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ORIGINAL PAPER

Economic assessment of use values of near-natural forestry compared with rotational forestry in Denmark

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Abstract The present study is a cost-benefit analysis of converting the current rotational forestry (RF) of Norway spruce stand into near-natural forestry (NNF) of beech, based on two representative soil conditions and visitors popular case areas in Denmark, considering welfare economic values of timber, recreation provision, and groundwater recharge. The study answers the major research question of how large the welfare economic values of recreation and groundwater benefits of the conversion are as compared with timber benefits. The net present values (NPV) of the benefits were calculated for an infinite time horizon at a 3 % discount rate. The results reveal that converting into NNF would result in a NPV of at least 6,832 € ha^{-1} from use values of recreation and water benefit on a site with good soil and a high visitor frequency, as is typical in the eastern part of Denmark. On a site in the west of the country, with poor growth conditions and a lower visitor frequency, the gain is still substantial, namely 5,581 € ha^{-1}. These benefits though come at a cost of 3,375 and 6,206 € ha^{-1} from timber production, respectively. This means that the economic value of use values of recreation and water benefits outweighs the loss of timber on good soil conditions but not on poor soil conditions.

Keywords Cost-benefit analysis · Near-natural forestry · Recreation score · Tree growth · Run-off · Water · Conversion

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Introduction

Conversion of the traditional rotational forestry (RF) of Norway spruce (*Picea abies*) into a more ecologically oriented and society-centred multi-functionality forestry approach called near-natural forestry (NNF), using native broadleaved species and mainly European beech (*Fagus sylvatica*), has been growing across many European countries. There are two underlying common factors for the conversion (Spiecker et al. 2004). First, with rising living standards over time, modern society's interest in multiple functions of forest, such as outdoor recreation provision, water protection, biodiversity conservation, and carbon storage, increases, and NNF is often better at securing these ecosystem services than RF. Second, the traditional monoculture management of Norway spruce has faced severe damages by storm, insect pests, and other disturbance.

Despite lively discussion of the development of society-centred and nature-based forestry policy, the welfare economic impacts assessment of the expected social and environmental benefits of the policy is yet at the young phase. The current study, therefore, aims at providing an economic assessment of the socio-economic effects of converting RF of Norway spruce stand into NNF of beech, based on two representative cases at each end of the spectrum of soil conditions and visitor frequencies in Denmark. We consider welfare economic values of the most demanded forest functions, namely timber production and two non-timber benefits (recreation provision, and groundwater recharge and protection). Conversion from one forest management into another, including a tree species change, is a long-term change, and many benefits may first be seen much later. Therefore, an important attribute of the study is that we make the flow of the non-timber benefits age dependent.

Apart from use values, forests also provide non-use values. However, the aim with the current study is alone to estimate the use values which are more tangible.

The study would give an important insight for policy makers and forest managers to scheme site-specific economic instruments, such as payment for ecosystem services (PES), so as to attain sustainable forest management.

The existing forest economics literature that has analysed the business economics of NNF compared with RF finds ambiguous results. Tarp et al. (2000) and Nord-Larsen et al. (2003) find NNF to be superior, mainly due to reduced establishment costs. Nord-Larsen et al. also attribute the result to more optimal harvest timing. Other studies find the profitability of conversion into NNF to be inferior to RF in some stable conditions (Jacobsen et al. 2004; Duncker et al. 2011). Yet, the business economics of the conversion is only one side of the coin. The other is the non-marketed ecosystem services.

Price and Price (2008) throw light on the economic cost-benefit analysis of continuous cover forestry or NNF of conifers trees with a monetary estimate of recreation benefit and water evapotranspiration loss against the RF system, assuming the benefits are constant over time. However, the recreational values are known to depend on age and forest structure (Boman et al. 2010). Consequently, we examined the dynamic welfare economic values of recreation benefit of different phases over a rotation of NNF beech. This was possible by tracing Danish recreationalists' willingness to pay (WTP) for attributes of NNF of beech (Nielsen et al. 2007) to different phases of the stand development, using the respective "recreational scores" developed in the EFORWOOD research project (Edwards et al. 2010).

Groundwater is an important resource in Denmark, fulfilling almost the entire water demand. In densely populated areas, the resource is becoming scarce, and increased demand for water is therefore an issue. The provision of groundwater underneath forests depends on age as does recreation (Boman et al. 2010). However, the biggest difference lies in the species change and thereby the amount of water running through.

The remainders of the paper are organised as follows. Section two discusses definition of the traditional and conversion scenarios, methodology and economic calculations of timber and non-timber benefits. Section three and four present and discuss the results, respectively.

Materials and methods

Site description and the scenarios

The study focuses on converting the current RF of Norway spruce stand into NNF of beech based on two different sites with respect to soil conditions and visitor frequency (Table 1). The conversion is meant to achieve two major objectives: wood production and recreation values on both sites (Larsen and Nielsen 2007). An important co-benefit is an increased amount of groundwater produced as broadleaved trees evaporates less. The forest areas on both sites are composed of different tree species, mainly Norway spruce, European beech, different species of oak (*Quercus*), and Douglas fir (*Pseuudotsuga menziesii*) (Rune 2009).

