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Landscape benefits of a forest conversion programme in North East Germany: results of a choice experiment

P. Elsasser, H. Englert, J. Hamilton

Abstract. The article describes the results of a choice experiment aimed at valuing landscape benefits of different kinds of forests in NE Germany by using computer generated images. Preferences for broadleaved/mixed forests over conifers amount to 40-85 € per year and household, additional visual diversity has a monetary value of about 20 €/a. This is true for the summer aspect of forests only. The same experiment conducted with winter images reveals no general preference for broadleaves, whereas visual diversity is valued even higher under winter conditions.The results are part of a study which aimed at valuing the impacts of a regional forest conversion programme. Beyond landscape value, the valuation has covered recreational value, the value for climate protection as well as timber production value. The development of landscape values over time can compensate for diminished timber returns until about 2080; afterwards the balance becomes negative. Carbon values are relatively minor in comparison to landscape and timber values.
Keywords: choice experiment, willingness to pay, landscape benefits, recreation, carbon sequestration, wood production, Germany.

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Introduction

Background of the study

Forest conversion is an important topic in German forestry due to several reasons (cf. Knoke et al. 2008). Many of today's forests consist of rather uniformly structured conifer stands, which feature low biodiversity rates and are often particularly endangered by calamities like storms, fire, and insects. Moreover, droughts are a growing concern specifically in the eastern part of the North German Plain which is already suffering from low annual precipitation - a situation which might even further aggravate due to climate change. Public as well as private forest enterprises aim at stabilising homogenously structured forests by investing in large forest conversion programmes which turn purely coniferous stands into mixed and broadleaved forests. These efforts are financially supported by subsidisation programmes at federal and at state level (Bundesregierung 2008). Arguments in favour of such forest conversion programmes are not only to reduce risks by diversification, but also to enhance the supply of ecological services like watershed and climate protection, biodiversity, and recreation opportunities for the population (Fritz 2006).

The background of the study presented here is the interdisciplinary research project "Newal-Net"[1] funded by the Federal Ministry of Education and Research (BMBF), which involved silviculturists, climatologists, ecologists, cultural and education scientists, and economists as well as practitioners. In this project, an overall concept ('*leitbild*') of future landscape development has been developed by the project partners and stakeholders for a model region in North East Germany, which is dominated by purely pine forests. Within the joint project the regional forest development up until 2100 has been modelled in steps of 20 years each for two scenarios: first, the overall concept of "climate adaptive deciduous mixed woodland" ('*leitbild*') and second, the continuation of the current forest management plans - "business as usual" ('*bau*'). The '*leitbild*'-scenario envisaged a continuous reduction of the conifer area in the region, from an original 76% in 2006 down to only 13% in 2100, correspondingly enhancing the area of mixed and deciduous forests up to 87% in 2100. Also in the "bau" scenario a reduction in conifer area was planned, which is however much more conservative (from 76% in 2006 to 67% in 2100). In this scenario, the final share of mixed and deciduous forests is 23% in 2100.

The goal of all project partners was to quantify and analyse on the basis of these data, from their respective expertise's point of view, the impact of putting the '*leitbild*' concept into practice, in comparison to the business as usual situation. The economic partner project (Elsasser et al. 2010) had as its central question whether from an economic perspective substantial changes in the range of services provided by the forest are to be expected, which would speak for or against implementing the concept of "climate adaptive deciduous mixed woodland". Thus, the focus was on the "services" side of the problem, specifically on the impacts on landscape value, recreational value, timber production and carbon sequestration, rather than on the "cost" side of forest conversion.[2]

In the remainder of this article, methods and results of the landscape valuation study will be presented at individual (household) and at aggregate (regional) level; afterwards landscape values will be compared to the aggregate values of the various other services of forestry mentioned above.

Landscape valuation: a choice experiment

Data collection

The valuation of the landscape change was carried out through as a regional survey. First, those surveyed were asked their opinion about the landscape of where they live as well as its design. Secondly, a choice experiment was carried out to investigate the monetary value of changes in the landscape and recreational value.

The basic principle of such a choice experiment is to let respondents choose their most preferred option out of a choice set which consists of several "offers", i.e. choices between different (bundles of) goods. These goods are characterised by various attributes, including a price attribute. Since the choices differ in the attribute levels, respondents' choices can be analysed using multinomial logit models if different choice sets are distributed systematically over a sample of respondents, i.e. by estimating the probability of choosing an alternative as a function of its attributes. Based on the

[1] "Nachhaltige Entwicklung von Waldlandschaften im Nordostdeutschen Tiefland" [Sustainable development of forested landscapes in the lowlands of North Eastern Germany], see http://www.zalf.de/home_newal-net/index.htm.

