between the most advantageous forms of use. On the part of the livestock, the entrepreneur is provided with recommendations as to the degree of utilization of the capacity (inc. number of heads of livestock) and normative feeding programmes. The solution of the model also reveals the annually required labour inputs in agriculture and the revenue from agriculture.

4.2.3 Supplementary income and associated means of livelihood

The farmer and the members of his family are also in position to earn work and/or entrepreneurial incomes from outside the farm's agricultural and forestry activities. Work income is accrued, for example, when the farmer or his wife do work outside the farm (supplementary income). Entrepreneurial incomes (associated livelihoods) can be obtained from production and services activities outside the spheres of agriculture and forestry (e.g. raising of fur animals, farm tourism services).

The central aspect of the model dealt with here is that it is possible, from the point of view of a farm enterprise, to clarify on the part of each potential line of activities the use of physical and financial resources and the corresponding revenues to be obtained. This being so, it is possible to "customize" the model and enter into it any associated livelihood or supplementary source of income and then examine which of them are, and to what extent, advantageous from the entrepreneur's point of view; i.e. the ones that will be included in the program solved by the model.

4.3 Investments

4.3.1 Real investments

The purpose in establishing a farm enterprise is to provide the owners with earnings — usually for a previously undefined length of time. Its continuous activity requires replacement and new investments from time to time on the part of machinery, equipment, buildings and other relatively long-term factors of production as well as the reforestation or improvement of the forests. The enterprise has to invest capital in projects that will yield returns later — years or even tens of years later. Because of the varying lengths of time for which the funds are tied up, investments are significant events that are characterizing the various activity alternatives in the economic sense. The model solves, which activity alternatives and associated investments are included in the solution and plan of action.

4.3.2 Financial investments

The planning model being dealt with here includes the investing of own or loan capital into two or more financial projects. The revenues obtainable from these projects are generally of different amounts, they may be either tax-free or taxable and so on. The period of time for which the funds are tied up also varies. In principle, the planning model is not tied to any previously defined financial investment projects; instead, the model can, for example, be applied to bank savings, bonds, debentures, shares or entire stock portfolios, etc.

As with loans, the model solution also provides the entrepreneur with programmes for carrying out various financial investments.

4.4 Financing

The investments and the current expenses of the enterprise and the cash withdrawals of the owners can be financed using its current cash flows, loans and, of course, by selling certain assets.

The model dealt with here contains three loan categories. The first category consists of the enterprise's loans in the beginning of the planning period. Generally, these loans are paid back according to a repayment programme, but loans with unadvantageous interest rates or repayment periods can, of course, be paid back over a period shorter than originally agreed. They can be replaced by fresh, more advantageous loans. The model solves the question of whether or not such action is appropriate. The second loan category consists of short-term loans that can be taken within the constraints set by the model for individual years. In the model, short-term loans are handled technically in such a way that the enterprise always pays back such loans within the next year. The third category consists of long-term loans available during the various years of the planning period. Owing to the nature of public and other such finance of agriculture and private forestry, these loans are often connected to the alternative of a certain line of activities. Whether or not these loans are taken, and if they are, how much is taken, is also solved by the model.

5 Illustration

The case calculation below, formulated and presented using the planning model developed in this research, has been made to consist of only two periods in order to make the presentation more concise. Other simplifications have also been carried out for the same reason; e.g. the number of treatment alternatives for the woodlot have been reduced to an unrealistically low level.

The remainder of the farm's assets (e.g. bank deposits and cash funds) are described in Section 5.5.

A two-period economic plan was drawn up for the farm. The required equations are described in the following chapters; the numbering of the equations and the nomenclature used for the variables corresponds to the numbering and nomenclature used in Appendices 1 and 2.

5.1 The planning object

The case farm is located in SW Finland with pig raising as the main line of activity. The farm is about to be transferred to the ownership of a descendant. The farm's maximum pork production capacity is defined by production hall with pens for 210 pigs. The production has been organized in such a way that the farm buys its piglets from a middleman and then raises them to 80 kg pigs for slaughter over a period of 120 days. When a batch of pigs is sent off to be slaughtered, the hall is cleaned and the next batch is taken in. On the average, this cycle is repeated 2.5 times per year.

In addition to pig production, the farm is provided with 20 hectares of arable land and a woodlot of 60 hectares. The production buildings are in fairly good condition. Nevertheless, the new owner is contemplating the building of a new grain dryer. In addition, the dwellinghouse of the farm is in immediate need of basic renovation.

5.2 Forestry

The farm's woodlot consists of three contiguous stands (Tables 1a–c). The variables $STAND^i_{kj}$ were constructed for the model. They refer to the treatments k to be implemented in the stand i during the year j. In addition to the non-action alternative, the alternatives of selling timber either in the form of a delivery contract or standing sales apply to each stand. The possibility of timber sales applies to both years of the planning period. Thinnings are possible in stands 1 and 2. Clear cutting applies to stand 3.

The following stand constraints are formed to apply to each stand.

$$(19)\quad \sum_{j=1}^{2}\sum_{k=1}^{4} STAND^i_{kj} = 1\ ,\quad i = 1,2,3$$

In the above constraints the treatment k refers to: 1) standing sales of timber, 2) delivery sales of timber, in which income from felling and extraction work is tax-free, 3) delivery sales of timber, in which income from felling and extraction work is taxable income and 4) abstaining from harvesting in the forest stand (non-action alternative).

Stand 1 consisted of even-quality Vaccinium type forest land, 25 hectares in area. At the time of the plan being formulated, the stand consisted of an even-aged crop of Scots pine, 40 years of age. The timber volume was 151 m³ per hectare of which sawlog timber represented 18 m³ and pulpwood 127 m³.

Stand 2 consisted of even-quality Oxalis-Myrtillus type forest land, 20 hectares in size and carrying a crop of even-aged Norway spruce, 45 years of age. The timber volume was 191 m³ per hectare of which sawlog timber represented 81 m³ and pulpwood 108 m³.

Stand 3 consisted of even-quality Myrtillus type forest land, 15 hectares in size and carrying a crop of even-aged Scots pine, 70 years of age.

Table 1a. Treatment alternatives in stand 1 (i=1). Removals according to Table M24:10 by Vuokila&Väliaho (1980); i.e. a stand of Scots pine, site index H_{100}=24.

Treatment	Year	Removals m³	Stumpage 1000 FIM	Delivery extra[1] 1000 FIM	Final value of stand 1000 FIM	Work hours
Thinning, 30 % removed standing sale	1	1130	129	–	638	–
	2	1170	141	–	614	–
Thinning, 30 % removed delivery sale	1	1130	129	104	638	1700
	2	1170	141	114	614	1760
No-action alternative		–	–	–	869	–

Table 1b. Treatment alternatives in stand 2 (i=2). Removals according to Table K27:21 by Vuokila&Väliaho (1980); i.e. a stand of Norway spruce, site index H_{100}=27.

Treatment	Year	Removals m³	Stumpage 1000 FIM	Delivery extra[1] 1000 FIM	Final value of stand 1000 FIM	Work hours
Thinning, 30 % removed standing sale	1	1150	109	–	645	–
	2	1200	120	–	621	–
Thinning, 30 % removed delivery sale	1	1150	109	102	645	1500
	2	1200	120	112	621	1560
No-action alternative		–	–	–	853	–

Table 1c. Treatment alternatives in stand 3 (i=3). Removals according to Table M27:18 by Vuokila &Väliaho (1980); i.e. a stand of Scots pine, site index H_{100}=27.

Treatment	Year	Removals m³	Stumpage 1000 FIM	Delivery extra[1] 1000 FIM	Final value of stand 1000 FIM	Work hours
Final cut standing sale	1	4000	726	–	169	–
	2	4140	811	–	163	–
Final cut delivery sale	1	4000	726	184	169	4280
	2	4140	811	206	163	4560
No-action alternative		–	–	–	1180	–

[1]) Difference between the delivery sales income and stumpage sales income

The timber volume was 259 m^3 per hectare of which sawlog timber represented 236 m^3 and pulpwood 22 m^3.

The removals in Tables 1a–c correspond to the removals of the Vuokila&Väliaho (1980) growth and yield models' alternatives mentioned in the tables. The value in money of the removals (both stumpage and delivery extra) have been obtained by multiplying the timber assortment specific removals by the corresponding prices. During the logging season 1.4.1987–31.3.1988, the basic components of the stumpage prices applied in the pricing region to which the case farm belonged, were as follows: pine logs FIM 190, spruce logs FIM 149, pine pulpwood FIM 84 and spruce pulpwood FIM 96 per cubic meter. The corresponding delivery sales prices were FIM 234, 197, 160 and 181. These prices are adjusted as necessary by applying the Recommended Price Agreement factors (e.g. stand density, diameter of stems, etc.). The number of hours of work required per unit of timber harvested is estimated on the assumption that the owner family carries out the harvesting of the entire stand in the one go.

