The Financial and Economic Profitability of Field Afforestation in Finland

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The aim of the study was to assess the rate of return on invested capital and soil expectation value in field afforestation from the financial (business economic) and economic (national economic) point of views in Finland using 1996 cost and price data. Risks for renewal planting and negative growth impacts of reduction in plantation density were explicitly included in the profitability assessments. Results indicated that due to the subsidies and favorable regulations for obtaining them in 1996, field afforestation was financially profitable for farmers regardless of what species was used for planting. From the national economic point of view, investments in field afforestation provided only substantial return on invested capital, being highest after risk adjustments in Norway spruce (*Picea abies*) plantations.

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1 Introduction

The basis of the Common Agricultural Policy (CAP) of the European Union (EU) prior to the 1990s was the creation of the common agricultural market, common market and price policy, and common structural policy within the member states. Since the EU agricultural reform of mid 1992, the previous market price support system for important agricultural products was superseded by more effective controls on quantity and, increasingly, direct aids to income. The principle measures to control agricultural production in the EU have been regulated producer prices, quotas for excess production and premiums for farmers who withdrew land from cultivation.

By joining the EU in 1995, the government of Finland agreed to follow the principles of the agricultural policy of the EU. For the Finnish farmers this meant sharply decreased subsidies and lower financial returns on especially meat, grain and vegetable production. With the adoption of the Agenda 2000 program by the EU, financial profitability of agriculture is likely to further decrease. The expected result of the forthcoming changes in agricultural policy is that large areas are left out of agricultural production.

Among the main tools for withdrawing land from cultivation permanently in Finland and to a large extent also in the EU, has been afforestation. In Europe, aside the objective to decrease agricultural production, field afforestation has been generally aimed at supporting the development of rational market structures in agriculture (Kuhmonen and Nerg 1995). In central and southern Europe, field afforestation programmes objectives have been particularly to increase forest area, to improve living conditions in rural areas, and to protect intensive agriculture from soil erosion (Kukkonen 1995). In Finland particularly, field afforestation programmes have been aimed at adjusting farms to the effects of the changes in agricultural markets by developing private farm forestry.

Although field afforestation is mainly a tool to implement agricultural policies, its rationality should be assessed also from a forest economics point of view. For the national economy, the profitability of afforestation programmes may vary considerably from those for the private farmers. The difference is chiefly due to different accounting for benefits and costs in financial and economic analyses. For a farmer, major benefits in afforestation include subsidies for tree planting, and later, income from wood and timber sales. The major costs for the farmer, on the other hand, are built up from the opportunity cost of land, and time used for afforestation. For the national economy, parallel benefit-cost comparisons include benefits from increased wood production, decreased costs in agricultural production if it was economically unprofitable, costs for supporting afforestation, and cost-benefit effects of the achieved external impacts.

Financial and economic profitability are important evaluation criteria for the selection of management options for fields. Key issues are whether the profitability in field afforestation is higher than in agriculture, and does the financial (business economic point of view) and economic (national economic point of view) profitability differ considerably in various land management options. From the national economic point of view, subsidies, for example, can be considered as transfer payments, which do not have direct cost effects in field afforestation. Various risks in production may also alter the order of profitability of the land management options in financial and economic analyses.

The aim of the study was to examine the financial and economic profitability of field afforestation in Finland. In addition, the study's objective was to study how the profitability changed after monetary impacts of risks in plantation development are included in the analyses.

2 Methods and Data

2.1 Study Methodology

The methodology used in this study is cost-benefit analysis (CBA). In principle, CBA is similar to profit calculation in private business, but CBA is traditionally used to aid decision making in government actions and government projects (e.g. Johansson 1991, Zerbe and Dively 1994). CBA can be defined as 'an economic appraisal of the costs and benefits of alternative courses of action, whether those costs and benefits are marketed or not, to whomsoever they accrue, both in present and future time, the costs and benefits being measured as far as possible in a common unit of value' (Price 1989, p. 253).

In CBA, benefits are defined relative to their effect on the chosen objective, and costs relative to their opportunity cost, which is the benefit forgone by not using the resources in the best available alternative (e.g. Mishan 1994, Dinwiddy and Teal 1996).