[2] The study did not aim at a full cost-benefit analysis, and direct costs of forest conversion investments have not been investigated within the project.

respective estimates the marginal willingness to pay (WTP) for an attribute can be calculated as the ratio of this attribute's coefficient to the price attribute's coefficient. The economic background of this kind of stated preference valuation is the demand theory of Lancaster (1966), according to which it is not the good per se which gives utility to the consumer, but its (specific combination of) characteristics. The mathematical background essentially goes back to Mcfadden (1973) who derived the multinomial logit model from random utility theory (Thurstone 1927). In the last years, choice experiments have been further methodologically refined (see e.g. Louiere et al. 2001, Hensher et al. 2005), and they are increasingly being applied for environmental valuation purposes all over the world.

In our choice experiments we presented to each respondent a choice card describing three alternative residential environments. Figure 1 shows an example. In each alternative, three attributes have been varied: the view of the landscape (as visualised by computer generated images), the possibility of entering forests and meadows for recreation purposes, and the cost of living there (as the price indicator).[3] After showing the choice card to the respondents, they were asked to choose their most preferred option in the following hypothetical situation:

"Please imagine you are about to move to the countryside and have to decide now upon where to live. Suppose that you have looked at all the possible places and have decided on your three favourites. The only important differences seem to be: (i) the view from each of the houses; (ii) the annual cost of living there (e.g. rent or mortgage, property tax, travelling to work); (iii) and the possibility of entering forests and meadows for recreational purposes.

I'm now going to show you six cards with pictures of the three views. These pictures show computer generated images of typical forest views. In each case the left picture shows the view from the house with the lowest price, and the others the views from two other houses where it would cost you a little more to live. Below the pictures, you can see how much extra a year living at each of the houses would cost you, and whether or not members of the public are able to use any of the forests and other land shown in the pictures for recreation. So which of the three choices do you prefer?"

The choice was noted in the interviewer sheet, and the experiment was then repeated five more times (with different choice cards). Afterwards we asked respondents for the reasons for their choices, in order to control for possible answer stereotypes (i.e. whether all three attributes had been considered equitably by the respondents, or whether any of the attributes had dominated the choices). Finally several sociodemographic characteristics were collected.

The levels of the three attributes were varied in the following manner: The attribute "landscape" was captured by seven different computer images showing typical landscapes of the

Figure 1 Example of a choice card

[3] A similar design of the choice situation has been developed and applied in a British study (Garrod 2002) which was then adapted to the conditions in north eastern Germany.

region in the summer aspect. Six of these images showed either a pine forest, a broadleaved forest, or a mixed forest, each of these either in a version with low or with high structural diversity; a seventh image presented a situation without any forest (i.e. grassland only). The attribute “recreation” had two possible values (forests and grassland were either accessible for recreation, or not accessible). The price attribute had again seven different levels, from 0 € up to 120 € per year in steps of 20 €. In all choice cards, the alternative displayed at the left side showed the same attribute combination (i.e. the “status quo”), namely a monostructured pine forest which could not be entered for recreation, with a price tag of 0 €/year (see figure 1, left). The middle and right alternatives each showed two of the other landscape images (i.e. the monostructured pine forest image did not appear again), with or without recreational access, and with additional costs of living of at least 20 € /year (i.e. the 0 € tag did not appear again). Altogether this resulted in 72 different possible attribute combinations (6 x 2 x 6) except of the Status Quo. These 72 combinations were distributed orthogonally over the sample.

Since our goal was not only to examine individual valuations, but also to identify aggregate values for a whole year and for different conceivable residential environments in the region, two further design problems had to be regarded. First, seasonal differences had to be taken into account, because some of our landscape images showed deciduous trees. Second, it had to be considered that the choice situation presented above suggests that forests and other elements of the natural environment are visible from each of the prospective houses - which is not realistic e.g. for houses located in a city centre. In order to account for the first problem, we modified each of our summertime landscape images by replacing each deciduous tree with a tree of the same species without foliage, thus generating a corresponding winter image for each of the landscape images.[4] The sample of respondents was then split into two parts, one being interviewed with “summer aspect” choice cards, the other with choice cards showing the same landscapes in the winter aspect. The second mentioned problem was solved by splitting both subsamples again: one half of each subsample was suggested that the displayed landscapes be directly visible from each of the houses in question (as quoted above), the other was suggested that the landscapes be visible at regular journeys only, but not from the houses under consideration.

After completing the pretests, the main study was realised as a regional household survey, with interviews taking place from January until April 2008. Respondents were sampled via random walk in those ten counties[5] which cover Newal-Net’s study region. Together, this area located north of Berlin has a population of 1,099,100 people who live in 548,572 households (Stlabb 2008, Stlamv 2008). With 29.4% interview refusals, the net sample size was 999 interviews in total. Table 1 shows their distribution over the four subsamples.