The value of each stand at the end of the planning period (in this case only two years) for the goal function has been determined as the present value of the net incomes estimated to be obtainable from each stand from the end of the planning period to infinity (see, for example Endres 1911). The interest rate used in the calculations was 4 %. This approximately corresponds to the average internal rate of return obtainable when practising forestry in the southernmost parts of the country; i.e. where the case farm is located (research carried out by the Finnish Forest Research Institute's Section of Business Economics of Forestry). In all treatment alternatives, the sales volumes that formed the basis of the discount calculations for the stands were evaluated according to the delivery prices; i.e. it was assumed that, after the planning period, the forest owner would always sell his timber on the delivery basis . The silvicultural costs and overall costs used in arriving at the discount values are in general use at the Finnish Forest Research Institute's Section of Business Economics of Forestry in calculations concerning the profitability of timber growing.

The constraints (20) are formed for tax-free earnings based on logging work in delivery sales equal or smaller than 150 m^3. The removal volumes $cubic^i_{kj}$ are given in Tables 1a–1c.

(20) $cubic^i_{kj}STAND^i_{kj} \le 150$, j=1,2

In addition, the constraints (21) were formed in order to take into account the calculatory "net income" that the currently valid Finnish forest taxation system routinely considers as having been earned from a woodlot, regardless of the actual net income accrued. Owing to inflation, the net income for taxation purposes of year 2 is 5 % higher than that of year 1.

(21) $FINC_1 = 31000$, $FINC_2 = 33000$

The other effects of forestry on the enterprise as a whole are dealt with in the coming sections.

5.3 Agriculture

5.3.1 Crop cultivation

The owner of the farm was of the opinion that four types of cereal crops can be grown on the farm (Table 2). He was not even prepared to consider the growing of others. Since barley is also suitable as fodder for pigs, the barley crop can be either sold or used as an internal performance on the farm specializing in raising pigs. These alternative cereals provide the model with six variables for both years of the planning period; i.e. variables $CERE_{bj}$, where the index b refers to the cereal and index j to time.

The total available area of arable land, 20 hectares, led to the following area constraints (22).

$$(22)\quad \sum_{b=1}^{6} CERE_{bj} \le 20 , \quad j=1,2$$

Owing to the rotational cultivation practised on the farm, the intention was to confine the annual growing of wheat to fifteen hectares; this was achieved by the following constraints (23):

(23) $CERE_{1j} \le 15$, j=1,2

Table 2. Alternative cereal crops.

Crop	Variable	Minimum cultivat. area	Maximum cultivat. area	Sales price FIM/kg in 1988	Yield per hectare, 1000 kg
Wheat	$CERE_{1j}$	–	15 ha	2.45	3.5
Oat	$CERE_{2j}$	–	–	1.66	3
Rye	$CERE_{3j}$	–	–	2.87	2.5
Barley	$CERE_{4j}$	–	–	1.79	3
Barley/	$CERE_{5j}$	–	–	–	3
own use	$CERE_{6j}$	–	–	–	3

Table 3. Contribution calculation for cereals, 1000 FIM/hectare.

	Wheat	Oat	Rye	Barley	Barley/used as pig fodder
Returns	8.6	5.0	7.2	5.4	–
Separate costs:					
Seed	0.7	0.6	0.7	0.6	0.6
Fertilization	0.7	0.7	0.7	0.7	0.7
Contribution I	7.2	3.7	5.8	4.1	–1.3

The per-hectare contribution profit produced by crop cultivation was calculated by using the contribution formula shown in Table 3. The variable costs do not include the costs resulting from seeding, threshing and drying, because these have been estimated as being the same for each cereal crop. They were included as a part of the total costs. Owing to the non-concurrency of the crop periods and the accounting periods, two variables were allocated annually to the barley used internally (own use). The variables $CERE_{5j}$ were reserved for fodder grown during accounting period j–1 and used during accounting period j. The variables $CERE_{6j}$ were reserved for fodder grown and used during accounting period j. When necessary, the same procedure can also be used to take into account the storing of grain on the farm.

The other effects connected to crop cultivation are dealt with in the coming sections.

5.3.2 Pig raising

Even though the farm has facilities to house a maximum of 210 pigs/batch, denoted by q'', normal production is 200 pigs/batch, denoted by q. On the average, the farm produces 2.5 batches of pigs yearly. The owner has decided that there have to be at least 150 pigs on the farm, denoted by q', otherwise pig raising will have to stop altogether. In other words, pig raising on the farm can vary between 150–210 head. Thus, the maximum yearly production reduction within the framework of the present "normally" used production capacity (q–q') is 2.5×50 and the maximum production increase within the present "normally" used production capacity (q''–q) is 2.5×10. The variables RED_j and ADD_j were formed for the purpose of adapting production. Thus, it is possible to enter into the model the pig production constraints (24) and (25), which define the limits to both increasing production and reducing production. It should be noted that a reduction/increase in production carried out during the first year will also influence production volume changes possibly carried out during the second year.

$$(24)\quad \sum_{j'=1}^{j} RED_j - \sum_{j'=1}^{j} ADD_j \le (q - q') , \quad j=1,2$$

$$(25)\quad \sum_{j'=1}^{j} ADD_j - \sum_{j'=1}^{j} RED_j \le (q'' - q) , \quad j=1,2$$

Assuming that 234 fodder units (1 fu = 1 kilo of barley) are required to feed one pig during the fattening period, then the total annual amount of fodder units required by pig raising operating at the normal output level, denoted by requi, can be computed as follows: 2.5×200×234 = 117000. Because of the crop periods, the model has been provided with two feeding constraints per period. If pig production is adapted, then the annual total fodder requirement will change by 2.5×234 or 585 fodder units per pig, that determines the value of the coefficient fod. Before the ripening of the new crop, one pig will consume 60 % (part1) of the yearly fodder requiment and after the ripening of the new crop 40 % (part2). The fodder is obtained by growing it on the farm (variables $CERE_{5j}$ and $CERE_{6j}$) or by buying it (variables BUY'_j and BUY_j). Thus, the feeding constraints (26) and (27) have the following syntax, in which the values for coefficient $crop_{bj}$ are obtained from Table 2.

Beginning of the year

$$(26)\quad BUY'_j - \sum_{j'=1}^{j} (part1 \times fod) ADD_{j'} + \sum_{j'=1}^{j} (part1 \times fod) RED_{j'} + crop_5 CERE_{5(j-1)} = (part1 \times requi) \qquad j=1,2$$

Rest of the year

$$(27)\quad BUY_j - \sum_{j'=1}^{j} (part2 \times fod) ADD_{j'} + \sum_{j'=1}^{j} (part2 \times fod) RED_{j'} + crop_6 CERE_{6j} = (part2 \times requi) \qquad j=1,2$$

Table 4. Annual contribution profit produced by pig raising, 1000 FIM.

Returns	
Pork	652.0
Variable costs	
Concentrate	27.0
Medication + power	0.5
Piglets	197.5
Contribution profit without subtracting fodder costs	427.0

The effect of pig raising on the enterprise's taxable income (variable $LINC_j$) is computed in the constraints (28). The contribution produced by pig raising at the normal output level ($linc_1$) without subtracting the cost of fodder is calculated as shown in the contribution schedule in Table 4. The contribution for the second year ($linc_2$) is obtained from the contribution, in Table 4, by multiplying by 1.05, which is the inflation factor. The coefficients $lcontr_j$ for the variables RED_j and ADD_j are calculated by dividing the total contribution of pig raising by the number of pigs (200). The coefficients $feprice_{bj}$ of the variables BUY_j and BUY'_j are prices per kilo of the fodder bought. For year one the fodder price is 2.3 FIM and for year two 2.4 FIM.

$$(28)\quad -\sum_{j'=1}^{j} 1contr_j RED_{j'} + \sum_{j'=1}^{j} 1contr_j ADD_{j'} - feprice_j BUY'_j - feprice_j BUY_j - LINC_j = linc_j \qquad j=1,2$$

The other effects of pig raising are taken into account in the coming sections.

5.4 Investments

5.4.1 Real investments

In conjunction with the forthcoming handing over of the farm to a descendant, there are also plans for carrying out a basic renovation of the dwellinghouse and the building of a new grain drier. Rough estimates have been made concerning what are referred to as farm loans granted by the state. The new owner (the descendant) will be eligible for them when he takes over the farm. An estimate of the costs of renovating the dwellinghouse has also been made and inquiries regarding the availability of loans for the purpose. On the part of the grain drier, the farmer has settled on one particular make of hot-air drier and he has decided to purchase it. The costs of building the drier, loans available for the purpose, the capacity of the drier and the possibilities for hiring out any unused capacity have been examined. Tables 5, 6 and 7 contain data connected to the above clarifications.