In this study, the profitability of field afforestation was assessed separately from the business economic and national economic point of views as suggested for example by Niskanen (1998). Net-present-value (NPV) criteria was used in financial and economic profitability assessments. When the NPV-criteria was applied for an infinite series of rotations it was considered to equal soil expectation value (SEV), or expected land rent (LR) (Nautiyal 1988, Price 1989, Klemperer 1996).

$$SEV(or\ LR) = \sum_{t=0}^{\infty}[(B_t - C_t)/(1+r)^t]$$

In Finland, low discount rates (1–5 %) have been traditionally used in the evaluation of the profitability of forestry investments. It can be argued that the basis for such relatively low discount rates are mostly based on national economic indicators, and therefore not necessarily applicable in the business economic analyses. Despite this, the discount rate used in this study was set at three and five percentage units. By applying these conventional discount rates, an additional benefit was obtained: it made possible the comparison of the results of this study with other profitability studies where the NPV (or SEV) criteria have been applied (e.g. Aarnio and Rantala 1994, 1995).

2.2 Cost and Price Data

In the assessment of the profitability of field afforestation investments in this study, all monetary payments and incomes were included in the financial analysis, and costs and benefits in resource use into the economic analysis. The difference between the financial and economic cost and price data was therefore due to:

- Taxes and subsidies being considered as transfer payments and therefore excluded from the economic analysis
- Use of land and labour was assumed to cause different opportunity costs to society than to the private farmers

From the farmers point of view, monetary support for material and labour costs reduced the amount of money needed for afforestation. In 1996, the subsidy rate for material costs was 100 % and for labour costs between 30–75 %, being highest in Northern Finland. For the profitability analyses an average 50 % subsidy rate for labour costs was assumed. Two major financial costs for the farmer in field afforestation were the opportunity costs of land and time (Table 1).

From the national economic point of view, subsidies paid for afforestation were assumed to cause no direct costs to society. Plantation establishment costs, like tending and material costs, were valued in the economic analysis with average market prices obtained from actual afforestation programmes (Hankesysteemiin perustuva toteutustilasto 1995). The highest costs in the economic analysis were material and plantation establishment costs (Table 1).

Land use opportunity cost was assessed from the average contribution margin in five different agricultural land uses in 1996. In financial analyses, the following money flows were considered: (1) Financial net incomes from agricultural production (Maaseutukeskusten Liitto 1995, Kettunen 1996), (2) totally or partly EU funded subsidies under the regulations of CAP and LFA (Less Favourable Area support mechanisms), (3) EU support for environment protection and improvement, and (4) national subsidies for agriculture (Kettunen 1996, Nordberg 1996). In the economic analysis, the subsidies 2–4 were neglected.

The financial and economic opportunity cost of land varied considerably in various land use opportunities and in different agricultural regions of the country (Table 2). In 1996, the annual financial and economic opportunity cost of land was assumed to be 1150 FIM/ha and 400 FIM/ha, respectively. The opportunity cost of land was included in the profitability analyses for the same ten year period as farmers got support for lost incomes.

2.3 Growth and Yield Data

In this study, eight different afforestation options were studied. Two of them were for Scots pine (*Pinus sylvestris*), three for Norway spruce (*Picea abies*) and three for silver birch (*Betula pendula*) (Table 3).

On average, the growth and yield of tree plantations established on agricultural fields in western Finland was equal to those found on forest site indices H_{100} = 30* for Norway spruce, H_{100} = 27 for Scots pine and H_{50} = 26 for silver birch (Kinnunen 1995). Since the growth and yield may in actual conditions vary considerably between different sites, the profitability of afforestation in this study was assessed for site indices H_{100} = 27, 30 and 33 for Norway spruce; H_{100} = 24 and 27 for Scots pine; and H_{50} = 24, 26 and 28 for silver birch. The site index H_{100} = 27 for

* The dominant height of trees equal to 30 meters at the age of 100 years.

Table 1. Financial and economic cost and price data in field afforestation (FIM/ha).

