Natural Capital in Germany – State and Valuation; with special reference to Biodiversity

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1 Introduction and summary

Natural capital can be understood as the potential of ecosystems to fulfil the needs and wants of current and future generations. Declining ecosystem services due to overexploitation, pollution or other factors either adversely affect human needs directly or must be compensated, with the effect that the ressources for mitigation are lacking elsewhere.

In the following, the state of ecosystem services in Germany is outlined along the main ecosystem components: climate, air, water, soil and biodiversity. The further discussion focuses on the biodiversity component. The political targets for biodiversity on German, EU and international level at first look seem to be linked to the concept of strong sustainability. A closer view however reveals that this is quite doubtful. Some political activities prove that there is a strong demand for additional, more neo-classical arguments for nature conservation, which rather belong to the concept of weak sustainability.

The commonly applied economic methods for nature valuation are based on neo-classical concepts. An evaluation of such studies in Germany shows that the most important component of the value of biodiversity seems to be constituted by people´s willingness to pay for biodiversity conservation based on ethical or esthetical reasons. The

Auszug aus: R. Döring (Hrsg.): Sustainability, natural capital and nature conservation. Marburg 2009

willingness to pay, as stated in interviews at – so called – contingent valuation studies, exceeds the required costs for biodiversity conservation greatly. This means that conserving biodiversity as a natural capital pays off very well in economic terms.

Stated preferences are, however, a weak argument in the political debate, at least in Germany. But this seems to be true also for other countries (Meyerhoff & Hartje 2008). Therefore the commonly applied neo-classical stated preference methods for nature valuation should be complemented by additional approaches.

One of these approaches could be the calculation of restoration costs taking account of restoration time, which is adopted in the "habitat equivalency analysis" method used in the USA to calculate for compensation in cases of liability for ecological damages (NOAA 1995, 2000, 2006) or as it was suggested by the author to determine compensation fees for the German "Eingriffsregelung" (regulation for the mitigation and compensation of impacts on nature and landscape) (Schweppe-Kraft 1996, 1998).

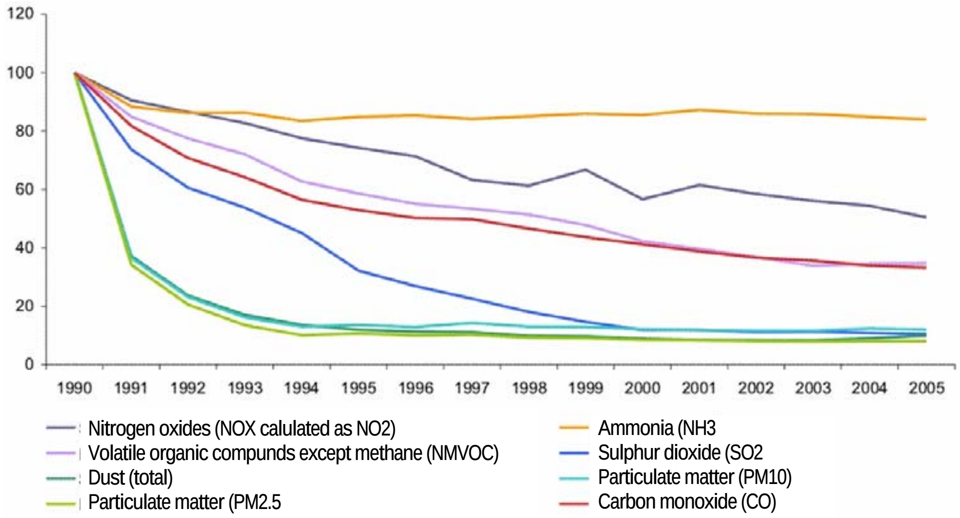
Based on this approach, the 10% of the terrestrial landscape of Germany covered by natural and semi-natural ecosystems which are understood to be essential for the conservation of threatened species have a value of about 740 Bio. €. This is more than 10% of the net fixed capital in Germany (7,286.81 Bio. € in 2007 at replacement costs), or about 80% of the value of Germany´s productive technical equipment (933.88 Bio. € in 2007).

2 Overview on the state of natural capital in Germany – climate, air, water, soil and biodiversity

Climate

Climate change is a global factor that influences the functioning of all our ecosystems. According to a recent study of the German Institute for Economic Research (DIW) (Kemfert 2008), Germany will have to face accumulated costs of up to 800 Bio. € until 1050 (shortfalls in crop production, additional flood damages etc.) if no action to reduce global warming was taken world-wide and the global surface temperature would rise up to 4.5 °C at 2100 (Scenario A1B, IPCC 2007). Mitigation measures to reduce green-house-gas emissions in Germany at 40% until

2020 (a rate that is considered to be a fair contribution to the world wide aim to prevent a rise of temperature of more than 2 °C) would need additional public expenditures of on avarage about 1 Bio € per year in the same period (Fraunhofer Institut 2007). These expenditures would pay off alone by its induced energy savings. This means that reducing temperature rise from 4.5 to 2 Grad Celsius has an economic value with respect to Germany of about 800 Bio. €.

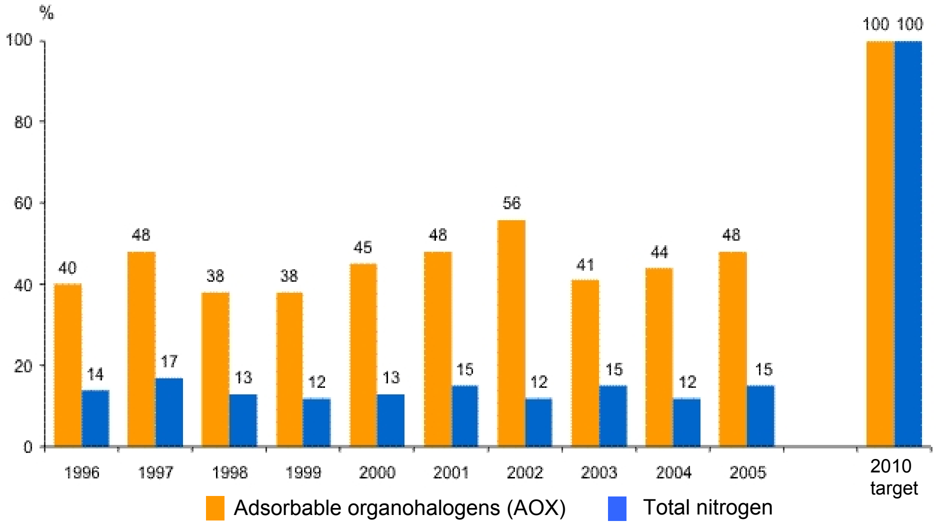


Source: Umweltbundesamt, Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen seit 1990, Emissionsentwicklung 1990-2005 (http://www.env-it.de/umweltdaten/public/theme.do?nodeIdent=2359)

