Economic analysis of field afforestation and forest clearance for cultivation in Finland

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Abstract— **Rational land use decisions of private landowners are analysed in the framework of Common Agricultural Policy and other public support schemes effective in Finland in 2003. Net present values are computed for a marginal hectare of a typical Finnish farm. Three alternative land uses are considered: traditional cultivation of oats (*Avena sativa L.*), cultivation of reed canary grass (*Phalaris Arundinacea L.*) for energy production, and production of Norway spruce (*Picea abies [L.] Karst.*) timber. Both arable land and forested land are considered as initial states. Experimental data from 38 afforested stands and distance-independent individual-tree stand growth model are used for computing discounted net returns from forestry. Statistics on market prices, average yields, prices and costs are used for obtaining estimates of land value under agricultural and energy production. Cultivation of energy grass gives clearly the highest economic outcome for arable land, but it has limited demand only in the neighbourhood of thermal power stations. Maintaining arable lands under traditional food production gives higher land value than afforestation. Without an option for agricultural use, public support makes afforestation investments profitable even for the least successfully established forest stands. However, possibilities to sell or to rent out retain arable lands under agricultural production, and explain poor success of the latest afforestation programme. Clearing additional forestland for agricultural production turns rational if clearing of the site is inexpensive, relative value growth of the existing timber stock is low, and future prospects of agricultural production are dependent on scale advantages.**

Keywords— **common agricultural policy, energy grass, incentives, land use**

I. INTRODUCTION

Agricultural land confronts competing policy incentives in the EU countries. Maintaining farmland under cultivation of agricultural crops is supported, for instance, to safeguard steady availability of food at national level, and to vitalize agricultural communities. At the same time, reduction of farming land area through afforestation has been encouraged by several incentives that aim at reducing overproduction of agricultural goods and converting the least productive agricultural land to more desirable uses.
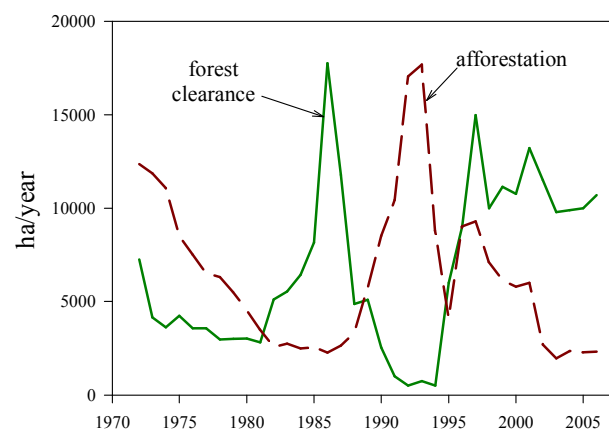

Fig. 1 The areas afforested and cleared for arable land annually during 1972-2006. Sources: [1], Yearbooks of Farm Statistics (various years), the level of forest clearance since 1991 is estimated by the authors from several sources.

Figure 1 shows how changes in public intervention and the future prospects of alternative land uses have guided private land use decisions in Finland. The Finnish government supported afforestation as an alternative to mandatory fallowing during the 70s and until the mid 80s. This led to steadily decreasing agricultural area between 1972 and 1983. Introduction of the forest clearance fee caused a temporary peak in the area of new farming land between 1985 and 1987. However, forest clearance became forbidden in 1992, and a new support scheme (Act of balancing agricultural production) led to a high level of afforestation between 1990 and 1994.

Finland joined EU in 1995. Introduction of hectare and investment-based CAP support measures for the Finnish agriculture stipulated the growth of the most competitive farms, accelerated the technological change and reduced the relative attractiveness of

forestry as a competing land use. These changes led to steady decline in annually afforested areas and increase in the area of agricultural land during the past 13 years. A new afforestation programme was launched for 1995-1999 to implement the Council Regulation 2080/92, but with poor success. Forest clearance for agricultural field, on the contrary, has remained at a high level through the time Finland has been a member in the EU.

Rational land use decisions of private landowners can be studied by computing the expected net present value of land for all alternative land uses. Research in this field has been active in Ireland, which has the lowest percentage of land covered by forests of all EU countries. McCarthy et al. [2] computed net present values for afforested land and build up a regression model for quantifying the relative importance of economic factors that influence the rate of afforestation. They found introduction of the large agro-environmental programme the most influential factor leading to the decline in the level of planting. Behan et al. [3] employed a theoretical real options model and dynamic panel data model to explain why farmers are slow to switch land from traditional agriculture to forestry.