Table 1 Number of interviews in the four subsamples

visibility of landscape	from home	at regular journeys only	sum
summer aspect	264	234	498
winter aspect	265	236	501
sum	529	470	999

[4] All landscape images have been created using the Visual Nature Studio software (VNS). Since winter trees are originally not available for this program, photographs of winter trees have been scanned and digitally processed in the IT laboratory of the Thuenen Institute in order to be readable by VNS. Because snow is the exception rather than the rule in Germany (as seen over the whole time of vegetation dormancy), the images did not show any snow.

[5] These are the counties Ostprignitz-Ruppin, Oberhavel, Barnim and Uckermark in the federal state of Brandenburg, and the counties Güstrow, Demmin, Müritz, Mecklenburg-Strelitz, Uecker-Randow and the city of Neubrandenburg in the federal state of Mecklenburg-Vorpommern.

Analysis methods

The alternatives presented in the choice experiment are characterised by different levels of the three attributes landscape view (*L*), recreational access (*E*) and additional cost of living (*K*). The probability (*P*) of choosing one of the alternatives (*a*) is a function of the utility (*U*) which an alternative gives to respondent (*i*); this utility is a function of the attributes (or their levels, respectively):

$$P_{ai} = f\ (U_{ai}) = f\ (L, E, K)_{ai} \tag{1}$$

According to random utility theory, total utility can be separated into a systematic component (*V*) and a random component (ε):

$$U_{ai} = V_{ai} + \varepsilon_{ai} \tag{2}$$

If a respondent has chosen a specific alternative out of a choice set (*C*), then it can be concluded that the utility of this alternative has been greater than the utility of each competing alternative (*r*):

$$P_{ai} = P\left(U_{ai} \rangle U_{ri}\right) = P\left(V_{ai} + \varepsilon_{ai} \rangle V_{ri} + \varepsilon_{ri}\right) \quad \forall a, r \in C, a \neq r \tag{3}$$

The analysis requires an assumption about the distribution of the random components (ε), because these are not independently observable. The multinomial logit model (MNL)[6] assumes that the ε_{ai} are distributed independently and identically (ε_{ai} ~ IID) and follow a (Gumbel-) extreme value distribution. Accordingly their probability density function (pdf) is:

$$f(\varepsilon_{ai}) = \mathrm{e}^{-\varepsilon_{ai}}\ \mathrm{e}^{-\mathrm{e}^{-\varepsilon_{ai}}} \tag{4}$$

with an associated cumulative distribution function (cdf)

$$F(\varepsilon_{ai}) = \mathrm{e}^{-\mathrm{e}^{-\varepsilon_{ai}}} \tag{5}$$

The probability in question can therefore be formulated as:

$$P_{ai} = \frac{\mathrm{e}^{\lambda V_{ai}}}{\sum_{r \in C} \mathrm{e}^{\lambda V_{ri}}} \tag{6}$$

(λ is a scale parameter which is usually assumed to equal 1). In the MNL the systematic utility component of alternative *a* is a linear function of the attributes (*L*, *B*, *K* - which may enter the MNL as continuous or as dummy variables):

$$V_a = \beta_0 + \beta_1 L + \beta_e E + \beta_k K \tag{7}$$

(β_0 is sometimes labelled “alternative specific constant” (ASC); it reflects the influence of other unobserved attributes of the good in question).

The estimated coefficients can now be used to compute implicit prices for each of the attributes (in other words, the marginal WTP for a supply change of a good by one unit):

$$WTP_L = -\frac{\beta_l}{\beta_k} \tag{8}$$

and accordingly

$$WTP_E = -\frac{\beta_e}{\beta_k} \tag{9}$$

The compensating surplus (CS) of a simultaneous change of several attributes (or their levels, respectively) by a specific policy can be calculated as:

$$CS = -\frac{V_0 - V_1}{\beta_k} \tag{10}$$

where V_0 is the utility given in the status quo, and V_1 the utility after the change.

All subsequent estimates have been computed using the Limdep/NLogit software (Greene 2007a). In order to find a well-suited model, we started by calculating a simple MNL for all four versions of the survey, which was then successively varied (for these intermediate results, see Elssaser et al. 2010). Here only results of the “final” error component model[7] will be presented.

[6] For a more comprehensive description of the multinomial logit model, see e.g. Andreß et al. 1997:299 ff.; Louviere et al. 2001:44 ff.; Hensher et al. 2005. For quicker orientation, see e.g. Mogss et al. 2006:7 f. and Meyerhoff et al. 2009:39ff. at which the presentation here is based.

