OPTIMAL LOCATION OF NEW FORESTS IN A SUBURBAN REGION

Ellen Moons, Bert Saveyn, Stef Proost, Martin Hermy

May 2005

Abstract

This paper looks at the optimal location of new forests in a suburban region under area constraints. The GIS-based methodology takes into account use benefits such as timber, hunting, carbon sequestration and recreation, non-use benefits (both bequest and existence values), opportunity costs of converting agricultural land, as well as planting and management costs of the new forest. The recreation benefits of new forest sites are estimated using function transfer techniques. We show that the net social benefit of the total afforestation project may vary up to a factor 6, depending on the forest sites that are selected. We show that the recreation value of a forest site varies considerably with the available substitutes.

Keywords

Benefit transfer, travel cost analysis, cost-benefit analysis, forest recreation, Geographical Information Systems (GIS)

JEL-classification

Q23, Q24, Q26, R14

1. Introduction

The United Kingdom, Ireland, Flanders (Belgium) and the Netherlands all have a low forest cover[1] (+/- 10% of the total area). In general, suburban regions are short of woodland from both an environmental and a recreational point of view. Recently, afforestation projects have taken place on agricultural land. In this paper we develop and apply a methodology for the optimal location of new forest sites in suburban areas. We rely on GIS for data collection and input. We select forest sites that maximize net social benefits given a constraint on the total area of new forests. Net social benefits include recreation values, other use values (e.g. timber, hunting, carbon sequestration), and non-use values (existence and bequest values), reduced by planting and management costs as well as opportunity costs of the lost agricultural area.

Recently, carbon sequestration and recreation have received more attention. STAVINS (1999) points out that carbon sequestration is an important issue in climate change negotiations. However, it is unlikely to be a decisive element for afforestation in suburban regions (GARCIA QUIJANO *et al.,* 2005). This paper shows that in urbanized areas, the recreation value is likely to be dominant. BENSON and WILLIS (1993) already state that recreation should be taken into account in forestry and conservation planning due to potential conflicts with other interests such as agriculture or wildlife conservation. The recreational value of a forest raises two issues. The first issue is whether benefit measures of other sites can be used to assess the recreation value of new or 'no-data' sites (ROSENBERGER and LOOMIS, 2000). Benefit transfer is usually considered to be a second-best strategy due to the high variation of spatial and temporal characteristics of forest recreation sites. However,

[1] Forest cover is defined as the ratio of forest land (both public and private) to total land area.

the benefit transfer is likely to give better results, compared to techniques that do not take into account recreation values at all. MOONS *et al.* (2000) estimate the recreation benefits of Heverleebos-Meerdaalwoud in Flanders using the travel cost method. This forest serves as base site in this paper, and we transfer the estimated recreation demand function to the multiple new forest sites in our new study area. The second issue is how the recreation benefit of a new forest is affected by the substitute sites in the selection. We show that the recreation value of a forest site may vary considerably with the available substitutes, given the area constraint.

The methodology for the estimation of the recreation demand function using GIS has been developed by LOVETT *et al*. (1997). Their analysis has shown that using GIS in benefit transfer increases efficiency and consistency. BATEMAN *et al*. (1998), BATEMAN *et al*. (1999) and BRAINARD *et al*. (1999) extend the analysis of LOVETT *et al.* (1997) by including socio-demographic variables, substitutes and site-characteristics in the recreation demand function. However, their analysis is limited to a single new forest. BATEMAN *et al.* (2005) provide recreation value maps as well as a spatial cost-benefit analysis but only include a travel cost variable in their calculation of recreation values. This paper extends the literature in four ways. First, we use GIS for a large number of feasible sites rather than un-detailed grid-shaped sites. Second, we transfer the recreation demand function to a large number of forest sites. We include the recreation value in the cost-benefit analysis along with other benefits and costs. Third, we emphasize the role of substitutes when several sites are valued and located simultaneously. Finally, we rank a large number of afforestation policies on different locations and select those with the highest net social benefit.

In section 2 we outline the methodology, in section 3 we present the base study and the main data sources. The estimation of the recreation values is the object of section

4. Section 5 presents the results. Section 6 contains conclusions and suggestions for future research.

2. Methodology

We develop a model to select the forest sites such that we maximize the net social benefits (NSB) subject to a maximal area constraint. The main challenge is to take into account substitution and complementarity effects, due to the geographical interdependence of the different forest sites. On the one hand, two forest sites located closely are substitutes, since visitors can choose between the two forests. None of the forests contribute to the recreation value of the other forests. On the other hand, the closer two forests are located, the higher the ecological values will be thanks to effects-of-scale. This geographical interdependence causes strong non-linearity and a complex optimization problem. Hence, the empirical application uses a discrete and heuristic optimization procedure. Moreover, we assume that all sites are afforested simultaneously and that there is no uncertainty.

2.1. Formulation

Set I includes all potential forest sites i ($i \in I$) that can be afforested to an extent x_i ($0 \leq x_i \leq 1$). We assume that all sites are afforested at the same point in time ($t=0$) but costs and benefits occur at different points in time ($t=0,1,\dots,T$), where T is sufficiently large to avoid end-of-horizon effects. S_i denotes the (surface) area of site i. S^{MAX} is the total afforestation area constraint for the region.

The discount factor is defined as follows: $d_t=(1+r)^{-t}$ (1)

where r is the discount rate.

