REPRINTED FROM:

Forest Ecology and Management

Forest Ecology and Management, 62 (1993) 51–72
Elsevier Science Publishers B.V., Amsterdam

Planning of forest plantation investments with the aid of linear programming: a case study of Sao Hill Forest, Tanzania

Aaron S.M. Mgeni[*,a], Colin Price[b]

[a]*Department of Forest Mensuration and Management, Faculty of Forestry, Sokoine University of Agriculture, P.O. Box 3013, Chuo Kikuu, Morogoro, Tanzania*
[b]*School of Agriculture and Forest Sciences, University College of North Wales, Bangor, LL57 2UW, UK*

(Accepted 8 July 1993)

ELSEVIER, Amsterdam – London – New York – Tokyo

Forest Ecology and Management, 62 (1993) 51–72
Elsevier Science Publishers B.V., Amsterdam

Planning of forest plantation investments with the aid of linear programming: a case study of Sao Hill Forest, Tanzania

Aaron S.M. Mgeni[*,a], Colin Price[b]

[a]*Department of Forest Mensuration and Management, Faculty of Forestry, Sokoine University of Agriculture, P.O. Box 3013, Chuo Kikuu, Morogoro, Tanzania*
[b]*School of Agriculture and Forest Sciences, University College of North Wales, Bangor, LL57 2UW, UK*

(Accepted 8 July 1993)

Abstract

Tanzania has adopted central planning. Since the realisation of the development strategy is essentially propelled by micro-level decisions, quantitative micro-planning is imperative. The feasibility of designing a planning scenario for forest projects along this locus is illustrated by a case study of Sao Hill Forest Project—the largest state-owned industrial plantation with 45 000 ha planted by 1990 of pines and eucalypts, supporting both a sawmill and an integrated pulp and paper mill. Planting activities include both afforestation and reforestation. Land evaluation is effected as a combination of biophysiographic approach and social cost–benefit analysis. Constrained by resource availability, the optimal combination of planting activities in a given year is determined using linear programming. This planning scenario is technically feasible.

The smallest land unit studied is called a 'land element' which is the simplest component of the landscape which for practical purposes is uniform in lithology, form, soil and vegetation. A stratum of similar elements is called a 'land facet'. Since the profitability of planting at Sao Hill partly depends on the species grown, site productivity, land preparation involved, terrain types and the forest products to be produced, the land elements are redefined as a function of these factors. All the plantable sites or land elements available in year 1984/1985 were inventoried covering 37 310 ha grouped into 62 land facets. Each land facet was identified as an independent forest plantation investment project. The resource demand for each operation on each land facet was gathered from the project management including costings. Financial cash flow was generated followed by shadow pricing, essentially based on the procedure of Little and Mirrlees and its variants. Land expectation value (LEV) was applied in evaluating land facets at financial, economic and social prices. All land facets had positive LEVs, implying that it was worth planting each land facet. Constrained by several resources, it is infeasible to undertake all technically feasible and economically desirable planting activities within the first plan period. Linear programming was found to be useful in solving this decision problem. The solution to the Sao Hill planting problem is given in terms of the number of hectares scheduled for planting between 1984/1985 and 1988/1989 inclusive, embodying the value of the objective function and the shadow prices of the binding constraints. The information generated is very useful to decision-makers and project management.

*Corresponding author.

Introduction

Tanzania has adopted central planning. Because Tanzania's development strategy is principally propelled by micro-level decisions, some quantitative micro-level planning is imperative. This is particularly important, bearing in mind that planning guidelines from the central government are essentially qualitative in content. At micro-level these qualitative guidelines need to be quantified into operational goals and targets. The feasibility of designing a planning scenario for forest project planning at the micro-level is attempted through a case study of Sao Hill Forest Project (see Fig. 1 for the location of Sao Hill in Tanzania).

Sao Hill Forest Project in Mufindi District of Iringa Region is the largest state-owned plantation project in Tanzania with 45 000 ha planted by 1990 with pines and eucalypts. The gazetted area is about 95 000 ha, of which 65 000 ha are suitable for production forestry. The project is administratively divided into three operational spatial divisions, i.e. Divisions I, II and III. Divisions I and III are situated in the high elevation region (1500–2200 m above sea level); Division II is in the low elevation region (100–1200 m above sea level).

Sao Hill Forest Project is the sole source of industrial roundwood input for the Sao Hill sawmill and southern paper mills, supplied annually with 50 000 m^3 and 300 000 m^3 (underbark) respectively. As the wood-based industries do their own logging, Sao Hill's plantation management consists of preparing land available for planting, production of seedlings in its own nurseries, planting and beating up, weeding, pruning, construction and maintenance of plantation roads, and forest protection.

The characteristics of terrain, soil and vegetation have an influence on the land preparation, weeding intensities, logging system adopted, physical productivity in general and cost of forest operations. Based on experimentation, strip ploughing is applied in pine afforestation on ploughable sites while clean weeding and pitting are carried out on sites which are either too steep or obstructed for tractor ploughing and those too broken for mechanical land preparation. However, complete ploughing and disc harrowing are necessary in the establishment of eucalypts.

The planting decision-making context

Investments in forest plantations begin with land preparation and planting operations. In any given year, Sao Hill Forest Project has several plantable sites available for stand establishment situated in various localities of all its three Divisions. Some sites are available for reforestation or artificial regeneration and others for afforestation. Such tracts of land vary in productivity