Table 2 Coefficients and model statistics of the “final” model

questionnaire version	1 - summer view from home	2 - summer view at journeys only	3 - winter view from home	4 - winter view at journeys only
variables				
cost of living	–0.0127***	–0.1956***	–0.0035***	–0.0050***
recreation access	+1.0475***	+2.6067***	+0.5641	+0.1494***
landscape view: diversity	+0.2891**	+0.3090**	+0.3087***	+0.8072***
landscape view: broadleaved	+1.0969***	+0.8150***	–0.0598	+0.1333
landscape view: mixed	+0.7112***	+0.8783***	+0.0888	+0.4248***
landscape view: grassland	+0.0176	–0.8502***	–0.5713***	–0.0239
constant (ASC)	+0.2305	–0.1676	–0.3893*	+0.5328**
model statistics				
max. log-likelihood	-1203.10	-942.50	-1470.90	-1323.60
pseudo R^2 %	22.61	34.16	10.38	12.63
Akaike-criterion (AIC)	1.71	1.46	1.98	1.93
Bayes-criterion (BIC)	1.74	1.49	2.01	1.96
N (valid observations)	1415.00	1303.00	1494.00	1379.00
N (respondents)	264.00	234.00	265.00	236.00

*: a < 10%, **: a < 5%, ***: a < 1%

Results

Parameter estimates

Corresponding to the description above, the attribute K (additional cost of living) entered the model as a continuous variable in 7 levels from 0 to 120 €/year. The attribute E (recreation access) was coded as a dummy variable. The attribute L (landscape view) was coded into two groups of dummy variables, one of these capturing structural diversity of the forest stands displayed, the other capturing their tree species composition (conifers, broad-leaves, mixed, or grassland). In order to avoid perfect multicollinearity the first category of each dummy group was left out from the model; together these constitute the status quo against which the estimated dummy coefficients have to be interpreted. The systematic part of the estimated utility function therefore is:

Table 2 presents the parameter estimates.

The price coefficent is significantly different from zero and negative in each case, as expected. All other significant variables (except of “grassland”) have a positive sign. “Recreation access” is highly significant in three of the four versions; only in version 3 (winter, view from home) the influence is rather weak. Looking at the variables coding the landscape views, it appears that the dummy for “structural diversity” is always significant or highly significant. Grassland is being valued significantly lower as compared to the status quo (i.e. a pine forest with low diversity) in two of the versions, in the other two versions the valuation is not significantly different from zero. When comparing coniferous to broadleaved and mixed forests, there is evidence that the latter are being preferred over conifers - but only when the landscape is shown in the summer aspect (versions 1 and 2). For the winter versions, this

$$V = \beta_0 + \beta_k K + \beta_e E_{access\ possible} + \{\beta_{l1} L_{high\ diversity} + (\beta_{l2} L_{broadleaved} + \beta_{l3} L_{mixed} + \beta_{l4} L_{grassland})\} \qquad (11)$$

[7] The MNL assumes that all choices are independent from each other. This does not exactly apply in our case, because each respondent did not answer just one single choice experiment, but six consecutive ones. As a consequence, the random errors (eai) are not independent within a series of choices. The error component model (ECM) is a variant of the MNL which allows for this problem by splitting the random error into an individual component (eai) and an alternative specific component (µa), so that $U_{ai} = V_{ai} + e_{ai} + \mu_a$ is being estimated instead of $U_{ai} = V_{ai} + e_{ai}$ (see Greene 2007b: chapter N14).

is not the case (with the exception of the mixed forest in version 4). The constant (ASC) is never highly significant, and in the two summer versions it is not significant at all. For the summer versions it can therefore be concluded that no additional systematic influences exist beyond those captured by the model variables, which would drive the choices between alternatives. In the winter case, this is at least much less obvious. Interpreting these findings jointly, it can be concluded that unequivocal preferences for broadleaved and mixed forests are verifiable, but only if the summer aspect of the landscape is being considered. In the winter aspect these preferences are less dominant, so that other ("accidental") considerations gain weight for the choices between alternatives which are reflected in the ASC. The same effect is also shown by the lower pseudo-R^2 of both winter models.

Marginal willingness-to-pay

As explained earlier, implicit prices for each attribute can be calculated as the negative ratio of the attribute's coefficient to the price coefficient. In the present case they represent marginal WTP as compared to a status quo in which the landscape consists of a pine forest with low diversity, which cannot be entered for recreation purposes. Table 3 shows the resulting implicit prices for each attribute.

The households' WTP for recreation (i.e. for the possibility of accessing the landscape for recreational purposes) is substantial. In the summer versions the WTP is between 80 and 130 €/year, depending on whether the shown landscape is visible from home or only at regular journeys. In the winter versions the amounts are considerably lower (between 16 and about 30 €/year; moreover the WTP in version 3 goes back to an insignificant coefficient). Obviously wintertime views are less attractive. Balancing the results according to the length of the vegetation period (i.e. assuming an approximate summer:winter relation of 7:5), then the weighted mean WTP for recreation is 54.91 €/year if the respective landscape is visible from home, and 90.01 €/year if it is not visible. This is well in line with other estimates of recreation values in Germany which have been researched over a whole year (Elssaser 1996, 2001). However, it seems strange that recreation values for landscapes visible from home are being valued lower than those for landscapes which are not visible. Although different explanations seem possible, this observation is most probably due to a sample artefact.[8]

