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Cost-effectiveness and cost-benefit analysis of maintenance measures for open landscapes

J. Müller
Centre for Sustainability Management (CSM),
University of Lueneburg, Germany

Abstract

One of the largest areas of open landscape in Germany is the "Lueneburg Heath", situated near Hamburg in Northern Germany. Mainly for nature conservation, but also for recreational reasons, this area is maintained using several methods like mowing, sheep grazing, controlled burning, removing sods and tilling with rotary hoes. All these methods aim at a discharge of important nutrients to abet the heather compared to other plants. The methods are carried out by a non-profit-organisation, which owns most of the area. The purpose of this study is to assemble the criteria, which lead to the decision about which maintenance method should be used, implement these into a cost-effectiveness-analysis and detect a cost-optimal combination of the methods. Furthermore a cost-benefit-analysis of the maintenance measures is to be carried out. So in a first step within the framework of the cost-effectiveness analysis the costs and values of effectiveness criteria are traced and assembled in a cost-effectiveness-matrix to give an overview to the decision-maker. Beyond this a set of linear equations is assembled with the data, which provides a possibility to optimise according to one criterion. In a second step a cost-benefit-ratio of the heathland conservation is assessed. The data for the cost-benefit-analysis come from a tourists survey which was also carried out within the study. As a result of the survey the willingness-to-pay of the visitors is calculated and compared with the cost data. The study is part of an ongoing interdisciplinary research project.

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1 Introduction

In the history of German landscape the human utilisation has lead to a composition of forest and open landscape. As forest in most areas is the natural vegetation, the accruement of the open landscape was caused by former deforestation, e.g. because of agricultural land use. Until today some relics of this open landscape have remained, which are preserved mainly for reasons of nature conservation and of recreation. In the beginning of nature conservation movement in the late 19th century the motivation was mainly intrinsic. During the last decades the nature conservation has more and more been subject to economic research. Especially the contingent valuation and the cost-benefit-analysis have been applied to valuate nature conservation and recreation projects (e.g. Elsasser [1], Garrod [2], Mitchell and Carson [3], Roschewitz [4]). This aimed at an assessment of the value of nature conservation or recreation within the national economy. Only a few economical studies deal with an operational perspective of nature conservation measures (e.g. Blab et al [5], Scholz [6]). Nevertheless this seems to be an interesting and useful research area. Therefore this study firstly analyses the cost-effectiveness of nature conservation measures and develop an optimisation method. Afterwards it will present the evaluation of a survey, in which visitor's benefits were asked by a question about the daily willingness-to-pay for heathland maintenance. Together with the cost data this leads to a first assessment of the cost-benefit-ratio of the conservation of the open landscape.

2 Research area

The nature reserve "Lueneburg heath" is the oldest nature reserve in Germany. With a size of about 23,000 ha, of which 3,100 ha are covered with heathland, it is also of great importance for nature conservation in Northern Germany in general and conservation of open landscape in particular. The area is subdivided as follows: 58% woodland, 13% heath, 13% former military area, 11,5% agriculture, 2% moor and 1,5% settlement and others. The areas, which were used for military purposes are currently reconverted, mainly to heath land. The share of heathland will therefore increase in the near future to about 4,500 hectares. The existing heathland represents the relic of a much larger area of heathland, which was used by a traditional kind of agriculture mainly practiced until the middle of the 19th century. The area was established as the first nature reserve in Germany in 1922 (cf. Cordes [7]).

Table 1: Heathland maintenance measures in the nature reserve "Lueneburg Heath", costs and area treated, data from [8].

Measure	Sheep grazing	Mowing	Controlled burning	Tilling	Removing sods
Costs/process €/hectare]	171 (1 year)	100	450	1,500	3,500

Today about 3 million visitors a year travel to this area, and in addition the area serves as a habitat for many specialized and endangered species. Three main benefits of this nature reserve are therefore nature conservation, recreation and protection of a heritage.
Due to the processes and techniques formerly used the soil had a very low content of nutrients, because the upper layer was often removed and there was pasture with sheep. To preserve the heathland today the same techniques must be used or at least imitated. There are different methods to maintain the heathland,

- mechanical methods: removing of sods, tilling with rotary how and mowing
- others: controlled burning or grazing with a race of robust sheep called "Heidschnucken".

Table 1 gives an overview of the measures, the costs and the area yearly treated. These methods differ relevantly in the effect they provide. The removing of sods and the tilling with rotary how allow a deep regeneration of the heath, because a large part or nearly all biomass is removed from the area, while the other methods reduce less biomass. The mechanical measures and the grazing are carried out regularly but with different frequencies, while successful burning depends on the weather conditions in winter (Cordes [7], Verein Naturschutzpark [8]).