Cost and price item	Spruce		Pine		Birch	
	Financial	Economic	Financial	Economic	Financial	Economic
Ploughing, farmer's income and economic cost [1)]	179	*–358*	179	*–358*	179	*–358*
Ploughing, farmer's OC [2)]	–240	0	–240	0	–240	0
Herbicides, material costs [3)]	0	–900	0	–900	0	–900
Herbicide spraying, farmer's income and econ. cost [4)]	120	–240	120	–240	120	–240
Herbicide spraying, farmer's OC [5)]	–120	0	–120	0	–120	0
Planting, material costs [6)]	0	*–1830*	0	*–1140*	0	*–2956*
Planting, farmer's income and economic cost [7)]	420	*–841*	428	*–857*	378	*–756*
Planting, farmer's OC [8)]	–552	0	–552	0	–442	0
Replanting, material costs	0	*87*	0	*165*	0	*128*
Replanting, farmer's income and economic cost [4)]	26	*–98*	80	*–290*	21	*–86*
Replanting, farmer's OC [5)]	–53	0	–160	0	–43	0
Tending costs [9)]	–955	*–573*	–955	*–573*	–955	*–573*
Fee paid for tending [10)]	500	0	500	0	500	0
Consultation, e.g. forest associations [11)]	0	–189	0	–189	0	–189
Compensation for lost incomes [12)]	1300	0	1300	0	1300	0
Annual OC of lost agricultural production [13)]	–1150	–400	–1150	–400	–1150	–400
Stumpage price of timber per cubic meter [14)]	201	201	249	249	247	247
Stumpage price of fiber wood per cubic meter [14)]	110	110	93	93	98	98
Taxation per cubic meter of timber [15)]	36	0	45	0	44	0
Taxation per cubic meter of small-size wood [15)]	20	0	17	0	18	0

1) *Paid to the farmer*: Average market price of ploughing (358 FIM/ha) multiplied with the assumed average subsidy rate, 50 %. *Economic cost*: Average market cost of ploughing.

2) Assumed that ploughing of one hectare area requires two hours tractor work, OC 120 FIM/hour (OC = Opportunity cost).

3) Whole area spraying one year before planting. *Financial material cost*: zero*; Economic cost:* 900 FIM/ha.

4) *Paid to the farmer*: Average market price of spraying (240 FIM/ha) multiplied with the assumed average subsidy rate, 50 %. *Economic cost*: Average market price of spraying.

5) Assumed that spraying of one hectare requires an hour tractor work, OC 120 FIM/hour.

6) Assumed plantation establishment density 2000 seedlings per hectare for spruce and pine, and 1600 seedlings for silver birch. *Financial material cost*: zero; *Economic cost:* 0.57–1.85 FIM/seedling.

7) *Paid to the farmer*: Average cost of planting multiplied with the assumed average subsidy rate, 50 %. *Economic cost*: Average market price of planting.

8) Assumed that planting of 500 seedlings requires one man-day work, OC 138 FIM/day, or 18 FIM/hour.

9) At the seventh year after planting. *Financial cost*: 955 FIM/ha. *Economic cost*: 955 FIM/ha minus 40 % of obligatory social overhead costs, which were considered as transfer payments in this study.

10) Paid to the farmer at the 2nd and 4th year after planting.

11) *Financial cost*: zero. *Economic cost*: 22 % from the monetary payments.

12) Subsidy paid for the for farmer ten years after afforestation (50 % higher if the farmer will give up farming, and about 20 % lower if the owner of the afforested field is non-farmer).

13) See Table 2. Assessed for a ten year period like [12)].

14) Aarne (1996).

15) Based on average 18 % net capital tax rate.

1), 4) and 7) According to the government regulations, the sum paid to the farmer in the case where he/she conducts afforestation, was equal to 50 % of the average afforestation costs.

Scots pine and Norway spruce and H_{50} = 24 for silver birch are similar to the blueberry forest site type (Myrtillus-type) on mineral soils (Cajander 1949) (Table 3).

The volume growth assessments for Norway spruce and Scots pine were based on stand level growth and yield models of Vuokila and Väliaho (1980), and for silver birch on similar models developed by Oikarinen (1983). Although the growth and yield models for Scots pine were developed for seeded forests, they were applied also to planted forests in this study, since according to Hägglund (1974) the method for establishment does not strongly influence the total volume growth and yield of the forests (cf. Vuokila and Väliaho 1980). Mean annual increment (MAI) with the applied 55–88 year rotation periods varied from 4.6 to 9.5 m^3/ha, having larger variation between the site indices than between the species (Table 3). For Norway spruce, the assessed volume growth at the rotation age was equal to that of Koivisto's (1959) growth and yield tables. For Scots pine the volume growth was approximately 10 % lower, and for silver birch 10 % higher than in the Koivisto's growth and yield tables.