2.1.1. Social cost

Social cost of afforestation of one site (*i*)

The different types of costs k ($k \in K$) include planting, management and the opportunity cost of converting agricultural land. c_{it}^{k} is the yearly cost per hectare of type k in period t (year) for site i. In the empirical analysis, we assume that all marginal costs are constant and that all costs are additive. Constant marginal costs for planting and management are currently used by the local forest institute (DVB[2], 2000). Data on (foregone) agricultural output show there are no scale effects (CVL[3], 2000). Moreover, the conversion of agricultural land to afforestation is marginally small compared to the total area of agricultural production or the total woodland area. Hence, this afforestation project will not affect the prices of agricultural products or timber. The total social cost of afforesting site i (C_{it}) in period t can be calculated as follows:

$$C_{it} = \sum_{k \in K} c_{it}^{k} x_i S_i \qquad for\ \forall i \in I; k \in K \tag{2}$$

Social cost of afforestation of multiple forests

We assume that, as far as costs are concerned, sites are geographically independent. This means that the cost of the afforestation of site i is independent of what happens to other sites. The total social cost of all potential forest sites in period t is

$$C_{It} = \sum_{i \in I} \sum_{k \in K} c_{it}^{k} x_i S_i \qquad for\ \forall i \in I; k \in K \tag{3}$$

or

$$C_{It} = \sum_{i \in I} C_{it} \tag{4}$$

2 Dienstenscentrum voor Bosbouw

3 Centrum voor Landbouweconomie

2.1.2. Social benefit

Social benefit of afforestation of one site (*i*)

The different types of benefits of afforestation l ($l \in L$) include direct and indirect use values such as timber, hunting, carbon sequestration and recreation values, and non-use values (both existence and bequest values). We assume that these benefit types have constant marginal values and that they are additive. As far as timber and carbon sequestration are concerned, the DVB (2000) and GARCIA-QUIJANO *et al.* (2005) show that there are no effects of scale. We assume hunting and non-use values are constant per ha and year. The different values are additive since each type of benefit is considered independent of other benefit types. b_{it}^{l} is the benefit per hectare of type l in period t to afforest site i. B_{it} is the total social benefit of afforesting site i in period t and is calculated as follows:

$$B_{it} = \sum_{l \in L} b_{it}{}^{l} x_i S_i \qquad for \,\forall\, i \in I; l \in L \tag{5}$$

Social benefit of afforestation of multiple forests

We distinguish geographically independent benefits $l \in A$ ($A \subset L$) and geographically dependent benefits ($l \in L \backslash A$). For independent benefits ($l \in A$), we assume that the benefit of afforestation of site i is independent from the other sites (e.g. timber sales, hunting and carbon sequestration). Therefore, for geographically independent benefits, the overall benefit in period t of afforestation of multiple forests equals the sum of the individual benefits of the sites:

$$B_{It}^{A} = \sum_{i \in I} \sum_{l \in A} b_{it}^{l} x_i S_i \qquad for \,\forall\, i \in I; l \in A \tag{6}$$

For recreation benefits, however, there is geographical interaction between sites due to substitution effects ($l \in L \backslash A$). The recreation value of site *i* decreases if other afforested sites can be found in its neighbourhood. Forest visitors consider all forests in their surroundings as substitutes.

Each time forest visitors intend to visit a forest, they choose only one site. When their choice set expands, the probability that they visit one particular forest decreases. The lower the number of visits to one particular forest, the lower the recreational value of that forest. For recreation, we find:

$$B_{It}^{rec} \leq \sum_{i \in I} B_{it}^{rec} \tag{7}$$

For most ecological values, such as biodiversity, the opposite is true: the proximity of other forests has a positive influence on the ecological value of one particular forest due to scale effects. Forests within the same geographical region are considered to be complements and parts of an ecological network:

$$B_{It}^{bio} \geq \sum_{i \in I} B_{it}^{bio} \tag{8}$$

2.2. Maximization problem

We want to afforest the forest sites *i* such that we maximize the net social benefits given an area constraint (a). The proportion of afforestation of a site (x_i) is in the model a continuous choice variable (b). This problem can be formulated as follows:

$$\underset{x_i}{Max} \frac{\sum_{t=0}^{T} d_t \sum_{i \in I} \left[\left(\sum_{l \in A} b_{it}^l + \sum_{l \in L \backslash A} b_{it}^l - \sum_{k \in K} c_{it}^k \right) S_i x_i \right]}{\sum_{i \in I} S_i x_i} \tag{9}$$

$$s.t. \quad (a) \quad \sum_i S_i * x_i \leq S^{MAX}$$

$$(b) \quad 0 \leq x_i \leq 1$$

The substitution and complementarity effects between sites make this a complex optimization problem. Hence, we use a discrete and heuristic optimization procedure in the empirical analysis. Here, the new forest sites i are either fully afforested ($x_i=1$) or not afforested at all ($x_i=0$). Z_j is a subset with fully forested sites I, respecting the area constraint. Z is the set of all possible subsets, Z_j, that respect the area constraint ($Z_j \subset Z$).

We distinguish five subsequent steps to be taken:

(1) Selection of subsets of new forest sites that meet the area constraint;

(2) Calculation of all costs and benefits of the additive type for each site;

(3) Calculation of recreation benefits for each forest site in each subset selected in (1);

(4) Calculation of net social benefit per hectare for each forest site in each subset and for the subset as a whole (i.e. the sum of (2) and (3) divided by the total area); and

(5) Ranking of subsets selected in (1) based on the net social benefit per hectare.

3. Data

We mostly use GIS-based data. This is the case for the selection of the 32 new forest sites, for the distances between these sites, for the agricultural input and manure deposition, and the socio-economic characteristics. All this leads to very precise outcomes of the calculations in a time-efficient way.