Table 5. Government-granted farm loans focusing on investments.

Farm loans / Target	Repayment period, years	Annual interest	Amount of loan
Farmhouse	18	5	40 % of cost estimate
Paying off siblings' shares when estate distributed	15	6	60 % of sum to siblings on distribution of estate
Sum to be paid to parents when estate distributed	15	6	65 % of selling price (paid in cash)
Grain drier	8	7	60 % of cost estimate

Table 6. Grain drier capacity 1000 kg/year.

Target	Required for farm	Availabe for hiring out to neighbours
Drier	60	30

Table 7. Single expenditures and returns on the investments.

Target	An single expenditure 1000 FIM	Returns 1000 FIM
Dwellinghouse	180	
Drier	95	3.5 /a
Siblings' shares	170	
Parents' shares	400	

Decisions have been made to carry out both of the real investments mentioned. The model was used as a means of deciding the timing of these investments and the kind of finance required in addition to the government-granted farm loans. As the new owner (son) is below 30 years of age, the repayments and interest payments on the loan granted by the government will commence four years after the loan has been granted and withdrawn. This is why these investments are taken into account in the 2-year planning model only to the extent that the investments require financing from sources other than government-granted loans.

The variables INV_{11} and INV_{12} were formed for the costs of renovating the farmhouse, INV_{21} and INV_{22} for the drier, INV_3 for the siblings' shares and INV_4 for the parents' share. The constraints (29) define that real investments (y=1,2) must be carried out either in year 1 or 2, and the payments connected to the handing over of the farm to a descendant must be carried out in year 1.

$$(29)\quad \sum_{j=1}^{2}\sum_{y=1}^{2} INV_{yj} = 1$$

$$INV_3 = 1,\ INV_4 = 1$$

5.4.2 Financial investments

In addition to short-term bank deposits, the owners of the case farm are also in a position to make financial investments, but only in the form of tax-free government bonds. For its bank deposits, the enterprise receives an annual interest of 2.75 % and for bonds 9.75 %. In the case of the government bonds, the loan period is 10 years and the repayments of the invested capital commence on the sixth year from the initial investment. The variables $SAVIN_1$ and $SAVIN_2$ were formed for bank deposits and constraints (10) are used to define the annual minimum savings sums:

$$(10)\qquad SAVIN_1 \geq 15000, \quad SAVIN_2 \geq 17000$$

The variables BON_1 and BON_2 were formed for government bond investments. These investments have no upper limit in the model; all surplus money may be invested in government bonds.

The other effects of the investments on the enterprise are dealt with in the coming chapters.

5.5 Financing

The private enterprise (personal enterprise) is in a position to finance its operations from income earned, loans or by selling certain assets. Financing by income earned is derived from the selling of commodities produced on the farm. In the model being dealt with here, the earned income on the part of taxable income is taken into account by constraints (2) and on the part of tax-free income and loans by constraints (3). In addition, it is assumed that in taxation the income obtainable from the practicing of agriculture is considered to form the taxable income of only one person (either the farmer or his wife).

In constraints (2), all taxable incomes are added together and all deductible items are subtracted from them at the taxation stage. Such farm expenditures as have not been directly allocated to a specific product (e.g. insurance fees, electricity bills, drying of grain, etc.) have been taken into account in the constants on the right-hand side. Included in the right-hand constants are also the reductions accepted in the farmer's personal taxation (inc. medical care costs, interest on personal loans up to a certain limit, reductions based on the number of children, etc.). Constraint (2) is used to define that in the year j the sum of the variables TAX_{vj} can, at the most, be equal to the difference between taxable incomes and deductible expenses. It is assumed, that in year 1 costs not allocated to specific products amount to FIM 90000 (nc_1) and owner's personal tax reductions are FIM 15000 (ded_1); the respective nc_2 and ded_2 figures for year 2 are assumed to be FIM 95000 and FIM 17000. All variables in constraints (2) affecting the amount of earned income (e.g. $CERE_{bj}$, $STAND^i_{kj}$) have already been defined in the preceding chapters. The taxable delivery sales harvesting work incomes due to accrue in year j $tmoney^i_{kj}$ are given in Tables 1a–1c, the contribution profits/hectare computed for year j for plant crop b $ccontr_{bj}$ can be found from Table 3 and incomes from investment 2 $cinco_j$ are given in Table 7.

Since interest paid on loans is a tax-deductible item and since depreciation can reduce the amount of taxes to be paid, it is necessary at this conjunction to define the variables needed for loan and depreciation. The variables $LOAN_{aj}$ are used to designate loans taken on terms a in the year j of the planning period. In this example, there are two types of loans: short-term loans (a=1) and long-term loans (a=2). The annual interests to be paid in year j are for the short-term loans with an interest rate of 12 % ($inter_{1j}$) and for the long-term loans with an interest rate of 9 % ($inter_{2j}$). The variables $DEPREC_j$ are formed for the purpose of determining the depreciation for machinery and equipment while for the depreciation of the production buildings there are the variables $BDEPREC_j$. Fixed costs and fixed incomes are

Table 8. The state tax categories for the year 1987 and the marginal tax percentage for each tax category (Communal income tax+Church tax+State income tax+Social security fee, %).

Taxable income, 1000 FIM	Range of tax category, 1000 FIM	Marginal tax percentage	Corresp. variable	Constant correspond. to size of tax category	Coefficient correspond. to marginal tax percent
0–15.6	15.6	0	TAX_{11}	tax_{11}	$perc_{11}$
15.6–21.8	6.2	27	TAX_{21}	tax_{21}	$perc_{21}$
21.8–27	5.2	34	TAX_{31}	tax_{31}	$perc_{31}$
27.0–32.2	5.2	40	TAX_{41}	tax_{41}	$perc_{41}$
32.2–41.6	9.4	44	TAX_{51}	tax_{51}	$perc_{51}$
41.6–53	11.4	49	TAX_{61}	tax_{61}	$perc_{61}$
53.0–76	23.0	50	TAX_{71}	tax_{71}	$perc_{71}$
76.0–102	26.0	54	TAX_{81}	tax_{81}	$perc_{81}$
102.0–159	57.0	59	TAX_{91}	tax_{91}	$perc_{91}$
159.0–265	106.0	66	TAX_{101}	tax_{101}	$perc_{101}$
265.0–475	210.0	71	TAX_{111}	tax_{111}	$perc_{111}$
475.0–		72	TAX_{121}		$perc_{121}$

taken into account in the constant on the right-hand side. When the thus computed sum of taxable incomes is given as the values for the variables TAX_{vj}, the equations (2) have the following syntax:

$$(2)\ -\sum_{v=1}^{12} TAX_{vj} - DEPREC_j - BDEPREC_j - \sum_{a=1}^{2} inter_{aj} LOAN_{a(j-1)} + \sum_{i=1}^{3} tmoney^i_{3j} STAND^i_{3j} + FINC_j + \sum_{b=1}^{6} ccontr_{bj} CERE_{bj} + LINC_j + \sum_{j'=1}^{j-1} cinco_j INV_{2j'} \geq ded_j + nc_j, \quad j=1,2$$

Constraints (4) are used to provide the model with the annual income tax categories. Constants tax_{vj} indicate the extent of the tax categories (Table 8). The figures for year 2 are obtained from the figures for year 1 by multiplying the later by the inflation factor (i.e. in this case 1.05).

$$(4)\ TAX_{vj} \leq tax_{vj}, \quad j=1,2 \quad \text{and } v=1,2,..,11$$

From constraints (2) the incomes after tax are transferred by means of variables TAX_{vj} to cash flows after tax channelling constraints (3) which regulate the enterprise's liquidity. At this point, the coefficients applying to the tax variables are the cofficients $perc_{vj}$ defined in Table 8. All tax-free incomes are collected to these equations (3); these include the stumpage obtained from the woodlot, since in Finland (in accordance with the currently valid forest taxation system) the actual income from selling timber does not affect the taxes to be paid by owner. The coefficients add^i_{kj} are reserved for tax-free incomes obtainable in year j from treatment k carried out in stand i. The numerical values for these coefficients are presented in Tables 1a–1c.

Equations (3) take also into account the withdrawals of loans in year j, the amortizing portion of loans in year j taken in year j', $amort_{aj'j}$. As mentioned above, there are only two types of loans: short-term loans (a=1) that have to be paid back one year after their wihdrawal and long-term loans (a=2) that have to be paid back in ten years (10 % per year). The investments in bonds and bank deposits have been handled in the same way as the short-term loans. The farm receives in year j the amount of money deposited in the account or invested in the bonds in year j–1 plus the interest $sinter_j$ for deposits or $binter_j$ for the bonds in year j. Moreover, that part of the financing of investments y in year j which exceeds the farm loans obtainable from the government, $expe_{yj}$, (cf. tables 5 and 7) is also taken into account.