This study combines experimental data, forest stand growth model and statistical data to analyse rational land use decisions for private farmland and forestland under Finnish policy conditions effective in 2003. Three alternative land uses are considered: traditional cultivation of oats (*Avena sativa L.),* cultivation of reed canary grass (*Phalaris Arundinacea L.)* for energy production, and production of Norway spruce (*Picea abies [L.] Karst.)* timber. Net present value of land under forestry is computed using experimental data from 38 afforested stands and distance-independent individual-tree stand growth model. Estimates on land value under agricultural production are obtained by using statistical data on average yields and economic parameters, and alternatively, market prices.

II. MATERIALS AND METHODS

A. Value of land under cultivation of agricultural crops, energy grass and forestry

Consider a marginal hectare of land in a typical Finnish farm. Rational landowner selects the land use that yields the highest net present value. If marginal hectare is arable land, the alternatives are to continue cultivation of agricultural crops, cultivate energy crop, or plant trees. The production period in traditional agricultural production of food or fodder crops is typically one season. The net present value of land, V_{agr}, is computed by:

$$V_{agr} = (1-\delta)\left[\frac{px - c - T + S}{r}\right]. \qquad (1)$$

Average annual net return is computed by multiplying the market price at industrial warehouse, p, and the average annual yield of crop, x, and subtracting the variable, c, and fixed, T, costs of cultivation. Public support, S, is added to annual net return, and the sum is divided by the real rate of interest, r, to attain pre-tax net present value of agricultural production. Possible trends and future fluctuations in the values of economic parameters are ignored. Post-tax value of land is attained by subtracting progressive income taxes, δ, from the capitalized net revenues. The parameter values in our computations are suited for cultivation of oats.

The net present value of agricultural land when cultivating perennial energy grass is computed by:

$$V_e = (1-\delta)\left[\frac{-\text{Re}^{-r} + \sum_{t=3}^{12}(px - g)e^{-rt} + \sum_{t=1}^{12}(S - T)e^{-rt}}{1 - e^{-12r}}\right]. \quad (2)$$

The production cycle of reed canary grass is 12 years. The establishment costs, R, occur at the first year of each production cycle. Harvesting is started at the third year and continued until the end of production cycle. The annual harvesting and tending costs are denoted by g. Public support, S, and the fixed costs of cultivation, T, occur each year.

The net present value of afforested farmland is given by:

$$V_{tim} = (1-\tau)\left\{-Q + \sum_{u=1}^{k} e^{-rt_u}\left[\sum_{i=1}^{n}\sum_{j=1}^{m} p_{uij}\, g_{uij} - C_u\right]\right\} + \overline{V}_{tim}\, e^{-rt_k}. (3)$$

Capital tax rate τ of 0.28 is applied in forestry. The net harvesting revenues are computed for each thinning ($u=1,\ldots,k$-1) and the final clearcutting ($u=k$) by summing the products of roadside prices, p_{uij}, and harvested volumes, g_{uij}, over n tree size classes and m roundwood categories, and subtracting the harvest

cost, C_u, from the total. Q denotes the cost of afforestation (i.e. stand establishment costs minus public support of afforestation). Public support is not available for establishing later tree generations. Thus, the net benefits from later rotation periods are computed by:

$$\overline{V}_{tim} = (1-\tau) \frac{-W + \sum_{u=1}^{k} e^{-rt_u} \left[\sum_{i=1}^{n} \sum_{j=1}^{m} p_{uij}\, g_{uij} - C_u \right]}{1 - e^{-rt_k}}. (4)$$

where W denotes the sum of stand establishment costs.