3.1. Description of the study area and selection of new forest sites

The study area is the region of Gent, the capital of the province of East Flanders. East Flanders has a forest cover of 5.6% which is the second lowest forest cover of all five

Flemish provinces in Belgium. Agriculture currently takes up 51.2% of the total area. The province counts approximately 1.33 million inhabitants with high population concentrations in cities like Gent. Overall, the province has a suburban character. All existing accessible forests are situated in open space around major population centres.

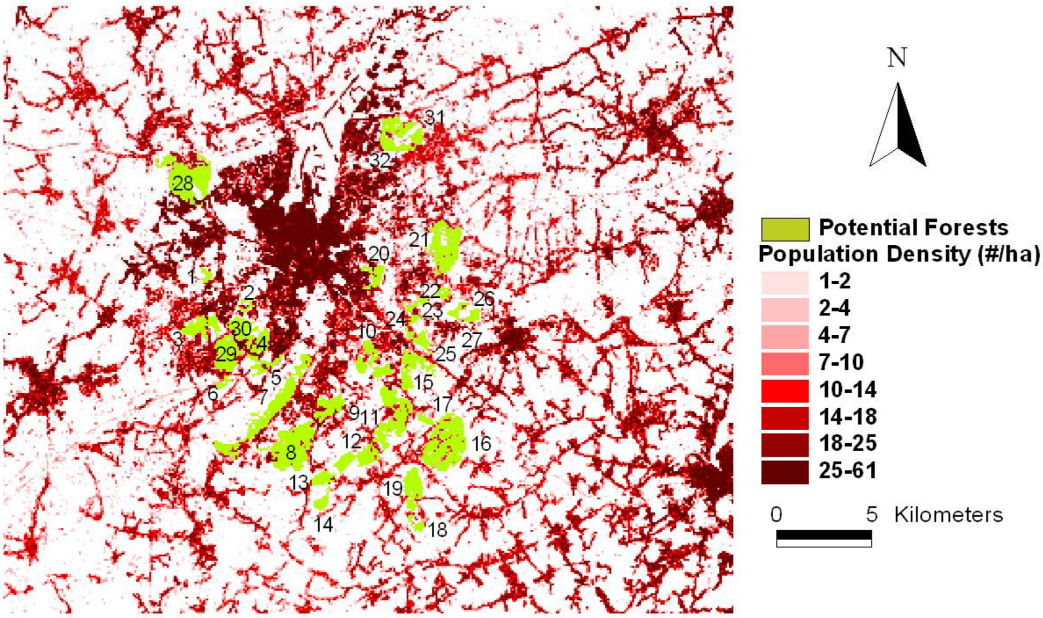

Figure 1: Map of the Gent region and its potential forest sites

In line with policy objectives, 550 ha of new forests are allocated to this region. Thirty-two new forest sites were selected (see Figure 1) by excluding the road network, valuable ecotopes, legally protected areas[4], built-on areas, existing forests, infrastructure, industry and residential areas, the sites most suitable for agricultural production, and the sites that are the furthest away from existing forests. Out of these

[4] Habitats Directive 92/43/EEC and Birds Directive 79/409/EEC.

32 sites, 569242 subsets of at least 2 and at most 16 forest sites meet the 550 ha area constraint[5].

On average, a forest site is 103 ha, the smallest site being 20 ha and the largest site being 350 ha. The shortest distance between the gravity points of two sites is 1.03 km. An overview of characteristics of the 32 sites can be found in Appendix A.

3.2. Overview of costs and benefits

Table 1 represents the annualized values of the costs and benefits included in the analysis. They are calculated for each forest site and for each possible subset of forest sites that meets the area constraint.

Table 1: Costs and benefits of afforestation with their annual value per hectare (annuities[6] – in € per ha)

COSTS (€ per ha and year)		BENEFITS (€ per ha and year)	
Planting and management	39	Timber sales	29
Opportunity costs		Hunting permits	15
(1) loss of agricultural production	-2522*	Carbon sequestration	25
(2) loss of manure deposition	355*	Non-use	3680
(3) loss of recreational and non-use values in agricultural environment	229	Recreation	32218*

* Average value over the 32 potential forest sites

PEARCE (1994) lists the costs of planting, forest management and the opportunity costs of foregone agricultural output as the main costs of afforestation. As benefits he includes direct and indirect use values such as timber, recreation, landscape, biodiversity, watershed protection, microclimate, clean air, carbon sequestration,

[5] In practice we used an interval (-3ha/+3ha). The distribution of subsets can be found in Appendix C.

[6] Discount rate 2.5%. All values in the paper are expressed in € (2000).

economic security, community integrity values and non-use benefits. Non-use benefits include both bequest and existence values (MITCHELL and CARSON, 1989). We are aware that our list of costs and benefits is incomplete. Several ecological function values such as biodiversity, watershed protection, microclimate, air pollution and water pollution have not been taken into account due to lack of data. Carbon sequestration is the only ecological benefit included in the analysis. Hence, the value of total benefits is rather conservative.

All new forest sites are multifunctional mixed oak-ash forests where wood production, characterized by long rotations (200 years), is combined with high ecological and recreational values. The forest is managed with a thinning frequency of 10 years and regenerated with a group selection system.

3.2.1. Costs

Annualised planting and management costs per hectare accrue to 39 € for a mixed oak-ash forest and are very modest compared to opportunity costs (DVB, 2000). As all new forests will be planted on current agricultural land, the loss of agricultural production, manure deposition and recreation and non-use values of agriculture must be taken into account.

The agricultural sector in East Flanders yields a broad mix of agricultural products (various crops alongside cattle for dairy and meat production). Due to high subsidization of the sector by the EU, the calculation of the correct opportunity cost is quite complicated. Agricultural yields of the past five years (1995-1999) are multiplied by world prices to get the approximate opportunity cost (NIS, 2000a; FAO, 2006a; FAO, 2006b). In this way, crop rotation is implicitly taken into account. For grassland we assume that one hectare of land is grazed by two heads of cattle. Each head produces 6000 l of milk and 200 kg meat per year.