Table 1 The number of visitors and soil conditions in two study forest areas in Denmark

Site characteristics	Gribskov	Klosterheden	Source
Number of visitors (visits ha^{-1} $year^{-1}$)	78 (448,000 visits over 5,698 ha)	25 (154,250 visits over 6,265 ha)	Jensen (2003)
Annual precipitation (mm)	613	850	DMI 2012
Location	Northern Zealand	Northwest Jutland	
Soil condition	Good soil class	Poor soil class	Møller (1933)
	For beech site class 1 (H_{50}) of 24 m (top height at age 50).	For beech site class 4 (H_{50}) of 17 m (top height at age 50)	
	For Norway spruce site class 2 (H_{50}) of 25 m	For Norway spruce site class 3 (H_{50}) of 22.5 m	

To make sure that we compare initiatives originating from the same state, the starting point for the developed scenarios is assumed to be bare land after the existing matured Norway spruce stand is clear-felled. Due to risk of windthrow in Denmark, it is normally not considered feasible to regenerate under shelter, and natural regeneration is not possible due to lack of seed trees in the conversion phase. The "baseline scenario" is a continuation of RF of Norway spruce using clear-felling and replanting in a 60-year rotation period on the good soil and 70 years on the poor soil, for an infinite time horizon (Forest Economics Table 2006). At the time of re-establishment, Norway spruce is planted at a density of 4,500 trees per hectare. We assume standard practice of a heavy thinning early in the stand's life whereafter it develops into a light thinning once the stand attains a height makes it susceptible to windthrow (12–14 m) (Danish Forest Society 1995, cited by Nord-Larsen et al. 2003).

The "conversion scenario" is defined by principles of NNF (Larsen and Nielsen 2007) of beech, using a uniform shelterwood system with a regeneration thinning at stand age 90 years and liquidation of the last holdovers at age

110 for an infinite time horizon on the good soil. The corresponding shelterwood stand ages on the poor soil are extended to 100 and 130 (Forest Economics Table 2006). At the time of establishment, beech is planted at a density of 5,500 trees per hectare and followed by continuous thinning, regeneration harvests, and initiation of natural regeneration.

Methods

The current study applied an economic cost-benefit analysis (cf Hanley and Barbier 2009) by means of benefit transfer to assess the monetary values of timber and non-timber benefits. We used net present value (NPV) for an infinite time horizon to evaluate the conversion (Davis et al. 2001, p. 332). The NPV formula for timber, recreation, and water are described below.

The NPV for an infinite time horizon of timber for RF is calculated as the sum of the discounted future benefits and costs with a discount rate (r) for infinite rotations of length R, using the following formula:

$$\mathrm{NPV_{RF}} = \frac{\mathrm{NPV}\ (1+r)^R}{(1+r)^R - 1}$$

The NPV for an infinite time of timber for NNF is calculated as the sum of the present value of net revenue (NR) of beech of the conversion phase and the present value of the expectation value of the final steady state as follows:

$$\mathrm{NPV_{NNF}} = \sum_{t=0}^{R} \frac{\mathrm{NR}_t}{(1+r)^t} + \left(\frac{\mathrm{NPV}\ (1+r)^R}{(1+r)^R - 1}\right) \times (1+r)^{-R}$$

The NPV of an infinite time horizon of the marginal increase in recreation benefit of the conversion into NNF is calculated as the sum of present value of recreation benefit of conversion phase and present value of the infinite value of recreation benefit of post-conversion using the above formula for NPV of NNF. This is because the recreationalists' WTP was estimated for an increase in WTP for changing from RF of Norway spruce stand to NNF of beech stand (Nielsen et al. 2007).

Water yield data are available only as an annual average over a rotation (Duncker et al. 2011), and hence, the infinite value of NPV of water benefit is calculated using annuity discounting factor and by discounting for water travel time (T) 20 years as follows:

$$\mathrm{NPV} = \left(\frac{\text{Annual water benefit}}{r}\right) \times (1+r)^{-T}$$

Total net present value (TNPV) for NNF and RF is calculated as the sum of NPV of timber, NPV of recreation benefit, and NPV of water benefit.

$$\mathrm{TNPV} = \mathrm{NPV_{Timber}} + \mathrm{NPV_{Recreation}} + \mathrm{NPV_{Water}}$$

In the following subsections, the economic calculation of timber, recreation benefit, and groundwater benefits are described.

Economic calculation of timber benefit

The tree growth model outputs are based on a standard growth and yield table (Forest Economics Table 2006). Economic data including regeneration costs and stumpage price were found from Forest Economics Table (2006) and adjusted for inflation to year 2012 (Statistics Denmark 2012). The regeneration costs for Norway spruce include soil preparation, plants, planting, and pesticides. The regeneration costs for conversion phase or initial stand establishment of beech include fencing besides the other costs. The regeneration costs of beech differ between the conversion phase and the post-conversion phase, as natural regeneration is possible in the latter due to the presence of seed trees, and also fencing cost is avoided. The stumpage price functions consider timber product categories/assortment of beech and Norway spruce ("Appendix B"). The stumpage prices are net mill selling price after deducting harvesting, bunching, and transport costs. Stumpage price of beech "without red-heart formation" was used because according to Nord-Larsen et al. (2003) shelterwood natural regeneration of beech in early years of liquidation has low propensity to such damage. Turnover balances for both scenarios on the two soil conditions are given in "Appendix A".