If the marginal hectare is initially covered by forest, alternative land uses are to retain land under timber production, or to clearcut and clear the land for agricultural or energy production. The net present value of forest stand maintained in timber production, J_{tim}, is computed by discounting the net harvest revenues from remaining k' harvests of the ongoing rotation period and bare land value from the end of the first rotation:

$$J_{tim} = (1-\tau)\left\{ \sum_{u=1}^{k'} e^{-r(t_u - t)} \left[\sum_{i=1}^{n} \sum_{j=1}^{m} p_{uij}\, g_{uij} - C_u \right] \right\} + \overline{V}_{tim}\, e^{-r(t_{k'}-t)}. (5)$$

The value of forested land when converted to agriculture, J_{agr}, is computed by subtracting the clearing costs, B, from the sum of net harvest revenues of clearcutting and net present value of land under agricultural production:

$$J_{agr} = \left[\sum_{i=1}^{n} \sum_{j=1}^{m} p_{ij}(\mathbf{Z}_{t_u}) g_{ij}(\mathbf{Z}_{t_k}) - C_k(\mathbf{Z}_{t_k}) \right](1-\tau) - B(1-\delta) + V_{agr}. (6)$$

Capital tax rate, τ, is applied for timber harvesting revenues and marginal income tax rate, δ, for clearing costs.

B. Development of afforested fields

The early development of afforested fields (11 first years after afforestation) is obtained from afforestation experiment [4]. A representative sample of stands (38 plots in 20 localities) planted for Norway spruce was selected for the purposes of this study (see Figure 2). The most vigorously grown stands are pure Norway spruce cultures. Less successful plantations contain some mixture of naturally regenerated silver birch (*Betula pendula Roth*), pubescent birch (*Betula pubescens Ehrh.*) and Scots pine (*Pinus sylvestris L.*).

Stand development after the age of 11 years and harvest removals are predicted using the forest stand growth model Motti [5]. The model falls into category of distance-independent individual-tree models. The model accounts for the effects of location (expressed in terms of temperature sum, altitude, nearness of lakes or sea) as well as soil fertility on tree growth. Stands are harvested according to the silvicultural recommendations [6].
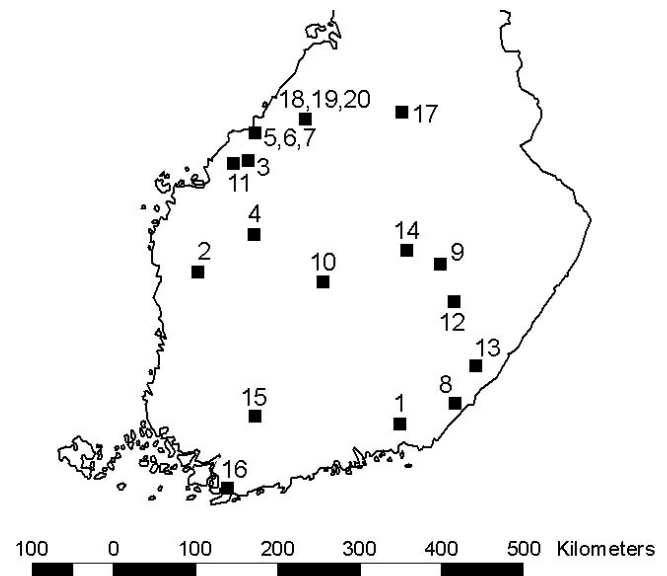

Fig. 2 Location of the afforested experiments

C. Cost and price data

Average prices and costs were adjusted for inflation. The parameter values for annual crop (x=3.13 ton/ha) and market price at industrial warehouse (p=124 €/ton) of oats are average levels from the time period 1995-2003 in Finland. The agricultural production costs and revenues are estimated for a marginal hectare of fixed-sized farm of about 40 hectares of agricultural land. Contractor pricing statistics were applied for estimating variable costs for cultivation of oats and reed canary grass.

For oats, the crop-dependent variable costs, c, consist of costs of soil preparation, seeding, fertilization, plant protection, harvesting and drying, and amount to 567.60 €/ha. The fixed, crop-independent annual cost for marginal hectare consists of insurance, planning and administrational work and amount to 38 €/ha. The hectare-based public support include support through CAP, support for the Least Favourable Areas (LFA), agri-environmental support

and national support, and amounts to 481.80 €/ha. The support is assumed equivalent to all arable hectares and is calculated according to middle Finland's support levels.

Cultivation of energy grass is much less capital and labour intensive than traditional agriculture. The crop-dependent variable costs of establishing a new grass field, R, consist of the costs of soil preparation, fertilization, plant protection and sowing, and amount to 272.20 €/ha for the marginal hectare. The annual crop-dependent variable harvesting and tending costs, g, are 156.70 €/ha, and the fixed administrical costs, T, are 38 €/ha for the marginal hectare. Annual crop is 7 ton/ha and the farm gate market price is 15 €/ton. The prices for oats and reed canary grass are expressed in dry tons. Cultivation of reed canary grass is limited at present by the fact that the farm gate price is valid only for farms located within 40 km radius of thermal power plants. Statistics on the market prices of agricultural land in 2003 [7] was used for comparison to net present value computations.