Costs per hectare of cultivated land include implicit wages for the farmer, wages paid to third parties, machinery depreciation, maintenance, purchased and self-produced feed, seeds, pesticides, fertilizers, capital costs, etc. These costs differ with respect to soil and crop type (CVL, 2000). The cost of the agricultural production loss is actually negative. This means that once agricultural subsidies are eliminated, the value of agricultural output is smaller than the cost of inputs (labour, capital, etc.). A second opportunity cost is the cost of the manure surplus. In Flanders there is an excessive production of manure from pig farms. Environmental laws only allow limited deposition of manure on agricultural land. Manuring norms have become more stringent over the last decades. Norms for nitrogen and phosphate differ per parcel of land in function of soil type, crop type, as well as laws for surface and ground water protection. When agricultural land is afforested, more manure will have to be processed at a cost instead of being spread on agricultural land. In Flanders, processing manure costs approximately 13 € per tonne. On average 27 tonnes can be spread on one hectare of agricultural land.

Finally, recreation values and non-use values of the agricultural land will be lost[7]. For data on these types of values, very few sources are available. DRAKE (1992) finds a value of 230 € per hectare and year for Sweden. This value is transferred to the study area.

[7] Lost recreation and non-use values of agricultural land will be completely offset and exceeded by recreation and non-use values of the new forests.

3.2.2. Benefits

On the benefit side we see that non-marketable benefits like non-use values are far more important than the benefits that are directly perceptible and create direct income for the forest owner (e.g. timber and hunting permits).

Timber values include the revenues of wood from thinning and final harvesting for a multifunctional mixed oak-ash forest with a 200 year rotation. Timber yield amounts to a yearly equivalent of 29 € per hectare. Revenue from hunting permits is more stable than revenue from timber sales and less dependent on external factors (DVB, 2000). We assume that only small game hunting will take place at the new forest sites. Average annual hunting values per hectare accrue to 15 € for Flanders for forests with small game hunting only (MOONS *et al*., 2000).

Carbon sequestration includes sequestration in above- and below-ground biomass, detritus and soil as well as sequestration in harvested wood. GARCIA QUIJANO *et al.* (2005) found long term figures of 2 to 2.75 tonnes C per hectare and year plus a more uncertain below-ground storage of 0.2 tonne C per hectare and year on average. We assume 2.5 tonnes C per hectare and year storage valued at 10 € per tonne C (CIEMAT, 1999).

Non-use values include a bequest value and an existence value. The bequest value is the benefit accruing to any individual from the knowledge that others might benefit from the forest in the future, whereas the existence value is the benefit accruing to any individual from the mere existence of that forest area (MITCHELL and CARSON, 1989). Monetary valuation of non-use values is based on the Contingent Valuation Method (CVM). Data for Flanders are available from the "Heverleebos-Meerdaalwoud" study (MOONS *et al*., 2000). A CVM-survey was conducted and approximately 800 families in Flanders were asked about their willingness to pay for transformation of a Military Domain adjacent to Heverleebos-Meerdaalwoud (HB-MW) into a closed access forest reserve. Respondents were asked if they would be willing to pay a single, non-recurring amount using the double bounded dichotomous choice method (CARSON *et al.*, 1986). The median once-only willingness-to-pay of households that had never visited HB-MW for the proposed project was 76 € in 1999. Extrapolation gives an annuity of 3680 € per hectare. This is a conservative estimate for non-use values as the conversion of a partly wooded Military Domain is less radical than the conversion of agricultural land into forest land.

4. The recreational value of new forest sites in the presence of a varying set of substitutes

As there are no data available for the new forest sites, we use the benefit transfer technique which 'transfers' the (monetary) value of one site to another (DESVOUSGES *et al.*, 1992). ROSENBERGER and LOOMIS (2000) distinguish two broad approaches to the benefit transfer: value transfers and function transfers. Value transfers include single point benefit estimates or average point benefit estimates. Function transfers imply the transfer/adaptation of either a benefit/demand function or a meta-regression analysis from several sites.

Transferring a pure benefit estimate leads to inaccurate results as the value of a site or a visit depends on the characteristics of both the site itself and its visitors. LOOMIS (1992) shows that more accurate results can be obtained by transferring a *recreation demand function* that is estimated for one or more base site(s). We apply the function transfer method.

GIS generates the distance and travel time data necessary to estimate the travel cost variable in the demand function of the new forest sites. BATEMAN *et al.* (1999) have shown that a zonal travel cost model (TCM) using function transfers benefits considerably from GIS in order to define origin zones and to measure travel time and travel cost.

4.1. Base site analysis: Heverleebos-Meerdaalwoud

The Heverleebos-Meerdaalwoud (HB-MW) is the largest forest in Flanders with 1890 ha. It is the only forest in Flanders for which an economic valuation study has been conducted (MOONS *et al.*, 2000). It is situated in the province of Vlaams-Brabant, 10 km south of Leuven, a university city approximately 25 km east of Brussels, the capital of Belgium.

A zonal TCM specifies a recreation demand function that predicts visit rates for the base site. We estimate the recreation demand function as follows:

$$visit\,rate = f\left[price, socio-demographics, substitutes\right] \quad (10)$$

Where:

- visit rate = (total visits/total visitors) x (total visitors/total population)
- price= cost per visit (monetary + travel time costs)
- socio-demographics= age, education, professional activity, population density
- substitutes= availability and characteristics of other forest sites

Limited variation in site characteristics and socio-demographic characteristics across the forests in Flanders justifies the use of HB-MW as base site and the transfer of its recreation demand function to the new forest sites in the Gent region.