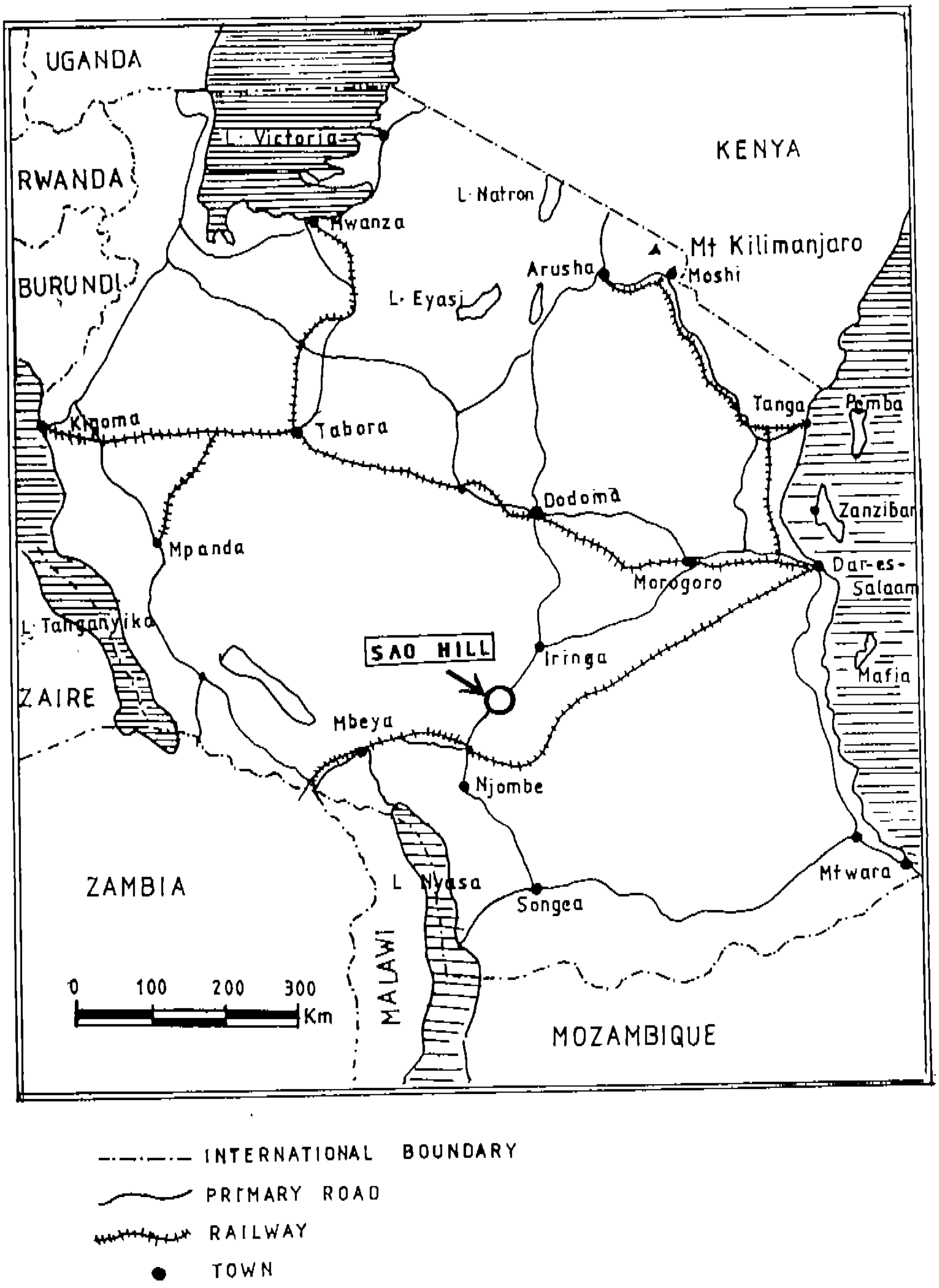

Fig. 1. Map showing location of Sao Hill, Tanzania.

and demand on the available resources. Therefore, the efficacy of investing in planting will depend on the tracts selected for establishment of forest stands.

As Sao Hill Forest Project is state-owned, evaluation of investment opportunities entails social cost–benefit analysis. Four levels of analysis are required: technical or physical appraisal, financial profitability analysis at market prices, economic profitability analysis at efficiency prices, and social profitability analysis at social prices.

Case study methodology

Physical appraisal

To visualise the efficacy of investing in planting a given forest tract during the planning stage, land evaluation is necessary. In project documentation, physical data are normally implicitly covered (Mgeni and Price, 1987). Much emphasis is laid on economic factors such as prices, interest rates and changes in technology. The exposition of physical factors in project planning is equally indispensable.

The quantification of the value of forest yields (project benefits) and project inputs in monetary terms (project costs) must be preceded by an estimation of project outputs and inputs in terms of physical units such as volume, weight, worker-days or machine-hours per hectare. Thus, one prerequisite in forest planning is the acquisition of knowledge on the productive capacity of various tracts of forest land with respect to alternative tree species and other plant cover that grow on them. This calls for an inventory of the forest land. Various pertinent concepts on land classification, land capability classification, land evaluation and site class system are important (Mgeni, 1986).

Various methods are available for classifying and evaluating forest lands. These include land evaluation, terrain classification and site class system. Land evaluation for forestry is "the process of assessing the performance (suitability) of land when used for specific present or projected forms of forestry" (Bennema et al., 1981). Several guidelines have been published on this subject (e.g. Carpenter, 1981; MacCormack et al., 1981; Food and Agriculture Organisation, 1984).

Terrain classification is from an operational point of view. The terrain is classified according to its limitations on the use of specified machinery, equipment and operational methods. The common terrain factors used are ground-bearing capacity, ground roughness and slope (e.g. Rowan, 1977; Berg, 1981; Terlesk, 1983). Since terrain classification is tailored for timber harvesting, it does not exactly provide a basis for planning silvicultural investments like planting.

Site class, site quality or site productivity is "the sum total of all the factors affecting the capacity to produce forests or other vegetation: climatic factors, soil (edaphic) factors and biological factors" (Spurr and Barnes, 1980). An estimation of forest site quality is needed for all tracts of land which differ in productivity, i.e. land units. The models developed for determining site productivity are based on measurements of either stand variables or a combination of site and stand variables. The factors included are those considered important in relation to forest yield.

Realising that site quality is the aggregation of all factors affecting the land capacity to produce forest products, the holistic or total site approach, also known as the multifactor approach (Spurr and Barnes, 1980) and biophysiographic method (Kilian, 1981) has evolved. It is based on interrelationships between forest crops and factors like climate, physiology, soils and vegetation, so that both biotic and environmental factors are considered simultaneously in an attempt to simulate forest ecosystems.

Soil–site index correlation studies and the use of plant species and communities as phytometers of site quality at Sao Hill have yet to be conducted. As a result, site class determination in this case study was guesstimated by the practising foresters aided by factors like indicator plants, surface soil colour, slope surface type (plateau, slope, valley bottom)—an 'informal' biophysiographic approach. The site classes for pines are based on the yield table of Adegbehin (1977) and those of eucalypts on the yield table of Kingston (1972).

The smallest administrative forest unit at Sao Hill is a compartment. Since the compartmentation is arbitrarily done, for appraisal the system should include all factors which affect operational techniques, costs and benefits. In this study, the smallest land unit used is a land element, defined as the "simplest part of the landscape, for practical purposes uniform in lithology, form, soil and vegetation" (Mitchell, 1973). A stratum of similar land elements is called a land facet.

The profitability of planting at Sao Hill partly depends on the species to be grown, site productivity, land preparation involved, the terrain types and the forest products to be produced. Consequently, the land elements are redefined here as a function of site class, tree species to be grown, land preparation type needed, terrain type, Division where the land element is located and the working circle (pulpwood or sawlog). All the plantable sites (land elements) available in the financial year 1984/1985 were inventoried. There were 375 land elements covering 37 310 ha. Since similar land elements will produce the same net benefit per hectare, defining planting projects at this level is an unnecessary detail. For planning purposes, the land elements available for planting in 1984/1985 were classified into land facets. There were 62 land facets—each identified as an independent forest plantation investment project.

The resource demand for each operation on each land facet was gathered from the project management. The operations are land preparation, nursery production, planting, weeding, tending, forest protection, infrastructure development and maintenance, marking of thinnings and administration. The information was decomposed into labour, machinery and equipment, and materials. When the site class of a given land facet is known, its yield or output ($m^3 ha^{-1}$) is extracted from an appropriate yield table.

The main drawback of quantitative physical evaluation is that it does not normally produce a basis for comparison between different forms of forest production. To overcome this obstacle, money is normally used as a numeraire. This is effected by converting quantitative physical data gathered through physical evaluation by the application of monetary values to obtain costs of inputs and value of benefits—financial and socioeconomic evaluations.