The length of the rotation periods and the timing of the premature thinnings were based on existing recommendations in 1996 where either the age or the medium diameter of the trees at breast height determine the maturity of the forests for harvesting (Metsäkeskus Tapio 1994). Accordingly, the rotation period was fixed at the time when the age of the forests, or the medium diameter of the trees equaled the value required for final cutting. In order to reduce the number of thinnings, and to increase the amount of wood harvested, the first thinnings were delayed until the average height of the forests reached 13 meters (Pesonen and Hirvelä 1992). The number of thinnings was two in all studied afforestation options (Table 3).

Table 2. Opportunity cost of land (FM/ha) in afforestation, assessed with financial and economic (in parenthesis) *contribution margin* in selected land use options and various parts of the country (A–C4) (Maaseutukeskusten Liitto 1995, Kettunen 1996, Nordberg 1996).

Land use option	Agricultural subsidy area A	B	C1	C2–C4
Pasture	1506 (1428)	1741 (1428)	1972 (1545)	1860 (850)
Oat feed	990 (199)	1171 (–137)	1260 (–58)	1360 (–230)
Open fallow	685 (–242)	1196 (–242)	1196 (–242)	1060 (–242)
Grass forage	675 (1060)	910 (1060)	1055 (1060)	1100 (780)
5-year green fallow	493 (–243)	877 (–243)	1036 (–243)	930 (–243)

Table 3. Site indices with respect of the forest site types on mineral soils, and the length of the rotation period applied in this study.

Site index	Forest site type in southern Finland [1]	Forest site type in Ostrobothnia and Kainuu provinces [1]	Rotation period (yr) [2]	Medium diameter at breast height (cm) [2]	Rotation period applied in this study (yr)	Mean annual increment at the rotation age (m^3/ha/yr)
Scots pine (H_{100}=24)	VT	EVT	90–100	27–29	88	4.6
Scots pine (H_{100}=27)	MT	VMT	80–90	29–31	86	5.9
Norway spruce (H_{100}=27)	MT	VMT	90–100	26–28	74	6.2
Norway spruce (H_{100}=30)	OMT	GOMT	80–90	28–30	64	7.6
Norway spruce (H_{100}=33)	OmaT	GOMaT	80–90	28–30	55	9.5
Silver birch (H_{50}=24)	MT	VMT	70–80	26–28	65	6.2
Silver birch (H50=26)	OMT	GOMT	60–70	28–30	60	7.0
Silver birch (H_{50}=28)	OmaT	GOMaT	60–70	28–30	60	7.5

1) For forest site types, see Cajander (1949).
2) Recommendation for a minimum value in harvesting in southern Finland (Metsäkeskus Tapio 1994).

2.4 Risk and Uncertainty

Often in field afforestation, survival rate, early growth and yield of planted trees have been poor (Hytönen 1991, 1995, Rossi et al. 1993, Valtanen 1991). The most important biotic causes for the death of seedlings and insufficient growth and yield, have been infections by fungi, browsing by moles and elk, and competition between the planted seedlings and grasses. The most important abiotic causes, on the other hand, have been frost damage and deficits of some specific soil nutrients like boron (Valtanen 1991, Hytönen 1991, 1995, Kinnunen 1995, Wall and Heiskanen 1995). Generally the survival, and juvenile growth of planted trees have been higher in mineral fields than in fields with organic soils (Hynönen and Saksa 1991, Hytönen 1995, Kinnunen 1995, Rossi ym. 1993, Valtanen 1991). Naturally regenerated seedlings of especially downy birch (*Betula pubescens*) have often considerably raised growing densities in plantations (Kinnunen 1991, Rossi ym. 1993, Valtanen 1991).

In this study, risk for the death of seedlings was based on field measurements from 15 afforestation sites, including 25 plantations. These plantations were established mainly in southern Finland, and followed continuously for seven years (Ferm 1991, Ferm et al. 1993, Ferm and Hytönen 1991, Hytönen and Polet 1995). Although the original plantation establishment density was assumed to be 2000 seedlings per hectare for spruce and pine and 1600 for silver birch (Metsäkeskus Tapio 1994), the actual growing density, due to the risk of the loss of seedlings, was assumed to be lower in this study.