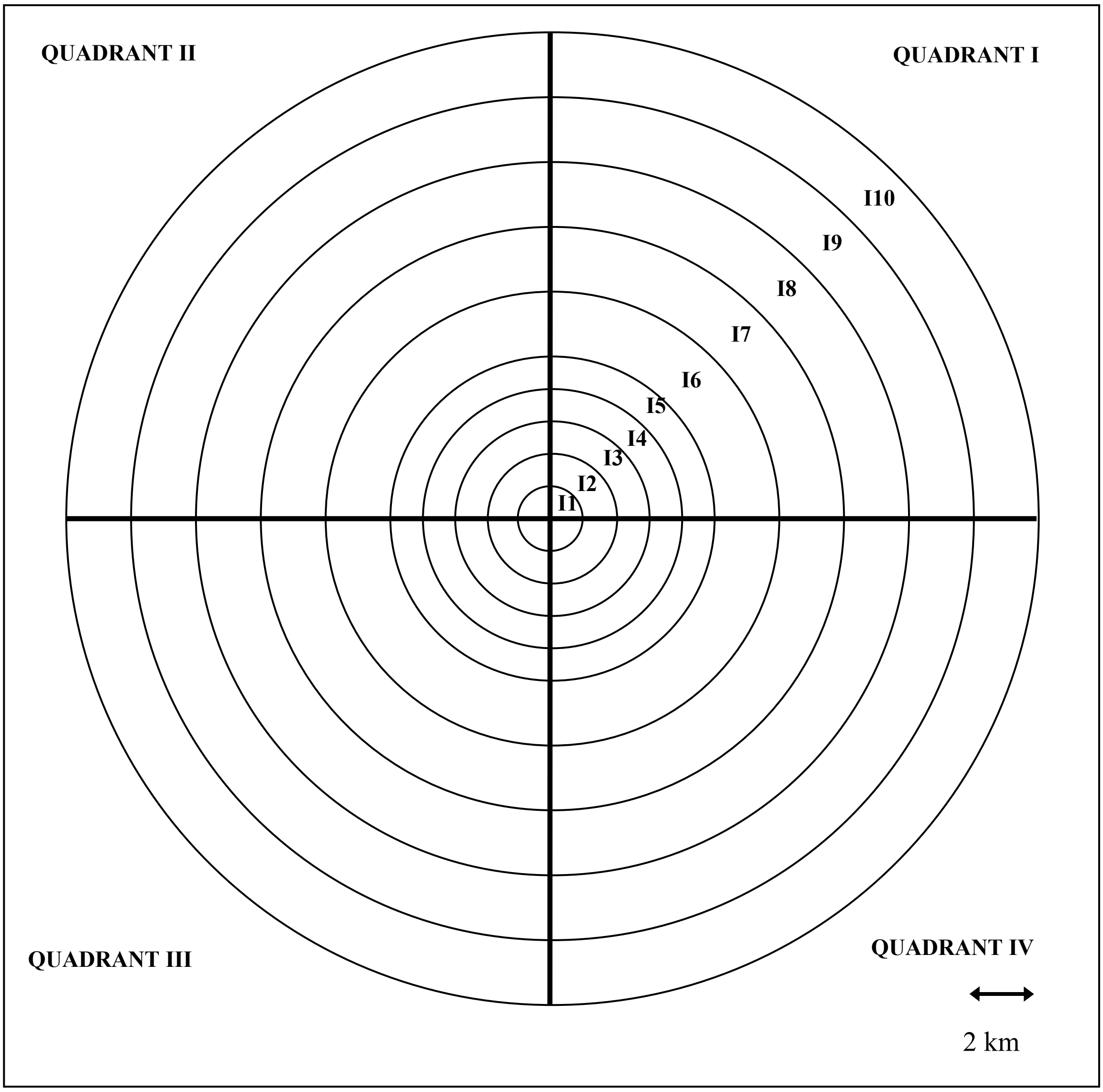

Figure 2: Origin zones for a forest site

4.1.1. Origin zones

We get four quadrants by drawing a vertical line and a horizontal line through the gravity point of HB-MW. Next, we draw ten concentric circles around the gravity point at 15 km maximum. This results in 40 origin zones for which we predict the visit rates. In Figure 2, we find four quadrants (I, II, III and IV) and ten concentric circles (1 to 10). E.g., origin zone *I1* is the zone in the north east quadrant within a distance of 1 km from the gravity point[8].

[8] The first 5 concentric circles are only 1 km one from the other. The following 5 are separated by 2km.

4.1.2. Visit rates

In 1998 and 1999 two surveys, namely, an on-site recreation survey of visitors (1100 persons) and an off-site household survey with person-to-person interviews across Flanders (800 households), were conducted regarding the economic valuation of HB-MW. The off-site household survey provided data on visit frequency for the origin zones that are less prone to truncation and endogenous stratification problems than the data gathered by the on-site survey (MOONS *et al.*, 2000).

4.1.3. Travel costs

Travel costs include both monetary and time costs. Monetary costs are the distance travelled multiplied by a fixed cost per km (e.g. fuel and insurance costs). Time costs are the travel time multiplied by the value of time in transportation[9]. Data on point of departure were drawn from both the on-site and off-site survey and GIS was used to calculate travel distances and times. For each origin zone we calculate the average travel costs taking into account the frequency of the various transport modes (car, bus, bike and on foot) (MOONS *et al.*, 2000).