Financial cash flow

Taking the information on the resource demand together with the cost per man-day, per kilometre or hour (machinery and equipment), and number of kilograms (materials), the costing for each operation in each land facet is calculated. Such costing constitutes the financial costs, with costs emanating from materials, machinery and equipment decomposed into local (non-traded) and foreign (traded) components.

The impact of Sao Hill Forest Project on the national economy is of import substitution. The forest project charges its dependent wood industry using controlled royalties. Such prices are not appropriate in project evaluation because they are not based on the impact of the forest on the national economy. Consequently, stumpage appraisal is imperative.

This has been approached using the conversion or residue value approach which entails first estimating the market prices of the end products manufactured from the roundwood. The stage of assessing the market prices is the earliest one where the products are sold freely in the market. From the market product price, the stumpage value is residually determined by subtracting from it the costs of logging, transport, milling or pulping and paper making and marketing. The import parity prices (financial, economic and social) for sawlogs and pulpwood produced at Sao Hill are determined using this approach (Mgeni, 1986; Mgeni and Price, 1993).

Using the financial stumpage prices, the financial stream of benefits is computed for each land facet. In any given year, total benefits minus total costs gives financial net benefit. When this is done for a whole rotation, financial net cash flow is created. This is done for all land facets available for planting.

Economic and social cash flows

The social objective of improving people's welfare pursued by many governments can be decomposed into a growth objective (raising the growth rate of national income) and an equity objective (improving the national income distribution). Several applications of cost–benefit analysis to project evaluation have pivoted on the growth objective only. The redistribution of incomes generated by a project has been assumed to be in the government's domain through taxation and subsidies.

Despite Tanzania's policies of redistributing national income through progressive taxation, indirect taxation, wage controls, price controls and subsidies, there are some technical, administrative and control factors which still impose severe limitations on the effectiveness of such policies (Williams, 1979). Thus the concurrent pursuit of growth and equity objectives is relevant in planning Tanzania's economy. Any project evaluation must explicitly embrace these objectives (Mgeni, 1986).

When a project input or output is priced according to the perfect competitive market model, the price of an output tends to equal its marginal cost of production, while that of factors of production is their opportunity cost. Under such a situation, market prices reflect the socially desirable prices for evaluating resource allocation alternatives. The Tanzanian markets for many factors of production and commodities do not follow the perfectly competitive market model. Under such conditions, the pricing of inputs and outputs is not based on equating marginal costs to marginal revenue or value, that is, the marginal value of the output or input is either overstated or understated. Correcting or adjusting the ruling prices fixed under imperfect market conditions is imperative if they are to reflect their marginal opportunity cost and marginal willingness to pay in project planning—a process called shadow or accounting pricing.

Shadow pricing is essentially based on the procedure of Little and Mirrlees (1974), including its variants (Squire and Van der Tak, 1975; Bruce, 1976; Irvin, 1978). In addition to whether the project input or output is freely marketed or not, and whether it is measured in domestic or border prices, the economic and social value of the project cost or benefit depends on: (1) whether the project benefit (income) is saved or consumed; (2) whether the project beneficiary is a private individual or government; (3) which private income group is the project beneficiary; (4) the point in time when the project cost is incurred or benefit realised.

These dimensions are incorporated in this study using the guidelines provided by Little and Mirrlees (1974), Squire and Van der Tak (1975), Bruce (1976) and Irvin (1978), where necessary modified to fit the planning situation. Based on all these shadow prices, flows of both economic and social costs and benefits are compiled for the whole rotation.

Evaluation of land facets

Land evaluation in forestry has been of interest for many years. As long ago as 1849, Martin Faustmann presented the Faustmann Formula or Land Expectation Value (LEV) formula as a basis for land taxation. The Faustmann Formula is the earliest known application of the discounted cash flow concept in a management context (Linnard and Gane, 1968). This contribution did not permeate into economics until the principles of discounted cash flow were independently expanded by Fisher (1907). Many variations of the Faustmann formula are used in computing LEV. The variations primarily depend on the ways in which costs and revenues of various kinds and timings are explicitly recognised (Davis, 1966; Gregory, 1972). The formula used in this study is:

$$\text{LEV} = \text{PNW}\frac{(1+r)^T}{(1+r)^T-1}$$

where LEV is the land expectation value, PNW is the present net worth or net discounted revenue of a single rotation, r is the discount rate and T is rotation age in years.

The LEV for each land facet available for planting in a given year was calculated using financial, economic and social cost and benefit flows computed as previously explained with a market rate of interest of 12% and economic accounting rate of interest of 10%. Social discount rates can be determined in several ways (Price, 1989). Since the appropriate method for Tanzania is still

Table 1
Examples of LEV per hectare of land facets available for planting in 1984/1985

T.Shs[1]			Border T.Shs						
			Social at discount rate						
Land facet	Financial	Economic	0.013	0.0225	0.026	0.032	0.035	0.039	0.041
1	123675	185406	10685539	2949485	2247630	1094444	926552	762302	710602
2	122930	187168	30986866	5221699	3562154	1478666	1186806	985000	900120
3	89532	146609	9618719	2599393	1965028	954839	804529	660321	613399
26	70668	107366	24767944	4078110	2742725	909882	725401	562918	512997
27	54994	83421	19747311	3248558	2184235	674868	540560	438374	399664
28	55306	83521	19747549	3248782	2184453	674074	540759	438567	399855
30	55694	83797	19747885	3249114	2184781	674397	541080	438887	400172
31	55694	83797	19749885	3249114	1184781	675397	541080	438887	400172
40	123607	185246	30987366	5222366	3562594	1479063	1187184	952354	900540
41	123928	185349	30987610	5222390	3562818	1479275	1187390	985553	900736
50	76031	126352	20742020	3545480	2441644	1096201	878386	681285	623041
51	76343	126452	20742257	3545704	2441862	1096407	878586	681479	623231
60	56912	97335	17606230	2989414	2048608	876257	702316	547159	499301
61	57223	97435	17606466	2989638	2048826	876462	702515	547352	499490
62	57223	97435	17606466	2989638	2048826	876462	702515	547352	499490

[1]Tanzanian shillings (T.Shs 230=US$1.00, 1991).

indeterminate, several rates have been calculated as social discount rates, i.e. 1.3, 2.25, 2.6, 3.5, 3.9 and 4.1%.

All land facets available for planting in 1984/1985 had positive LEVs at financial, economic and social analyses, implying that it was worth planting each land facet (see Table 1 for some selected land facets for illustration of changes in financial, economic and social prices).

Application of linear programming to the planting decision problem

Because of limits on the availability of labour, seedlings, and budget, it will not be possible to undertake all technically feasible and economically desirable planting activities within the first plan period. There are also long-term constraints enforced by the limited capacity of pulp and sawmill to absorb production. The problem therefore arises of the best order in which to undertake the activities without infringing any of these constraints. Giving priority to land facets with the highest LEV implicitly takes the land to be the binding resource. This is not necessarily the case.