The stand establishment costs, Q, consist of material and labour costs of mowing, chemical weed control, soil preparation and planting done during the two first years and precommercial thinning carried out 11 years after the start of afforestation activities. Without public support, the sum of undiscounted establishment costs varied between 1288 and 1553 €/ha in investigated stands. With public support, stand establishment costs were reduced on average by 67% and varied between 351 and 624 €/ha. The stand establishment cost for later rotation periods, W, was assumed to equal to the costs of the first rotation without support. The roadside prices of sawlogs, small-dimension sawlogs and pulpwood are 45.95, 35.00, and 31.00 €/m^3 for Norway spruce, 47.15, 35.00, and 25.35 €/m^3 for birch and 48.25, 40.00, and 24.55 €/m^3 for Scots pine.

III. RESULTS

A. Marginal hectare is arable land

Figure 3 shows net present values computed for 48 afforested stands in comparison to average net present values of land under cultivation of oats and reed canary grass at 3% rate of interest. Equal marginal and fixed tax rate ($\tau=\delta=0.28$) is assumed for all land uses. Cultivation of energy grass gives clearly the highest economic outcome. Production of oats gives also higher net present value of land than afforestation for

all 38 experiments. The net present values of investigated stands vary considerably depending on the success of forest stand establishment and soil properties. With public support, the present values are in the range of -41 and 5549 €/ha.

Public support of afforestation compensates 60-74% of stand establishment and silvicultural costs depending on stand's location (support zone) and the proportions of material and labour costs in production process. It makes stand establishment activities profitable even for those stands that have the lowest potential for tree growing. Thus, public support is likely to be an efficient policy means to increase afforestation for those fields, which have been abandoned from agricultural production. Without public support, investments in afforestation would lead to negative net present value in 39% of the investigated stands.
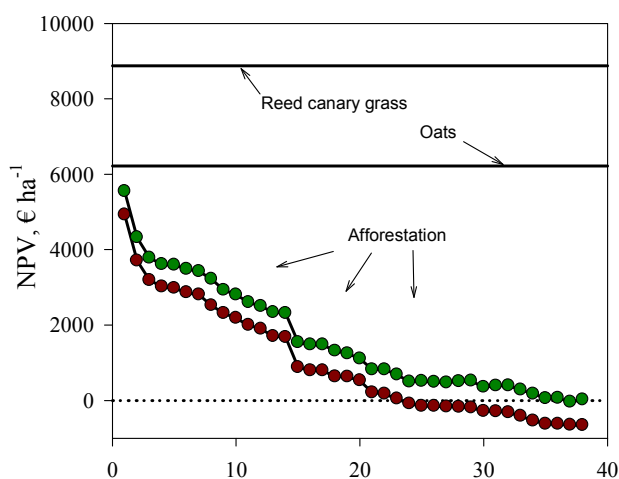

Fig. 3 Net present value of afforested plots in descending order with and without public support (green and red circles) compared to expected net present values from cultivation of oats and energy grass. The rate of interest is 3%.

On the other hand, public support for afforestation does not alter the ranking of alternative land uses. Continued agricultural production, or selling or renting out the field remain as rational actions with or without public support to afforestation. Sensitivity analysis with respect to the rate of interest (not shown) revealed that increase in the rate of interest somewhat reduces the relative attractiveness of afforestation. This is due to shorter production periods in agriculture (1 year) and energy production (12 years) than in forestry (70-95 years).

The net present values from afforestation depend on site's timber production capacity, quality of the harvested timber, occurrence of natural hazards, and level of stand establishment and silvicultural costs. The early development during the first 12 years largely determines the trajectory of future stand development and the level of timber production. Temperature sum turns out another critical factor reflecting the effects of climatic factors on timber production capacity in boreal conditions.