Fig. 1: Trends in emissions of selected air pollutants since 1990 (1999 = 100)

Air quality

Although there has been a significant overall decline of air pollution during the last decades (fig. 1), some factors are still to be seen as problematic, such as particulate matter or ammonia emissions.

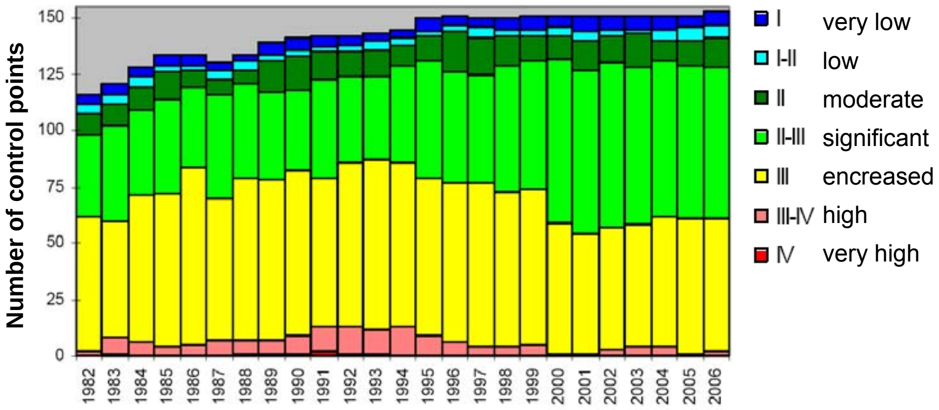


Source: Umweltbundesamt: Umweltdaten Deutschland, Umweltindikatoren, Ausgabe 2007

Fig. 2: Percentage of control points with chemical water quality class II and better (surface water)

Running and ground water

There has been a continuous improvement of water quality, both in surface water and ground water, during the last decades.



Source: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (Hrsg.) 2008: Nitratbericht 2008. http://www.bmu.de/files/pdfs/allgemein/application/pdf/nitratbericht_2008.pdf

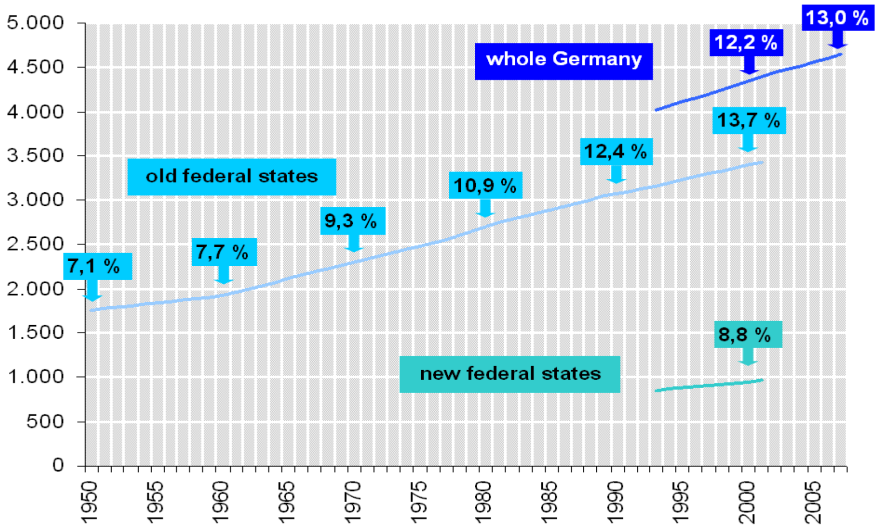
Fig. 3: Trend of the groundwater nitrate (NO3) load 1982 to 2002

Remaining problems concern nitrate and organic halogen compounds that have their origin primarily in agricultural practicies (fig. 2 and 3).

Besides some few regional cases, Germany currently does not face any serious problems with water shortages.

Soil and land use

Although there are some problems with soil erosion, they are not to be considered as severe. More relevant than this is the continuous loss of arable land due to the expansion of settlements, industry and infrastructure (fig. 4).

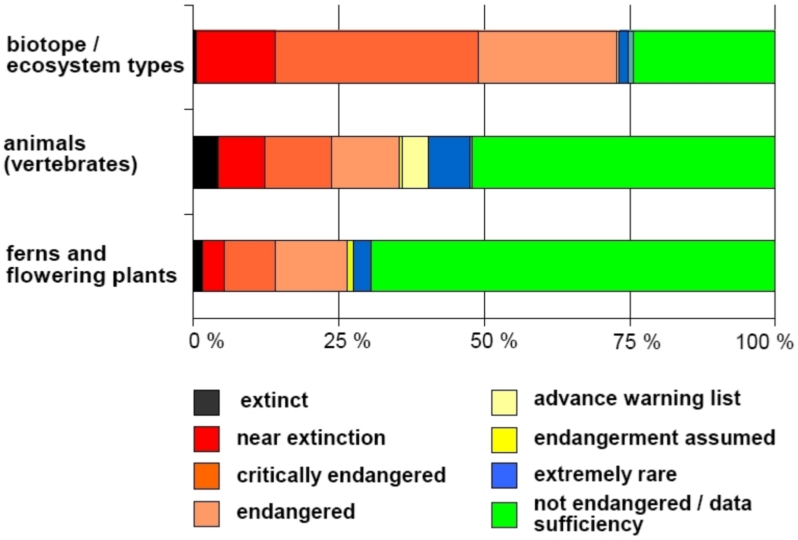


Source: Bundesamt für Naturschutz: Daten zur Natur 2008

Fig. 4: Percentage of area used for settlements, industry and infrastructure 1950 to 2006 (in 1000 ha)