Constraints (3) are also made to include the depreciations deducted above in constraints (2). Depreciations are not actual cash transactions; they are calculatory parameters needed to determine the income after tax. The variables $FINC_1$ and $FINC_2$ (calculatory variables needed for the determination of tax and connected to the Finnish forest taxation system's calculatory forestry net income concept) are deducted in constraints (3); in the above, these were added in constraints

(2). The money withdrawals by the entrepreneur family for their private consumption and fixed tax-free incomes and fixed costs that have not been allocated to specific products or product groups are included in the right-hand constants of constraints (3). The personal tax deductions, ded_j, are deducted from the income in the constraints (2) (i.e. FIM 15000 in year 1 and FIM 17000 in year 2) and added to the income in the constraints (3). Allocation for money withdrawal for private consumption in year 1, prv_1, amounts to FIM 50000 and in year 2, prv_2, to FIM 53000 correspondingly.

$$(3)\ -\sum_{v=1}^{12} perc_{vj} TAX_{vj} + DEPREC_j + BDEPREC_j + \sum_{a=1}^{2} LOAN_{aj} + \sum_{a=1}^{2}\sum_{j'=1}^{j-1} amort_{aj'j} LOAN_{aj'} - SAVIN_j + \sum_{i=1}^{3}\sum_{i=1}^{3} add^i_{kj} STAND^i_{kj} - FINC_j + (1+sinter_j) SAVIN_{(j-1)} - BON_j + (1+binter_j) BON_{(j-1)} - \sum_{y=1}^{4} expe_{yj} INV_{yj} - RESUL_j \geq prv_j - ded_j, \quad j=1,2$$

The maximum depreciations are set by constraints (5):

$$(5)\ 3.33\ DEPREC_j + \sum_{j'=1}^{j-1} DEPREC_{j'} \leq mundepr, \quad j=1,2$$

in which the constant mundepr is the as yet not depreciated residual value of the farm's machinery and equipment (here FIM 30000). The maximum depreciation percentage is 30; the model decides whether maximum depreciation is worthwhile doing for a particular year. Constraints (6) set the maximum depreciation limit (10 %) for production buildings.

$$(6)\ 10.0\ BDEPREC_j + \sum_{j'=1}^{j-1} BDEPREC_{j'} - \sum_{j'=1}^{j} bprice_{2j'} INV_{2j'} \leq bundepr, \quad j=1,2$$

in which the constant bundepr is the as yet not depreciated residual value of the production buildings (here FIM 125000); it is added to by the amount indicated by the coefficients of variables INV_{yj} according to the year j of building and the cost of the drier investment ($bprice_{2j}$). In the year one that investment will cost 95000 FIM and in the year two 99750 FIM.

Equations (9) set the upper limits to drawing of fresh loans. In this simplified example, it is assumed that the enterprise has no previous loans and that the enterprise is in a position to take only two separate bank loans in addition to the farm loans granted by the government for the investments on the farm.

The variables $LOAN_{11}$ and $LOAN_{12}$ were formed in the model to account for short-term loans with a repayment schedule of one year. The enterprise has to pay 12 % of annual interest on these loans. The variables $LOAN_{21}$ and $LOAN_{22}$ were formed to account for long-term loans. These loans are to be paid back by equal annual instalments over a period of ten years ($amort_{201}$ = 0, because there were no previous loans and $amort_{212}$ = 0.10) and the annual interest on them is 9 %. The total amount of short- and long-term loans during the first year was limited to a maximum of FIM 150000 ($loan_1$) and during the second year to FIM 170000 ($loan_2$).

$$(9)\ \sum_{a=1}^{2} LOAN_{aj} + (1 - amort_{2(j-1)j}) LOAN_{2j} \geq loan_j, \quad j=1,2$$

5.6 Common resources

It was assumed that the only scarce resource on the farm that was common to the various lines of activities was that of the labour force available during the winter, which is the season of the year when most of the timber harvesting work is intended to be carried out. The labour hours required by timber harvesting work $fwork^i_{kj}$ were set out earlier in Tables 1a–c. It is assumed that the maximum annual number of man hours available for harvesting work is 480 hours (lim). This being so, the labour force constraints (17) have the following syntax:

$$(17)\ \sum_{i=1}^{3}\sum_{k=2}^{3} fwork^i_{kj} STAND^i_{kj} \leq lim, \quad j=1,2$$

5.7 The goal function

As was mentioned in Section 41., the goal of the enterprise is to maximize the property in possession of the enterprise at the end of year 2. In addition to this, the solution presupposes that the entrepreneur family takes annually for consumption a predefined sum of money. The solution also includes the condition that a certain sum of money is withdrawn either in year 1 or year 2 for the purpose of renovating the dwellinghouse. The final assets will include the sum of only such property components as have been involved in the comparisons carried out with the model. This being so, the equation (1) has the following syntax:

$$\text{(1)}\quad \text{Max OBJ} = \sum_{i=1}^{3}\sum_{k=1}^{4}\sum_{j=1}^{2} \text{lvalu}_{kj}^{i}\text{STAND}_{kj}^{i} + \text{SAVIN}_2 + \sum_{j=1}^{2}\text{BON}_j - (1-\text{amort}_{2(j-1)j})\text{LOAN}_{21} - \sum_{a=1}^{2}\text{LOAN}_{a2} + \text{RESUL}_2 + \sum_{y=1}^{2}\sum_{j=1}^{2}\text{pv}_{yj} \times \text{INV}_{yj}$$

The coefficients lvalu_{kj}^{i} for variables STAND_{kj}^{i} in the goal function have been obtained from Tables 1a–c. The coefficients for the loan and financial investment variables have been obtained by evaluating the loans and financial investments to their nominal values at the end of period 2. The coefficients pv_{yj} for the real investments correspond to the acquisition prices of the investment projects with the portion financed by government farm loans having been subtracted from them. The coefficients corresponding to investments due to be carried out in year 1 have been reduced by the amount of calculatory depreciation. The depreciation on production buildings amounts to a maximum of 10 % of the as yet not depreciated residual value of the original expenditures (i.e. diminishing balance depreciation). The amount of the depreciation percentage within the scope of the upper limit will depend on the amount of the incomes.

5.8 The solution provided by the model

The case was solved using the Helsinki School of Economics' HP-3000 computer and the LINDO software. In this chapter, the solution is dealt with variable by variable in the same order as the variables were presented in the preceding chapters.

Variables related to activities in the woodlot and with value differing from zero can be seen from table 9.

Thus, it is to be noted that in the case of stand 1, timber is sold from it only in year 1 and then in the form of delivery sales. The income received from this timber sale falls within the tax-free constraints (20) and is therefore fully tax-free. This brings a total of FIM 31000 into the enterprise's cash. In accordance with the solution, no timber is sold from stand 2 during the planning period. But in the case of stand 3, timber is sold during year 1 in the form of both standing sales and delivery sales, and the work earning from the delivery sales is thus subject to being taxed. All in all, the sales of timber from stand 3 during year 1 amounts to FIM 109000 of sales income, of which sum FIM 11000 is work earning that is subject to being taxed according to the current regulations. In year 2, only delivery sales timber is sold from stand 3; it brings in sales income of FIM 75000, and of this FIM 8000 is work earning subject to being taxed.

On the part of forestry, the enterprise's taxable incomes are thus influenced firstly, by the variables corresponding to the above extra net incomes from delivery sales of timber. Secondly the variables FINC_1 and FINC_2 which are fixed calculated values corresponding to the Finnish forest taxation system (i.e. during year 1 FIM 31000 and during year 2 FIM 33000) are included in the taxable incomes. On the part of the forestry constraints, only the labour input constraint for year 2 left some slack. The other constraints were binding.

Table 9. Forestry variables with values differing from zero.

Variable	Value in solution (%)
STAND^1_{21}	13
STAND^1_{42}	87
STAND^2_{42}	100
STAND^3_{11}	8
STAND^3_{31}	6
STAND^3_{22}	3
STAND^3_{32}	4
STAND^3_{42}	79

Table 10. The taxable income for the farm, 1000 FIM.

Type of income and tax deductions	Year 1		Year 2	
Incomes:				
Harvesting work in own forest	11		7	
Calculatory net income from forestry (area-based taxation)[1]	31		33	
Contrib. of pig raising	177		186	
Contrib.of crop cultivation	137	356	144	370
Minus tax deductions:				
– Depreciation on machinery and equipm.	9		6	
– Depreciation on production buildings	12		21	
– Costs not allocated to products	90		85	
– Interest on loans	–		14	
– Personal tax	15	126	17	143
Taxable income		230		227

[1] Calculatory average income according Finnish areal basis forest taxation.