Figure 3 contrasts the variation in net present value of afforestation to average values of land under agricultural production. However, there is a great deal of variation also in farmland values depending on accessibility, acreage, shape, microclimate and soil properties of the field. Figure 4 contrasts the net present value of each afforested stand with average market price and standard deviation in the same region. This more itemized analysis shows that in 4 out of 38 stands afforestation yields higher net present value than average market price for farmland. In 10 stands, the value of land under forestry falls within the confidence interval described as standard deviations around the arithmetic mean of farmland price.
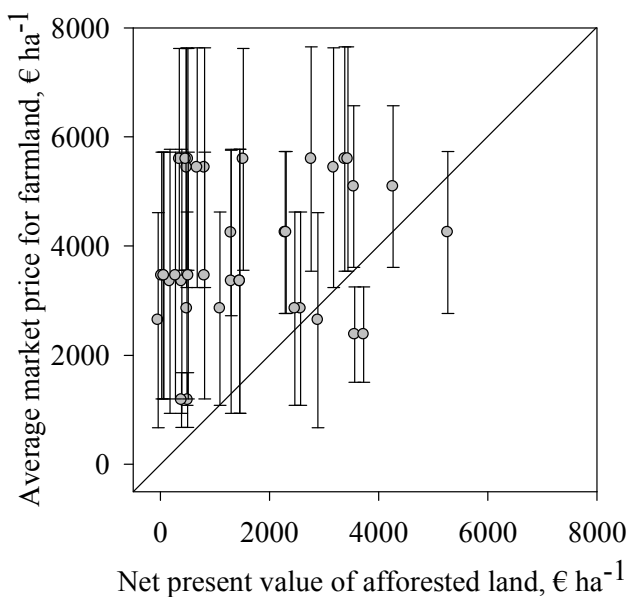

Fig. 4 Net present value of afforested stands (at 3% rate of interest, with public support) in comparison to variation in market prices of farmland by regions. The bars show average market prices and confidence interval described as standard deviations around the arithmetic mean

Figure 4 illustrates that it is not necessarily rational to plant those fields that have the greatest prospects in timber production. Rather, it is reasonable to select for

afforestation those fields that have good or moderate timber production capacity, and whose value or market price as farmland is low due to small size, distant location, stoniness or some other reason.

B. Marginal hectare is forestland

Next we consider rational land use decisions for an area that is initially forested. Conversion to agricultural production (production of oats) is considered as an alternative to continued forestry. Figures 5a and b show rational land use decisions for an exemplary Norway spruce stand for three levels of conversion costs and exogenously given thinnings. Feasible combinations of initial stand age and basal area are divided into three classes according to whether it is rational to continue growing of the present stock, to clearcut the existing stock and establish a new regeneration of trees, or to convert land to agricultural production.

Figures 5a and b are based on computations for evenly distributed grid of about 190 combinations of initial stand age and basal area. Inventory information concerning site properties is obtained from experiment number 2. Land value under continued forestry and immediate conversion to agriculture are computed for each initial state using equations (5) and (6), respectively.

With conversion costs higher than 2890 €/ha (Figure 5a) the value of land under agriculture, J_{agr}, is lower than the value of land under forestry, J_{tim}, for all feasible combinations of stand age and stand basal area. In this case, it is rational to continue growing of the present timber stock and, following the Faustmann solution, to clearcut and regenerate the stand when its relative value growth (annual change of timber value divided by the sum of bare land and timber stock values) becomes lower than the rate of interest [8].

Conversion to agricultural production after clearcutting becomes rational for stand states where $J_{agr} > J_{tim}$. Figure 5b illustrates how reduced conversion cost shortens rotation length and lifts up the threshold of minimum initial basal area for continued forestry. With very low clearing costs (B=1000 €/ha) in Figure 5b, only the most vigorous highly stocked stands between ages of 10 and 30 years are retained under timber production for a while.

