TREE SPECIES CONVERSION TO DIMINISH FOREST'S WATER USE — FINANCIAL CONSEQUENCES OF A CONTROVERSIAL FOREST MANAGEMENT PRACTICE IN THE NETHERLANDS

BRAM M. FILIUS AND ONNO R. ROOSENSCHOON*

ABSTRACT

The increase in water consumption in recent decades has caused the groundwater level to decline over much of the Netherlands, often resulting in parching. Conversion of forest tree species has been recommended as a measure to increase this level to restore the vegetation and soil life, because converting from so-called dark coniferous species to so-called light coniferous species and broadleaved species should diminish the forest's water use. The financial consequences of this for the forest owner are calculated. They comprise the cost of converting existing stands — mainly Douglas-fir — to oak, Scots pine and Japanese larch and the cost of abandoning the expansion of the area under Douglas-fir. The costs of converting existing stands depend on the replacement species, the discount rate and the age at which Douglas-fir is converted. The costs of conversion are expressed per m³ difference in water use between species. The arguments of the Dutch forestry community against conversion are discussed. Some are ideological, others refer to uncertainty or to the financial consequences.

Keywords: water use, species conversion, costs.

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INTRODUCTION

The industrial, agricultural and domestic consumption of water in the Netherlands has increased considerably in recent decades in the Netherlands. Because much of this water has been withdrawn from the groundwater, the groundwater level has been declining in many parts of the country, often resulting in parching; a phenomenon observed on about one third of the forest area. The understorey vegetation of forests is more sensitive than trees to a groundwater level decline. The Dutch government has developed policies to diminish the area affected by parching (Min. van Landbouw, Natuurbeheer en Visserij, 1993).

Bram M. Filius and Onno R. Roosenschoon, Dept. of Forestry, Agricultural University, P.O. Box 342, 6700 AH Wageningen, The Netherlands. Onno R. Roosenschoon is currently at the Winand Staring Centre Wageningen.

A Steering Group on Groundwater Management in the Netherlands (Stuurgroep Grondwaterbeheer Midden Nederland, 1992) identified the conversion of so-called dark conifers (such as Douglas-fir and Norway spruce) to broadleaved species and so-called light conifers (such as Scots pine and Japanese larch) as one of the solutions to the problems with respect to groundwater withdrawal, because light conifers and broadleaved species use less water than dark conifers. This conversion, however, conflicts with the earlier government policy aiming at increasing the Douglas-fir area and goes against the trend in the species choice of private forest owners. Because of its high timber yield, Douglas-fir is considered to be a bread-and-butter tree which can considerably contribute to the profit of forest enterprises. Conversion would mean replacing it with a less profitable species, and therefore, it is unlikely that forest owners will start species conversion voluntarily. It was against this background that a water company requested the Department of Forestry at Wageningen Agricultural University to calculate the financial consequences of conversion for the Veluwe Region — a region in the centre of the Netherlands in which this issue is topical — to provide a basis for compensating forest owners.

The financial consequences of species conversion mainly consist of the cost of converting existing stands of dark conifers and the cost of abandoning expansion of the area under dark conifers. Before presenting these consequences we will first discuss the relationship between species choice and water yield. Finally, these costs will be related to the expected augmentation of the potential water yield, and the resistance to this forest management practice in the Dutch forestry community will be discussed.

Tree Species and Water Use

Some decades ago, researchers had already confirmed that many coniferous species use more water than hardwoods. This greater water use can largely be ascribed to interception of more precipitation because conifers retain their foliage in the winter. Some of the intercepted water evaporates if the temperature is high enough, and does not reach the soil. For the Southern Appalachians of western North Carolina, Helvey (1967) reports estimates of an annual interception loss of 21 inches from white pine stands aged

60 years in comparison to 10 inches for mature mixed hard-woods. Swank (1968, quoted by Douglass, 1983) estimates that differences in interception could account for three to four inches of difference in water yield between pine and hardwood in the South Carolina Piedmont and Coastal Plain. But transpiration also seems to contribute to white pine's use of more water (Douglass, 1983). Benecke & Van Der Ploeg (1974) report a difference in annual water use between spruce and beach of 100 mm in Germany.