Biodiversity

Germany has lost a reasonable share of its biodiversity particularly due to the intensification of agricultural production during the first three decades post 1950. Today, 40% of the vertebrates, 25% of the ferns and flowering plants and 75% of the different ecosystem types are considered endangered (fig. 5). The breeding bird indicator applied in the German National Sustainability Strategy (Presse- und Informationsamt der Bundesregierung 2002) and the National Strategy for Biological Diversity (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2007) shows a relative stable situation during the last fifteen years, but on a relatively low level (fig. 6). The downward trend, however, seems to have been stopped. This could be the result of reforming the agriculture policies by refocusing the support schemes towards preserving, or at least considering, biodiversity issues. Another factor has been the introduction of the EU Habitats and Birds Directives, which set clear targets for the conservation of species and habitats of particular concern.



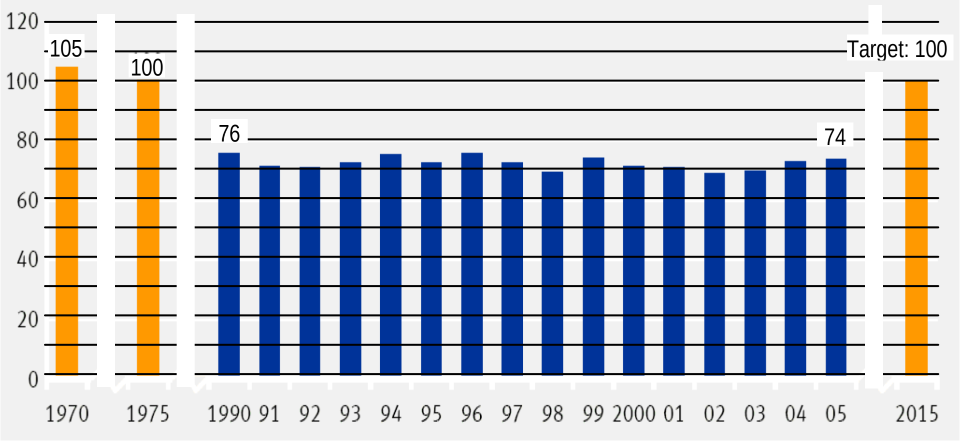
Source: Bundesamt für Naturschutz: Daten zur Natur 2008

Fig. 5: Share of endangered species and biotope types

The future trends will largely depend on the further development of agricultural production and the direct and indirect impacts of climate change.

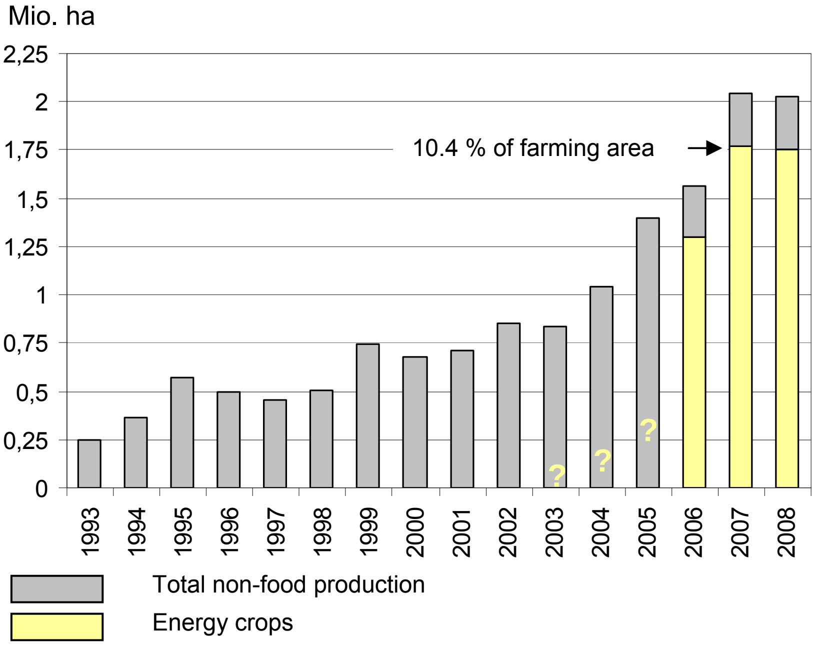
Rising world market prices for agricultural products and a fast growing politically induced energy crop production puts an increased pressure on arable land, which leads to a re-intensification of agricultural production. The recent successes of agro-environmental schemes may therefore soon be jeopardized.

As a consequence, there is still an urgent demand for further research that demonstrates the value of biodiversity for society.



Source: Statistisches Bundesamt: Nachhaltige Entwicklung in Deutschland, Indikatorenbericht 2006.
For detailed information on the indicator: http://www.bfn.de/fileadmin/MDB/documents/themen/monitoring/Sukopp_2007_Nachhaltigkeitsindikator_Bericht-2_Brutvoegel_Deutschland.pdf

Fig. 6: Sustainability indicator for species diversity (Aggregated population development of selected breeding birds)



Source: Fachagentur Nachwachsende Rohstoffe e.V. (FNR) 2009: http://www.nachwachsenderohstoffe.de/service/daten-und-fakten/anbau.html?spalte=3; Agrarbericht der Bundesregierung 2007; Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2006): Nationaler Strategieplan der Bundesrepublik Deutschland für die Entwicklung ländlicher Räume 2007- 2013

Fig. 7: Growth of cultivated area for energy crops in Germany

3 Natural capital in the political debate – strong or weak sustainability?

Concepts of strong sustainability normally ask for conserving a minimum stock of natural ressources as the basis to allow for economic activities in the long run whereas concepts of weak sustainability look for a long-term maximization of highly aggregated welfare indicators assuming general substitutability between natural and man-made capital.

The relevant political strategies for sustainability and nature conservation in Germany set physically defined objectives for maintaining natural capital and hence at first look seem to be in line with the idea of strong sustainability. However it is quite questionable wether they really can secure sustainability.