The solution provided by the model on the part of the cropping plan was such that in year 1 wheat would be grown on 15 hectares (the maximum allowable area) and rye on 5 hectares. In year 2, the areas for wheat and rye would be the same. Taxable income from the cereal crops would amount to FIM 128000 during year 1 and FIM 135000 in year 2. These incomes have been obtained by subtracting the seed and fertilizer costs from the gross sales incomes.

On the part of pig raising, the solution indicates that it is profitable to expand production already during year 1 to the full capacity of the pig house (i.e. by 10 more pigs per batch). According to the solution, the pigs would be fed entirely on fodder bought for the purpose; this would mean the purchasing of 132000 kilos each year. The contribution provided by pig raising would be FIM 177000 during year 1 and FIM 186000 during year 2. These contributions include the fixed costs of heating and lighting.

On the part of the real investments, the model was used only for the purpose of solving the year in which the dwellinghouse and grain drier investments should be implemented. According to the solution obtained, both investments should be carried out during year 2. During year 1 the new owner of the farm enterprise will have to provide a total sum of FIM 328000 to his parents and siblings. This is the sum that has been agreed upon in connection with the handing over of the farm to a descendant (the young farmer).

The optimal solution does not include investments in bonds during the planning period. But, as a means of preserving the enterprise's liquidity, the required bank deposits are included in the solution; thus, in year 1 a deposit of FIM 15000 is made and in year 2 a further deposit of FIM 17000.

The taxable income accrued to the owner is shown in Table 10. The above incomes lead to taxes (state tax, communal income tax etc.) amounting to FIM 121000 in year 1 and FIM 118000 in year 2.

The solution provided by the model also enables a clarification of the sources of money and its use as shown in Table 11.

Table 11. The sources and use of money during the planning period, 1000 FIM.

Target	Year 1	Year 2
Sources of money		
Taxable income	230	227
+ Depreciation on machinery and equipm.	9	6
+ Depreciation on production buildings	12	21
+ Personal tax reductions	15	17
+ Income from timber sales	129	67
+ Borrowing	150	35
+ Maturing deposits and interest on these	–	15
– Calculatory net income[1] from forestry	31	33
Total	514	355
Money uses		
To pay taxes	121	118
Payments to parents and siblings in connection with transfer of farm ownership	328	–
Construction of production build.(drier)	–	39
Bank deposits	15	17
Instalments of loans	–	15
Basic renov. of f'house	–	113
Money withdrawals for consumption	50	53
Total	514	355

[1] See footnote 1, table 10.

5.9 Concerning the multi-objective planning model

This planning model can be expanded in many directions in the future. As was mentioned earlier, in Section 3.3, the entrepreneur or the entrepreneur family may also have goals other than that of maximizing the value of the farm assets by the end of the planning period. The entrepreneur may strive simultaneously towards both the maximization of the final assets and as large as possible cash withdrawals from the enterprise. Another often stated goal is to achieve or maintain as even as possible an age structure in the woodlot. These additional goals can be expressed mathematically as follows:

$$\max V_a = \sum_{j=1}^{10} (1+r)^j \times PRV_j$$

min TADEVI

including the extra constraint

$$TADEVI \geq gol_m - \sum_{i \in K} \sum_{k \in N_j^i} \sum_{j=1}^{10} age_{mk}^i STAND_{kj}^i$$

for each m

In the former objective function the variable PRV_j is reserved for the sum of cash withdrawals for private consumption during year j. Its coefficient consists of a compound interest factor in which r stands for the entrepreneur's calculatory interest rate. If the maximization of cash withdrawals is also to be included in the model, then the factor pr_{vj} is removed from the right hand side constant of constraint (3) and the variable PRV_j is inserted to the left hand side of this constraint, whereupon its coefficient will be –1. Thus, the coefficient r stands for the term of exchange at which the entrepreneur is prepared to exchange for one another for the amount of the final assets the cash withdrawals of the various years.

The second objective function requires extra constraints. These constraints are used to impose each growing stock age class m an areal goal gol_m in hectares. If a stand i is subjected to treatment option k in the year j, the age_{mk}^i hectares of it belong to age class m in accordance with the definition. When the area of all stands belonging to age class m is summed together and substracted from the age class's area goal of gol_m, the difference is the deviation from the age class's goal value. TADEVI minimises the age class-specific maximum deviation within all age classes.

A multi-objective optimization task solution such as this can be carried out using standard optimization software such as LINDO or MINOS. It is, however, necessary to reformulate the task when this is done. At present, the authors are in the process of refining the optimization model presented to make it suitable for multi-objective solutions. The reformulation of the task will be based on the reference point method (Kallio et al. 1980).

6 Conclusions

At the beginning of this paper, the authors presented some central special features of a combined agricultural and forestry enterprise that are of relevance to planning. Then the paper went on to deal with the basic concepts of the planning model and, with the help of an example, described how a multi-period plan of action may be drawn up for a farm enterprise. Also illustrated was the kind of information concerning the enterprise that has to be collected as material for the plan. Detailed mathematical equations and the associated lists of variables are presented as appendices to the study report.

The model developed by the authors has been tested on two case farm enterprises. In these two cases, the smaller model consisted of 2 periods (years) and it had 411 variables and 103 constraints. The bigger model consisted of a 10-year planning period; it had 1955 variables and 383 constraints. Only the former model has been described in this report. However, simplifications were made on the part of the activity alternatives, also concerning the forestry ones. The basic material was collected from a real-life farm. The feedback from the tests has been mainly positive and the experience has been that this type of an approach is well suited for making economic plans for farm enterprises.

We should see the plan produced at the end of the planning process as not being the entrepre-

neur's action decision as such. Especially the planning of the whole enterprise is such a complex process that decision making requires consideration and intuition, too. On the other hand, a considerable amount of consideration and partial solutions are already involved in those stages of planning where non-desirable alternatives, for instance, are excluded from the planning model. All in all, owing to the above reasons, it would seem that in combined agriculture and forestry there are, perhaps, more than in many other lines of activities, regularities, institutional factors and development trends that ease planning, which is always a difficult task. But it is also true that there has recently been a significant increase in uncertainty connected to the economic and institutional factors in agriculture and forestry. We cannot , for example, say how and to what extent the unification of Europe will influence the practicing of agriculture and forestry in Finland — trends have been demolished or they are in the process of being demolished. Prognoses are becoming increasingly difficult to make.

Acknowledgement

The authors would like to thank Erkki Pekkinen, M.Sc.(For.), for his contiribution in the translation from Finnish into English.

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APPENDIX 1. Legend to symbols used.

The indices and index sets:

- a Loan term
- b Plant species (b=1,...,B)
- e Species of livestock $e \in E$
- i Stand number $i \in K$
- j Period (j=1,...,10; in the illustration j = 1,2)
- j' Period preceding the year j (j'=1,...,9 if the planning period is 10 years)
- k The character $k \in N^i_k$ for a treatment (both silvicultural and harvesting treatment) to be carried out in a stand i
- q Machine or equipment investment alternative $q \in Q_x$
- t An index that defines which sub-set of K or N^i_j is in question (t=1,...,9, when planning period is 10 years)
- v The character indicating the income category when taxable income is being calculated (v=1,...,12)
- w Work opportunity (job) $w \in W$ outside the farm
- x Machine or equipment $x \in X$ to be replaced
- y Real investment alternative $y \in Y_z$
- z The project $z \in Z$ to be replaced
- B The set of all potentially cultivatable plant species
- B_e The set of fodder plants suitable for feeding livestock species e
- E The set of possible livestock species in animal husbandry
- K The set of all possible stands whose sub-set is $K^1,...,K^5$, when planning period is 10 years
- K^1 The set of stands where sales of standing timber is possible
- K^2 The set of stands where delivery sales is possible, and where all harvesting work is possible to carry out using the farm's own labour force
- K^3 The set of stands where delivery sales is possible, and where only the forest haulage work is possible to carry out using the farm's own labour force
- K^4 The set of stands where delivery sales is possible, and where only felling work can be carried out using the farm's own labour force
- K^5 The set of stands where forest improvement treatments are possible
- L The number of different loan terms
- N^i_j The set of activities possibly to be implemented in stand i in the year j; sub-sets are $N^i_{1j},...,N^i_{9j}$
- N^i_{1j} The set of treatments connected to standing sales of timber
- N^i_{2j} The set of treatments connected to delivery sales, in which case all harvesting work is carried out using the farm's own labour force and the work income is tax-free
- N^i_{3j} The set of treatments connected to delivery sales, in which case only the forest haulage work is carried out using the farm's own labour force and the work income is tax-free
- N^i_{4j} The set of treatments connected to delivery sales, in which case only the felling work is carried out using the farm's own labour force and the work income is tax-free
- N^i_{5j} Otherwise similar to N^i_{2j} but the work income is taxable
- N^i_{6j} Otherwise similar to N^i_{3j} but the work income is taxable
- N^i_{7j} Otherwise similar to N^i_{4j} but the work income is taxable
- N^i_{8j} The set of treatments connected to forest improvement, in which case the interests on the loans are deductible in taxation
- N^i_{9j} The set of treatments connected to forest improvement, in which case the interests on the loans are not deductible in taxation
- Q_x The set of investment alternatives planned to replace machine or equipment x
- W The set of all potential work opportunities (jobs) outside the farm
- X The set of machines or equipments to be replaced
- Y_z The set of real investment alternatives planned to replace project z
- Z The set of real investment projects to be replaced (also includes the zero alternative as an element; that is, none of the old projects are replaced). This involves major investment projects that can affect buildings, land-use, machines and equipment.