Estimation of recreation benefit

The change in recreation benefit of converting RF of Norway spruce stand into NNF of beech was estimated considering the influence of tree size on recreationalists' preferences. The value is based on Nielsen et al. (2007) who used the choice experiment method to elicit the Danes' WTP for RF of Norway spruce and NNF of beech represented by different stand characteristics in a maturity phase. The respondents' preferences for changing from RF with clear-felling, Norway spruce trees and no deadwood trees into NNF with shelterwood, beech trees, and few deadwood trees scenario were estimated at € 28, 103, and 15 per person per year, respectively. The NNF scenario would thus consist of all three aspects i.e. € 146 per person per year or € 172 in 2012 prices. The authors argue that the values might partly be rooted in the positive cognitive value ascribed to nature-based forest management, and thus not solely relates to the recreational use value. We take up a conservative approach here and divide this number by

Table 2 Recreational benefits for the two locations once a mature NNF beech forest stand has been established

	Gribskov	Klosterheden
Area (ha)	5,698	6,265
Visiting cars per year (2.5 persons per car; Jensen 2003)	179,200	154,250
Visits per hectare	79	25
WTP € ha^{-1} $year^{-1}$	119	38

WTP is € 1.5 per visit

three due to hypothetical bias (cf List and Gallet 2001), which gives € 57. As the average Dane visits the forest 38 times per year (Jensen and Koch 2004), the WTP per visit is € 1.5. Table 2 shows the resulting WTP for recreation per hectare for the two sites. The value of deadwood was implicitly excluded in the first rotation or conversion phase by using a lower recreation score for conversion phase than post-conversion phase (see Table 3).

The WTP per ha value was estimated at a maturity phase. Following the EFORWOOD project (Edwards et al. 2010), the forest was decomposed into an establishment, a young and a medium phase as seen in Table 3. The WTP was reduced for the respective phases by dividing the recreational score by the score of the maturity phase. WTP for the conversion phase was traced using recreation score for clear-felling of beech. WTP for post-conversion phase was traced using recreation score for NNF. Then, NPV of recreation for infinite time horizon was estimated using the NPV formula for NNF discussed in section "Methods."

Estimation of groundwater benefit

The demand for groundwater is high in northern Zealand and Jutland, where some portions of both case areas are classified as a "particularly valuable" groundwater abstraction areas (GEUS 2009). Hence, a monetary value of the gain in groundwater recharge of converting the RF of Norway spruce into NNF of beech was estimated considering the use value of water for drinking purpose and the existence value of water in Denmark. Duncker et al. (2011) found that NNF of beech increases water yield (run-off) by about 66 mm (660 m^3 ha^{-1} $year^{-1}$) above RF of Norway spruce. This run-off difference is also assumed to represent Denmark's forest ecosystem (Raulund-Rasmussen 2012). Another study in Denmark found that the evapotranspiration of mature conifers forest exceeded evapotranspiration of mature deciduous forest by up to 35 mm $year^{-1}$, in years 2001–2003 where the mean annual precipitation was 886 mm (Boegh et al. 2009). Therefore, to be conservative, a water gain of 330 m^3 ha^{-1} $year^{-1}$ (half of 66 mm) was assumed in the present study. Furthermore, the water conversion efficiency from run-off state to groundwater recharge was discounted for 50 % water loss through percolation process, and so the water gain is 165 m^3 ha^{-1} $year^{-1}$. This efficiency rate is assumed to reflect the average hydrological cycle of Denmark (Raulund-Rasmussen 2012). The water conversion efficiency was also discounted for an average delay of water "travel time" of 20 years (Loubier 2003). Klosterheden receives an annual precipitation of 850 mm, whereas Gribskov receives 613 mm (DMI 2012). Nevertheless, the run-off difference between NNF and RF is approximately the same (Raulund-Rasmussen 2012).

Table 3 Adjustment of recreation benefit using the recreation score of different phases of stand development of near-natural forestry of beech composed of conversion phase and post-conversion (Edwards et al. 2010, p. 9)

Phases	Year	Conversion phase			Post-conversion		
		Recreation score	Recreation score factor	WTP € ha^{-1} $year^{-1}$	Recreation score	Recreation score factor	WTP € ha^{-1} $year^{-1}$
(a) Gribskov: conversion phase (0–89 years) and post-conversion (90 years–infinity)							
Establishment	0–5	2	0.33	26	4	0.44	53
Young	5–15	3	0.50	40	5	0.56	66
Medium	15–50	5	0.83	66	7	0.78	92
Mature	>50	6	1.00	79[a]	9	1.00	119
(b) Klosterheden: conversion phase (0–99 years) and post-conversion (100 years–infinity)							
Establishment	0–5	2	0.33	8	4	0.44	17
Young	5–15	3	0.50	12	5	0.56	21
Medium	15–50	5	0.83	21	7	0.78	29
Mature	>50	6	1.00	25	9	1.00	38

For conversion phase, a recreation score of clear-felling of beech (Forest Management 4) and for post-conversion phase, a recreation score of near-natural forestry of beech (Forest Management 2) were assumed

[a] Recreation benefit of post-conversion at maturity (119 € ha^{-1} $year^{-1}$) times the ratio of recreation score of clear-felling of beech to recreation score of near-natural of beech at maturity (6/9)

Table 4 Groundwater benefit of converting rotational forestry (RF) of Norway spruce into near-natural forestry (NNF) of beech considering sum of drinking water price of 1.65 € m^{-3} (DANVA'S Benchmarking and Water Statistics 2010) and existence value of 1.12 € m^{-3} (Campbell et al. 2012)

Items	Value
Run-off difference between NNF and RF (m^3 ha^{-1} $year^{-1}$) (Duncker et al. 2011)	330
Groundwater recharge (%) (Raulund-Rasmussen 2012)	50
Groundwater recharge (m^3 ha^{-1} $year^{-1}$)	165
Groundwater benefit (€ ha^{-1} $year^{-1}$)	456.5
Groundwater benefit assuming 20 years delay (€ ha^{-1} $year^{-1}$)	252.7