Nonhebel (1987) has estimated the water use of various tree species with the help of a hydrological model for Dutch conditions during the period 1974–1978. The research done by Nonhebel indicates that the average annual difference between dark coniferous species and light coniferous and broadleaved species varies among sites between 198 and 250 mm. Uncertainties about the results of this model are due to the influence of the understorey vegetation and to that of turbulence. Both aspects can differ among tree species. The age of the stand also influences water use: young stands use less water than older stands. In the research mentioned earlier, Helvey (1967) found that annual loss to interception loss in white pine stands aged 10 years was only 12 inches. This difference in water use between young and old stands can be ascribed to a difference in forest cover (Rakei *et al.*, 1992). The outcome of Nonhebel's research (1987) refers to the water use of stands of the most common age-class in the Netherlands of the species concerned according to the 1985 forest survey. This age-class may not be representative for the water use of species. The water use of a specific species may differ among regions because of a difference in species age distribution.

COSTS OF CONVERSION

Starting Points

The costs of converting a stand is defined as the difference in net present value with and without conversion. In the calculation in the "without" situation only Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) has been considered, since Norway spruce (*Picia abies* Karst.) plays only a minor role in the Veluwe region at present and this is expected to remain the case. In the situation with conversion it is assumed that 40% of the Douglas-fir area will be converted to oak (*Quercus robur* L.) and the remainder to Scots pine (*Pinus sylvestris* L.). On some sites in the region, also Japanese larch (*Larix leptolepis* Gord.) is a suitable species from a silvicultural point of view; calculations have therefore been made with the species oak, Scots pine and Japanese larch, assuming that their shares of the area will be 20, 60 and 20%, respectively. The calculations have been made for a moderate site quality; costs and revenues are based on those used in a recent study on the profitability of species in even-aged stands in the Netherlands (Bosschap, 1990). For details of calculations and outcomes see Filius & Roosenschoon (1993).

The outcomes of the research have to be relevant for several categories of stakeholders — public as well as private — each probably having different discount rates. The calculations have therefore been made using several discount rates. The rotations applied below are actual rather than financially optimal rotations. Below, calculations have been made at different (real and before tax) discount rates, but always with the same rotations. At a 4% discount rate the species have the following Land Expectation Value (LEV) in Dutch guilders (*f*) per hectare: Douglas-fir -*f*2844 (rotation 80 years); oak -*f*12410 (rotation 150 years); Scots pine -*f*4793 (rotation 65 years); Japanese larch -*f*3611 (rotation 60 years).

In a preliminary study of the Ministry of Agriculture (Consulentschap Natuur, Bos, Landschap en Fauna in Gelderland, 1992) it was suggested that the Steering Group recommended an immediate conversion — within a period of 10 years. This would not only cause considerable disruption to the landscape, but would also entail high costs of conversion. Therefore options other than immediate conversion will also be considered below.

Option 1: Immediate Conversion

Table 1 gives the costs of this option. The costs of conversion per hectare are calculated as: Net Present Value (NPV) without conversion minus NPV with conversion.

The NPV without conversion in this table consists of the NPV of future cost and revenues of the current Douglas-fir stand plus the present value of the LEV of future Douglas-

TABLE 1. IMMEDIATE CONVERSION COSTS.

The table shows costs of immediate conversion of Douglas-fir to oak+Scots pine, per hectare and per age-class and for the Veluwe region (discount rate 4%).

AGE CLASS	NET PRESENT VALUE WITHOUT CONVERSION	STUMPAGE VALUE AT IMMEDIATE CONVERSION	PRESENT VALUE OF LAND EXP. VALUE OAK / SCOTS PINE	COSTS OF CONVERSION	AREA TO BE CONVERTED[i]	TOTALCOSTS OF CONVERSION
years	*f*/ha				ha	*f*1000
0–10	3 055	–1 779	–7 840	12 674	1 199	15195
10–20	5 203	–1 408	–7 840	14 522	607	8815
20–30	10 262	1 419	–7 840	16 682	1 217	20302
30–40	12 678	9 969	–7 840	10 548	1 749	18449
40–50	16 215	14 939	–7 840	9 116	1 747	15925
50–60	18 272	20 198	–7 840	5 914	1 282	7582
60–70	24 402	26 109	–7 840	6 133	705	4324
70–80	30 083	31 846	–7 840	6 076	269	1635
All	15 508	10 837	–7 840	10 510	8 775	92227

[i] Based on 4th Forest Survey (CBS, 1985) and Min. van Landbouw, Natuurbeheer en Visserij (1992)

fir stands. It is assumed that within an age-class of ten years each age is represented by an area of the same size. As a result, the calculation of the NPV without conversion is more accurate than when it is assumed that all stands are the age of the median age of the age-class. The stand has already been planted in the first year, which implies that no planting costs are involved. This NPV increases with age-class because the number of years between conversion and clearcut decreases and therefore so does the discount factor by which the value of the clearcut has to be multiplied. The NPV with conversion consist of the stumpage value of Douglas-fir at immediate conversion, plus the present value of the LEV of the species converted to.