4.1.4. Socio-demographic factors

Data on population such as age, education and activity are available on community level (NIS, 2000b). Using GIS we construct a data set where these socio-demographic

[9] See GUNN *et al.* (1997) for the value of travel time savings in the Netherlands. The authors use stated and revealed preference data on actual trips and choices between alternative travel time and travel cost settings.

characters are known at the level of 1 ha. The following variables[10] are aggregated for each of the 16 origin zones.

- Age: ≤ 19, 20-34, 35-54 and ≥ 55 years
- Education: primary school, lower secondary school, higher secondary school, higher education (including university)
- Professional activity: student younger than 18 years, student older than 18 years, unemployed, employed and retired
- Population density: number of inhabitants per km²

4.1.5. Substitutes

The number of visits to HB-MW is affected by the number of forests the visitors can choose from each time they plan to visit a forest. Therefore we need to know which substitute sites are available for all visitors living in the different origin zones (*I1, I2, etc.*). In each origin, we construct four concentric zones around its gravity centre at four distances (0-2, 2-5, 5-10 and 10-15 km). For each distance we determine the total area of the substitutes. The result is that we know the total area of substitute forest sites for four distances for each origin zone of HB-MW[11].

We take into account the diminishing importance of substitutes located further away by dividing the total substitute area of each distance by the weighted travel time from the origin zone. A similar, though not identical, approach was proposed by BRAINARD *et al.* (1997). Finally, we obtain a substitution index for each origin zone

[10] The categories of age, education or professional activity level are measured as shares in the total population.

[11] This means that for each of the 40 origin zones around the base site one measures substitutes at four distances. For the base site we take therefore 160 substitution zones into account.

by aggregating the total area of substitutes of the four distances (in ha per minute travel time). Equation (11) represents how the substitution index of an origin zone is calculated for M distances and N different travel modes.

$$\text{Substitution Index} = \sum_{m=1}^{M} \frac{WOOD_m}{\sum_{n=1}^{N} p_{mn} TT_{mn}} \tag{11}$$

Where:

- Substitution Index = expressed in ha per minute travel time
- $WOOD_m$ = area of substitute woodland (ha)
- P_{mn} = proportion of visitors using a particular travel mode
- TT_{mn} = travel time from origin zone to substitutes at distance *m* using a particular travel mode (minute)

4.1.6. The recreation demand function for the base site

With the recreation demand function we can estimate the visit rates and the total yearly visits at the base site. For each origin zone, visit rates are explained by travel cost (both monetary and time costs), population density, substitution index and the proportion of people of 55 years and older[12]. Regression results are based on the 40 observations of the origin zones. For each origin zone, the independent and dependent variables are defined as follows:

- visit rate = total visits/total population
- travel cost = cost of travelling to HB-MW (two-way)
- population density = within the origin zone (inhabitants per km²)

[12] We do not control for site characteristics. We assume all potential new forest sites have approximately the same characteristics as HB-MW – apart from size –.

- substitution index = measure for total area of substitutes (in ha per minute travel time)
- proportion 55^+ = proportion of people older than 55 years per origin zone

Statistical tests[13] indicate that the linear regression model in Table 2 fits the data best.

Table 2: OLS estimation results of the recreation demand model

Variable	Coefficient	Standard Error	t-ratio	Significance level[14]
constant	250.595	59.579	4.206	***
travel costs	-0.085	0.041	-2.056	*
population density	-0.024	0.013	-1.876	*
proportion 55^+	-774.205	262.776	-2.946	***
substitution index	-1.156	0.493	-2.344	**

N=40 *R²adj=0.759* *F=20.639****

Increasing travel costs decrease visit rates. More availability of substitutes leads to lower visit rates to HB-MW. The higher the proportion of people older than 55, the lower are the visit rates. Similarly, LOOMIS and WALSH (1997) find a negative relation between age and the participation in outdoor activities in the United States. The negative sign of population density might not be obvious at first sight. We may expect city dwellers to be more frequent forest visitors than people living in the countryside. However, BATEMAN *et al.* (1998) state that city dwellers have a wider choice of alternative leisure activities (e.g. cinema, shopping, museums and concerts). Hence, the negative sign of population density may be due to other substitute leisure activities than forest visits. This recreation demand regression predicts an average

[13] Comparison between models is based on R²adj. and F-values. The selected model does not include education or professional activity as explaining variables, although they were present in alternative models.

[14] Significance levels: *: significant at 0.10%; **: significant at 0.05%; ***: significant at 0.01%

number of 12.5 visits per inhabitant and year for the base site. The on-site recreation survey gives an actual average of 11 visits per inhabitant and year. Non-parametric tests show that there is no significant difference between the actual and predicted numbers of visits per origin zone. Hence, the estimated recreation demand function is suitable for the benefit transfer technique.

4.1.7. Consumer surplus estimates

Consumer surplus is the difference between the actual (travel) cost of a visit and the willingness to pay for a visit. On average, the yearly consumer surplus for a single visitor from a single origin zone is 40 € per capita. Using the consumer surplus and the predicted visits, the total recreational value of the base site HB-MW amounts to 2720000 € or 1440 € per hectare and year.

4.2. Analysis for new forest sites: benefit transfer of the recreation demand function

We transfer the estimated recreation demand function for HB-MW to each of the 32 new forest sites in the Gent region. The transfer of the demand equation gives us an estimate of the number of yearly visits to the new forest site. Further, we calculate the consumer surplus per visit and total recreational value of each forest site. A site may have a different recreation value due to the varying number of substitutes in the subset it belongs to.