The Sao Hill Forest planting problem may be solved by linear programming methods. Among others, Dantzig (1963) has detailed the exposition of the linear programming model. The literature on linear programming in general is vast, including its application in forestry—particularly in scheduling of timber harvests (see e.g. Clutter et al., 1983; Dykstra, 1984; Buongiorno and Gilless, 1987; Davis and Norman Johnson, 1987; Garcia, 1990; Jamnick, 1990; Hof and Baltic, 1990; Sherali and Liu, 1990; Pickens et al., 1990; Nelson et al., 1991; Weintraub and Cholaky, 1991). The model is limited to situations where the objective function and all constraints can be expressed mathematically as linear equations and inequalities. Each production alternative is called an activity or decision variable. The assumptions embodied in linear programming are determinacy, linearity and fixed (static) technology.

In the Sao Hill Forest planting problem, the expected land management practices for each land facet represent the activities or decision variables. The constraints are quantities of inputs needed and outputs of pulpwood and sawlogs in each time period. The objective function is maximisation of global LEV under financial, economic or social pricing and using the appropriate discount rates. The solution of a linear programming problem gives the optimal values of the decision variables, that is, the number of hectares of different land facets to be planted. The mathematical formulation of the Sao Hill planting decision problem is presented in Appendix A.

Based on the Sao Hill logging plan, the areas which were available for reforestation and artificial regeneration were pulled together with areas available for afforestation. However, the industrial roundwood constraint has been formulated in such a way that volume from thinnings and clearfelling of a given land facet is obtainable as if at one point in time. Furthermore, the volume obtainable from a given year planting programme is assumed to be available at one point in time in the future. This is an abstraction because volumes from thinnings and clearfelling for a given land facet will be realised at different points in time and such a sequence will vary from one land facet to another. Consequently, there exists interdependence in terms of volume production among different year planting programmes. If the wood constraint as formulated in this study is consistently annually applied in scheduling planting, it is assumed to mimic actual sustained yield scheduling in harvesting. The silvicultural budget constraint had been formulated as a means of forecasting the budget required for implementing the linear programming solution to the planting decision problem. The actual silvicultural budget was available only for the year 1984/1985.

The objective function value coefficients, technological coefficients per hectare for all land facets and the bounds of constraints (right-hand side constraint values) were assembled in a form of tableaux using financial, economic and social prices. The aim of the study was to schedule a 5 year (1984/1985–1988/1989) planting programme for Sao Hill Forest. The 5 year planting programme was designed sequentially on an annual basis. In a given year, any land facet or portion of it left unplanted was carried forward to the following year.

The problem was run at the University of Manchester Regional Computer Centre using MPOS (version 4) (University of Manchester Regional Computer Centre, 1980) revised simplex method.

Results and discussion

The solution to the Sao Hill planting problem is given in terms of the number of hectares scheduled for planting between 1984/1985 and 1988/1989 inclusive, embodying the value of the objective function and the shadow prices of the binding constraints. These are presented in Tables 2–9. To reduce the number of tables, Table 6 summarises scheduled planting using social prices while Table 7 illustrates shadow prices for the binding constraints in 1984/1985 with binding constraints during the planning period listed in Table 8. Table 9 contains the total value of the linear programming objective function at financial, economic and social prices.

When the sequence of land facets scheduled for planting for the period 1984/1985–1988/1989 is compared with the ranking according to LEV, the results are inconsistent (see Table 10). The demand for unskilled labour per hectare differs considerably among various land preparation types. Under this planning situation, the way unskilled labour is priced affects the ranking of land facets for planting according to LEV. Economic and social rankings tend to favour land facets whose land preparation is labour intensive. This empha-

Table 2
Linear programming solution using financial prices

Land characteristics						Hectares to be planted				
Number	Terrain[1]	Division	Species[2]	Site class	Working circle[3]	1984/85	1985/86	1986/87	1987/88	1988/89
9	Plateau	I	Euc.	II	PWC	191.0	191.0			
14	Slope 1	II	P_c	I	PWC	382.1	443.0			
15	Slope 1	II	P_c	I	PWC	25.0				
16	Slope 1	II	P_c	I	PWC	149.0				
17	Slope 2	II	P_c	I	PWC	40.0				
18	Slope 1	II	P_c	I	PWC	27.0				
19	Slope 2	II	P_c	I	PWC	54.0				
21	Slope 1	II	P_c	II	PWC		83.1			
22	Slope 1	II	P_c	II	PWC		151.0			
41	Slope 1	III	P_p	I	SWC	108.3	111.0			
Total hectares						976.4	979.1	No feasible solution		
Total value of the objective function (million T.Shs[4])						110.4	105.2			

[1]Slope 1, terrain with gradient 5.1–10%; Slope 2, terrain with gradient over 10.0%.
[2]Euc., *Eucalyptus* spp.; P_c, *Pinus caribaea*; P_p, *Pinus patula*.
[3]PWC, pulpwood working circle; SWC, sawlog working circle.
[4]Tanzanian shillings (T.Shs 230 = US$1.00, 1991).

Table 3
Areas selected for planting in 1984/1985 by the Sao Hill Forest management

Land facet characteristics						Hectares planted in 1984/85
Number	Terrain	Division	Species	Site class	Working circle	
1	Slope 1	I	P_p	I	SWC	5.6
7	Plateau	I	Euc.	I	PWC	7.5
9	Plateau	I	Euc.	II	PWC	4.9
22	Slope 1	II	P_c	II	PWC	11.0
23	Slope 2	II	P_c	III	PWC	480.0
25	Slope 1	II	P_c	III	PWC	35.0
26	Slope 1	II	P_c	III	PWC	75.0
27	Slope 1	II	P_c	IV	PWC	28.0
28	Slope 1	II	P_c	IV	PWC	60.0
33	Plateau	II	Euc.	I	PWC	55.0
50	Slope 1	III	P_c	III	SWC	120.0
52	Slope 1	III	P_c	III	SWC	360.0
53	Slope 1	III	P_c	III	SWC	70.0
58	Slope 1	III	P_c	IV	SWC	340.0
Total hectares planted						1652.0

Symbols as defined in Table 2.

Table 4
Linear programming solution using economic prices

Land facet characteristics						Hectares to be planted				
Number	Terrain	Division	Species	Site class	Working circle	1984/85	1985/86	1986/87	1987/88	1988/89
1	Slope 1	I	P_p	I	SWC	6.0	74.0	18.0	106.8	4.0
9	Plateau	I	Euc	II	PWC	43.3	169.6	145.5	145.5	145.5
13	Plateau	I	Euc	IV	PWC	218.0				
14	Slope 1	II	P_c	I	PWC	652.1	173.0			
15	Slope 1	II	P_c	I	PWC	25.0				
16	Slope 1	II	P_c	I	PWC		149.0			
17	Slope 2	II	P_c	I	PWC		40.0			
18	Slope 1	II	P_c	I	PWC		27.0			
19	Slope 2	II	P_c	I	PWC		54.0			
20	Slope 1	II	P_c	II	PWC			370.1	677.1	677.1
21	Slope 1	II	P_c	II	PWC		83.1	307.0		
22	Slope 1	II	P_c	II	PWC		151.0			
38	Plateau	II	Euc	IV	PWC	56.3	4.8	29.0		
39	Plateau	II	Euc	IV	PWC			27.3	56.3	56.3
41	Slope 1	III	P_p	I	SWC	91.5	26.7	88.8		33.3
42	Slope 1	III	P_p	I	SWC					69.9
Total hectares						1092.0	952.2	985.7	985.7	958.8
Total value of the objective function (million T.Shs)						156.5	146.6	134.2	134.1	134.1

Symbols as defined in Table 2.