For example, the National Sustainability Strategy target of reducing the daily extension of the area for settlements, infrastructure and industry from 113 ha (average between 2003 and 2006) to 30 ha in 2020 (Presse- und Informationsamt der Bundesregierung 2002), though it is very challenging, does not represent strong sustainability. Strong sustainability in its strict meaning would only be reached when the turnover rate has reached 0.

The political targets for biological diversity even seem to be beyond strong sustainability at first look. The objective stated in the Sustainability Strategy and repeated in the National Strategy for Biodiversity is to regain by 2015 a situation that is similar to the level of 1975, which was clearly higher than the present biodiversity situation. But although reaching this target would not only mean preserving but also improving the situation of biodiversity at its current state, it can still be questioned whether this would fulfil the criteria of strong sustainability due to the grave loss of biodiversity before 1975.

The EU biodiversity target of the Renewed EU Sustainable Development Strategy (Council of the European Union 2006) and the international one set at the World Summit on Sustainable Development in Johannesburg (UN 2002) are “halting the loss of biodiversity by 2010” or “significantly reducing the current rate of loss of biological diversity” respectively.

As with the German target concerning the previous losses, it is questionable whether the EU target represents a concept of strong sustainability. The Johannesburg goal clearly fails of the requirements for strong sustainability. In both cases it is quite uncertain if they will be reached in any case.

In view of a likely policy failure, there are strong efforts underway at both EU and international level to define further economic arguments for conserving biodiversity. One example is a study, carried out by IEEP and assigned by the EC, on European case-studies where biodiversity loss has led to economic costs (Kettunen & Brink 2006). Another, more prominent example is the decision of the G8 Environment Ministers Meeting in Potsdam 2007 to carry out a global study to "initiate the process of analysing the global economic benefit of biological diversity, the costs of the loss of biodiversity and the failure to take protective measures versus the costs of effective conservation" (for an interim report of the study see European Communities 2008).

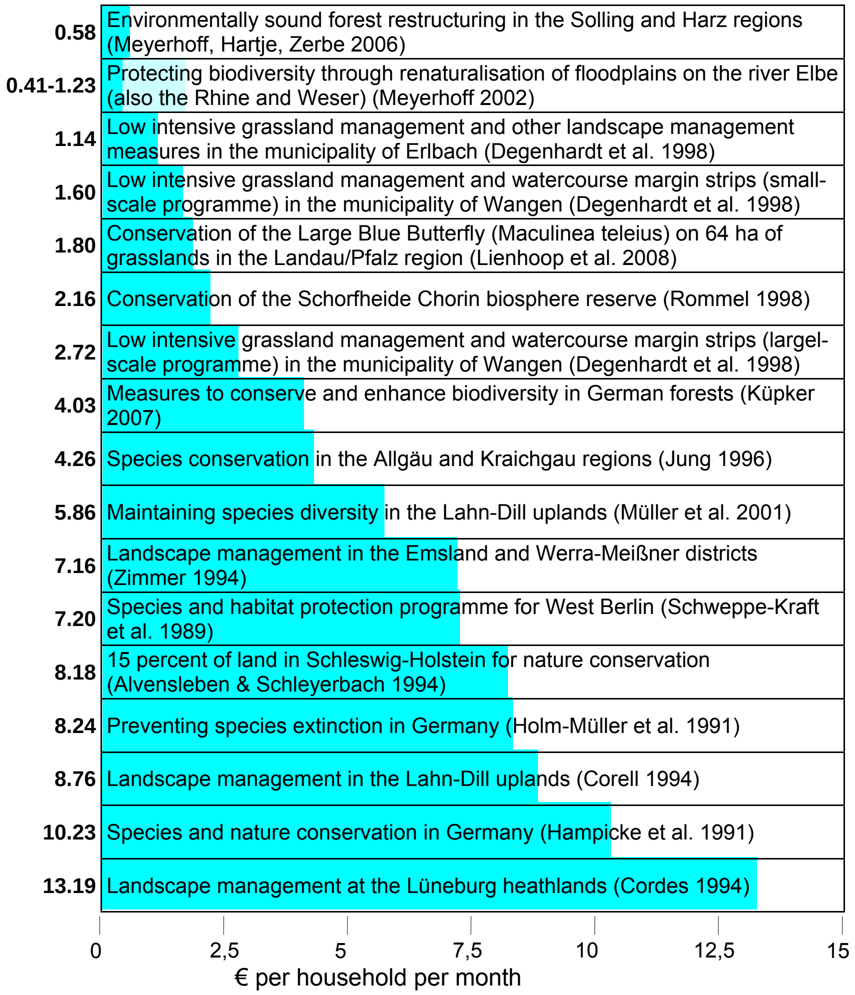
The main aim of both initiatives is finding arguments that sustaining biodiversity is not (only) an end in itself but has also positive effects on income and human welfare. The long term maximisation of income and human welfare, as mentioned above, is a typical aim in concepts of weak sustainability. The methods applied to prove for positive income effects of biodiversity as the cost-benefit-analysis are based on neoclassical welfare theory.

4 The value of biodiversity in Germany – neo-classical results and political shortcomings

The most prominent economic concept for valuing ecosystems and biodiversity in the framework of neoclassical welfare theory is the concept of total economic value (Millenium Ecosystem Assessment 2005, OECD 2002, Pearce 1993). According to this concept the valuation of an ecosystem or parts of it has to consider its

● direct use values	e.g. for agricultural production, forestry, recreation, angling, hunting, aesthetic value / scenic beauty;
● indirect use values:	e.g. improvement of water quality, carbon sequestration, flood prevention, pollination;
● option value:	benefit from ensuring the option for a future use;

- existence value: benefit from conserving resp. willingness to forgo a part of ones income in order to conserve a resource – especially natural amenities or species – without having any direct or indirect use of it, i.e. due to ethical or religious motives;
- bequest value: benefits from ensuring that certain goods will be preserved for future generations.



Source with complete citations: Bundesamt für Naturschutz: Nature Data 2008, updated

Fig. 8: Willingness to Pay for different area and resource specific conservation measures in Germany

Empirical studies often show that considerably more than half of the value of threatened ecosystems result from option, existence or bequest value (Dziegielewska et al. 2007).These “non use” value components, which are often difficult to be separated from each other, can only be assessed by stated preference techniques like contingent valuation or choice experiments using interviews to ask people more or less directly for their willingness to pay to keep biodiversity and the associated intact ecosystem services.