We define origin zones around each forest in the study area (as described in section 4.1.1.). For each origin, we calculate the travel costs to the new forest sites (monetary and time costs) and calculate a substitution index (as described in section 4.1.5.). Further, we aggregate socio-demographic data for each origin zone. There are two differences with the base site. First, one particular forest can have a varying set of substitutes as each forest site may belong to several subsets that meet the area constraint (cfr. 2.2). Second, the base site and new forest sites differ quite substantially in size and this needs to be corrected for. Preferably we could add a ‘size’ variable in the demand equation. But as there are no data available in Belgium on the visitor numbers to forests of different sizes, we use on-site experience from foresters to make an ex-post correction. Small forests (< 20 ha) attract few to no visitors. The marginal change in visitor numbers for forests larger than 300 ha when enlarged with one hectare seems to be negligible. Therefore, we linearly correct predicted zonal visit numbers through size-corrected participation rates, with the participation rates for HB-MW (1890 ha) as an upper limit for all forest sites of at least 300 ha. Moreover, we assume that our forest sites only attract visitors within a radius of 15 km. The larger base site, however, attracts 25% of its visitors beyond 15 km.

5. Results and discussion[15]

In the final step we rank all subsets of new forest sites that meet the area constraint according to their NSB per hectare. This NSB is presented by the following equation:

$$NSB_{z_j}^{\text{lim/full}} = \frac{\sum_{i \in Z_j} Benefits_i - Costs_i}{\sum_{i \in Z_j} S_i} \tag{12}$$

We calculate two types of net social benefits:

- NSB^{lim} : without recreation;

[15] Figure 1 shows the location of each of the 32 forest sites. Appendix B gives an overview of the values of the non-constant costs and benefits for the 32 new forest sites.

- NSB^{full} : with recreation.

The NSB^{lim} of a single forest site is independent of the subset it belongs to. The variation in NSB^{lim} between forests is solely due to variation in opportunity costs of foregone agricultural production and manure deposition, as all other costs (planting and management, loss of recreation and non-use value of converted agricultural land) and benefits (timber, hunting, carbon sequestration and non-use value) are taken constant per hectare for all forests.

The NSB^{full} of a forest site depends on the subset, the new forest site belongs to. This is due to the variation in the set of substitutes determining the recreational value. We first discuss the ranking of subsets for both NSB^{full} and NSB^{lim}. Then, we take a closer look at the recreation value.

5.1. Ranking of subsets based on NSB^{full} and NSB^{lim}

Table 3 presents the subsets for the best and worst NSB^{full} and NSB^{lim}, respectively. The best NSB^{full} amounts to almost 58000 € per ha and year. The worst NSB^{full} is 10000 € per ha and year. The best and worst NSB^{full} differ with almost a factor 6. The subset with the best NSB^{full} consists of seven forests, whereas the subset with the worst NSB^{full} only has five forests. Leaving out recreation values shows quite a different picture. The best and worst NSB^{lim} differ only with a factor 1.5. The best subset has a NSB^{lim} of nearly 7000 € per ha and year, whereas the worst subset has a NSB^{lim} of nearly 4500 €. The best subset consists of three forests, whereas the worst subset has four forests. The best NSB^{full} is 8.6 times higher then the best NSB^{lim}. Figure 3 shows the distribution of NSB^{full} over all subsets. We find a steep decline in NSB^{full} both in the highest and lowest range, whereas the decline in the middle group is more moderate.

Table 3: Best and worst subsets based on NSB^{full} and NSB^{lim} in € per ha and year

	NSB^{full}		NSB^{lim}	
Forest site	**Best subset**	**Worst subset**	**Best subset**	**Worst subset**
3	54914			
6		7956		3796
10			6899	
13	54215			
15	68602			4654
16				5244
19	54415			
20	50487			
26	60128			
27	60803			
28			6666	
29		15823	6481	
30		8324		
31		6176		4003
32		12866		
Average value*	**57652**	**10229**	**6682**	**4424**
Average recreation value**	**51881**	**4762**		
# forests in subset	**7**	**5**	**3**	**4**
Total recreation value (550 ha)	**28.5 million**	**5.6 million**		

** Per ha of new forest (weighted for area)*

*** Per ha, average over the sites belonging to the best/worst subset*

Appendix B gives an overview of the non-constant costs and benefits. We see that the recreation value and NSB^{full} of a single forest site varies considerably, depending on the subset and the substitutes (up to factor 50).

The values in Table 3 and Appendix B correspond to a discount rate of 2.5%. Increasing this discount rate reduces the absolute value of the NSB's. The ranking of the subsets, however, persists as the timing of costs and benefits is identical for all forest sites. Costs and benefits are assumed to have a constant marginal value across the sites and final ranking of subsets is independent on the absolute value of these costs/benefits, although the absolute value of the NSB would be different. The ranking of subsets is however dependent on the marginal values for agriculture and manure deposition as these vary across sites. Moreover, the recreation value of a site depends on its location with respect to major population centers and the location of the substitutes. Changing assumptions regarding the variables in the recreation demand function changes the recreation value of a site and may change the NSB of afforestation, as well as the ranking of subsets.