3 Cost-effectiveness-analysis and optimisation

3.1 Cost-effectiveness-analysis

The cost-effectiveness-analysis is used to evaluate projects or measures. Costs are compared to the parameter values of effectiveness achieved with the projects or measures analysed. The first important step of the cost-effectiveness analysis is the determination of the objectives that are to be achieved by the measures. Depending on the complexity of the researched system the objectives, criteria and the units by which the effectiveness is measured are more or less difficult to define.

The effectiveness is not necessarily measured in monetary units, but in the basic units of each measurement. The different criteria of effectiveness can be measured cardinally, ordinally or nominally (Muehlenkamp [9]). If the criteria of effectiveness are measured in different units they cannot be compared directly with each other.

A matrix can be drawn to show the costs of each measure opposed to the different values of effectiveness. It can help to give a decision-support to the decision-maker concerned. It will, however, not be able to express the absolute advantage and can therefore not substitute the decision-making process itself (Hanusch [10], Sugden and Williams [11]. By now the cost-effectiveness analysis has been applied only a few times in the range of nature conservation (e.g. Wilhelm [12]).

The decision about nature conservation measures contains several criteria of effectiveness. Figure 1 gives an overview of these criteria for the example "maintenance of heathland". There are constraints (shaded), which exclude some methods on certain areas. These constraints are fixed and will not be considered in this study.

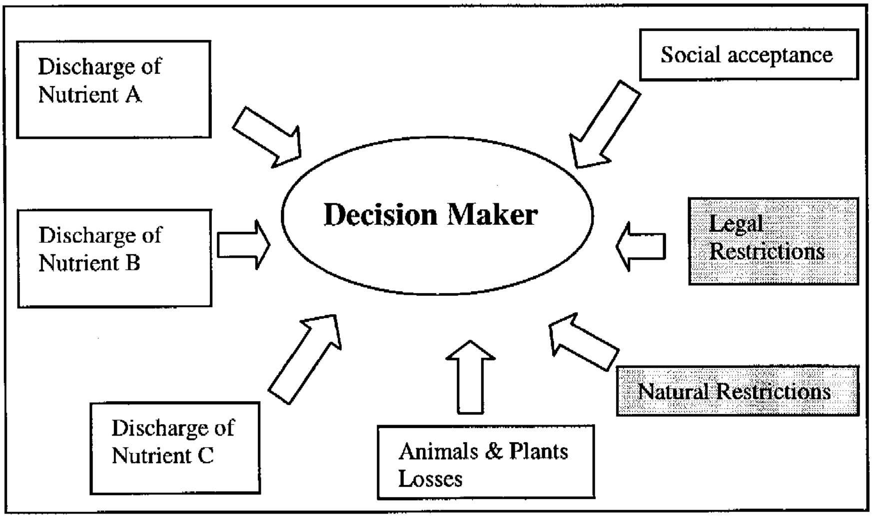

Figure 1: Influencing factors of the decision about heathland maintenance measures.

Beyond this several criteria are embraced in the decision about the method to choose. The main issue for the decision-maker is the physical effectiveness of the measure, it must help the heather plants and reduce its competitors. This represents the nutrients discharge, which gives the heather an advantage in competition in plants´ competition, and the humus discharge. Furthermore there are unwanted physical effects, which should be minimized, e.g. the loss of animals or desirable plants. Finally for sake of recreation the measure must preferably show a high tourist acceptance. In a first step of decision aiding these criteria can be assembled in a cost-effectiveness-matrix. Figure 2 shows a simplified example for a cost-effectiveness-matrix of heathland maintenance measures containing values of nutrients and biomass discharge. Some of the values are still missing, because research is not yet completed.