On the basis of the measurements in the mentioned 25 field trials, the share of destroyed plantations where the expected stand density was less than 900 seedlings per hectare after seven years from plantation establishment, was 6 % for Norway spruce (*Picea abies*), 31 % for Scots pine (*Pinus sylvestris*) and 50 % for silver birch (*Betula pendula*). The expected growing density was assessed to vary between 1140–1479, 1391–1752 and 975–1199 seedlings per hectare in Norway spruce, Scots pine and silver birch plantations, respectively (Table 4).

Financial and economic risks related to the survival of seedlings after planting, were divided accordingly into two parts. Firstly, it was assessed how high the costs are of the expected stand density decrease. This resulted in expected, upper and lower values for the profitability of field afforestation. Secondly, it was assessed how high are the costs of the risk for renewal planting. It was set equal to the expected additional costs in afforestation, equal to the probability of renewal planting multiplied with the present value of the plantation establishment costs. The expected additional costs of renewal planting were assessed for three subsequent efforts for afforestation, as for example with silver birch it is likely that even three efforts for plantation establishment may be needed.

Uncertainty differs from risk in that in an uncertain action the probability of an outcome is not known as in the case of risk. Among the major sources of uncertainty in the profitability analyses in this study were the growth and yield of timber and the opportunity cost of land. The impacts of these two sources of uncertainty to the profitability of afforestation were studied with a sensitivity analysis, where the effects of the declining percentage share of timber, and the effects of the increasing opportunity costs of land to the profitability of afforestation were analysed.

Table 4. Risk for renewal planting and expected stand density in those plantations that did not require replanting with a 95 % confidence interval (lower and upper density).

Species	Risk for renewal planting (%)	Lower stand density (trees/ha)	Expected stand density (trees/ha)	Upper stand density (trees/ha)
Pine	31	1140	1310	1479
Spruce	6	1391	1571	1752
Birch	50	975	1087	1199

3 Results

3.1 Financial Profitability

From the business economic point of view, silver birch (*Betula pendula*) planting was assessed more profitable than Norway spruce (*Picea abies*) or Scots pine (*Pinus sylvestris*) planting. With a three percent discount rate, the soil expectation value (SEV) for silver birch was 21–29 % higher than the SEV for Norway spruce, and 16–27 % higher than the SEV for Scots pine on similar sites. With a five percent discount rate, and when the expected costs of renewal planting were included in the assessment, the SEV for silver birch was 1–3 % and 19–35 % higher than the SEV for Norway spruce and Scots pine respectively (Tables 5–7).

The differences in profitability between the lower, expected and upper plantation densities were small especially in the case of silver birch plantations. For example, the relative difference in SEV between the lower and upper expected stand densities for Norway spruce and Scots pine was 12 and 13 percent respectively, but only one percent for silver birch (Tables 5–7).

Table 5. Financial soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{100} = 27 with Norway spruce (*Picea abies*).

Profitability criteria	Expected stand density 1391 (Lower)	1571 (Average)	1752 (Upper)
Financial SEV (3 %)	10233	11411	11594
– expected NPV of renewal planting	–110	–110	–110
Expected financial SEV (3 %)	10123	11301	11484
Financial SEV (5 %)	3702	3784	3866
– expected NPV of renewal planting	–103	–103	–103
Expected financial SEV (5 %)	3599	3681	3763

3.2 Economic Profitability

Without the assessment of the costs of renewal planting, silver birch (*Betula pendula*) planting was more profitable than Norway spruce (*Picea abies*) or Scots pine (*Pinus sylvestris*) planting from the national economic point of view. With a three percent discount rate, for example, the soil expectation value (SEV) for silver birch was 32–37 % higher than the SEV for Norway spruce, and 48–73 % higher than the SEV for Scots pine on similar sites. Opposite to what was visible in the financial profitability analysis, Norway spruce was economically more profitable to grow than Scots pine (Tables 8–10).

Table 6. Financial soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{100} = 27 with Scots pine (*Pinus sylvestris*).

Profitability criteria	Expected stand density 1140 (Lower)	1310 (Average)	1479 (Upper)
Financial SEV (3 %)	10587	10815	12212
– expected NPV of renewal planting	–787	–787	–787
Expected financial SEV (3 %)	9800	10028	11425
Financial SEV (5 %)	3145	3269	3802
– expected NPV of renewal planting	–734	–734	–734
Expected financial SEV (5 %)	2411	2535	3068

Table 7. Financial soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{50} = 24 with silver birch (*Betula pendula*).