In many cases, recreational and aesthetical values are also being included in the result of stated preference studies, either because alternative methods to derive values from observable behaviour and real decisions according to the so called “revealed preference” methods” are not applicable, or due to the fact that the interview questions on willingness to pay do not distinguish between recreational / aesthetical values and option, existence and bequest values.

Fig. 8 shows results of stated preference studies from Germany. They reveal a clear tendency that people are willing to pay more for comprehensive conservation aims at a national level and less for specific aims on a regional or local level. Nevertheless there can also be seen a clear preference for local aims: if one would add up the willingness to pay for local conservation schemes for all of Germany, the result would be high above the willingness to pay for a national conservation programme, which may be explained by local preferences as well as by other interpretations of the so called “embedding effect”.

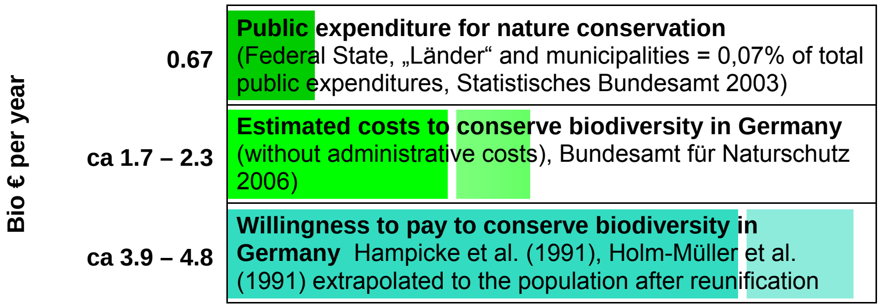


Fig. 9: Costs and benefits of nature conservation in Germany

Regarding the national level people state that they would pay 99 – 123 € per year for a conservation programme to halt the loss of biodiversity in Germany. This would add up to an amount of 3.9 – 4.8 Bio € per year

German-wide (see Fig. 9). Which represent solely the value of ethical and (partly) aesthetical aspects of biodiversity. This value is more than twice the estimated cost of 1.7 to 2.3 Bio. € for measures necessary to preserve all ecosystems essential for the conservation of species in Germany (Bundesamt für Naturschutz 2006). The cost-benefit-ratio is positive which means that sustaining biodiversity is economic even if only existence and aesthetical motives are considered.

The problem however is that in Germany and this might be true also for other countries, politicians, decision makers, opinion leaders as well as the man in the street do not put much confidence in values that are based on money people are just stating to be willing to pay without being obliged to really do this. The mistrust towards the results of valuation methods such as contingent valuation and choice experiments may be scientifically unfounded or not, anyway it is a widespread attitude that will not change in the short run.

The fact that a high share of the evaluated effects of biodiverity normally is determined by stated willingness to pay leads to severe problems regarding public acceptance.

Hitherto only a smaller share of the total economic value of threatened and species rich ecosystems is determined on (seemingly) hard facts like prices and costs as for flood mitigation, carbon sequestration or water quality improvement. In developing countries the situation might differ because of the additional functions natural ecosystems have there to meet basic human needs.

Accounting specific use values on price or cost basis normally is much more difficult than asking for willingness to pay. Another problem with use values is the fact that they vary substantially from place to place due to differences in demand (e.g. for recreation, flood-protection or water purification) as well as in productivity (e.g. site specific effects of swamps for carbon sequestration). This makes it very complicated to assess such benefits German-wide or for the German "Länder" and for the towns and districts what would be necessary to compare the benefits with the public expenditures for nature conservation programmes that are enacted on the respective political levels.

In Germany there are only a few case studies that made assessments for the value of biodiversity for both aspects – existence and aesthetical/recreational values on the basis of stated preferences and other use values on the basis of costs and prices. Bräuer (Fig. 10) found that people were willing to pay 567 Thsd. € per year for the beaver repatriation programme in Hessen (one of the German “Länder”). He also evaluated the benefits of the programme for enhanced nutrient retention and decomposition, based on saved expenses for equivalent technical measures to reduce the nutrient load and found that it was worth 12 to 36 Thsd. € per year, which is only 2% – 6% of the value determined by contigent valuation. Grossman et al. (2008) analysed the economic values of dike shifting measures to extend flood plains along the river Elbe. They found that existence and recreational/aesthetical values determined on the basis of a contigent valuation study constituted about 30% percent of the overall economic value. Whereas the benefits of water purification and flood prevention made up the remaining 70%.

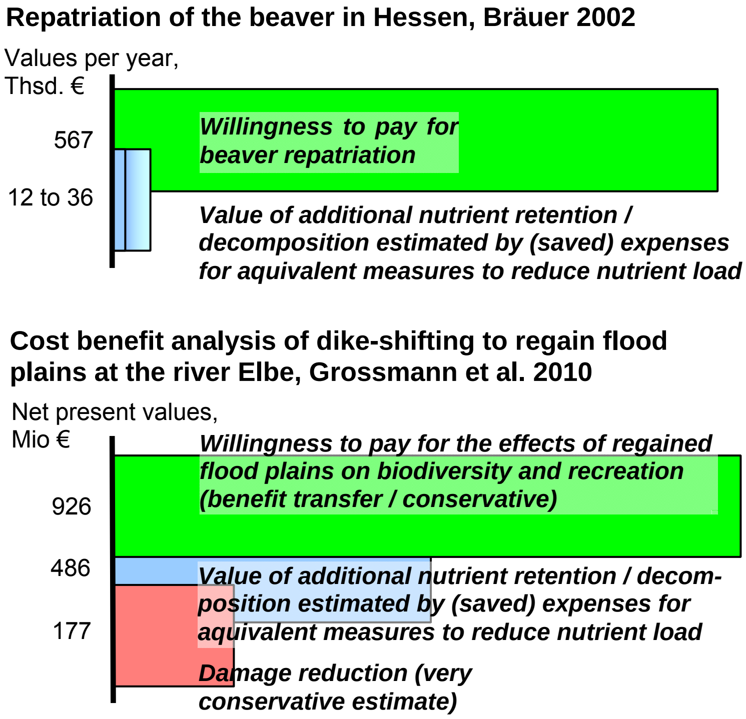


Fig. 10: Amount of different value components in German cost-benefit-analysis

The average between the two ratios (2% – 6% and 70%) is 37%. If you take this for a (very) rough estimation of the overall ratio between existence/aesthetical values and other use values then you would come to the conclusion that the amount of the use values that can be measured on cost/price basis would be only slightly above or even below the cost of nature conservation.