Turning to the landscape values, it seems sensible to start with the summer results. These are substantial, too, but lower than the recreation values. Broadleaved and mixed forests are preferred over coniferous ones by amounts between 40 and more than 85 €/year. As expected, these preferences are even stronger if the landscape is visible from home (version 1). The WTP for additional structural diversity is somewhat lower (about 20 €/year). Grassland, as shown by our computer images, is being valued much lower than each of the forest views (only in version 1 there is no significant difference to the conifer forest); the negative sign for grassland in version 2 implies that clearing a pine forest would cause disutility to the respondents (i.e. they would require compensation rather than being willing to pay in this case. The compensation requirement would be even higher if a broadleaved or mixed forest was cleared rather than a coniferous one).

The WTP estimates for winter landscape views are very different, and also their structural pattern is less homogeneous than with the summer views. An important result is the gene-rally much weaker preference for broadleaved and mixed forests (which is in most cases even based at insignificant coefficients). Only in version 4 there is a clear preference for the mixed over the coniferous forest view, which goes back to a significant coefficient. While a general preference for

[8] The mean forest visit frequency of the respondents in versions 2 and 4 is about 42 visits/year, whereas in versions 1 and 3 it is only about 27 visits/year (Elsasser et al. 2010 46p). These frequency differences probably determine the ostensible value differences: Dividing the WTP estimates by the respective number of forest visits results in a WTP of 3.07 and 3.18 € per visit and household for the two summer versions, and in a WTP of 0.59 and 0.70 € for the two winter versions. Hence location differences seem negligible (in contrast to seasonal differences).

Table 3 Marginal willingness-to-pay (compared to status quo) [€/year/household]

questionnaire version	1- summer view from home	2- summer view at journeys only	3- winter view from home	4- winter view at journeys only
recreation access	82.65	133.24	(16.08)	29.49
structural diversity	22.81	15.80	87.97	159.33
broadleaved forest	86.55	41.66	(-17.03)	(26.31)
mixed forest	56.11	44.90	(25.30)	83.86
grassland	(1.38)	-43.46	-162.82	(-4.73)

(numbers in brackets are based at insignificant coefficients)

broadleaved and mixed forests is not verifiable with the winter views, the structural diversity of forest stands is valued even higher in wintertime than in summertime; here WTP ranges from about 90 €/year (version 3) to about 160 €/year (version 4). The grassland view is again being valued much lower than all forest stands. However it has to be kept in mind that the winter based estimates are generally more uncertain than their summer counterparts (cf. Table 2).

Aggregate willingness-to-pay

Eventually, the agregate utility of the landscape change for the regional residents shall be evaluated, which is induced by the forest conversion programme as developed by our partners in the Newal-Net project. The WTP estimates disclosed above cannot be directly aggregated to the whole regional population, because even at the end of the modelling period in the year 2100, the forest area will only partly have become converted: In the business as usual scenario, the conifer area will be continuously reduced from 76% (in the year 2006) to 67% (2100), and in the leitbild-scenario from 76% to 13%. Accordingly the broadleaves area will be increased from 13% to 26% (bau) or to 25% (leitbild), respectively, and the area covered by mixed forests will change from 11% to 7% (bau), or to 62% (leitbild), respectively.

Therefore the ratio of the forest area which has been converted until a specific year T (i.e. $\sum Au_t$) to total forest area (Aw)[9] will be used as a measure of the probability that forest conversion has occurred in the environment of a regional resident. For both scenarios, this ratio is multiplied by the average WTPL for the respective landscape changes, and then aggregated to the number of households (N) in the region [units in square brackets]:

$$\sum_{i=1}^{N} WTP_{Lt}\left[\frac{€}{\text{year}}\right] = \frac{\sum_{t=2006}^{T} Au_t\,[\text{ha}]}{Aw\ [\text{ha}]} \cdot WTP_L\left[\frac{€}{\text{year}}\right] \cdot N \quad (12)$$

The difference of both scenarios' WTP aggregates is the monetary value of the landscape change due to the forest conversion programme in the region. The following assumptions apply. (1) Mean WTP estimates for the summer and winter versions, respectively, are weighed according to the length of the vegetation period (i.e. in a ratio of 7:5, as above); WTP estimates for the "views from home" and the "regular journeys only" versions are weighted according to the respective percentages of residential locations in the region (i.e. in a ratio of 42.8:57.2)[10]. (2) For simplicity it is assumed that the probability that a forest is converted is equally distributed over the whole area (i.e. that there is no spatial concentration).[11] (3) Possible changes of preferences over time, possible changes in population numbers (e.g. by migration), different preference relations for younger and older forest stands, as well as the possibility of diminishing

[9] Total forest area is constant over time, because none of the scenarios includes afforestations or deforestations.