Table 1 shows that the costs of conversion per hectare of older Douglas-fir stands are less than that of younger stands. It is more costly to remove young stands, and therefore the costs of immediate conversion of the whole Veluwe region are considerable. The NPV without conversion as well as the stumpage value at immediate conversion do not increase very smoothly with increasing age. The reasons for this include the jump of the stumpage price in age-class 30–40 years and the heavy thinnings between the age 50 and 55 years.

Table 2. Converting Costs.
Cost of converting of Douglas–fir to oak/Scots pine or to oak/Scots pine/Japanese larch per hectare and for Veluwe region (discount rates 2, 4 and 6%).

	Discount Rate	Net Revenue without Conversion	StumpageValue at Direct Conversion	LEV New Species	Costs of Conversion	Total Costs Conversion
		f/ha				*f*1 000
Conversion to oak/Scots pine	2%	30 018	11 050	−2 974	21 942	192 542
	4%	13 508	10 837	−7 840	10 510	92 227
	6%	8 008	10 633	−8 411	5 786	50 773
Conversion to oak/Scotspine/ Japanese larch	2%	30 018	11 050	−1 227	20 195	177 209
	4%	13 508	10 837	−6 080	8 750	76 785
	6%	8 008	10 633	−7 045	4 421	38 792

Table 2 indicates that the costs of conversion significantly depend on the discount rate used: they are lower at a higher discount rate. The costs of conversion can be reduced if it is also possible to replace Douglas-fir by Japanese larch. The difference with the option in which conversion is solely to oak/Scots pine is relatively large at a high discount rate, because of the short rotation of Japanese larch which gives a high yield.

Option Two: Spreading the Conversion

Because of the drawbacks of mass conversion for the landscape and since it is relatively costly to convert young stands, we studied the influence of delaying conversion. Table 3 shows the outcomes of delaying conversion to 10, 20, 30, 40 and 50 years from 1993. In this option, mature stands — that is to say stands that have reached the rotation age — are converted and not reforested with Douglas-fir; stands which have not reached maturity are only converted if the adopted conversion period makes this necessary. The costs of converting stands which reach the rotation age consist solely of the difference in LEV between Douglas-fir and oak/Scots pine/(Japanese larch). Delaying conversion slashes the costs of conversion: at 4% discount rate, a conversion period of 50 years and conversion to oak/ Scots pine they only are about 11% of those of immediate

TABLE 3. COSTS OF DELAYED CONVERSION.
Present value of the costs of converting to oak/Scots pine or to oak/Scots pine/Jap. larch) at 2, 4 and 6% if conversion is delayed.

	DISCOUNT RATE	TOTAL COST IF CONVERSION IS REALIZED IN YEAR:				
		2003	2013	2023	2033	2043
		f1 000				
Conversion to oak/ Scots pine	2%	149 287	114 634	83 987	65 389	53 206
	4%	54 192	32 941	19 156	13 468	10 539
	6%	20 281	9 223	4 409	3 634	3 377
Conversion to oak/ Scots pine/Jap. larch	2%	136 560	103 779	74 305	56 304	44 363
	4%	43 743	25 738	13 946	9 367	7 003
	6%	13 560	5 321	1 928	1 803	1 806

conversion. However, there is an equivalent delay in reaping the benefits of conversion.

The costs of conversion increase somewhat in the situation in which there is conversion to Japanese larch in the year 2043 only and at 6% discount rate because it is less costly to convert Douglas-fir stands that are slightly younger than 70 years than it is to convert stands older than 70 years, especially at higher discount rates. At 6% discount rate conversion of the age-classes 50–60 years and 60–70 years to oak/Scots pine/Japanese larch is even profitable. This has to be ascribed to the fact that especially at a high discount rate 80 years is not the financially optimal rotation.

Option Three: Conversion at the End of the Rotation of Douglas-fir

This option means that no Douglas-fir stand is felled before the rotation age is reached. In this option the costs of conversion solely comprise the difference between LEV of Douglas-fir and the species to which Douglas-fir is converted.