Variables:

- ADD_{ej} Production adaptation measure carried out in year j which means adding the number of livestock for species e
- $AMORT_{aj}$ The portions of loans taken on terms a in earlier years j' (j' <j) to be amortized in year j
- $AMOUNT_j$ Sales income obtained in year j from selling shares bought during the planning period in year j' (j' <j). Surplus is tax-free if j–j' > 5 years
- $BDEPREC_j$ The residual cost depreciation on production buildings to be carried out in year j
- BON_j A bond investment to be carried out in year j
- $BUY_{e'j}$ Amount of fodder cereal to be bought in year j for livestock e for the needs of the beginning of the year (before the harvesting of the new crop)
- BUY_{ej} Amount of fodder cereal to be bought in year j for livestock e following the harvesting of the new crop
- $CERE_{bj}$ In year j, the number of hectares on which plant species b is grown
- $DEPREC_j$ The residual cost depreciation on machinery and equipment to be carried out in year j
- $DEVIC_{xj}$ Estimated realization price of machine or equipment x in year j
- $FINC_j$ Calculatory forestry net income determined for year j on the basis of the Finnish area-based forest taxation
- INV_{yzj} Real investment alternative y planned to replace project z in year j
- INV_{0zj} Project z to be replaced in year j
- $LABOR_{wj}$ The amount of work in hours of a job w done outside the farm in year j
- $LINC_j$ Taxable income obtained from livestock in year j
- $LOAN_{aj}$ Loan possibly to be taken in year j on terms a
- $LOAN2_{aj}$ Residual in year j of loans taken on terms a prior to year j
- $MINV_{qxj}$ Investment option q to be implemented in year j to replace machine or equipment x
- $MINV_{0xj}$ Machine or equipment x to be replaced in year j
- OBJ Objective to be maximized
- RED_{ej} Production adaptation measure carried out in year j which means reducing the number of livestock for species e
- $RESUL_j$ The cash funds that have accumulated in the enterprise by year j (the last year of the planning period;in illustration the year 2) and that have not been invested in long-term projects
- $SAVIN_j$ Bank deposit to be made in year j
- $SHARE1_j$ Investment in shares in year j; dividend obtained is tax-free
- $SHARE2_j$ Investment in shares in year j; dividend obtained is taxable
- $STAND^i_{kj}$ Treatment alternative k to be implemented in year j in stand i
- $SUM1_j$ Dividend income in year j on share investments made during the planning period prior to year j; income is tax-free
- $SUM2_j$ Dividend income in year j obtained on share investments during the planning period prior to year j; income is taxable
- TADEVI Maximum deviation of age class-specific area from the target area over all age classes
- TAX_{vj} The taxable income proportion that accrues in income category v in year j
- V_a The compounded target value of withdrawals from enterprise at the end of the planning period

Coefficients of variables:

- $add^i_{kj'j}$ Tax-free incomes obtainable in year j (less costs incurred earning incomes) from treatment k carried out in stand i in year j'(j'<j)
- $add_{j'j}$ The change in value of a share portfolio purchased in year j' (j'<j) and sold in year j
- age^i_{mk} The area of stand i of age class m in forest holding following treatment k
- $amort_{aj'j}$ The portion of loan a due to be amortized in year j; the loan has been taken in year j' (j'<j)
- $area_{yzj}$ The change in cropped area caused by real investment alternative y acquired to replace project z in year j
- $area_{0zj}$ The change in cropped area attributable to project z to be replaced in year j
- $(1+binter_j)$ In year j, 1+ (interest rate on bond investments)/100
- $bprice_{yzj}$ The addition in year j to the undepreciated residual value for production buildings caused by the real investment alternative y intended to replace the project z in year j
- $ccontr_{bj}$ The contribution profit/hectare computed for year j for plant crop b
- $cinco_{yzj'j}$ The incomes (less servicing, maintenance and upkeep costs) to be obtained in year j from the real investment alternative y acquired in year j' to replace project z
- $cinco_{zj}$ The contribution profit at a normal production level of the livestock project z ($z \in Z$) to be replaced in year j
- $cost_{xj}$ Servicing, maintenance and upkeep costs in year j attributable to machine or equipment x owned by the enterprise at the beginning of the planning period
- $cost_{qxj'j}$ Servicing, maintenance and upkeep costs in year j attributable to machine or equipment q that is to be acquired in year j' (j'<j) to replace the machine or equipment x
- $crop_b$ Crop yield per hectare of crop plant b
- $cubic^i_{kj}$ The volume in cubic meters of the timber to be obtained from stand i in year j when treatment k is implemented
- $cwork_b$ The annual number of work hours required by the cultivation of plant b
- $divid_{j'j}$ The dividend obtainable in year j expressed as a percentage of the purchasing price of the share portfolio acquired in year j'(j'<j)
- $expe_{qxj'j}$ Repayments of loans in year j attributable to machine or equipment q acquired in year j' to replace machine or equipment x
- $expe_{yzj'j}$ Repayments of loans in year j attributable to real investment y implemented in year j' to replace project z
- $fall_{qxj'j}$ The fall in the sales price in year j of investment alternative q acquired in year j'(j'<j) to replace machine or equipment x
- $feprice_{ej}$ The price per kilo paid in year j for fodder used to feed livestock e
- $finter^i_{kj'j}$ Interest to be paid in year j on a government loan taken out for forest amelioration treatment k to be carried out in year j' (j'<j) in stand i
- $fmach^i_{kxj}$ The work time required in carrying out treatment k in stand i using machine or equipment x in year j

$fwork^i_{kj}$ The time in hours required in carrying out treatment k in the stand i in year j

$imach_{yzxj'j}$ The amount used in year j of the capacity of machine or equipment x when investment alternative y (planned to replace the project z) is implemented in year j'(j'<j)

$imach_{0zxj'j}$ The number of operating hours of machine or equipment x liberated in year j from project z that is intended to be replaced in year j'(j'<j)

$inter_{aj}$ The annual interest, expressed as percent, to be paid in the year j for loan type a

$iwork_{yzj}$ The annual number of hours of work required in year j by investment alternative y that will replace project z in year j' (j'<j)

$iwork_{0zj}$ The annual number of hours of work to be liberated in year j from project (activity) z that is intended to be replaced in year j'(j'<j)

job_{wj} Income obtained from a job outside the farm ($w \in W$) in year j

$lbuy_{ej'j}$ The sum to be paid in year j per head of livestock e to be bought in year j'(j'<j)

$lcontr_{ej}$ The unit contribution produced in year j by livestock e

$lmach_{bx}$ The yearly number of operating hours per hectare of machine or equipment x when raising the crop plant species b

$loan_j$ The maximum allowable joint sum of short- and long-term loans in year j

$lsales_{ej'j}$ The income obtained in year j for per head of livestock e to be sold in year j'(j'<j); inc. government subsidy, accounts receivable and other referred assets (claims)

$lsellp_{ej}$ Selling price in year j of the adapting (reduction) batch of livestock e

$lvalu_{aj}$ Residual portion at the end of the planning period of a loan taken out in year j on terms a

$lvalu^i_{kj}$ Present value of the post-planning horizon net incomes from stand i at the end of the planning period when the treatment k is carried out in the stand i in year j

$lwork_e$ The annual number of hours of work liberated or taken up in adapting livestock species e

$mach_{qxj'j}$ The capacity to be obtained in year j from machine or equipment investment alternative q that is intended to replace machine or equipment x in year j'(j'<j)

$mprice_{qxj}$ The addition in year j to the undepreciated residual value for machines and equipments by the investment alternative q intended to replace machine or equipment x in year j

$mprice_{yzj}$ The addition in year j to the undepreciated residual value of production buildings and fixed machineries caused by the real investment alternative y intended to replace the project z

$part1_e \times fod_e$ The amount of fodder per head required by livestock e before the ripening of the new crop

$part2_e \times fod_e$ The amount of fodder per head required by livestock e after the ripening of the new crop

$part1_e \times requi_e$ The annual amount of fodder required by livestock e ("normally" used production capacity) before the ripening of the new crop