Profitability criteria	Expected stand density 975 (Lower)	1087 (Average)	1199 (Upper)
Financial SEV (3 %)	14410	14517	14604
– expected NPV of renewal planting	–1396	–1396	–1396
Expected financial SEV (3 %)	13014	13121	13208
Financial SEV (5 %)	4992	5045	5079
– expected NPV of renewal planting	–1295	–1295	–1295
Expected financial SEV (5 %)	3697	3750	3784

Table 8. Economic soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{100} = 27 with Norway spruce (*Picea abies*).

Profitability criteria	Expected stand density 1391 (Lower)	1571 (Average)	1752 (Upper)
Economic SEV (3 %)	4011	4229	4452
– expected NPV of renewal planting	–244	–244	–244
Expected economic SEV (3 %)	3767	3985	4208
Economic SEV (5 %)	–3725	–3625	–3525
– expected NPV of renewal planting	–234	–234	–234
Expected economic SEV (5 %)	–3959	–3859	–3759

Table 9. Economic soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{100} = 27 with Scots pine (*Pinus sylvestris*).

Profitability criteria	Expected stand density 1140 (Lower)	1310 (Average)	1479 (Upper)
Economic SEV (3 %)	1699	2037	3405
– expected NPV of renewal planting	–2423	–2423	–2423
Expected economic SEV (3 %)	–724	–386	982
Economic SEV (5 %)	–5987	–5820	–5265
– expected NPV of renewal planting	–2335	–2335	–2335
Expected economic SEV (5 %)	–8322	–8155	–7600

The economic NPV of the costs of renewal planting with a three percent discount rate was assessed at 244 FIM/ha for Norway spruce, 2423 FIM/ha for Scots pine and 4134 FIM/ha for silver birch. The costs of renewal planting were highest for silver birch that had the lowest survival rate. When the costs of renewal planting were included in the profitability assessment, Norway spruce was the most profitable species to grow (Tables 8–10).

Table 10. Economic soil expectation value (SEV) in field afforestation with 3 and 5 % discount rates on site index H_{50} = 24 with silver birch (*Betula pendula*).

Profitability criteria	Expected stand density 975 (Lower)	1087 (Average)	1199 (Upper)
Economic SEV (3 %)	6327	6458	6564
– expected NPV of renewal planting	–4134	–4134	–4134
Expected economic SEV (3 %)	2193	2324	2430
Economic SEV (5 %)	–3299	–3234	–3193
– expected NPV of renewal planting	–3983	–3983	–3983
Expected economic SEV (5 %)	–7282	–7217	–7176

3.3 Comparison between the Financial and Economic Profitability

The expected NPV of renewal planting was assessed approximately two to three times higher in economic (Tables 8–10) than financial (Tables 5–7) terms. This was to a large extent due to the different accounting of costs and benefits in financial and economic analyses. Since materials and planning for renewal planting were available free of charge for land owners, they were not accounted in the financial analysis. However, as additional costs in materials, labour and machine use in renewal planting were assumed to represent resource use costs to the society, they were included in the economic profitability analysis.

With fixed discount rates and site conditions, the expected financial SEV (Fig. 1) was higher than the expected economic SEV (Fig. 2). The site quality seemed to impact more on the SEV in field afforestation than the species used for planting. This can be noticed especially from the results of the financial analysis, where the SEV did not vary as much between the species as between the site indices. This indicates that from the financial profitability point of view, the difference in profitability was not due to what species was used for afforestation. The results of the economic analysis, on the other hand, indicated

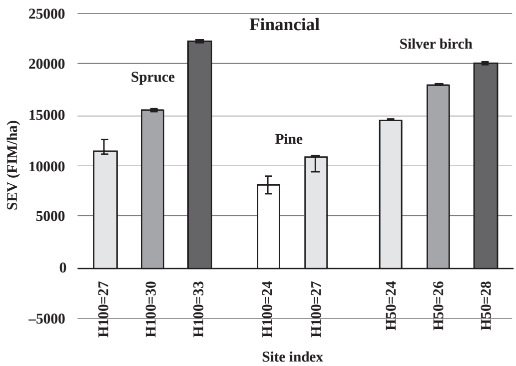

Fig. 1. Financial SEV (FIM/ha) assessed with a 3 % discount rate for expected (bars), and upper and lower stand densities (segments of lines) in field afforestation with different species and site quality. The bars representing similar site quality are colored similarly.