The annual groundwater benefit per ha was then calculated by considering the use value and the existence value of water. As Hasler et al. (2005) argues, the value of clean groundwater is to a large extent a value consisting of the knowledge of knowing that we have clean groundwater, as even without, it would just be cleaned. Thus, it is too simple to look at the use value alone. We try to split the two in order to get a conservative estimate, as well as a more realistic one. The use value of groundwater benefit was calculated by multiplying the above groundwater recharge by the price of drinking water in Denmark. The average price of water as perceived by consumer in Denmark is 7.02 € m^{-3}. This price consists of 22 % clean groundwater, 48 % waste water fee, and 30 % state taxes and VAT (DANVA'S Benchmarking and Water Statistics 2010). Hence, the price of groundwater in the current study was estimated at 1.54 € m^{-3} (0.22 × 7.02), by excluding the values of other utilities, in year 2009 and adjusted to 1.65 € m^{-3} in 2012. The existence value was calculated by multiplying the above groundwater recharge by the WTP of Danish households for an increase in groundwater recharge. A choice experiment survey undertaken in August–September 2011 by Campbell et al. (2012) estimated Danish household's WTP for an increase in groundwater recharge under forests by 40 million m^3 at 53.82 € $year^{-1}$. We divide this number by three due to hypothetical bias (cf List and Gallet 2001), which gives € 17.94. This value was further converted into 1.12 m^{-3} by multiplying the household's WTP to the ratio of total number of households in Denmark, 2.5 million (Statistics Denmark 2012) to the assumed increase in groundwater recharge, 40 million m^3.

The use value alone was considered as a lower-bound value in the CBA, and the sum of use value and existence value was considered as a higher-bound value (Table 4).

Relevant assumptions of CBA

The economic calculations of timber, recreation, and groundwater benefits were made on a common unit of account (€ per hectare) that allowed both aggregation of and comparison between the benefits. An exchange rate of 1 Euro (€)= 7.45 Danish Kroner in 2012 was assumed. The economic values were adjusted for inflation towards year 2012 using national consumer price index (Statistics Denmark 2012). Future benefits and costs were discounted at a baseline discount rate of 3 %, and 1, 2, and 4 %.

Results

The results are presented in three main sections. The first section presents developments of annual timber and non-timber benefits over time. The second section compares the NPV of timber benefit between NNF and RF in the two soil conditions under different discount rates. The third section presents the change in NPV of non-timber benefits for the conversion into NNF in the two site conditions and compares it with the change in NPV of timber.

Development of annual recreation benefit

Figure 1 below shows the development of annual recreation benefit of NNF over the conversion phase (0–90 years in Gribskov and 0–100 in Klosterheden) and post-conversion phase afterwards. The recreation benefit increases over time as it is a function of increasing recreational scores from establishment phase to maturity phase. For equivalent phases of stand development, the recreation benefit is higher in the post-conversion phase than in the conversion phase, which reflects a higher recreation value of shelterwood regime, and old and deadwood trees as compared with initial uniform plantation, and no old and deadwood trees (Edwards et al. 2010). The recreation benefit in Gribskov is about 3 times higher than in Klosterheden at all times, attributed to the number of visits.

Development of annual timber and non-timber benefits

The development of annual timber cash flow difference between NNF and RF is compared with the development of annual non-timber benefits in Fig. 2a, b below. The annual non-timber benefit development is the sum of annual recreation benefit and annuity water benefit of 457 € ha^{-1} for use value and existence value, considered after 20 years of water travel time. Figure 2a shows the developments for Gribskov over the first two rotations (0–179 years), and Fig. 2b shows the developments for Klosterheden over the first two rotations (0–199 years). Positive cash flows of timber indicate the gain from the conversion, and negative cash flows indicate the opportunity cost of the conversion, particularly from final harvesting of RF. When comparing timber cash flow between the two figures, the conversion to

Fig. 1 Development of annual recreation benefit of the conversion into near-natural forestry of beech in Gribskov and Klosterheden, Denmark. The vertical break lines at year 90–99 and 100–109 are the conversion ages in Gribskov and Klosterheden, respectively

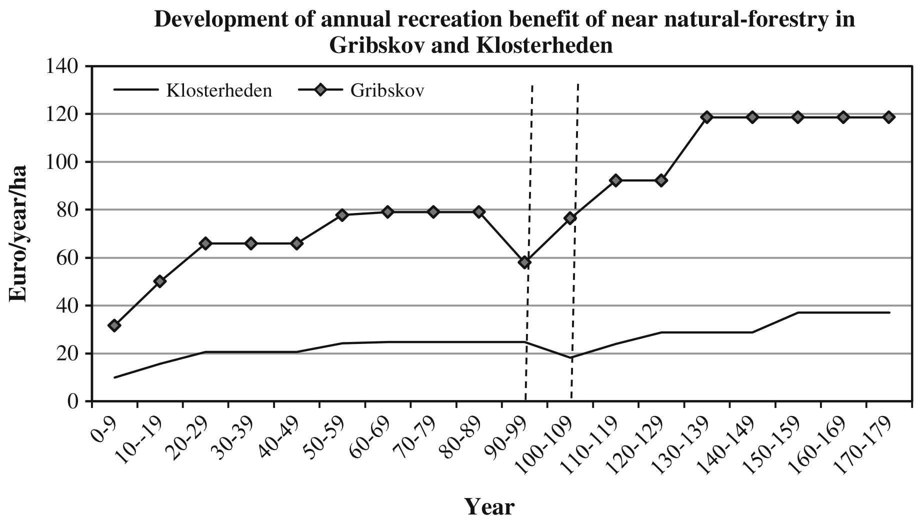

Fig. 2 Developments of annual timber net cash flow and non-timber benefits of the conversion to near-natural forestry of beech in Gribskov (**a**) and Klosterheden (**b**). Annual timber cash flow is the difference between near-natural forestry of beech and rotational forestry of Norway spruce. Water benefit of use value and existence value added to recreation benefit after 20 years of water travel time