This shows a certain dilemma when using conventional neo-classic methods for valuing biodiversity: Those methods that show values that outweigh the costs of conservation and are relatively easily to apply are suffering from low public acceptance whereas the methods that produce much more accepted results are difficult to apply and could deliver values that would be possibly too small to justify the amount of public expenditures that is sufficient to stop the loss of biodiversity.

As a consequence policy-advisors that are asked to help politicians to find economic arguments for preserving biodiverity should look also for other possible evaluation methods that could complement conventional neo-classic approaches.

5 The value of high biodiversity ecosystems in Germany - a supplementary second best approach based on costs and recovery time

One possible approach for complementing conventional neo-classic valuation methods is calculating the economic value of biodiversity on the basis of restoration costs and restoration time. Restoration costs can be taken as an approximation of benefit losses only in those cases where a full restoration of all beneficious functions of an asset is possible and the respective costs are lower than the benefits gained from the preservation of that asset. If the benefits of an asset cannot be determined directly for instance because of lacking applicable or accepted other methods then restoration costs stand for the maximum possible benefit loss.

The costs for restoring habitats however could also be interpreted as revealed public preferences. Habitats should be developed or restored only in those cases where the benefits of restoration exceed its costs. Otherwise there would be a policy failure. If there is the public consensus that all the ongoing habitat restorations are beneficial after costs, then you can easily calculate a minimum gross benefit (benefit before costs) for every habitat development by working out the present value of its respective costs.

The next step would be to determine gross (minimum) benefits of the respective mature habitat by comparing the development of physical indicators, like the number or abundance of rare species during the whole life-cycle between the just restored ecosystem and the matured one.

The gross value of the matured ecosystem minus possible maintenance costs can then be taken for the minimum welfare loss that would be associated with its destruction – all this under the above mentioned condition that all the ongoing restoration activities are not subject to a policy failure. The method just outlined will be explicited more detailed in the following.

It is based on two existing approaches. Firstly the "Habitat Equivalency Analysis" (HEA) developed in the USA to determine the extent of measures to compensate for ecosystem damages, particularly for interim losses (NOAA 1995, 2000, 2006). Secondly the "Investment Model" developed by the author (Schweppe-Kraft 1996, 1998) as a model to determine compensation fees for the German "*Eingriffsregelung*", a requirement of ecological offsets if nature and landscape is impaired by construction activities or other kinds of land use change in German legislation.

The underlying idea focuses on measures to restore or create habitats like natural creeks, species rich meadows or semi-natural forests with a high proportion of mature timber and deadwood. A considerable part of the expenditures for nature conservation in Germany is dedicated to such kind of restoration efforts.

Most kinds of habitat restoration require some initial actions to change underlying natural or economic conditions for the desired habitat development, for example the rise of the groundwater level to restore pens or the reintroduction of sheep grazing to develop semi-natural dry grasslands.

These initial actions require one-off expenditures that can be treated as investment costs. They are added by opportunity costs, e.g. for reduced yields and running or periodically occurring costs for maintenance or management measures (Fig. 11).

Restored ecosystems or newly created habitats do commonly not reach their full range of ecological functions as soon as the initial actions are taken. Their full development often takes more than one decade, and sometimes even several hundreds of years.

Our society accepts the costs of restoration activities as well as the associated development times, as we value them as necessary to save biodiversity and biodiversity as worth saving.

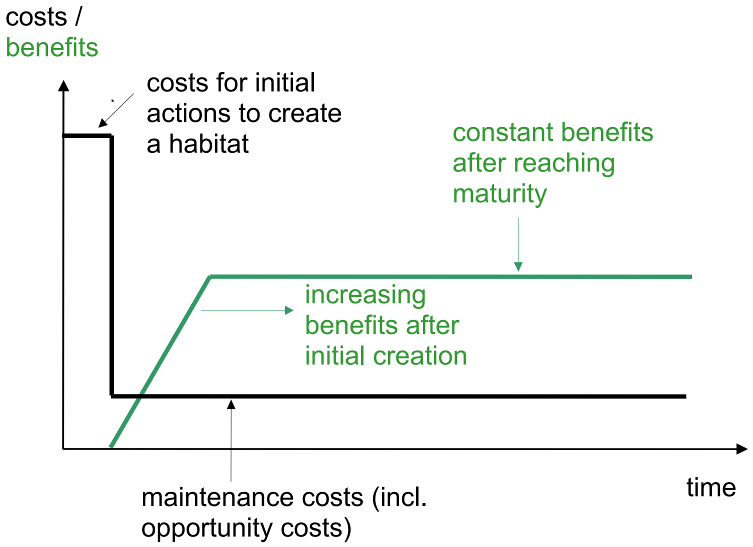


Fig. 11: Costs and benefits of an ecosystem restoration/creation

Accepting expenditures in economic terms means that the present value of benefits, i.e. the sum of discounted benefits per year, exceeds or at least equals the present value of the costs for initial restoration measures and the present value of maintenance costs ($B_{eco\text{-}rest} \geq C_{init.rest} + C_{maint}$; fig. 12 and box 1, equation 1).