In the matrix the costs of the measures are assembled with the values of the different effectiveness criteria, in the example five nutrient discharge values and two humus discharge values. The measures are divided in two parts, marked with a thick line. The upper part subsumes three measures, which bring out overground effects and can be characterised as sustentation measures (Controlled burning, Mowing and sheep grazing). The lower part contains the restoration measures, causing a more or less complete removal of the upper soil layer. The

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Measure	Net-Cost/ Hectare [€]	Effectiveness						
		[kg/hectare] nutrient reduction					[kg/hectare] biomass reduction	
		N	P	K	Mg	Ca	Humus	Vegetation
Controlled Burning	450	82.33						
Mowing	100	96.27	5.78	32.91	7.88	32.74	0	8,077
Sheep grazing	171						0	
Tilling	1,500	999.79	42.87	48.42	33.06	117.24	38,940	8,979
Removing sods	3,500	1953.12	93.95	235.4	73.94	244.98	69,942	12,382

Figure 2: Cost-effectiveness-matrix for heathland maintenance measures. Data from NNA [13].

effects of the measures within one group are comparable. The cost-effectiveness-matrix supports the decision-maker with the overview of the relevant values, so that he can deliberate about the weight of the criteria, even fuzzy parameter values like "big, middle, small" can be taken into account.

3.2 Optimisation method

Some of the criteria values are convenient for an optimisation by mathematical programming (cf. Kistner [14]; for a similar case study Tucker et al. [15]). For this programming cardinally scaled values are necessary. Provided that the nutrient discharge values in figure 2 (column 3–7) can be weighed equally (or can be adjusted by correction factors), with these values a set of linear equations can be assembled. As an example for three measures and three nutrients this can be formulated as follows:

$$C_T = X_1C_1 + X_2C_2 + X_3C_3 \quad \text{Min!} \tag{1}$$

$$R_{Na} <= X_1W_{a1} + X_2W_{a2} + X_3W_{a3} \tag{2}$$

$$R_{Nb} <= X_1W_{b1} + X_2W_{b2} + X_3W_{b3} \tag{3}$$

$$R_{Nc} <= X_1W_{c1} + X_2W_{c2} + X_3W_{c3} \tag{4}$$

$$F = X_1 + X_2 + X_3 \tag{5}$$

With:

With:	C_T:	Total costs
	$C_{1\text{-}3}$:	Costs of the measures 1–3 per hectare
	$R_{Na\text{-}c}$:	Goal for reduction of nutrients a-c (e.g. [kg/hectare])
	$X_{1\text{-}3}$:	Required quantity of the measures 1–3 (here: [hectare])
	W_{nm}:	Effectiveness of the measures to reduce the nutrients
	F:	Total area processed

Eqn (1) is a Total Cost Function and in this case represents the objective function of the linear programming. Solving the system will minimize the total costs. Inequalities (2)-(4) provide the limits to the cost-minimisation of the objective function. The nutrient discharges, which are achieved with the required quantities of the measures (right side), must be equal or exceed a given aim of nutrient discharge (left side). In this case the decision-maker must define a minimum discharge for each nutrient, e.g. according to its deposition or accumulation. Eqn (5) makes sure that the whole area will be treated.

This set of equations can be solved by the Simplex Method to find out the cost-minimal combination of methods provided that a given aim of nutrient discharge is achieved. Another case of optimisation can be constructed including an objective function, which is to maximise the nutrient discharge under the constraint of adhering to a given budget. As further development a more complex set can be formulated with the possible frequency of the measures, minimum or maximum areas for certain measures or an index of social acceptance of the measures.

4 Cost-benefit-analysis

4.1 Method

Different to the just discussed CEA the cost-benefit-analysis (CBA) takes a look at the valuated societal benefit of the subject matter (Muehlenkamp [9], Hanusch [10]). As in Europe normally no market exists for the benefit, which is provided by a nature reserve, it cannot be valuated by market prices. Based on the neoclassical approach of environmental economics there are several methods to

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valuate this benefit, e.g. hedonic price method, contingent valuation method, travel cost method etc. One of the most applied methods is the contingent valuation method (CVM). The keynote of this approach is to reveal the personal valuation of the relevant societal groups for an unpriced good by using contingent markets. The personal valuation is asked for in surveys, in which the respondent is to express his willingness-to-pay (for the good) or willingness-to-accept (for the loss of the good) (cf. Garrod [2], Mitchell and Carson[3]). For this study a survey of the visitors was carried through in the "Lueneburg Heath". During one year 820 face-to-face questionnaire-based interviews were lead within the heathland area in the nature reserve. The questionnaire contained 20 technical questions about the respondents´ opinion concerning heathland maintenance and six statistical questions. The survey took place at seven fixed points within the nature reserve. Within the technical block the respondent was asked for his willingness-to-pay for heathland maintenance (question 18):

"Please imagine it would be necessary to raise a contribution of the heathland visitors to cover the expenses emerging altogether from the landscape maintenance. How much would you personally pay at maximum per leave day?"