[10] These percentages have been estimated by asking respondents of our survey for the landscape elements they could see from their home (question A3b; cf. Elssaser et al. 2010:51). 42.8 % of the respondents could see some kind of forest or the other from their home, 57.2% could not see any forest.

marginal utility of forest conversion are neglected. (4) In order to allow for variations in the perceived structural diversity of the converted forests, two variants will be calculated: in the "lower" variant visual diversity is assumed not to be affected by the forest conversion measures (i.e. the estimated WTP for high structural diversity is not included); in the "upper" variant it is assumed that forest conversion always leads to more diverse landscape views (i.e. the estimated WTP for high structural diversity is fully included).

Figure 2 shows the development of the aggregate utility due to the landscape change for both scenarios over time. Since both scenarios envisage a successive conversion of coniferous forests into broadleaved and mixed ones (albeit in different intensity), the landscape value increases in both scenarios. In the short run, the value differences between the scenarios are comparatively low; in 2020 they amount to 3.0 million €/year (lower variant), or to 6.2 million €/year, respectively (upper variant). Until 2100 these differences increase to 16.0 million, or 34.1 million €/year, respectively. However it should be kept in mind that such projections into the far future are quite speculative due to the large amount of assumptions upon which they necessarily rely.

Comparison to other benefits

As already mentioned, the landscape valuation exercise described here was embedded in a broader valuation study (Elssaser et al. 2010) about how forest conversion might affect goods and services provided by the regional forests. However, presenting all of the other valuations in detail would go beyond the scope of this article. Hence only their results will be reported in the following, as far as these are necessary for a comparison to landscape values.

The methods utilised for the valuation of timber production and carbon sequestration have been based on forest development and utilisation models, in combination with price data which have been derived from observed market values. With regard to timber production, it turned out that even a strong change in the forest management concept, as simulated in the leitbild scenario of "climate adaptive deciduous mixed woodland", affects the vol-

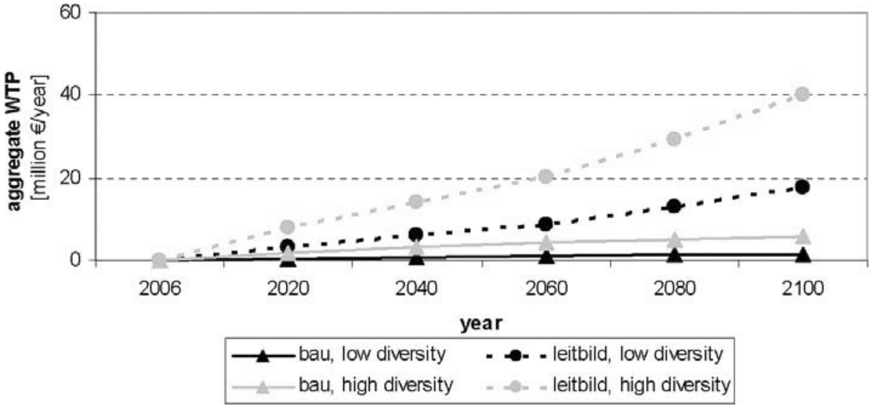

Figure 2 Development of the landscape value in two forest conversion scenarios in comparison to the year 2006

[11] The selection of stands for conversion is guided by silvicultural rather than economic parameters (like age and, of course, tree species of the existing stand) in our partners' conversion program. Although these parameters are spatially clustered, they do not depend on the spatial distribution of the human population in the region. Avoiding the mentioned simplification would have forced us not only to model the spatial distribution of converted stands over time, but also of the people benefiting from the conversion in the future. The latter would have severely complicated the calculations, while remaining highly speculative at the same time.

ume of timber production (and other woody biomass) with a delay of 50 years only. However, from 2060/2080 onwards the development of the sustainably harvestable volumes and their values start to follow different paths for the two scenarios. The total aggregate in the scenario business as usual grows from 120 million € in 2006 by 43% to reach 171 million € in 2100. In contrast, the prediction for the leitbild scenario is a negligible to small decrease of 14% to 103 million € in 2100 (Figure 3). Thus the difference of the potential revenues between the two scenarios is quite small in the first decades, but it grows to 68 million € per year in 2100. This loss clearly dominates the gain in landscape value, even when the respective upper variant is being considered.

The quantity of carbon sequestered in the living tree biomass is directly dependent on the development of the growing stock. Analysing this development, it was found out that the carbon stock in the model region will slightly increase in both scenarios by 2040/2060 and then decrease again by approximately the same amounts until 2100. However, both the increase and the later decrease are stronger in the bau scenario. Therefore the annual carbon sequestration under business as usual exceeds the one in the leitbild scenario in the first half of the investigation period, whereas this is being reversed in the second half. The biggest differences appear at the beginning and at the end of the investigation period; they amount to 200 Gg C/year in the period 2006-2020 (bau > leitbild), and to 145.9 Gg C/year in the period 2080-2100 (leitbild > bau), respectively (Figure 4).