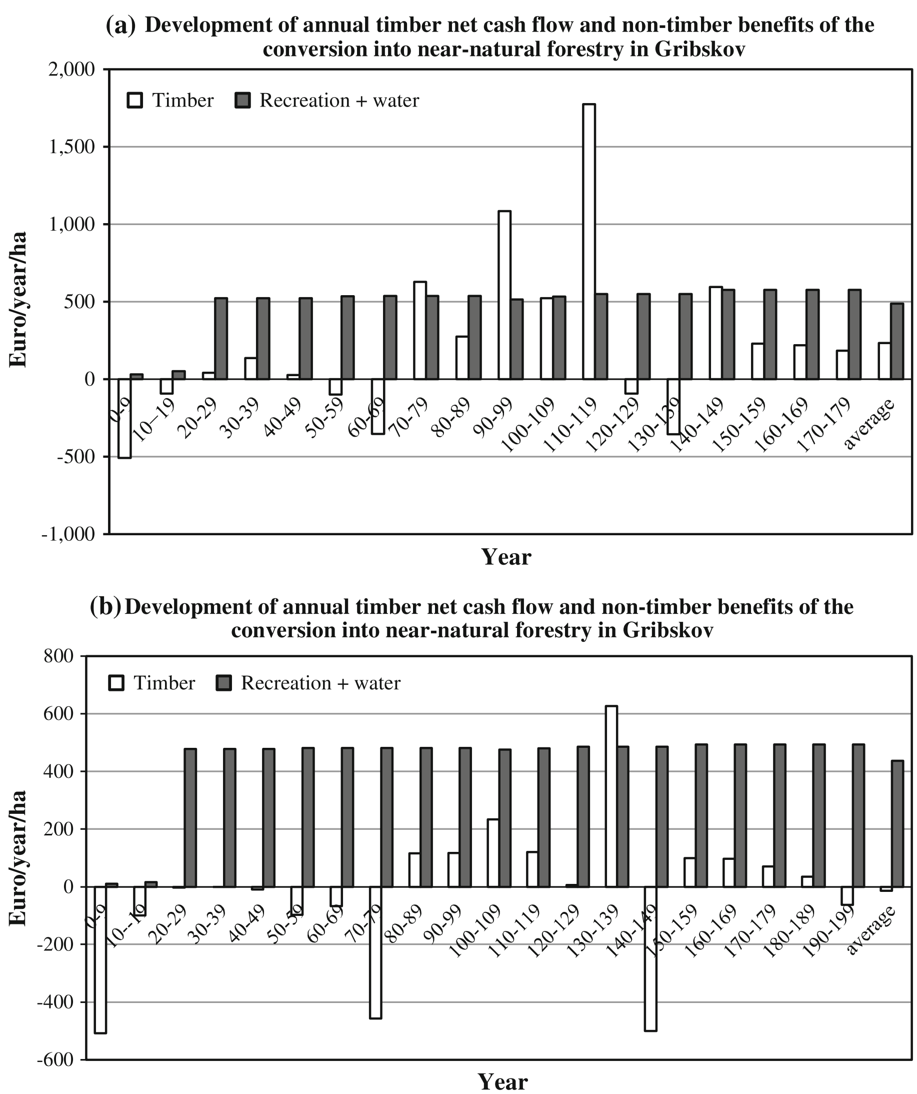

Table 5 Net present value (€ ha^{-1}) of timber of NNF of beech and RF of Norway spruce in Gribskov and Klosterheden under different discount rates

Discount rate (%)	Gribskov (good soil)			Klosterheden (poor soil)		
	NNF	RF	NNF–RF	NNF	RF	NNF–RF
1	27,962	12,933	15,029	2,528	7,922	−5,394
2	2,987	2,801	186	−5,866	562	−6,428
3	−3,738	−362	−3,375	−7,872	−1,666	−6,206
4	−6,279	−1,794	−4,484	−8,504	−2,631	−5,874

Table 6 Differences in net present value (€ ha^{-1}) of timber, recreation, and water benefits between near-natural forestry (NNF) of beech and rotational forestry (RF) of Norway spruce in Gribskov and Klosterheden

Benefits	Net present value (NPV) for perpetuity (NNF–RF)			
	Gribskov		Klosterheden	
	1 %	3 %	1 %	3 %
Timber	15,029	−3,375	−5,394	−6,206
Recreation	7,366	1,822	2,310	571
Water	22,249 (37,410)	5,010 (8,425)	22,249 (37,410)	5,010 (8,425)
Recreation and water	29,614	6,832	24,558	5,581
Total	44,643	3,457	19,165	−625

The values of water in the parenthesis indicate the higher-bound values when considering the sum of use values and existence value of water

NNF gains a significantly larger annual net revenues in Gribskov, during the period of 90–110 years where regeneration harvests initiated, than in Klosterheden in the corresponding periods. The difference in average annual benefit between timber and non-timber benefits is higher in Klosterheden than in Gribskov. The average annual gain from timber and non-timber in Gribskov, being 234 and 488 € ha^{-1}, respectively (Fig. 2a), whereas, in Klosterheden being minus 14 and 437 € ha^{-1}, respectively (Fig. 2b).