$part2_e \times requi_e$ The annual amount of fodder required by livestock e ("normally" used production capacity) after the ripening of the new crop

$perc_{vj}$ In year j, [1 – (government marginal tax as percentage + municipal tax percentage + church tax percentage + social security fee percentage)]/100 in the income category v

pv_{yzj} The esitimated realization value at the end of the planning period (in year 10) of investment alternative y intended to replace project z in year j

pv_{0zj} The sum at the end of the planning period of the present values of the post-planning period costs caused by the project z due to be replaced in the year j. Such costs include, for instance, the repair costs caused by a cow shed that may possibly be taken out of use (unless it is demolished)

$pvalu_j$ The probable selling price at the end of the planning period of a portfolio of shares bought in year j (j=6,...,10) (According to Finnish tax regulations, sales profit is taxable income when the shares have been owned by for less than five years)

$(q_e - q'_e)$ The maximum production reduction for livestock e within the framework of the present "normally" used production capacity

$(q''_e - q_e)$ The maximum production increase for livestock e within the present "normally" used production capacity

r The calculation rate of interest in decimals

$rloan_{qxj}$ The residual loan sum at the end of the planning period of a loan taken out in year j for financing the investment alternative q to replace machine or equipment x

$rprice_{qxj}$ The payment in year j in connection with the acquisition of investment alternative q to replace machine or equipment x (the seller receives x)

$(1+sinter_j)$ In year j, 1+ (interest rate on bank savings)/100

$stand^i_{yzj}$ The area demand on stand i (change in land use category) of investment alternative y planned to replace project z in year j (e.g. clearing of forest stand into arable land)

$tmoney^i_{kj}$ The taxable delivery sales harvesting work income due to accrue in year j from stand i when the work is carried out by implementing treatment alternative k

Right-hand side constants:

$area$ The total area of arable land on the farm

$area^-_{bj}$ The minimum area (in hectares) allocated to the cultivation of crop plant b in year j

$area^+_{bj}$ The maximum area (in hectares) allocated to the cultivation of crop plant b in year j

$bundepr$ The undepreciated residual value on production buildings at the beginning of the planning period

bon_b The sales income from bonds possessed at the peginning of the planning period; the income is obtainable at the beginning of year 1. Thus the bonds are sold at the beginning of the planning period and the model then decides yearly whether new bonds are to be bought in.

$const_j$ Fixed government agricultural supports obtainable in year j; e.g. support paid according to farm size

$dcost_{xj}$ Servicing, maintenance and upkeep costs in year j attributable to machine or equipment x owned by the enterprise at the beginning of the planning period

ded_j Personal tax deductions per farmer's family in year j

$devic_x$ The number of machine or equipment type x at the beginning of planning period

$dfall_{xj}$ The fall in the selling price in year j of machine or equipment x possessed by the enterprise at the beginning of the planning period

$devalu_{x10}$ The secondhand selling price of a machine or equipment type x at the end of planning period (in illustration in year 2)

f_j The calculatory forestry net income for the year j calculated on the basis of the Finnish area-based forest taxation

gol_m The target total area of stands of age class m in forest holding

$lhour_e$ The annual number of hours of work required by livestock e at so-called "normally" used production capacity

lim The annual number of work hours (the farmer and his family) available during the planning period

lim_x The capacity available to machine or equipment x at the beginning of the planning period

$linc_{ej}$ The contribution profit obtained from livestock e in year j at the normal production level

$loan1_j$ The interest in year j accrued from existing loans at the beginning of the planning period

$loan2_j$ The amortization sums in year j resulting from existing loans at the beginning of the planning period

$mundepr$ The undepreciated residual value of machines and equipments at the beginning of the planning period

nc_j The total of costs not allocated to specific products (fixed costs) in year j

$numb_x$ The number of machine or equipment x deemed necessary during the planning period

$part1_e$ That part of the fodder consumption of livestock e that will be consumed annually before the ripening of the new crop

$part2_e$ That part of the fodder consumption of livestock e that will be consumed annually after the ripening of the new crop

prv_j The sum of money to be reserved for private consumption (money withdrawals) in year j

$plim_j$ The upper limit (FIM) for tax-free income from capital in year j

q_e The annual production volume of livestock e at the present production capacity ("normally" used capacity)

q'_e The minimum profitable annual production volume for livestock e at the present production capacity

q''_e The maximum possible annual production volume for livestock e at the present production capacity

$requi_e$ The annual amount of fodder ("normally" used production capacity) required by livestock e in terms of equivalent fodder units

$savin_j$ The minimum deposit in year j in a short-term account

$savin1_j$ The interest obtainable in year j on taxable savings existing at the beginning of the planning period

$savin2_j$ The capital liberated in year j from taxable savings existing at the beginning of the planning period

$savin3_j$ The capital liberated + interest in year j from tax-free savings existing at the beginning of the planning period

$share1_j$ The tax-free sales income obtainable in year j from shares possessed at the beginning of the planning period

$share2_j$ The tax-free dividends obtainable in year j from shares possessed at the beginning of the planning period

$share3_j$ The taxable dividends obtainable in year j from shares possessed at the beginning of the planning period

$stor_e$ The amount of fodder required for feeding livestock e in storage at the beginning of the planning period

tax_{vj} The interval in FIM of tax category v in year j

APPENDIX 2.

The goal function

1)

$$OBJ = \sum_{k\in N_j^i} \sum_{i\in K} \sum_{j=i}^{10} 1valu_{kj}^i \, STAND_{kj}^i + \sum_{j=6}^{10} pvalu_j SHARE1_j + \sum_{j=6}^{10} pvalu_j SHARE2_j$$

$$+ BON_{10} - \sum_{a=1}^{L} \sum_{j=1}^{11} 1valu_{aj} LOAN_{aj} + \sum_{e\in E} \sum_{j=1}^{10} 1sellp_{e10} ADD_{ej}$$

$$- \sum_{e\in E} \sum_{j=1}^{10} 1sellp_{e10} RED_{ej} + \sum_{y\in Y_z} \sum_{z\in Z} \sum_{j=1}^{10} pv_{yzj} INV_{yzj}$$

$$- \sum_{z\in Z} \sum_{j=1}^{10} pv_{0zj} INV_{0zj} - \sum_{q\in Q_x} \sum_{x\in X} \sum_{j=1}^{10} rloan_{qxj} MINV_{qxj} + RESUL_{10}$$

Taxable incomes and deductible expenses

2)

$$- \sum_{v=1}^{12} TAX_{vj} - DEPREC_j - BDEPREC_j - inter_{1j} LOAN_{1(j-1)}$$

$$- \sum_{a=2}^{L} \sum_{j'=1}^{j-1} inter_{aj'} \, LOAN2_{aj'} + SUM2_j + \sum_{k\in N_{tj}^i} \sum_{i\in K^{t'}} tmoney_{kj}^i \, STAND_{kj}^i$$

$$+ FINC_j - \sum_{k\in N_{8j}^i} \sum_{i\in K^5} \sum_{j'=1}^{j-1} finter_{j'j} STAND_{kj'}^i + \sum_{b=1}^{B} ccontr_{bj} CERE_{bj}$$

$$+ LINC_j + \sum_{j'=1}^{j} \sum_{z\in Z} \sum_{y\in Y_z} cinco_{yzj'j} INV_{yzj'} - \sum_{z\in Z} cinco_{zj} INV_{0zj}$$

$$+ \sum_{w\in W} job_{wj} \, LABOR_{wj} - \sum_{j'=1}^{j} \sum_{x\in X} \sum_{q\in Q_x} cost_{qxj'j} MINV_{qxj'}$$

$$\leq -const_j + loan1_j - share3_j - savin1_j$$

$$- ded_j - nc_j + \sum_{x\in Q_x} dcost_{xj}$$

for all $j, t = \{5,6,7\}, t' = \{2,3,4\}$

The after-tax cash flows

3)

$$\sum_{v=1}^{12} perc_{vj} TAX_{vj} + DEPREC_j + BDEPREC_j + LOAN_{1j} - LOAN_{1(j-1)}$$

$$+ \sum_{a=2}^{L} LOAN_{aj} - \sum_{a=2}^{L} \sum_{j'=1}^{j-1} amort_{aj'j} LOAN_{aj'} - SAVIN_j$$

$$+ (1 + sinter_j) SAVIN_{(j-1)} - BON_j + (1 + binter_j) BON_{(j-1)}$$

$$- SHARE1_j - SHARE2_j + AMOUNT_j + SUM1_j$$

$$+ \sum_{i\in K} \sum_{k\in N_j^i} \sum_{j'=1}^{j} add_{kj'j}^i STAND_{kj'}^i - FINC_j$$

$$- \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} expe_{yzj'j} INV_{yzj'}$$

$$- \sum_{x\in X} \sum_{q\in Q_x} \sum_{j'=1}^{j} expe_{qxj'j} MINV_{yxj'} - RESUL_j$$

$$\geq loan2_j - savin2_j - savin3_j - bon_1 - share1_j - share2_j + prv_j$$

$$+ ded_j$$

for all j

The magnitude of income categories in the tax scales

4)