The figures in Table 4 are the present values of this difference in LEV multiplied by the number of hectares of Douglas-fir in a particular age-class that reach the age of 80 years. The costs of conversion in this option are lower than in the former option, except if compared with conversion in the year 2043 of the latter table at a 6% discount rate. The reason for this is again the lower costs of converting of Douglas-fir stands somewhat younger than 70 years.

TABLE 4. COSTS OF CONVERSION AT THE ROTATION AGE.

Present value of the costs of conversion of Douglas-fir at the rotation age to oak/Scots pine or to oak/Scots pine/Japanese larch per hectare and for the whole region (discount rates 2, 4 and 6%).

	DISCOUNT RATE	COST PER HA f/ha	TOTAL COST f1000
Conversion to oak/ Scots pine	2%	4902	43019
	4%	1034	9070
	6%	395	3465
Conversion to oak/ Scots pine/Jap. larch	2%	3907	34280
	4%	669	5875
	6%	231	2026

Note, however, that in this option in the year 2043, 3023 hectares Douglas-fir have not yet been converted because the rotation age has not yet been reached.

COST OF ABANDONING THE EXPANSION OF THE AREA UNDER DOUGLAS-FIR

The Dutch government's Master Plan for Forestry (Min. van Landbouw en Visserij, 1986) aimed at increasing the area under Douglas-fir in the Veluwe region to 14500 hectares by the middle of the next century. This is an increase of 13560 hectares compared with the year 1993. The water use could be diminished if forest owners also abandon expanding the Douglas-fir area. What costs would this abandonment entail?

Let us assume that forest owners plant oak and Scots pine or oak, Scots pine and Japanese larch instead of Douglas-fir. The costs per hectare can then be calculated as the difference in LEV between Douglas-fir and these replacing species. However, this difference only occurs at the time Douglas-fir would have been planted. The present value of one hectare not planted with Douglas-fir in the future is lower than that of one hectare abandoned now, as Table 5 shows. In that table it has been assumed that the expansion will be evenly spread over the next 50 years. This means that every ten years the planting of Douglas-fir can be aban-

TABLE 5. REFORESTATION COSTS.

Cost of reforestation with oak/Scots pine and of abandoning expanding the area under Douglas–fir in the period 1993–2043 per ha and the Veluwe region (discount rate 4%).

PERIOD OF REFORESTATION	AREA OF THE REFORESTATION	PRESENT VALUE OF THE COST	
		PER HA	VELUWE REGION
	ha	*f*/ha	*f*1000
1993–2003	2 712	4 107	11 137
2004–2013	2 712	2 774	7 524
2014–2023	2 712	1 874	5 082
2024–2033	2 712	1 266	3 433
2034–2043	2 712	855	2 320
Total	13 560	2 175	29 496

doned on 2712 hectares. The costs are further based on the assumption that, on average, expansion would have taken place in the middle of a period.

Table 6 shows that these costs depend considerably on the discount rate and that a substantial decrease in these cost can be achieved if Japanese larch can be planted.

Note that the figures in Tables 5 and 6 are based on the

TABLE 6. COST OF ABANDONING EXPANDING THE AREA.

Cost of abandoning expanding the area under Douglas-fir; reforestation with oak/Scots pine or oak/Scots pine/Japanese larch (discount rates 2, 4 and 6%)

	DISCOUNT RATE	AREA OF THE EXPANSION	PRESENT VALUE OF THE COST	
			PER HA	VELUWE REGION
		ha	*f*/ha	*f*1 000
Reforestation with oak/ Scots pine	2%	13 560	7 736	104 903
	4%	13 560	2 175	29 496
	6%	13 560	1 053	14 278
Reforestation with oak/ Scots pine/Jap. larch	2%	13 560	6 164	83 589
	4%	13 560	1 409	19 105
	6%	13 560	616	8 352

assumption that a) the expansion of the area under Douglas-fir will be realised and b) that this objective of the government will be achieved without financial incentives of the government.

Costs of Conversion per M³ Difference in Water Use

Is it desirable to implement this conversion? To answer this question, not only the costs but also the benefits of conversion have to be known. To know the benefits the following questions have first to be answered:

1. For what purposes will the extra water yield be used: to reduce parching or increase the water supply? The provincial authorities have denied that the extra water yield will be used for water supply; they will use it to reduce parching (Provincie Gelderland, 1992).