Under realistic assumptions about the carbon markets and expected prices, the calculated difference in value pales in comparison to the (negative) development of the timber and biomass production as well as the (positive) development of the landscape value: even if a carbon price of 100 €/t CO_2 is assumed (which is far above the prices which are currently being realised e.g. in the European emission trading system)[12], the value difference between the two scenarios never even reaches 5 million €/year.

In total, looking at the balance of the various forest services examined here, there are no significant monetary losses up until 2060 to be expected for the implementation of the leitbild of "climate adaptive deciduous mixed woodland". For the upper variant of the landscape valuation (which assumes a forest conversion with forest stands of very high visual diversity) the balance is even slightly positive. After the year 2060, however, neither the positive impacts from the landscape change nor the slightly positive impact from carbon sequestration can compensate for the losses from the reduced timber production. By 2100 the imple-

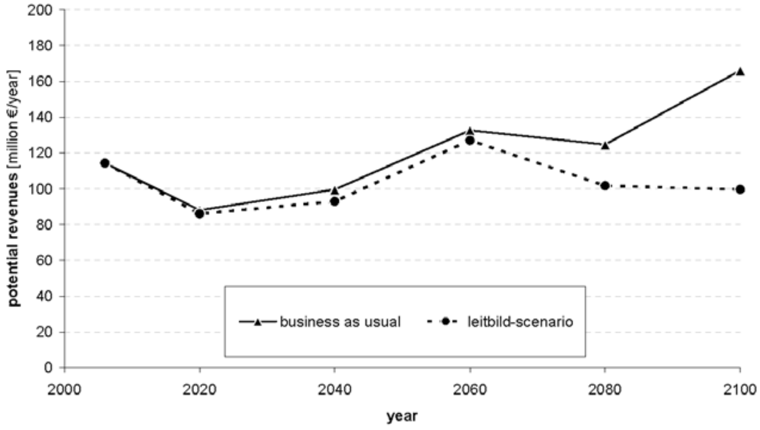

Figure 3 Development of the raw wood value in two forest conversion scenarios

mentation of the leitbild in comparison with continuing with business as usual results in a loss of around 30 to 50 million € per annum, depending on the calculation variant (Figure 5).

Conclusion

Even though the value losses induced by a forest conversion according to the leitbild scenario are significant only in the remote future, this result violates norms of sustainability as well as intergenerational justice. In order to duly interpret this finding, some caveats have to be kept in mind:

(1) Due to the lack of better information, the very long term projections undertaken here imply economic continuity in the sense that the value relation between the wood markets (which dominate the overall result) and other services of forestry remains constant over time.

(2) Also the growth dynamics of trees is regarded as staying constant in the long run. If changing environmental conditions lead to growth depressions in the future (e.g. because of increasing drought stress), then the influence of the timber values on the overall result will decrease - at least as long as other services of forestry are not (or less strongly) being influenced by such a reduced tree growth.

(3) The present study neither regards production risks nor their possible modifications due to a future climate change. This applies to physical risks (e.g. drought, fire, or pests) as well as to financial risks (including shifts in the price relations between tree species). Basically forest conversion programmes contribute to a better distribution of unknown risks, and they may therefore be rational also in an economic perspective (Knoke et al. 2008). However, both of the scenarios investigated here provide for a forest conversion (albeit in different intensity). It cannot be generally determined which magnitude of forest conversion is "better" than the other - such a decision is directly dependent on the decision maker's risk aversion.

(4) Although the study captures the values of several important goods provided by forests including environmental services, the value of further services which might be influenced by forest con-