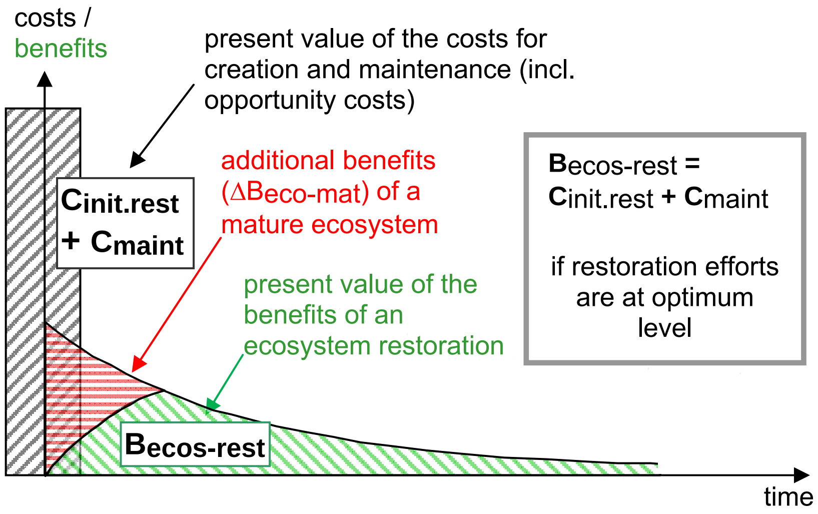


Fig. 12: Costs and benefits of an ecosystem restoration and mature ecosystem – a simplified picture

If the ecosystem restoration activities of a society would be at an optimum level, then the “last” (marginal) restoration carried out would be characterized by a parity between costs and benefits, whereas in all other pre-marginal restoration cases benefits would exceed costs. Benefits that are generally exceeding costs – also in the marginal case – would mean that society is performing to little restoration and nature conservation activities, whereas benefits that are generally below costs would indicate too much of these activities.

As mentioned above restoration activities are interpreted as revealed preferences. Based on the fact that all of the species rich ecosystems of Germany valued below are subject to some kind of restoration avctivities and considering that one of the political goals expressed in the National Biodiversity Strategy is to extend the area covered by this habitats, it is assumed that the relation that benefits of restoration activities exceed costs holds for all species rich ecosystems. To simplify the following equations we further assume that benefits just only equal costs. Loosening this restriction would mean that our results turn from assessments of values to assessments of minimum values.

If benefits equal costs then the net benefit of an ecosystem restoration ($NB_{eco\text{-}rest}$) – the present value of benefits minus costs – is zero. This means that the internal rate of return of an investment in restoration activities is the same as the relevant market rate. Benefits equalling costs thus does not mean a bad investment but one, that shows a “normal” return.

If parity between costs and benefits is assumed, and an approximation of the relative increase of ecological functionality during the whole restoration period can be calculated, one can also determine the monetary value of the benefits per year. This value rises in the beginning and gets stable when the ecosystems has reached maturity.

The present value of the benefits of a mature ecosystem ($B_{eco\text{-}mat}$) lies above the present value of the benefits of an ecosystem which is at the beginning of its restoration ($B_{eco\text{-}rest}$) because the ecological functions of a mature ecosystem are already at optimum level whereas those of an ecosystem that is just restored are still encreasing. Thus the present value of the benefits of a mature ecosystem does not equal but exceeds the present value of its restoration and maintenance costs. The difference in value between mature and developing ecosystems of the same type ($\Delta B_{eco\text{-}mat} = B_{eco\text{-}mat} - B_{eco\text{-}rest}$) is the present value of the deviations in value per year during the restoration period, the former showing already full functionality whereas the latter are still developing. For every ecosystem type this difference can be expressed as a certain share (d) of the present value of the ecological benefits or the costs of an ecosystem restoration ($\Delta B_{eco\text{-}mat} = d \bullet B_{eco\text{-}rest} = d \bullet (C_{init.rest} + C_{maint})$, box 1, equations 2 and 3).

Box 1: Relationship between value and costs on the basis of the habitat equivalency / investment model - approach

$$\begin{array}{lllllll}
1. & B_{eco\text{-}rest} & = & C_{init.rest} + C_{maint} & & & \\
2. & B_{eco\text{-}mat} & = & B_{eco\text{-}rest} + \Delta B_{eco\text{-}mat} & & & \\
3. & \Delta B_{eco\text{-}mat} & = & d \bullet B_{eco\text{-}rest} = d \bullet (C_{init.rest} + C_{maint}) & & & \\
4. & NB_{eco\text{-}rest} & = & B_{eco\text{-}rest} - (C_{init.rest} + C_{maint}) = 0 & & & \\
5. & NB_{eco\text{-}mat} & = & NB_{eco\text{-}rest} & + C_{init.rest} & + \Delta B_{eco\text{-}mat} & \\
6. & NB_{eco\text{-}mat} & = & 0 & + C_{init.rest} & + d \bullet (C_{init.rest} + C_{maint}) & \\
7. & \underline{\underline{NB_{eco\text{-}mat}}} & \underline{\underline{=}} & & \underline{\underline{C_{init.rest}}} & \underline{\underline{+ d \bullet (C_{init.rest} + C_{maint})}} &
\end{array}$$

$$\begin{array}{llll}
8. & \text{as:} & \Delta B_{eco\text{-}mat} = B_{eco\text{-}mat} - B_{eco\text{-}rest} & \\
9. & \text{and} & B_{eco\text{-}rest} = C_{init.rest} + C_{maint}) & \\
10. & \text{it is also:} & \underline{NB_{eco\text{-}mat}} = C_{init.rest} + B_{eco\text{-}mat} = \underline{B_{eco\text{-}mat} - C_{maint}} &
\end{array}$$

$NB_{eco\text{-}rest}$ = net benefits of ecosystem restoration
$NB_{eco\text{-}mat}$ = net benefits of a mature ecosystem
$B_{eco\text{-}rest}$ = benefits of an ecosystem restoration
$B_{eco\text{-}mat}$ = benefits of a mature ecosystem
$\Delta B_{eco\text{-}mat}$ = additional benefits of a mature ecosystem due to the missing restoration period
d = additional benefits of a mature ecosystem as a share of the benefits / costs of an ecosystem restoration
$C_{init.rest}$ = costs of initial restoration measures
C_{maint} = maintenance costs

The net benefit (NB) of an ecosystem is the difference between its benefits and its costs. A mature ecosystem does not only offer more benefits than an ecosystem restoration, it also causes no restoration costs. So the net benefits of a matured ecosystem ($NB_{eco\text{-}mat}$) are its additional benefits plus the saved restoration costs ($NB_{eco\text{-}mat} = d \bullet (C_{init.rest} + C_{maint}) + C_{init.rest}$). Given the above assumptions the benefits can be fully defined on cost-basis as (box 1, equations 5 to 7). If a mature ecosystem is destroyed the welfare loss equals its net benefits.