Table 5
An example of linear programming solution using social prices with a discount rate of 0.032

Land facet characteristics						Hectares to be planted				
Number	Terrain	Division	Species	Site class	Working circle	1984/85	1985/86	1986/87	1987/88	1988/89
10	Plateau	I	Euc.	II	PWC	59.6	169.2	169.2	169.2	106.0
12	Plateau	I	Euc.	III	PWC					88.6
13	Plateau	I	Euc	IV	PWC	218.0				
14	Slope 1	II	P_c	I	PWC	248.3	543.3	34.0		
15	Slope 1	II	P_c	I	PWC	25.0				
16	Slope 1	II	P_c	I	PWC	149.0				
17	Slope 2	II	P_c	I	PWC	40.0				
18	Slope 1	II	P_c	I	PWC	27.0				
19	Slope 2	II	P_c	I	PWC	54.0				
20	Slope 1	II	P_c	II	PWC			55.0	635.8	635.8
21	Slope 1	II	P_c	II	PWC			390.0		
22	Slope 1	II	P_c	II	PWC			151.0		
41	Slope 1	III	P_p	I	SWC	49.0	49.0	49.1	49.2	44.0
42	Slope 1	III	P_p	I	SWC					5.2
Total hectares						869.9	761.5	848.3	854.2	879.6
Total value of the objective function (million T.Shs)						918.5	917.9	879.8	877.1	877.1

Symbols as defined in Table 2.

Table 6
Linear programming solution (in hectares to be planted)

Discount rate	1984/85	1985/86	1986/87	1987/88	1988/89
0.013	878.8	884.0	917.0	917.0	917.0
0.0225	878.8	884.0	917.0	917.0	917.0
0.026	878.8	884.0	917.0	917.0	917.0
0.032	869.9	761.5	848.3	854.2	879.6
0.035	799.6	802.0	887.2	856.9	934.2
0.039	782.2	784.6	862.3	857.5	935.8
0.041	783.2	785.6	863.4	858.3	936.6
0.10	1092.2	952.2	985.7	985.7	958.8
0.12	976.4	979.1	–	–	–

Table 7
Shadow prices (T.Shs[1]) for binding constraints in 1984/1985

Constraint	Financial	Economic	Social with discount rate (%)						
			1.3	2.25	2.6	3.2	3.5	3.9	4.1
Pinus caribeae seedlings in Division II	50	64	16536	2717	1507				
Maximum eucalypt pulpwood	185	212	15969	3027	2160	1030	868	742	701
Maximum pine sawlog	284	424	58858	9582	6537	1594	1393	1044	988
Labour available during planting in Division II		562							
Maximum pine pulpwood						2035	1702	1513	1370

[1]Tanzanian shillings (T.Shs 230 = US$1.00, 1991).

sises the importance of applying social cost–benefit analysis in land evaluation where plantation programmes are created partly to effect employment opportunities and equity dimensions.

The total value of the objective function generally decreases with time at all levels of analysis (financial, economic and social). Linear programming selected land facets in descending order of productivity and net benefits. Furthermore, for each financial year, the value of the objective function increases as one moves sequentially from financial, economic to social stages of analysis (see Table 9).

The 1984/1985 planting programme selected by Sao Hill management (see Table 3) was compared with that of linear programming. The summed LEVs of the activities selected by the Sao Hill management exceeded the value of

Table 8
Binding constraints during 1984/1985–1988/1989

Constraint	Financial	Economic	Social with discount rate (%)						
			1.3	2.25	2.6	3.2	3.5	3.9	4.1
Pinus caribaea seedlings in Division II	+	+	+	+	+	–	–	–	–
Maximum eucalypt pulpwood	+	+	+	+	+	+	+	+	+
Maximum pine sawlog	+	+	+	+	+	+	+	+	+
Labour available during planting in Division II	–	+	–	–	–	–	–	–	–
Maximum pine pulpwood	–	–	–	–	–	+	+	+	+

+, binding constraint; –, non-binding constraint.

Table 9
Total value (million T.Shs[1]) of the objective function during 1984/1985–1988/1989

Year	Financial	Economic	Social with discount rate (%)						
			1.3	2.25	2.6	3.2	3.5	3.9	4.1
1984/85	110.4	156.5	28371.3	4727.0	3197.0	918.5	774.1	667.4	611.3
1985/86	105.2	146.6	27176.9	4530.1	3064.7	917.9	773.9	667.3	611.2
1986/87	–	134.2	33921.7	4157.2	2814.2	879.8	708.8	586.6	557.7
1987/88	–	134.1	24911.6	4157.2	2814.2	877.1	704.7	580.4	553.6
1988/89	–	134.1	24911.6	4157.2	2814.1	877.1	704.5	580.2	553.4

[1]Tanzanian shillings (T.Shs 230=US$1.00, 1991).

the linear programming solution. However, the value calculated for the Sao Hill management programme assumed that no binding constraints existed, in particular that all the wood produced could be sold at current prices. As the strategy involves overproduction of sawlogs for current mill capacity, this may not be true. Also, the strategy fails to meet minimum targets for the production of industrial eucalypt wood. Hence, the marketing of roundwood regarded by Sao Hill Forest management as not being a binding constraint is not valid, as demonstrated in the linear programming solution (see Tables 7 and 8) unless the wood industry processing capacities are expanded.

In Table 2, from 1986/1987 to 1988/1989, no feasible solution was found. An oversight was made in not carrying out a sensitivity analysis to identify the factors which caused such an infeasibility. Such information would have been useful to management. However, it is a pointer that it is not feasible to

Table 10
Scheduling of land facets for planting by linear programming compared with that of LEV

Criterion	Discount rate (%)	Working circle		
		Eucalypt pulpwood	Sawlog	Pine pulpwood
Financial	12	0	×	×
Economic	10	0	×	0
Social	3.2	0	×	×
	3.5	0	0	×
	3.9	0	×	×
	4.1	0	×	×
	1.3	0	×	×
	2.25	0	×	×
	2.6	0	×	×

×, LEV chronological order of ranking of land facets is observed by linear programming; 0, LEV chronological order ranking of land facets is violated by linear programming.

achieve sustainable yield strictly on a financial basis. Being feasible at economic and social levels of analysis, the realisation of sustainable yield at Sao Hill can be said to be a socio-economic goal.

Conclusion

Public industrial afforestation and reforestation programmes should be designed in such a way that they are environmentally sound, technically feasible, economically viable and socially acceptable. This can be achieved by combining quantitative physical land evaluation like the biophysiographic approach and social cost–benefit analysis in the planning scenarios.

Where a number of constraints are binding, these approaches may be further combined with linear programming techniques. This seems to be particularly appropriate in a centrally planned system as in Tanzania where the method of decision-making sets constraints on the availability of resources which cannot be readily eased at the local level. The linear programming solution also gives decision-makers information on the value of easing constraints, for instance by increasing the availability of seedlings of a particular species or expanding the capacity of processing industries. Some of these actions may lie within the scope of local management while others must be passed to a higher political level for consideration.