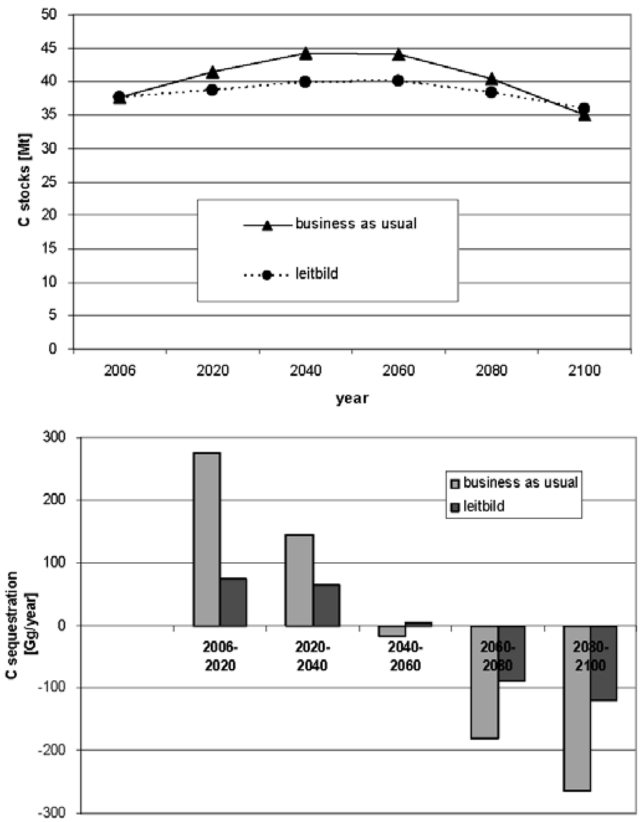

Figure 4 Development of carbon stocks and carbon sequestration in two forest conversion scenarios

[12] For actual prices see e.g. http://www.ecx.eu/ECX-Historical-Data. Prices in the ETS currently fluctuate between 12 and 15 €/t CO_2; they have never exceeded 30 €/t CO_2 since the start of the ETS.

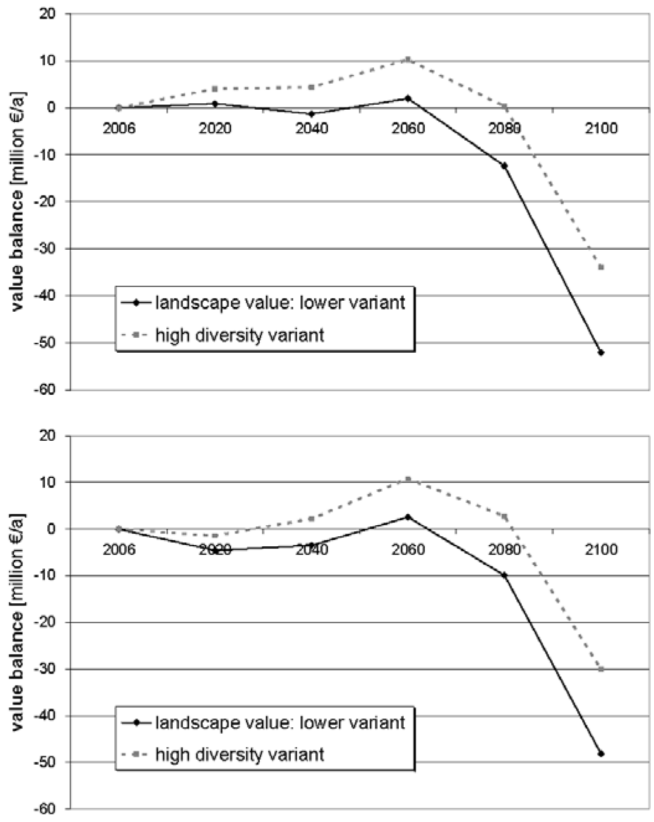

Figure 5 Development of the net benefit under the leitbild scenario (reference: business as usual scenario) (top: assuming a carbon value of 0 €/t CO_2; bottom: assuming a value of 100 €/t CO_2)

version remain unconsidered (notably, influences on watershed protection and biodiversity). However, a well comparable study exists about the influence of a similar forest conversion programme on biodiversity values in two regions of the German federal state of Lower Saxony (Liebe et al. 2006 in Meyerhoff et al. 2006). Here the proportion of broadleaves in the public forests was to be increased from between 30 and 40% to 60% according to governmental planning (Niedersachsische Landesregierung 1991). In the quoted study, the WTP for a biodiversity increase induced by forest conversion was in the same order of magnitude as the WTP for landscape changes found in the present study (annual biodiversity values amounted to about 6 to 15 € per person, i.e. approximately 15-30 € per household). Yet even if we included these values in our balance, this would not suffice to turn the balance positive for the leitbild scenario.[13]

(5) Finally it must be recalled that the present study did not aim at a full cost-benefit analysis; it therefore does not include investment costs for forest conversion measures. Such costs will very probably dominate the results if bigger investments are required, and they are directly dependent on the size of the forest area to be converted. The higher the costs for tree planting and maintenance are (including protection against game animal damages), the less probable is it that a forest conversion according to the leitbild scenario will turn out to be efficient, even if environmental values are taken into account.

As a conclusion, very strong assumptions would be necessary for maintaining that a forest conversion according to the leitbild of “climate adaptive deciduous mixed woodland” might be consistent with efficiency and sustainability goals. If, despite this, such a forest conversion was planned, conversion costs should be restricted to the indispensable minimum.

[13] The value balance becomes positive over the whole investigation period only if the most favourable of our calculation variants (i.e. the 'upper' landscape value and a carbon value of 100 €/t CO_2) are combined with an assumed annual biodiversity value of at least 108 € per household, which is more than three times the biodiversity value estimated by Liebe et al. 2006. All three assumptions are rather unrealistic.

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