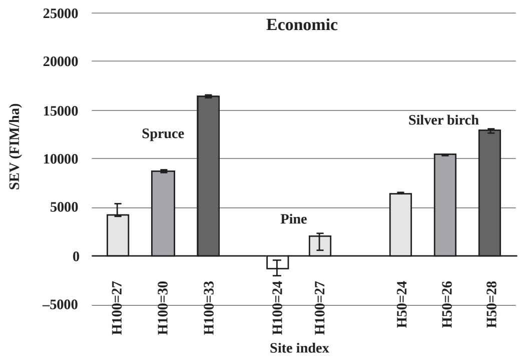

Fig. 2. Economic SEV (FIM/ha) assessed with a 3 % discount rate for expected (bars), and upper and lower stand densities (segments of lines) in field afforestation with different species and site quality. The bars representing similar site quality are colored similarly.

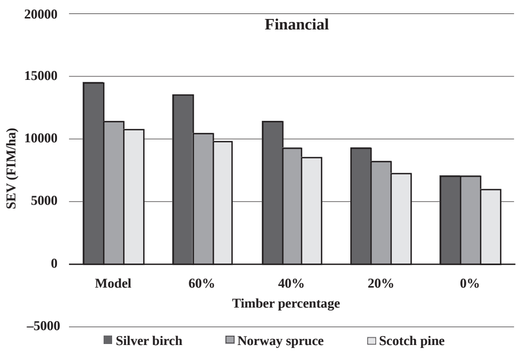

Fig. 3. Sensitivity of the financial SEV on the changes in timber percentage.

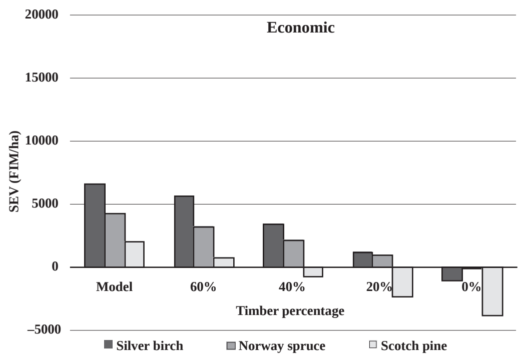

Fig. 4. Sensitivity of the economic SEV on the changes in timber percentage.

that the species selection was equally important for the profitability as for the site quality (Figs. 1–2).

3.4 Sensitivity Analyses

Poor quality may severely decrease the amount of timber harvested especially if Scots pine or silver birch are used for afforestation. Based on the growth and yield models applied, 77 %, 78 % and 69 % of the total volume growth for Scots pine (H_{100} = 27), Norway spruce (H_{100} = 27), and silver birch (H_{50} = 24) respectively, were valued as timber. When part of the timber was valued as pulpwood in the sensitivity analysis due to assumed quality reduction, the financial and economic SEV decreased. The decrease was higher, in relative terms, for the economic SEV than for the financial SEV (Figs. 3–4).

Even a slight increase in the opportunity cost (OC) of land decreased considerably the economic and financial SEV. The financial SEV assessed with a three percentage discount rate, however, remained positive even when the annual financial OC was higher than 2000 FIM/ha. When the annual economic OC of land was higher than 1200 FIM/ha, investments in spruce (H_{100} =

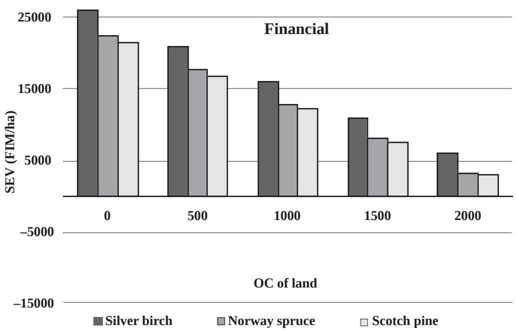

Fig. 5. Sensitivity of the financial SEV on the opportunity cost of land.

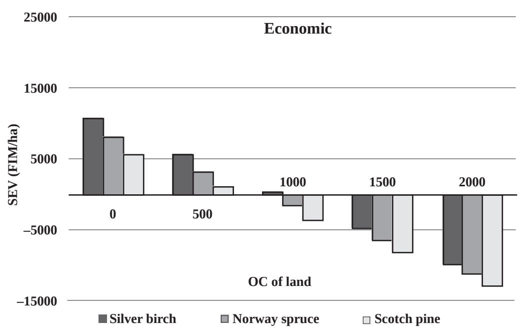

Fig. 6. Sensitivity of the economic SEV on the opportunity cost of land.