(a) high conversion cost
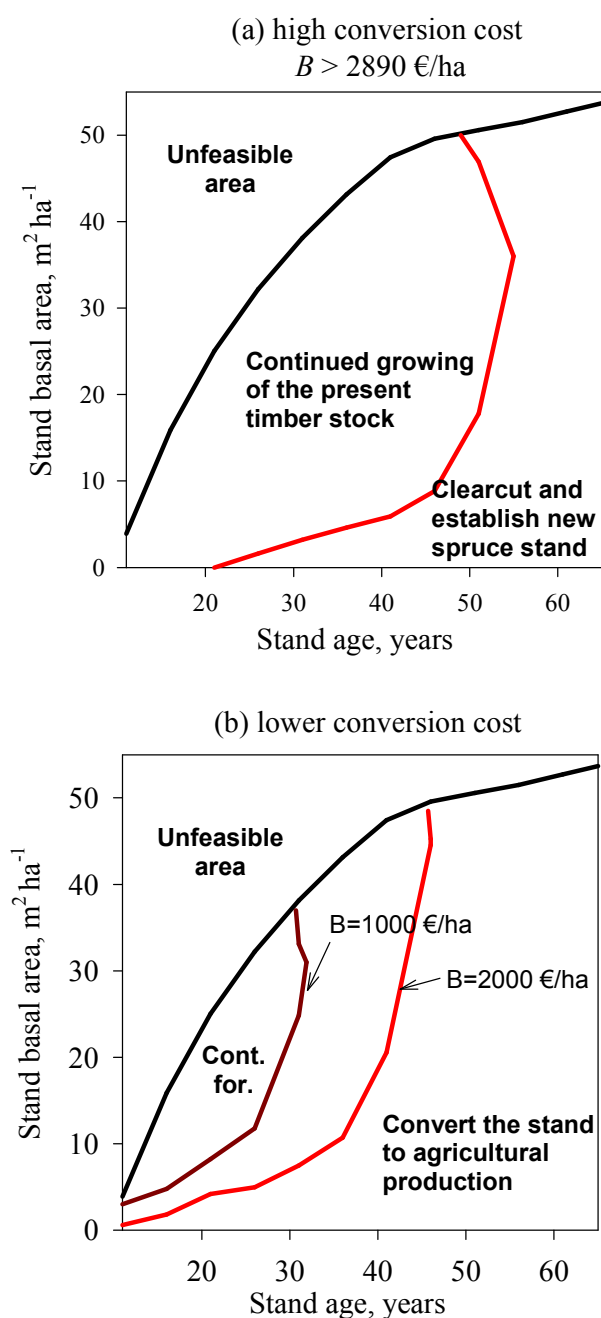$B > 2890$ €/ha

(b) lower conversion cost

Fig. 5 Rational land use decisions for forested Norway spruce stand at 3% rate of interest. Bare land value under forestry for this site is 1978 €/ha.

IV. DISCUSSION

This paper analyses rational land use decisions under present support measures for agriculture and forestry in Finland. Continued agricultural production turned out clearly superior land use for most case study fields according to our results. This implies that even the smallest (inactive) farms have an incentive to maintain their arable lands in agricultural production, if there is an opportunity to rent or sell out the fields. Field afforestation is likely to turn out as an economically attractive alternative only for those fields that are no more suitable for agricultural production.

Converting forestland to arable lands turns rational for forest stands that are inexpensive to clear or where value growth of trees is modest (see Figure 5). Positive future prospects of agricultural production and scale advantages are obviously the most important incentives of switching land from forestry to agriculture. The area of arable land cleared annually from forest has been at a rather steady level during the time Finland has been a member in the EU (see Figure 1). Even the decision to exclude arable land cleared after October 2004 from LFA, agri-environmental and national support has not stopped forest clearance. Reduced forestland area is undesirable development from the point of view of national economy: reduced forestland area is a carbon sink and it is accounted for in the net emissions balance under the Kyoto Protocol.

Former fields that are no more suitable for agricultural production may not be suitable for afforestation, either. The discounted future harvest revenues are not high enough to cover the expenses of stand establishment without public support particularly in peatland soils (see Figure 3). Less capital and labour-intensity land use options may be rational for such fields. One option is to aim at afforestation with smaller initial investments. Allocating part of the set-aside fields to game management is another option.

Cultivation of reed canary grass is promising alternative for traditional agricultural crops. Allocating part of the arable lands to the cultivation of reed canary grass is an attractive alternative also as it relieves annual work seasonality of farms. Harvesting is normally carried out in early spring. Environmental benefits can be achieved from the vegetation cover on fields especially during wintertime. On the other hand, independent contractors and animal farms having forage-harvesting machinery, like mowers and balers, can benefit from increased use of the machinery capital. The limiting factor for increasing energy grass cultivation in Finland is scarcity and low capacity of existing power plants.

Albeit out of the scope of this study, land use changes often involve strong cultural attitudes. Madsen [9] shows that Danish farmers and officials regard afforestation rather as a means to securing environmental and recreation services than as an

alternative to agriculture. On the other hand, badly located tree plantations may destroy rural landscapes. Historical trends in prior land use affect whether people feel positively or negatively about afforestation and forest clearance [10].

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