$TAX_{vj} \leq tax_{vj}$ for all v and j

The depreciation on machines and equipments

5)

$$3.33 \times DEPREC_j + \sum_{j'=1}^{j-1} DEPREC_{j'} - mprice_{yzj'} INV_{yzj'}$$

$$- mprice_{qxj'} MINV_{qxj'} \leq mundepr$$ for all j and $j' \leq j$

The depreciation on buildings

6)

$$10 \times BDEPREC_j + \sum_{j'=1}^{j-1} BDEPREC_{j'} - bprice_{yzj'} INV_{yzj'} \leq bundepr$$

for all j and $j' \leq j$

The annual repayments on loans

7)

$$\sum_{j'=1}^{j-1} amort_{aj'j} LOAN_{aj'} - AMORT_{aj} = 0$$

for all a > 1, j > 1 and j' < j

The amount of loans at the beginning of the year

8)

$$\sum_{j'=1}^{j-1} LOAN_{aj'} - \sum_{j'=1}^{j} AMORT_{aj} - LOAN2_{aj} = 0$$

for all a > 1, j > 1 and j' < j

The loan granting constraint

9)

$$\sum_{a=1}^{L} LOAN_{aj} + \sum_{a=2}^{L} LOAN2_{aj} \le loan_j \quad \text{for all j}$$

The minimum limits for annual bank deposits

10)

$$SAVIN_j \ge savin_j \quad \text{for all j}$$

Tax-free annual dividends

11)

$$\sum_{j'1}^{j-1} divid_{j'j} SHARE2_{j'} - SUM2_j = 0 \quad \text{for all } 1 < j < 7$$

Taxable annual dividends

12)

$$\sum_{j'=1}^{j-1} divid_{j'j} SHARE1_{j'} - SUM1_j = 0 \quad \text{for all } 1 < j < 7$$

Tax-free annual dividends

13)

$$\sum_{j'=j-5}^{j-1} divid_{j'j} SHARE2_{j'} - SUM2_j = 0 \quad \text{for all} > 6$$

Taxable annual dividends

14)

$$\sum_{j'=1-5}^{j-1} divid_{j'j} SHARE1_{j'} - SUM1_j = 0 \quad \text{for all } j > 6$$

The maximum limits to tax-free annual capital income

15)

$$SUM2_j \le plim_j \quad \text{for all j}$$

The fall in value of the stock portfolio

16)

$$add_{j'j} SHARE1_{j'} + add_{j'j} SHARE2_{j'} - AMOUNT_j = 0$$

for all j > 5 so that (j − j') ≥ 5

The labour input constraint

17)

$$\sum_{i\in K^t} \sum_{k\in N^i_{tj}} fwork^i_{kj} STAND^i_{kj} + \sum_{b=1}^{B} cwork_b CERE_{bj}$$

$$- \sum_{e\in E} \sum_{j'=1}^{j} lwork_e RED_{ej'} + \sum_{e\in E} \sum_{j'=1}^{j} lwork_e ADD_{ej'}$$

$$+ \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} iwork_{yzj} INV_{yzj'} - \sum_{z\in Z} \sum_{j'=1}^{j} iwork_{0zj} INV_{0zj}$$

$$+ LABOR_{wj} \le lim - \sum_{e\in E} lhour_e$$

for all j and t = {2,...,9}

The machine capacity constraint

18)

$$\sum_{i\in K^t} \sum_{k\in N^i_{tj}} fmach^i_{kxj} STAND^i_{kj} + \sum_{b=1}^{B} lmach_{bx} CERE_{bj}$$

$$+ \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} imach_{yzxj'j} INV_{yzj'} - \sum_{z\in Z} \sum_{j'=1}^{j} imach_{0zxj'j} INV_{0z...}$$

$$- \sum_{q\in Q_x} \sum_{j'=1}^{j} mach_{qxj'j} MINV_{qxj'} + \sum_{j'=1}^{j} lim_x MINV_{0xj'} \le lim_x$$

for all j, x and t = {1,...9}

The stand constraint

19)

$$\sum_{j=1}^{10} \sum_{k\in N^i_j} STAND^i_{kj} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j=1}^{10} stand^i_{yzj} INV_{yzj} = 1$$

for all i

The maximum limit to tax-free delivery work

20)

$$\sum_{i\in K^t} \sum_{k\in N^i_{tj}} cubic^i_{kj} STAND^i_{kj} \le 150$$

for all j and t = {2,3,4}

The forestry net income

21)

$$FINC_j = f_j$$

for all j

The maximum limit to the area of cultivated land

22)

$$\sum_{b=1}^{B} CERE_{bj} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} area_{yzj} INV_{yzj'}$$

$$- \sum_{z\in Z} \sum_{j'=1}^{j} area_{0zj} INV_{0zj'} \le area$$

for all j

The maximum/minimum limits to cultivating a specific plant species

23)

$$area^-_{bj} \le CERE_{bj} \le area^+_{bj}$$

for all b and j

The adaptation constraint applying to livestock production

24)

$$\sum_{j'=1}^{j} RED_{ej'} - \sum_{j'=1}^{j} ADD_{ej'} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} (q_e - q'_e) INV_{yzj'}$$

$$\le (q_e - q'_e)$$

for all e and j

The adaptation constraint applying to livestock production

25)

$$\sum_{j'=1}^{j} ADD_{ej'} - \sum_{j'=1}^{j} RED_{ej'} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} (q''_e - q'_e) INV_{yzj'}$$

$$\le (q''_e - q_e)$$

for all e and j

The feed requirement during the first half of the year

26)

$$BUY_{e'j} - \sum_{j'=1}^{j} (part1_e \times fod_e) ADD_{ej'} + \sum_{j'=1}^{j} (part1_e \times fod_e) RED_{ej'}$$

$$+ \sum_{b\in B_e} crop_b CERE_{b(j-1)} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} (part1_e \times requi_e) INV_{yzj'} \ge$$

$$(part1_e \times requi_e) - stor_e$$

for all e and j

The feed requirement during the second half of the year

27)

$$BUY_{ej} - \sum_{j'=1}^{j} (part2_e \times fod_e) ADD_{ej'} + \sum_{j'=1}^{j} (part2_e \times fod_e) RED_{ej'}$$

$$+ \sum_{b\in B_e} crop_b CERE_{bj} + \sum_{z\in Z} \sum_{y\in Y_z} \sum_{j'=1}^{j} (part2_e \times requi_e) INV_{yzj'} \ge$$

$$(part2_e \times requi_e)$$

for all e and j

The taxable income from livestock husbandry

28)

$$- \sum_{e\in E} \sum_{j'=1}^{j} (lcontr_{ej} - lsellp_{ej'}) RED_{ej'}$$

$$+ \sum_{e\in E} \sum_{j'=1}^{j} (lcontr_{ej} - lbuy_{ej'j}) ADD_{ej'} - feprice_{ej} BUY_{e'j}$$

$$- feprice_{ej} BUY_{ej} - LINC_J = \sum_{e\in E} linc_{ej}$$

for all j

The investment constraint

29)

$$\sum_{y\in Y_z} \sum_{j'=1}^{j} INV_{yzj} \le 1$$

for all z and j

The requirement to eliminate from use a project to be replaced

30)

$$INV_{0zj} - \sum_{y \in Y_z} \sum_{j'=1}^{j} INV_{yzj'} = 0$$

for all z and j

The value of all machinery at the end of year j

31)

$$\sum_{q \in Q_x} mprice_{qxj}\, MINV_{qxj} - \sum_{q \in Q_x} \sum_{j'=1}^{j-1} fall_{qxj'j}\, MINV_{qxj'}$$

$$+ \; DEVIC_{x(j-1)} - DEVIC_{xj} = dfall_{xj}$$

for all x and for all j < 10

The value of machine x at the end of the planning period

32)

$$\sum_{q \in Q_x} mprice_{qx10}\, MINV_{qx10} - \sum_{q \in Q_x} \sum_{j'=1}^{9} fall_{qxj'10}\, MINV_{qxj'} \geq$$

$$devalu_{x10} + dfall_{x10}$$

for all x

The annual number of machines

33)

$$\sum_{j'=1}^{j} \sum_{q \in Q_x} MINV_{qxj'} = numb_x - devic_x$$

for all j and x

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ACTA FORESTALIA FENNICA

Acta Forestalia Fennica 234 – Hämäläinen & Kuula

ISBN 951-40-1273-9
ISSN 0001-5636