The scope of the methodology in this study runs the whole way from physical and biological land classification through financial and social economics to the political structure of decision-making. As such it broadly confronts the realities of forest management decision-making and attempts to integrate the range of relevant factors rather than set physical, biological, financial, economic, social and political factors in opposition to each other.

The main limitation with this methodology is that it demands detailed quantitative information, ranging from national accounts to forest project operations. Depending on data availability and with some modification, the methodology can be applied elsewhere.

Acknowledgement

The authors are grateful to the Norwegian Agency for International Cooperation (NORAD) for financial support of this work. They are also grateful to anonymous reviewers.

References

Adegbehin, J.O., 1977. The studies of dominant height development and yield of *Pinus patula* at Sao Hill, Southern Tanzania. M.Sc. (For.) Thesis, University of Dar es Salaam, 83 pp. (Unpublished.)

Bennema, J., Gelens, H.F. and Laban, P., 1981. Principles, basic concepts and procedure in land evaluation considered from a forestry angle. In: P. Laban (Editor), Proc. of the Workshop on Land Evaluation, Publ. 28, ILRI, Wageningen, pp. 181–202.

Berg, S., 1981. Terrain classification systems for forestry in the Nordic countries. In: P. Laban (Editor), Proc. of the Workshop on Land Evaluation, Publ. 28, ILRI, Wageningen, pp. 152–166.

Bruce, C., 1976. Social cost–benefit analysis: A guide for country and project economists to the derivation and application of economic and social accounting prices. World Bank Staff Working Pap. 239, Washington, DC, 143 pp.

Buongiorno, J. and Gilless, J.K., 1987. Forest management and economics. Macmillan, New York, 288 pp.

Carpenter, R.A. (Editor), 1981. Assessing Tropical Forest Lands: Their Suitability for Sustainable Uses. Tycooly, Dublin, 337 pp.

Clutter, J.L., Fortson, J.C., Piennar, L.V., Brister, G.H. and Bailey, R.L., 1983. Timber management: A quantitative approach. John Wiley, New York, 333 pp.

Dantzig, G., 1963. Linear Programming and Extensions. Princeton University Press, 632 pp.

Davis, K.P., 1966. Forest Management: Regulation and Evaluation. McGraw-Hill, New York, 519 pp.

Davis, L.S. and Norman Johnson, K., 1987. Forest Management, 3rd edn. McGraw-Hill, New York, 790 pp.

Dykstra, D.P., 1984. Mathematical programming for natural resource management. McGraw-Hill, New York, 318 pp.

Fisher, I., 1907. The Rate of Interest. Macmillan, New York, 566 pp.

Food and Agriculture Organisation, 1984. Land evaluation for forestry. For. Pap. 48, FAO, Rome, 123 pp.

Garcia, O., 1990. Linear programming and related approaches in forest planning. N.Z. J. For. Sci., 20(3):307–331.

Gregory, G.R., 1972. Forest resource economics. Ronald Press, New York, pp. 270–304.

Hof, J.G. and Baltic, T.J., 1990. Cost effectiveness from regional optimization in the USDA forest service. For. Sci., 36(4):939–954.

Irvin, G., 1978. Modern Cost–benefit Methods. An Introduction to Financial Economics and Social Appraisal of Development Projects. Macmillan, London, 257 pp.

Jamnick, M.S., 1990. A comparison of FORMAN and linear programming approaches to timber harvest scheduling. Can. J. For. Res., 20(9):1351–1360.

Kilian, W., 1981. Site classification systems used in forestry. In: P. Laban (Editor), Proc. of the Workshop on Land Evaluation, Publ. 28, ILRI, Wageningen, pp. 134–151.

Kingston, B., 1972. Growth, yield and rotation of seedling crops of *Eucalyptus grandis* in Uganda. Tech. Note 193/72, Uganda Forestry Department, Entebbe, 6 pp.

Linnard, W. and Gane, M., 1968. Martin Faustmann and the evolution of discounted cash flow. Two articles from the original German 1849. Institute Pap. No. 42, Commonwealth Forestry Institute, University of Oxford, 55 pp.

Little, I.M.D. and Mirrlees, J.A., 1974. Project appraisal and planning for developing countries. Heinemann, London, 388 pp.

MacCormack, D.E., Hartung, R.E. and Larson, K.N., 1981. Evaluation of forest land in the United States. In: P. Laban (Editor), Proc. of the Workshop on Land Evaluation, Publ. 28, ILRI, Wageningen, pp. 167–179.

Mgeni, A.S.M., 1986. Planning of forest investments with aid of quantitative models: A case study at Sao Hill Project in Tanzania. Ph.D. Thesis, University College of North Wales, Bangor, UK, 312 pp. (Unpublished.)

Mgeni, A.S.M. and Price, C., 1987. Land evaluation for industrial afforestation and reforestation programmes: A case study of Sao Hill Forest Project in Tanzania. In: H.G. Lund, M. Caballero-Deloya and R. Villarreal-Canton (Editors), Land and resource evaluation for national planning in the tropics. Rep. WO-39, USDA Forest Service, Washington, DC, pp. 476–480.

Mgeni, A.S.M. and Price, C., 1993. Stumpage appraisal in public forestation planning situations. A case study of Sao Hill Forest Project, Tanzania. Rec. 58, Faculty of Forestry, Sokoine University of Agriculture, Morogoro, 18 pp.

Mitchell, C.W., 1973. Terrain Evaluation. Longman, London, 211 pp.

Nelson, J., Douglas Brodie, J. and Sessions, J., 1991. Integrating short-term, area-based logging plans with long-term harvest schedules. For. Sci., 37(1):101–122.

Pickens, J.B., Kent, B.M. and Ashton, P.G., 1990. The declining even flow effect and the process of national planning. For. Sci., 36(3):665–679.

Price, C., 1989. The Theory and Application of Forest Economics. Basil Blackwell, Oxford, 402 pp.

Rowan, A.A., 1977. Terrain classification. Forestry Commission Forest Record 114, HMSO, London, 22 pp.

Sherali, H.D. and Liu, C.M., 1990. Identification of a network substructure and some algorithmic considerations for large-scale harvest scheduling problems. For. Sci., 36(3): 199–613.

Spurr, S.H. and Barnes, B.V., 1980. Forest Ecology, 3rd edn. John Wiley, New York, pp. 297–335.

Squire, L. and van der Tak, H.G., 1975. Economic analysis of projects. Johns Hopkins University Press, Baltimore, MD, 153 pp.

Terlesk, C.J., 1983. A proposed terrain classification for harvesting in New Zealand. N. Z. J. For., 28:43–57.

University of Manchester Regional Computer Centre, 1980. MPOS, Version 4.

Weintraub, A. and Cholaky, A., 1991. A hierarchical approach to forest planning. For. Sci., 37(2):439–460.

Williams, D., 1979. National planning and the choice of technology. In: K.S. Kim, R.B. Mabele and N.J. Schultheis (Editors), Papers on Political Economy of Tanzania. Heinemann, Nairobi, pp. 41–46.