Net present value of timber

Table 5 presents profitability or NPV of NNF and RF in Gribskov and Klosterheden under different discount rates. In Gribskov, NNF would be more profitable than RF at 1 and 2 % discount rates. However, NNF of beech would be more costly than RF of Norway spruce at 3 and 4 % discount rates. In Klosterheden, NNF would be by far more costly than RF at 2 % and higher discount rates. The NPV of NNF is positive at 1 % discount rate but is still by far lower than the NPV of RF.

Present values of non-timber benefits

Table 6 shows the change in present values of non-timber benefits for the conversion from RF into NNF at the two site conditions at a baseline discount rate, 3 %, and at a low discount rate, 1 %. The difference in NPV of timber between NNF and RF is also included in the table to compare it with that of non-timber benefits.

In Gribskov, the conversion into NNF would gain an NPV of 6,832 € ha^{-1} from the recreation and the use values of water benefit at a 3 % discount rate. This value is large enough to compensate for the loss of timber, which equals 3,375 € ha^{-1}. However, in Klosterheden, the conversion gains an NPV of 5,581 € ha^{-1} from recreation and water benefit which is 1,251 € ha^{-1} less than that in Gribskov (i.e. attributed to difference in recreation benefit). This is worth 625 € ha^{-1} less than the loss of timber. However, when considering the sum of use value and existence value of water, the worth would be large enough to over-compensate the loss of timber. Also, the value of non-timber benefits of the conversion would be by far larger than the cost of timber, giving a net worth of 19,165 € ha^{-1} at 1 % discount rate. The corresponding value in Gribskov is € 44,643.

Concluding discussion

This study assessed the welfare economic values of timber and non-timber benefits of the conversion of RF of Norway spruce into NNF of beech based on two site conditions in Denmark. We find that the economic value of use values of recreation and water benefits outweighs the loss of timber on good soil conditions but not on poor soil conditions. This means that from a welfare economic point of view, it will be beneficial to convert forests on the better soils, but obviously it does not mean that the full surplus should be spend on e.g. transfer to landowners for providing these services. As always, efficiency should be sought. The result of a cost-benefit analysis like the one provided here hinges on the underlying assumptions. In particular, the stated preference methods have been criticized (see e.g. Price 1996). Nevertheless, they are the only way to estimate non-use values, and ignoring these would clearly make flaws to the CBA. Therefore, we have been very conservative in the estimation of timber, and recreation and water benefits are based on conservative assumptions. In the following, we discuss the arguments for where we have been most conservative.

Estimates of timber and non-timber benefits of near-natural forestry

First of all, the estimates of NPV of timber for converting RF into NNF is conservative since the negative impact of storm risk on the RF is ignored. The vulnerability of RF of Norway spruce to storm risk is a serious problem, particularly in the Atlantic region of Europe (Vedel et al. 2010). For instance, in Denmark, a mean annual storm probability of 8 % is assumed in RF of Norway spruce, which causes associated wind throw problem especially for larger diameter classes (Østergaard 1988, cited by Schou et al. 2012).

Danes' € WTP of 1.5 per visit (Nielsen et al. 2007) for changing from RF of Norway spruce into NNF of beech is assumed to be conservative. Because the estimate ignores some positive recreational values of NNF such as off-site visual experiences of landscape (Larsen and Nielsen 2007) and non-use values (Zandersen et al. 2007; Campbell et al. 2012), and negative recreational values of RF of Norway spruce such as fresh windthrown trees (Lindhagen and Hörnsten 2000) and application of chemicals (Jensen and Koch 2004). Prokofieva et al. (2011) reviewed that in Denmark forest, WTP per visit on a low level is € 1.1, a medium level is € 4.8, and a high value is € 10.5 in 2005. More importantly, the estimated recreation benefit is very realistic since the WTP estimate was adjusted for change in recreational values over different phases of stand development (Edwards et al. 2010). Estimation of water benefit is conservative because run-off difference between NNF of beech and RF of Norway spruce (330 m^3 ha^{-1} $year^{-1}$), which is half of the estimate of Duncker et al. (2011), was considered due to high uncertainties with change in climate factors in the future. Change in climate factors in the future, especially prediction of warmer and drier summers, will likely put pressure on water supplies in Europe (Prokofieva et al. 2011). Additionally, groundwater recharge was considered as 50 % of the run-off and discounted for a 20-year water travel time (Loubier 2003). However, the estimation of present value of water benefit is likely to be slightly overestimated as compared with the present values of recreation and timber benefits since it was calculated by applying an annuity factor (i.e. dividing water benefit by discount rate). This is due to lack of available run-off database over a rotation, where only the average run-off is available, in Duncker et al. (2011). Nevertheless, the run-off is stable over a rotation, meaning the uncertainty on present value would not be as high as in recreation.