30) and birch (H_{50} = 26) plantations resulted in negative economic SEV (Figs. 5–6).

4 Discussion and Conclusions

The business economic approach has dominated the studies on the profitability of field afforestation in Finland (e.g. Aarnio and Rantala 1994, 1995). The results of this study however, supported the approach to assess the financial and economic profitability separately: with three and five percent discount rates, the financial profitability of field afforestation was approximately 5800–7200 FIM/ha, 8800–9300 FIM/ha and 7200–8100 FIM/ha higher than the economic profitability for Norway spruce, Scots pine and silver birch, respectively.

The difference between the financial and economic profitability was lowest on the most fertile sites, where the expected income from wood sales relative to plantation establishment costs was highest. This indicates that the government subsidies for afforestation may be most affective if targeted on less fertile sites where the financial profitability otherwise would be relatively low. On less fertile sites the most profitable option from the national economic point of view however, could be also to have left the fields to reforest naturally. This option was not studied in this study, but Aarnio and Rantala (1999) estimated that the financial return in natural regeneration with downy birch (*Betula pubescens*) in peat land fields was nearly as high as the return in afforestation with artificial regeneration.

Although the physical risks in plantation growth and success are similar for the private land owners and society, the monetary impacts of risks were higher for society than for the private land owners. This was particularly due to material and labour cost subsidies provided for renewal planting investments. For the same reason, it made little difference from the business economic point of view what species was used for afforestation. From the national economic point of view however, equally important for the profitability as the growth and yield potential of the site, was the species selection. This indicates that it is more important from the national economic point of view than from the business economic point of view to plant species like Norway spruce that can best survive in the harsh conditions of field afforestation.

Since realistic assessments for the reduction in timber quality in field afforestation at the rotation age were not available, the basic results of the study were calculated by obtaining timber volumes directly from the growth and yield models applied. This assumption obviously resulted in too high timber volumes especially in Scots pine and silver birch plantations. In the sensitivity analysis, where part of the timber was valued as pulpwood, especially the economic profitability of field afforestation decreased. Financial profitability with three and five percent discount rates was positive even when all the volume growth was valued with pulpwood prices.

The most important impact on both the financial and economic profitability of afforestation was formed by the opportunity cost of land. Its value depends principally on for what the land could be used, and on how high the production potential of the site was. In Table 2, several alternatives were assessed, representing options with relatively low intensity for farming, and perhaps high potential for field afforestation. In the studied options the opportunity cost of land was assessed with a contribution margin in agriculture. In these options, the financial and economic opportunity cost of land was at maximum 2000 and 1400 FIM/ha, respectively. The results of the study indicated that the financial SEV assessed with a three percentage discount rate remained positive with all studied species and afforestation options, even the 10-year financial opportunity cost was higher than 2000 FIM/ha/yr. Investments for Norway spruce (H_{100} = 27) and silver birch (H_{50} = 24) plantations produced negative economic results of SEV when the 10-year economic opportunity cost of land was higher than 1000 FIM/ha/yr.

Traditionally, the most important reason for field afforestation at the farm level in Finland has been the decisions to give up permanent farming. Afforestation decisions have been common especially in farms where owners have been old or where field areas have been small. In addition, those farmers who own large areas of forests have afforested their fields more often than on average. At the stand level, afforestation has concentrated on fields that are remote or that have suited poorly for agriculture (Mustonen 1990, Petäjistö et al. 1993, Petäjistö and Selby 1994). Due to these reasons, field afforestation programmes in Finland have not been able to a decrease agricultural production as much as expected.

To conclude, aside the less than expected reduction in agricultural production, it seems, on the basis of the results of this study, that field afforestation is not highly profitable from the forest economic point of view either. From the national economic point of view, for example, when the subsidies for afforestation were at the same level as in 1996, none of the studied afforestation options were able to produce a five percent rate of return on investment. In the case of Scots pine, the soil expectation value was negative even with a three percentage discount rate. The soil expectation value would be even lower than indicated if the obvious reduction in timber quality were taken into account.

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