Appendix A

Mathematical formulation of Sao Hill planting decision problem

Definition of subscripts

j = site class
$j = 1, 2, ..., q'$ (*Eucalyptus* spp. in Division I)
$j = q'+1, q'+2, ..., q$ (*Pinus patula* in Division I)
$j = q+1, q+2, ..., s$ (*Pinus caribaea* var. *hondurensis* in Division II)
$j = s+1, s+2, ..., m'$ (*Eucalyptus* spp. in Division II)
$j = m'+1, m'+2, ..., m$ (*Pinus patula* in Division III)
k = species
$k = 1$ (*Eucalyptus* spp.)
$k = 2$ (*Pinus caribaea* var. *hondurensis*)
$k = 3$ (*Pinus patula*)
l = land preparation type
$l = 1$ (trash piling and burning in clearfelled stands)
$l = 2$ (clearing damaged and non-utilised tree crops, for instance fire burnt or drought)
$l = 3$ (complete ploughing without scrub clearing)[1]
$l = 4$ (scrub clearing and complete ploughing)[1]
$l = 5$ (scrub clearing and strip ploughing)[2]
$l = 6$ (strip ploughing without scrub clearing)[2]
$l = 7$ (scrub clearing, spot weeding and pitting)[3]
$l = 8$ (spot weeding and pitting without scrub clearing)[3]
Explanation for 1, 2 and 3 on land preparation types
1 = Plateaux with gradients of 0–5.0% in Divisions I and II
2 = Slopes with gradients of 5.1–10.0% in Divisions I and II while in Division III includes plateaux with gradients of 0–0.5%
3 = Slopes with gradients of more than 10.0% or land elements with gradients 0–10.0% but inaccessible to land preparation by tractor because they are encircled by elements with gradients of more than 10.0% or too loose for mechanical land preparation.
v = terrain type
$v = 1$ (plateau)
$v = 2$ (slope)
$v = 3$ (valley bottoms)
v' = Division of the project
$v' = 1$ (Division I)
$v' = 2$ (Division II)
$v' = 3$ (Division III)
w = working circle
$w = 1$ (sawlog working circle)
$w = 2$ (pulpwood working circle)

w' = harvesting type
$w'=1$ (thinning)
$w'=2$ (clearfelling)
y = wood assortment type
$y=1$ (pulpwood)
$y=2$ (sawlog)
z = silvicultural treatment type
$z=1$ (planting)
$z=2$ (regenerating eucalypt by coppicing)
$z=3$ (pruning)
$z=4$ (marking thinnings)
T = rotation age in years
t = Year ($t=0, 1, 2, ..., T$)

Definition of decision variables using social[1] prices, coefficients and right-hand side values

$X_{jklvv'w}$ is the number of hectares of a land facet on site class j planted with species k under land preparation type l situated on terrain type v in Division v' under working circle w.
$N_{jklvv'w}$ is the net discounted social benefit (T.Shs worth) obtainable by investing on a hectare of a land facet on site class j with species k under land preparation type l situated on terrain type v in Division v' and under working circle w.
$S_{jklvv'w}$ is the transplant demand in planting a hectare of a land facet on site class j with species k under land preparation type l situated on terrain type v in Division v' and under working circle w.
$C_{jkltvv'wz}$ is the cost (T.Shs) of treating a hectare of a stand on land facet j with species k subjected to land preparation type l given a silvicultural treatment in year t situated on terrain type v in Division v' under working circle w and given a silvicultural treatment type z.
$Q_{jkltvv'ww'y}$ is the volume (m^3, under bark) of roundwood obtainable by planting a hectare of a land facet on site class j with species k subjected to land preparation type l harvested in year t situated on terrain type v in Division v' under working circle w by harvesting type w' and of wood assortment type y.
$L_{jklvv'w}$ is the labour (man-days) demand in planting a hectare of a land facet on site class j with species k subjected to land preparation type l situated on terrain type v in Division v' under working circle w.
$A_{jklvv'w}$ is the total number of hectares of a land facet on site class j with species k subjected to land preparation type l situated on terrain type v in Division v' under working circle w.
$D1_e$ = Minimum annual demand (m^3, under bark) of eucalypt pulpwood

[1]The same format is applicable when using financial and economic costs.

$D2_e$ = Maximum annual demand (m³, under bark) of eucalypt pulpwood.
$D1_p$ = Minimum annual demand (m³, under bark) of pine pulpwood
$D2_p$ = Maximum annual demand (m³, under bark) of pine pulpwood
$D3_p$ = Minimum annual demand (m³, under bark) of pine sawlogs
$D4_p$ = Maximum annual demand (m³, under bark) of pine sawlogs
$E1$ = Total number of eucalypt transplants available for planting in Division I
$E2$ = Total number of eucalypt transplants available for planting in Division II
P_c2 = Total number of transplants of *Pinus caribaea* var. *hondurensis* available for planting in Division II
P_p1 = Total number of transplants of *Pinus patula* available for planting in Division I
P_p3 = Total number of transplants of *Pinus patula* available for planting in Division III
$M1$ = Total number of man-days that can be recruited for planting operations in Division I
$M2$ = Total number of man-days that can be recruited for planting operations in Division II
$M3$ = Total number of man-days that can be recruited for planting operations in Division III

Objective function and constraints

Objective function

$$\text{Maximise } Z=\sum_{j=1}^{m}\sum_{k=1}^{3}\sum_{l=1}^{8}\sum_{v=1}^{3}\sum_{v'=1}^{3}\sum_{w=1}^{2} N_{jklvv'w}\times X_{jklvv'w}$$

subject to:

(1) Seedling constraint: where the total number of transplants planted cannot exceed the total of transplants available for planting.

(a). *Eucalyptus* spp.:

(i) Division I

$$\sum_{j=1}^{q'}\sum_{l=1}^{4} S_{j1l112}\times X_{j1l112}\leqslant E1$$

(ii) Division II

$$\sum_{j=s+1}^{m'}\sum_{l=3}^{4} S_{j1l122}\times X_{j1l122}\leqslant E2$$

(b) *Pinus caribaea* var *hondurensis*:

(i) Division II only

$$\sum_{j=q'+1;\,m'+1}^{qm} \sum_{k=2}^{3} \sum_{l=1:5}^{2;\,8} \sum_{t=8}^{T} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} \sum_{w'=1}^{2} Q_{jkltvv'ww'1} \times X_{jklvv'w} \geqslant D1_{\mathrm{p}}$$

(ii) Maximum

$$\sum_{j=q'+1;\,m'+1}^{q;\,m} \sum_{k=2}^{3} \sum_{l=1:5}^{2;\,8} \sum_{t=8}^{T} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} \sum_{w'=1}^{2} Q_{jkltvv'ww'1} \times X_{jklvv'w} \leqslant D2_{\mathrm{p}}$$

(c) Pine sawlog

(i) Minimum

$$\sum_{j=q'+1;\,m'+1}^{q;\,m} \sum_{k=2}^{3} \sum_{l=1;\,5}^{2;\,8} \sum_{t=10}^{T} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} \sum_{w'=1}^{2} Q_{jkltvv'ww'2} \times X_{jklvv'w} \geqslant D3_{\mathrm{p}}$$

(ii) Maximum

$$\sum_{j=q'+1;\,m'+1}^{q;\,m} \sum_{k=2}^{3} \sum_{l=1;\,5}^{2;\,8} \sum_{t=10}^{T} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} \sum_{w'=1}^{2} Q_{jkltvv'ww'2} \times X_{jklvv'w} \leqslant D4_{\mathrm{p}}$$

(4) Area constraint of each land facet: where the total area planted on any land facet cannot exceed its total area.

$$X_{jklvv'w} \leqslant A_{jklvv'w}$$

(5) Silvicultural budget constraint: a required budget for a specified silvicultural treatment during the implementation of the optimum solution in 1984/1985 prices.