Based on such conservative estimates, the study shows that the non-timber benefit of NNF is superior to RF, which illuminates the importance of providing adequate incentives for provision of non-marketed goods such as recreation and water benefit of NNF to compensate for the loss of timber value (Fig. 2; Table 6). This evidence reinforces the argument of Wobst (2006). He argued that NNF sounds a promising strategy to overcome the economic crisis of forestry, caused by lower timber prices and higher costs, by claiming a fair payment for environmental and recreational functions of NNF. As shown in Fig. 2, the conversion into NNF provides a stable flow of non-timber benefits to compensate for part of the regeneration costs and supports the positive net revenues. The current study further shows that the contribution of non-benefits is significantly dependent on site attributes. While on a good soil conditions and high visitor frequency site, the sum of NPV of use values of recreation and water benefits is capable of compensating for a modest loss of timber benefits, in a poor soil and low visitors frequency site, the NPV of use values of recreation and water benefits is not large enough to over-compensate a high loss on unproductive soil (Table 6). The loss of timber in poor soil is over-compensated by including the existence values of water in addition to the use values of recreation and water benefit. Some studies found that the recreational value of NNF is substantial and capable of compensating for the loss of timber. For instance, Bostedt and Mattsson (2006) evidenced that transformation from the RF-dominant forest landscape into a more recreation-oriented NNF in the county of Vasterbotten (Sweden) would yield a three times larger NPV from recreation benefit than the loss of timber discounted for 100 years of rotation at a 3 % discount rate. The study applied an average Swedish recreationalist annual WTP of € 134 per person, which was not corrected for a hypothetical bias. However, in the current study, the recreation benefit alone is not large enough to over-compensate for the loss of timber even at a 1 % discount rate, mainly because the WTP is corrected for hypothetical bias (Table 6).

In a meta-analysis, List and Gallet (2001) found that WTP from hypothetical stated values is overstated by three as compared with the actual values. This was in the current study used to correct all stated preference study values. This may be seen too as a conservative approach, but is made here to avoid criticism of using stated preference results in a CBA.

It should be noted that incorporating the welfare economic values of non-use benefits, such as biodiversity conservation in the current cost-benefit analysis, would magnify the value of NNF policy. Duncker et al. (2011) show that the biodiversity score of NNF of beech is 129, whereas that of RF of Norway spruce is one. The biodiversity score was based on important attributes such as the abundance of deadwood, number of big trees, and number of tree species. From the demand side, Jacobsen et al. (2012) provide evidence that Danish households are willing to pay up to 80 € $year^{-1}$ for increasing the population of endangered species in Denmark's forests. NNF may be better than RF at securing that.

A challenge for an economic assessment of timber and non-timber benefits in a multi-purpose NNF is the trade-offs between the benefits. In this regard, an important methodological contribution of the present study is to address trade-offs between timber production and recreation provision. The average recreationalists in Denmark in particular and in Europe in general have shown low preferences for heavy interventions during the establishment and young phases of the forest stand (Edwards et al. 2010). By employing low recreation score for such phases of stand development (Edwards et al. 2010), it was possible to translate the effect of timber production activities into a reduction in recreation benefit (Fig. 1).

Limitations of the study

The stand-level estimates of timber and non-timber benefits of the current study, estimated per ha, can be used be to extrapolate a forest value in the study areas or elsewhere. However, when extrapolating the results, the user needs to consider specification of the baseline and conversion scenarios of forest management, limitations of the stand-level analysis, and the variations of socio-economic and site characteristics.

The current study is based on a generic European forest management regime classification(Raulund-Rasmussen et al. 2011) where the baseline scenario, RF of Norway spruce, represents FM4[1] (forest management) and the conversion scenario, NNF of beech, represents FM2. NNF of beech is based on uniform shelterwood system. Some studies have shown that the recreational value of NNF of beech using uniform shelterwood system is lower than that of selective logging system (Nielsen et al. 2007). Timber benefit is also found to be lower in shelterwood than in selective logging system (Nord-Larsen et al. 2003; Price and Price 2008). Water run-off is relatively higher in shelterwood system than in selective logging due to a higher water evaporation loss in a continuous vegetation cover in selective logging (Dalsgaard 2008; Katzensteiner et al. 2011). Therefore, such differences in timber and non-timber benefits between shelterwood system and the alterative, selective logging system of NNF, need to be considered when using the alternative system.

Making an economic estimate of recreation benefit at stand level in the present study would conceal an actual value generated as a result of spatial interaction or arrangement of different stands in the forest landscape. This is because the mosaic of different "forest development type" (FDT), such as open lands, broad-leaved-dominant FDT, and conifers-dominant FDT, would increase the attraction value at the landscape level (Danish Ministry of the Environment, Forest and Nature Agency 2005; Price and Price 2008). Another important limitation of stand-level recreation benefit estimate is using per hectare metric. Calculating number of visitors per hectare assumes uniform distribution of visitors to each hectare of the forest. However, practically each FDT in the forest receives different recreationalists depending on their attributes. In the present case, for example, NNF of beech become bare and unattractive during winter season, and may receive very low visits and so loss of recreation value.

The economic valuation of timber, recreation, and water benefits might be higher than in many other countries, given relatively higher socio-economic conditions of Denmark than the average of European countries (OECD 2012).

[1] The number in the forest management regime indicates the intensity of silvicultural intervention in an increasing order.

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Appendix

Appendix A: Net revenue of timber in Gribskov and Klosterheden

See Tables 7, 8, 9, 10, 11 and 12.

Appendix B: Stumpage price curves

See Fig. 3.