Additionally a card was shown to the respondents with possible amounts from 0 to 10 € to ease their choice. The following question gave the respondents the chance to reconsider their choice and express a new amount. As a preparation for this valuation a short explanation of the measures was given to the respondent before these questions. This appeared to be necessary, because during the pre-tests a great number of respondents could not imagine anything of the circumstances of heathland maintenance and thus did not understand the questions.

4.2 Results of the survey

Table 2 shows the results of the survey. 803 of 820 respondents (97.9%) answered the question, 734 expressed a willingness-to-pay greater than 0. The average mean amounts to 1.80 €/day for raw data without weighting.

Table 2: Statistical values of raw data daily willingness-to-pay, in [€].

Average mean	1.80
Standard deviation	1.31495
Median	1.50
Minimum	0
Maximum	10

For several reasons in the sample the different visitor groups are not represented equally. That is why a weighting of the raw sample data can improve the validity of the results. One main weighting reason is that people visit this location with different visit time (visit time is time of all visits during the research period). Thus visitors with high visit time are over represented in the sample, because they have a higher probability to be surveyed. A question for the frequency of visits was also part of the survey and with this information a probability of the visitors to be surveyed could be calculated:

$$P_g = \frac{\text{Number of visit days within research period}}{\text{Days of research period}}$$

The weighting factor different visitor groups according to their visit time follows as:

$$w_g = 1/P_g$$

So e.g. a daily guest coming to the Lueneburg Heath for one day a year gets a weighting factor of 365.

Table 3 shows the results after this weighting process, which do not differ relevantly from the not weighted results, but provide more valid data. Therefore these results will be used for the further calculations.

Table 3: Statistical values of weighted data daily willingness-to-pay, in [€].

Average mean	2.02
Standard deviation	1.35986
Median	2.00
Minimum	0
Maximum	10

4.3 Comparison of costs and benefits

All values of these expansions describe a worst-case scenario: The costs are assessed on a very high level, while the benefit is assessed very cautiously. For the highest areas ever treated with the maintenance measures yearly costs of 433,000[€] result. For the comparison the visitors' total yearly benefit must be assessed. This consists of the benefit of the three subgroups overnight staying guests, daily guests and inhabitants. The inhabitants are disregarded, because their number in the survey seemed to be insufficient. Table 4 shows the expansion of the total yearly willingness-to-pay for the two resting subgroups and in summa. For the purpose of a cautious assessment the overnight stays only of a 10km-zone around a central point of the heathland were embraced. The number of overnight stays (for 2001) could then be acquired from the statistics office of Lower Saxony (Niedersaechsisches Landesamt fuer Statistik [15]). The number of daily guests was assessed by the ratio of overnight staying and daily guests in the survey. This ratio was assigned to the real number of overnight staying guests in 2001 and so the number of daily guests could be calculated. As result the total yearly benefit for the visitors amounts to at least 1,078,191[€].

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Table 4: Yearly expansion of the willingness-to-pay, weighted data, in [€].

Subgroup	Number	Daily willingness-to-pay	Total willingness-to-pay
Overnight stays	376,531	2.065	777,536
Daily guests	157,000	1.915	300,655
Summa	533,531		1,078,191

The resulting valued benefit exceeds the heathland maintenance costs more than twice (149%).

5 Discussion

5.1 Cost-effectiveness analysis and optimisation

The cost-effectiveness-matrix is a useful support for the decision-maker in the range of nature conservation measures. However, outside of research projects there will often be a lack of data. For example the nutrient discharge is difficult to determine and frequently will be unavailable. In some cases the results achieved in this study can be assigned to other areas. But even if completed with fuzzy data the cost-effectiveness-matrix can be a useful tool to get an overview of possibilities and limits.

The optimisation also provides important information for the decision-maker. It shows the best combination according to the two parameters costs and nutrient discharges by now. Thus it forms a base for the decision. In a further development of the optimisation other parameters can be embraced like unwanted effects, an index of social acceptance, etc.

5.2 Cost-benefit-analysis

The cost-benefit-analysis consists of the most important parts by now. Yet it can be completed by some smaller parts, which are currently in process, e.g. the results of a farmers´ survey and a survey of persons trading with goods, which are characteristic for the heathland area. The current results show, that the valuated appreciation of the visitors by far exceeds the costs for the heathland maintenance. One doubt about the method used to valuate the visitors´ benefit is, that the respondent could have misunderstood the question in a way, that some of them would pay their contribution for all amenities in the region, not only for the heathland maintenance. This effect should, however, be off-state by the cautious assessment. Other criticisms of the CVM shall not be discussed here.

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