(a) Planting[2]

$$\sum_{j=1}^{m} \sum_{k=1}^{3} \sum_{l=1}^{8} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} \sum_{z=1}^{2} C_{jkl1vv'wz} \times X_{jklvv'w} \geqslant 0$$

(b) Pruning

$$\sum_{j=q'+1;\,m'+1}^{s;\,m} \sum_{k=2}^{3} \sum_{l=1;\,5}^{2;\,8} \sum_{v=1}^{3} \sum_{v'=1}^{3} \sum_{w=1}^{2} C_{jklt=4-8;\,10;\,vv'w3} \times X_{jklvv'w} \geqslant 0$$

(c) Marking thinnings

$$\sum_{j=q'+1;\,m'+1}^{q;\,m} \sum_{l=1;\,5}^{2;\,8} \sum_{v=1}^{3} C_{j3lt=10,12,14,15,19,20,23\text{–}25;\,vv'=1,3;\,14} \times X_{j31vv'1} \geqslant 0$$

(6)Non-negativity condition: this is to ensure that all the activity levels in the solution are at least equal to zero. Without this restriction, a negative number of hectares may be assigned by the computer to be planted.

$$X_{jklvv'w} \geqslant 0$$

[2]Includes land preparation and beating up.

$$\sum_{j=q+1}^{s}\sum_{l=5}^{8}\sum_{v=2}^{3} S_{j2lv22}\times X_{j21v22}\leqslant P_c 2$$

(c) *Pinus patula*

(i) Division I

$$\sum_{j=q'+1}^{q}\sum_{l=1}^{2}\sum_{v=2}^{3} S_{j31v11}\times X_{j31v11}\leqslant P_p 1$$

(ii) Division III

$$\sum_{j=m'+1}^{m}\sum_{l=4}^{8}\sum_{v=1}^{3} S_{j3lv31}\times X_{j31v31}\leqslant P_p 3$$

(2) Labour constraint in planting operation: where the total number of man-days which can be utilised in planting cannot exceed the total number of man-days that can be feasibly recruited.

(a) Division I

$$\sum_{j=1}^{q}\sum_{l=1}^{2}\sum_{v=1}^{3}\sum_{w=1}^{2} L_{jk=1,3;\, lv1w}\times X_{jk=1,3;\, lv1w}\leqslant M1$$

(b) Division II

$$\sum_{j=q+1}^{m}\sum_{l=3}^{8}\sum_{v=1}^{3} L_{jk=1,2;\, 1v22}\times X_{jk=1,2;\, 1v22}\leqslant M2$$

(C) Division III

$$\sum_{j=m'+1}^{m}\sum_{l=5}^{8}\sum_{v=1}^{3} L_{j3lv31}\times X_{j3lv31}\leqslant M3$$

(3) Industrial roundwood demand constraint: where the wood production from a planting programme should meet the annual wood quantity demanded by the wood-based industry.

(a) *Eucalypt* pulpwood

(i) Minimum:

$$\sum_{j=1;\, s+1}^{q';\, m'}\sum_{l=1}^{4}\sum_{t=7}^{T}\sum_{v'=1}^{2} Q_{j1ltlv'221}\times X_{j1l1v'2}\geqslant D1_e$$

(ii) Maximum:

$$\sum_{j=1;\, s+1}^{q';\, m'}\sum_{l=1}^{4}\sum_{t=7}^{T}\sum_{v'=1}^{2} Q_{j1ltlv'221}\times X_{j1l1v'2}\leqslant D2_e$$

(b) Pine pulpwood

(i) Minimum

Submission of manuscripts.
The **preferred** medium of submission is on disk with accompanying manuscript (see "Electronic manuscripts" below). Manuscripts should be submitted in triplicate with the disk. Authors from the Americas, Australia, New Zealand and the Pacific are requested to send their manuscripts to *Forest Ecology and Management*, Dr. Richard F. Fisher, Department of Forest Science, Texas A&M University, College Station, TX 77843-2135, USA; all other authors are requested to send their manuscripts to the Editorial Office, *Forest Ecology and Management*, P.O. Box 181, 1000 AD Amsterdam, The Netherlands.

Authors in Japan please note: if you would like information about how to have the English of your paper checked, corrected and improved (*before submission*), please contact our Tokyo office who will inform you of the services provided by language correctors: Elsevier Science Publishers (Japan), 20-12 Yushima 3-chome, Bunkyo-ku, Tokyo 113; tel. (03)-3833-3821; fax (03)-3836-3064.

All questions arising after acceptance of the manuscript, especially those relating to proofs, should be directed to Elsevier Editorial Services, Mayfield House, 256 Banbury Road, Oxford OX2 7DH, UK, tel. (+44-865) 54252, fax (+44-865) 516120 or 56472.

Electronic manuscripts: Electronic manuscripts have the advantage that there is no need for the rekeying of text, thereby avoiding the possibility of introducing errors and resulting in reliable and fast delivery of proofs.
The preferred storage medium is a 5¼ or 3½ inch disk in MS-DOS format, although other systems are welcome, e.g., Macintosh (in this case, save your file in the usual manner, do not use the option 'save in MS-DOS format'); if you use NEC, please submit your article on a double density or high density 5¼ inch disk or double density 3½ inch disk (**not** a high density 3½ inch disk). Please **do not split** the article into separate files (title page as one file, text as another, etc.). Ensure that the letter 'I' and digit '1' (also letter 'O' and digit '0') have been used properly, and structure your article (tabs, indents, etc.) consistently. Characters not available on your wordprocessor (Greek letters, mathematical symbols, etc.) should not be left open but indicated by a unique code (e.g. gralpha, @, #, etc., for the Greek letter α). Such codes should be used consistently throughout the entire text. Please make a list of such codes and provide a key. Do not allow your wordprocessor to introduce word splits and do not use a 'justified' layout. Please adhere strictly to the general instructions on style/arrangement and, in particular, the reference style of the journal. It is very important that you save your file in the wordprocessor format. If your wordprocessor features the option to save files "in flat ASCII", please do **not** use it. Format your disk correctly and ensure that only the relevant file (one complete article only) is on the disk. Also, specify the type of computer and wordprocessing package used and label the disk with your name and the name of the file on the disk. After **final acceptance**, your disk plus one, final, printed and exactly matching version (as a printout) should be submitted together to the accepting editor. **It is important that the file on disk and the printout are identical**. Both will then be forwarded by the editor to Elsevier. Further information may be obtained from the Publisher.

***Forest Ecology and Management* has no page charges**

For a full and complete Guide for Authors, please refer to pages 361–365 of this issue.

0378-1127/93/$06.00

This journal is printed on acid-free paper.

Printed in The Netherlands