Box 2: Parity between net benefit loss and costs to regain full ecological functionality

$$\begin{aligned}
NB_{\text{eco-mat}} &= C_{\text{init.rest}} + d \cdot (C_{\text{init.rest}} + C_{\text{maint}}) \\
C_{\text{reb}} &= (1 + d) \cdot (C_{\text{init.rest}} + C_{\text{maint}}) - C_{\text{maint}} \\
&= C_{\text{init.rest}} + C_{\text{maint}} + d \cdot C_{\text{init.rest}} + d \cdot C_{\text{maint}} - C_{\text{maint}} \\
&= C_{\text{init.rest}} + d \cdot C_{\text{init.rest}} + d \cdot C_{\text{maint}} \\
&= C_{\text{init.rest}} + d \cdot (C_{\text{init.rest}} + C_{\text{maint}}) \\
C_{\text{reb}} &= NB_{\text{eco-mat}}
\end{aligned}$$

C_{reb} = Costs for restoration and maintenance measures to regain ecological benefits

Other variables = see box 1

If one was to compensate the loss of the ecological benefits of a mature ecosystem by the creation or restoration of an ecosystem of the same kind in a different place, more than a simple 1 : 1 restoration is required, as this would fail to compensate for the lower benefits during the restoration period ($\Delta B_{\text{eco-mat}}$). A full compensation of all ecological benefits can only be achieved if restoration actions are extended to 1 + d; “d” being $\Delta B_{\text{eco-mat}} / B_{\text{eco-rest}}$ which is the same “d” as used above.

Taking into account that maintenance costs – if applicable – stop if an ecosystem is destroyed, the costs for regaining ecological functionality are the sum of restoration and maintenance cost multiplied with 1 + d minus simple maintenance costs. The result of this calculation is the same amount as the net benefit loss caused by the ecosystem destruction. This means that the net benefit loss is as high as the costs (C_{reb}) to regain the ecological benefits (s. box 2).

On the basis of these equations, calculations of the net benefit loss or the costs to regain full functionality respectively were made for the natural and semi-natural ecosystems that are considered to be essential for the conservation of biodiversity in Germany. These ecosystems cover about 10 to 15% of the German landscape.

Average values for every ecosystem type were taken from Schweppe-Kraft (1998), where calculations were made

- on the assumption of a linear development of functionality during the restoration period,
- for alternative restoration methods and restoration times and
- with a discount rate of 4%.

Data on the area covered by the different ecosystems are based on Güthler & Oppermann (2005), Statistisches Bundesamt (2005), Enzian & Gutsche (2004), Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2007), Schweppe-Kraft (1998) und Hampicke et al. (1991). The result of the analysis is shown in table 1.

On the basis of the applied habitat equivalency / investment model, natural and semi-natural ecosystems beeing essential for the conservation of biodiversity and covering about 9.5% of the area of Germany have a value of nearly 740 Bio. €, calculated on the basis of restoration costs and recovery periods. This is more than 10% of the net fixed capital in Germany (7,286.81 Bio. € in 2007), or about 80% of Germany´s productive technical equipment (933.88 Bio. €).

The comparison between estimated costs for maintaining biodiversity of 2 – 3 Bio. € per year, a stated willingness to pay for conserving biodiversity of 3 – 5 Bio. € per year and restoration costs of more than 700 Bio. € (being 28 Bio. € per year at a discount rate of 4%) if the 10% most valuable ecosystems for biodiversity were destroyed and had to be redeveloped leads to the conclusion that accepting further biodiversity loss would be a high risk strategy not only for biodiversity itself, but also for human welfare. The welfare gain of biodiversity measured by willingness to pay seems to be clearly above the cost of conserving biodiversity. The restoration costs exceed the conservation costs about seven times. Restoration is so expensive that it can be questioned whether society decides for redevelopment once biodiversity is destroyed. Taking the risk to accept further loss would most likely result in a disaster for both human being and wildlife.

Table 1: Value of ecosystems essential for nature conservation in Germany calculated on the basis of the habitat eqivalency / investment model - approach

Habitat / Ecosystem	***Area (ha)***	**% of German landcover**	**Euro / m^2**	**Value (Mio. €)**
Dwarf shrub heathlands	83,170	0.22	41.83	34,790.01
Natural and semi-natural dry grasslands	99,720	0.27	8.06	8,037.43
Molinea meadows	14,000	0.04	18.51	2,591.40
Riparian grasslands and tall herbaceous perennial vegetation of moist to wet sites	37,700	0.10	6.14	2,314.78
Low intensively used meadows	179,000	0.48	6.14	10,990.60
Fens and swamps free of woodland	11,100	0.03	9.80	1,087.80
Other types of agricultural grasslands with a high species diversity	447,264	1.19	2.66	11,897.22
Arable land with threatened herbaceous vegetation communities	473,124	1.26	0.49	2,318.31
Low intensively managed vineyards	7,380	0.02	13.31	982.28
Traditionally managed orchards	350,000	0.93	9.75	34,125.00
Low intensively used ponds for fish farming	3,150	0.01	48.93	1,541.30
Copses, thickets, scrub, hedgerows and tree rows in agricultural used areas	750,000	2.00	16.28	122,100.00
Natural woods and low intensively used species-rich forests	734,438	1.96	18.44	135,430.28
Pasture woodland	31,950	0.09	20.64	6,594.48
Coppice and coppice with standard	182,813	0.49	4.47	8,171.72
Nature-like woodland edge communities	3,450	0.01	22.79	786.26
Species-rich herbaceous forest fringe communities	788	0.00	2.82	22.21
Raised bogs including less degraded restoreable forms	67,489	0.18	195.46	131,914.41
Transition mires and strongly degraded raised bogs	78,498	0.21	127.42	100,022.52
Nature-like running and standing surface waters	246,675	0.66	48.93	120,698.08
Total	3,555,033	**9.48**		**736,416.07**

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