Table 7 Calculation of net revenue of beech for conversion phase in Gribskov, site class 1

Age	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})
2	6,713				−6,713
3–9	2,183				2,183
10–19	1,097	6	5.5	14.7	−1,009
20–29		29	9.1	23.3	676
30–39		72	13.0	30.3	2,182
40–49		73	18.1	29.6	2,162
50–59		73	23.7	29.1	2,122
60–69		74	28.1	29.7	2,197
70–79		72	33.0	34.1	2,453
80–89		68	36.7	39.1	2,656

The regeneration cost is for planting of beech in the initial stand establishment phase. Based on data from Forest Economics Table (2006)

Table 8 Calculation of net revenue of near-natural forestry of beech for post-conversion phase in Gribskov, site class 1

Age	Thinning					Regeneration harvest			
	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})
0/90	837				−837	86	43.9	53.1	4,556
0–9/90–99						123	46.6	60.3	7,408
10–19/100–109	600	6	5.5	14.7	−512	105	52.0	62.5	6,573
110				0		276	55.0	72.5	19,994
20–29	1,010	29	9.1	23.3	−334				
30–39		72	13.0	30.3	2,182				
40–49		73	18.1	29.6	2,162				
50–59		73	23.7	29.1	2,122				
60–69		74	28.1	29.7	2,197				
70–79		72	33.0	34.1	2,453				
80–89		68	36.7	39.1	2,656				

The regeneration cost is for the natural regeneration of beech. Based on data from Forest Economics Table (2006)

Table 9 Calculation of net revenue of rotational forestry of Norway spruce in Gribskov, site class 2

Age	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price(€ m^{-3})	Net revenue (€ ha^{-1})
4	3,207				−3,207
5–9	612				−612
10-19	105	14	7.2	1.7	−81
20–29		82	10.2	3.3	271
30–39		119	15.0	7.0	836
40–49		132	20.7	14.3	1,898
50–59		133	26.7	23.4	3,111
60		377	34.1	25.3	9,543

Based on data from Forest Economics Table (2006)

Table 10 Calculation of net revenue of beech for conversion phase in Klosterheden, site class 4

Age	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})
2	6,713				−6,713
3–9	2,183				−2,183
10–19	1,097				−1,097
20–29		6	3.2	8.4	50
30–39		17	6.9	18.4	313
40–49		24	9.9	25.0	599
50–59		30	13.0	30.3	894
60–69		35	15.7	29.9	1,048
70–79		35	18.7	29.5	1,034
80–89		36	21.8	29.1	1,049
90–99		43	25.2	29.1	1,237

The regeneration cost is for planting of beech in the initial stand establishment phase. Based on data from Forest Economics Table (2006)

Table 11 Calculation of net revenue of near-natural forestry of beech for post-conversion phase in Klosterheden, site class 4

Age	Thinning					Regeneration harvest			
	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})
0/100	837				−837	48	28.9	30.3	1,449
0–9/100–109						62	32.0	33.3	2,052
10–19/110–119	600				−600	66	35.5	37.8	2,497
20–29/120–129	1,010	6	3.2	8.4	−960	62	40.3	46.8	2,887
130						142	44.8	54.1	7,673
30–39		17	6.9	18.4	313				
40–49		24	9.9	25.0	599				
50–59		30	13.0	30.3	894				
60–69		35	15.7	29.9	1,048				
70–79		35	18.7	29.5	1,034				
80–89		36	21.8	29.1	1,049				
90–99		43	25.2	29.1	1,237				

The regeneration cost is for the natural regeneration of beech. Based on data from Forest Economics Table (2006)

Table 12 Calculation of net revenue of rotational forestry of Norway spruce in Klosterheden, site class 3

Age	Regeneration cost (€)	Harvest (m^3)	DBH (cm)	Stumpage price (€ m^{-3})	Net revenue (€ ha^{-1})
4	3,207				−3,207
5–9	612				−612
10–19	105				−105
20–29		40	7.7	1.9	75
30–39		80	11.4	4.1	326
40–49		90	15.7	7.7	692
50–59		131	20.7	14.3	1,868
60–69		78	25.8	22.1	1,724
70		378	29.1	24.9	9,419

Based on data from Forest Economics Table (2006)

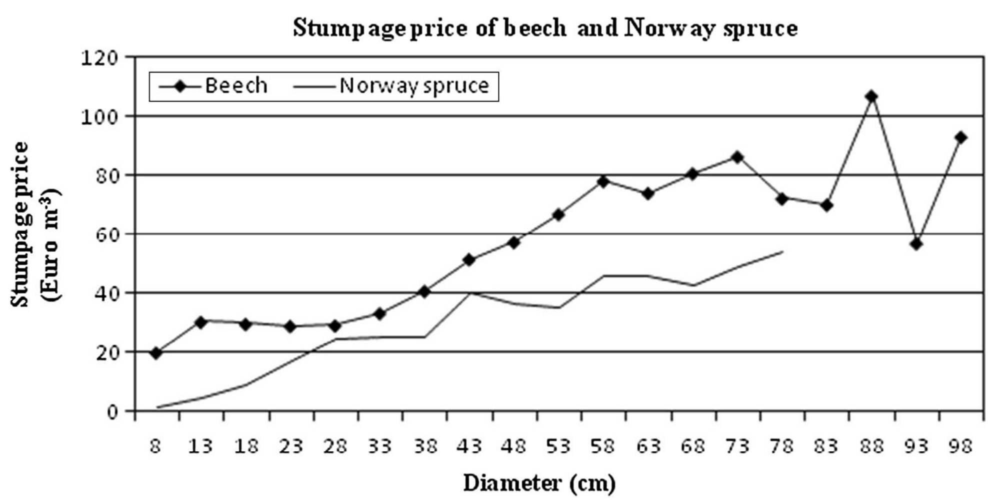

Fig. 3 Stumpage price of beech and Norway spruce: Based on data from Forest Economics Table (2006)

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