2. What are the benefits of conversion for nature conservation and recreation? Conversion can have direct effects on the attractiveness of the Veluwe region for recreation. The disappearance of Douglas-fir will diminish the variety of tree species, which will make the region less attractive to visitors. On the other hand, diminishing parching will have a positive influence on the vitality of forests and on the understorey of the vegetation which is beneficial for nature conservation and makes the region more attractive to visitors. From the point of view of nature conservation, the disappearance of Douglas-fir — being an exotic species — and the increase in the area under indigenous species — such as oak and Scots pine — is considered positive. In fact, nature conservation organisations in the Netherlands are already reducing the area under Douglas-fir for this reason.

3. Does conversion influence groundwater quality? There are indications that the aluminium, nitrate and sulphate contents of groundwater in poor sandy soils are lower under broadleaved species than under coniferous species (Bleuten *et al.*, 1993; Smittenberg, 1993).

4. What are the consequences of conversion for timber supply to the Dutch timber industry and what are the effects on employment?

Although it is expected that conversion will have consequences for recreation, nature conservation, water quality,

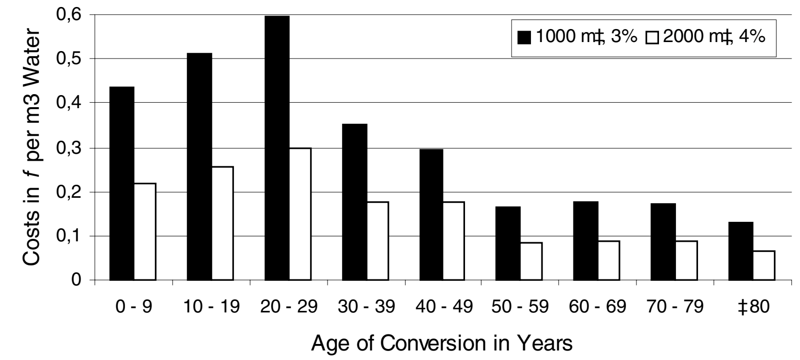

Figure 1. Costs per m^3 Difference in Water Use between Douglas-fir and Oak/Scots pine/Japanese larch

Costs per m^3 difference in water use between Douglas-fir and oak/Scots pine/Japanese larch at different age of conversion and at a difference in water use between these species of 1000 m^3 and 2000 m^3 per annum (discount rate 4%). The column for the age class ≥ 80 years gives the costs of abandoning of expansion of Douglas-fir.

timber industry and employment, the quantitative relationships are not known and even if they were, they would be difficult to assign a value to. Therefore, the analysis will be confined to figures on the cost of conversion per m^3 difference in water use (see Figure 1).

If surface water is an alternative source of water supply, these figures can be used to compare cost of water production from groundwater and surface water. For this purpose the costs of conversion are first expressed in annual cost per hectare and then divided by the annual difference in water use per hectare. If the value of one m^3 water is known, they can be compared with these costs and it can be decided which age-classes are attractively to convert.

The annual difference in water use between dark coniferous species and light coniferous and broadleaved species is assumed to be 200 mm which is 2000 m^3 per hectare. Because, as already mentioned, the difference in water use is rather uncertain, the calculations of the cost per m^3 difference in water use have also been made for 1000 m^3 per hectare. Thus, Figure 1 shows that at a difference in water use of 2000 m^3 it is financially attractive to convert a Douglas-fir stand in the age-class 20–29 year if the value of one m^3 water exceeds about ƒ0.30; stands older than fifty years can already beneficially be converted if this value is about ƒ0.09. The costs per m^3 difference in water use for age class 80 years have been based on the cost of abandoning expanding the area under Douglas-fir. These are the differences between the annual value per hectare of Douglas-fir and oak/Scots pine/Japanese larch divided by 1000 m^3/ha and 2000 m^3/ha respectively.

Is It An Acceptable Practice to Convert Forest Stands to Increase Water Yield?

Conversion of forest stands to increase water yield is a controversial practice in the Netherlands. Various arguments against conversion have been put forward: some are based on forestry ideology, others refer to the uncertainty of the effects or to the financial consequences. Some of them will be discussed below (which is largely based on Filius, 1994).

— *Conversion is Unacceptable in Principle*

This argument has been put forward by the Dutch Association of Foresters (KNBV, 1994). The Association compares and ranks conversion with acid deposition: just as the solution to the problem of acid deposition lies in diminishing air pollution and not within forestry, the solution to the problem with the groundwater level should be found outside forestry. However, both the decrease of vitality of trees because of acid deposition and the parching of the environment are negative external effects. Effective and efficient ways of diminishing these external effects should be sought. The conversion of tree species to diminish water use is considered to be such a method, and a forest owner will be willing to apply this if he is financially compensated. The Association's gloomy prognostication of a worsening financial position is not justified. If the forest owners are able to manoeuvre themselves into a good negotiating position then the compensation could exceed the cost. Then they might be better off than in the situation in which planting Douglas-fir in the future will be prohibited by the government to diminish parching. Any such prohibition should be the result of an investigation that shows that conversion leads to the optimal fulfilment of forest functions for society and of weighing the interests of forest owners against those of other social groups.

— *Water Consumption Should Be Reduced*

In several responses on the conversion issue it has been pointed out that diminishing water consumption should be the solution to the problem of groundwater management (Bosraad, 1994; Bosschap, 1993; KNBV, 1994). In this view, water is considered to be partly used for trivial purposes which do not justify the modifying forestry. It should be admitted that "the prices charged by water distribution utilities do not promote efficiency of use either" (Tietenberg, 1996). But it can be expected that the water sector will respond to this by pointing to the waste of wood, e.g. for the production of advertising material. It is not up to the forest sector to make judgements about the utility of water consumption.

— *Only Marginal Effects Are to Be Expected*

The Evaluation of the Master Plan for Forestry (Min. van Landbouw, Natuurbeheer en Visserij, 1992), contends that conversion will be very costly and will have only marginal effects on the reduction of parching. In general, it will be rather ineffective. This expectation is based on the assumption that the entire area under dark coniferous species will be felled within a short period. The calculations show that the costs can be considerably reduced if conversion is spread over a long period so that conversion can be limited to older stands (be it that the benefits will be delayed also). In addition, conversion should be limited to sites where parching can be effectively alleviated by conversion. Research done by IWACO (1993) shows that conversion is most effective if combined with other measures and if conversion focuses on areas with a concentration of dark coniferous species close to nature conservation areas. In some locations conversion is one of the most effective measures.

— *Uncertainty*

There is uncertainty about the difference in water use between dark coniferous species and light coniferous and broadleaved species and about the effects on parching as has been noted above. This difference is being investigated with the help of models in the Netherlands (Dolman & Kabat, 1993). Further, there is uncertainty about the financial consequence. In this study, a deterministic approach has been applied, but in reality prices and volumes are stochastic. Lastly, there is uncertainty about the effects on recreation, nature conservation and groundwater quality.

— Loss of Investment in Douglas-fir

The Association (KNBV, 1994) also rejects conversion because this leads to a disinvestment in the stands that were established with the help of government subsidies. Conversion leads to the destruction of capital (Van Der Meiden, 1994). The investment in Douglas-fir, however, has to be considered as a sunk cost.

— It Is Absurd to Replace a Forest That Is Increasing in Value

Whether conversion is absurd — as the Association puts it (KNBV, 1994) — depends not only on the increase in the value of the current stands, but also on the value of the new forest. The change in the value of timber production as well as in the value of water yield, recreation and nature conservation of the old and new stands should be taken into account.

The conclusion must be that most arguments against conversion can be disproved. Uncertainty about its consequences is the most impressive argument.

Discussion and Conclusions

The foregoing shows a competitive relationship between the classical goal of forestry — timber production — and water yield. Augmenting water yield by means of species conversion will diminish financial returns from timber production. Forest enterprises that have water supply as a goal — for example municipalities owning a water company — will therefore scrutinise the trade-off between water supply and timber production. But forest enterprises that do not have water supply as a goal will also consider conversion if other goals are served such as the reduction of the area under exotic species and alleviating parching. Since conversion will diminish the profitability of forest enterprises having the classical goal of timber production, such forest enterprises must be compensated. This article gives an indication of the amount of compensation required to cover the silvicultural costs of conversion. The transaction costs and costs of adapting of the management plan to accomodate conversion have to be added to these costs.

Whether it is attractive from a point of view of society to apply conversion can only be determined if the effects on non-timber functions have been assessed; conversion seems to have impact on the recreation function and the nature conservation function. These effects are not fully known.

If fair compensation is provided it is not necessary to reject conversion for reasons of principle as has been suggested in the Netherlands. The objectives of forest management have changed in the past as a result of new scarcity arising in dynamic societies. Water is already a scarce resource in many industrialised countries (Tietenberg, 1996) and forest management can contribute to the availability of this resource. It can be considered that this availability does not have to be provided as a positive external effect but can be negotiated with water companies/authorities. Foresters should not a priori reject the possible contribution of forests to the fulfilment of this function of forests.

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