Recreation values for each of the 32 sites are given in Appendix B. The lowest value per hectare and year is 365 € (site 30), the highest value amounts to almost 70000 € per hectare and year (site 15). The total yearly recreation value for the area constraint (550 ha) depends on the subset and varies from 5.6 to 28.5 million €. Empirical research has found recreational values or net benefits of forestry or afforestation that are generally lower. This can be explained by major demographic and land use differences between the study sites, as well as differences in valuation methods used and the type of recreation value that is valued in a particular study. Most studies concern the recreation value of one or several existing forest sites and do not look for optimality of the location of sites. SCARPA *et al.* (2000) study the creation of nature reserves in (existing) Irish forests using a random utility model of contingent valuation responses: They estimate the yearly change in visitors' welfare (limited to recreation values only) to be about £ 570000[16], with an average value per hectare of £154 per year. BATEMAN *et al.* (2005) perform a spatial cost-benefit analysis taking into account lost agricultural output, timber, carbon, and recreation values and find that highly populated, readily accessible areas are most suitable for the conversion of agricultural land into woodland. They find yearly median net benefits of conversion to

[16] The appropriate exchange rate is £ 1=€1.634 (2000).

broadleaf woodland[17] of £ 125-150 (per ha and year in £1990) for sheep farming and £ -175- -200 (per ha and year in £1990) for milk farming. The highest achievable values amount to approximately £ 350 (sheep farming) and £ 150 (milk farming) per hectare and year. ZANDERSEN *et al*. (2005) find forest recreation values for Denmark using value function transfers range from € 121 to € 24547 per hectare and year. BOSTEDT and MATTSSON (2006) find a recreation value of approximately SEK 500 billion[18] per year for forests in Västerbotten in Sweden where the management meets recreational demands as much as possible.

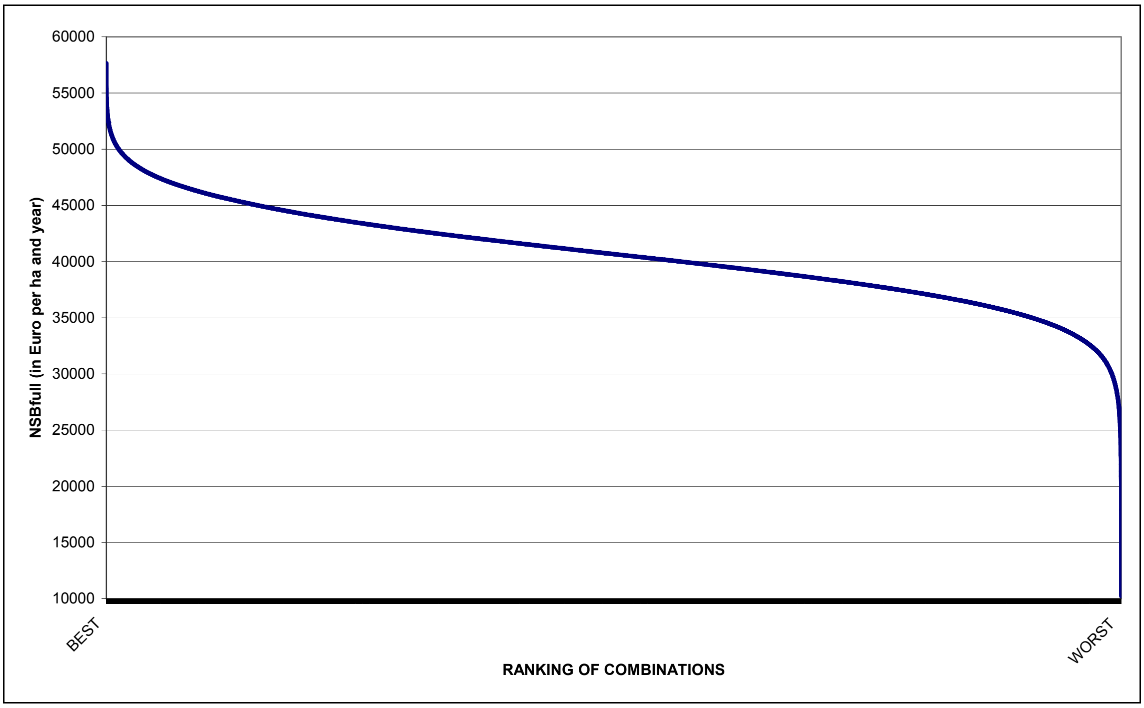

Figure 3: Distribution of NSB^{full} over all subsets

[17] 3% discount rate.

[18] Approximately € 59.5 billion euro.

5.2. Testing the results

First, we test[19] whether the forest composition of the 100 best/worst subsets differs significantly from the forest composition of all 569242 subsets. In other words, we compare the frequency of the forest sites appearing in the 100 highest/lowest ranked subsets with the frequency of appearance in all subsets. We do this both for NSB^{full} and NSB^{lim}. Table 4 shows that the composition is indeed significantly different, both for NSB^{full} and NSB^{lim}, as well as for both the best and worst subsets. This implies that some forests can be found more frequently in the 100 best/worst subsets compared to the total sample of subsets. This result suggests that the best/worst subsets are not randomly chosen from the total sample, but that our methodology is suited to select afforestation policies which are significantly better (or worse) than a random afforestion policy.

Table 4: Non-parametric test for the composition of subsets and the NSB values

	Subsets
100 highest ranked NSB^{full} – All subsets	Z= -1.926*
100 lowest ranked NSB^{full} – All subsets	Z= -2.543**
100 highest ranked NSB^{lim} – All subsets	Z= -2.468**
100 lowest ranked NSB^{lim} – All subsets	Z= -1.702*

** significant at 0.1, ** significant at 0.05, *** significant at 0.01*

Second, we decompose the NSB into its costs and benefits. We perform a T-test on the non-constant costs and benefits per ha and year (Table 5). Here, we test whether the values of the highest/lowest ranked subset differ significantly from the average values for the total sample of subsets. We find that the values of foregone agricultural production of both the best and worst NSB^{lim} is significantly different from the

19 We use the Wilcoxon Signed Ranks Test. This is a Two-Related-Samples Tests procedure that compares the distributions of two variables. It is designed to detect differences between populations, regardless of whether the populations are normally distributed or not. More information can be found in BERENSON *et al*., 2002.

average of the full sample of subsets. The foregone manure deposition is not significant. This obvious result means that the value of the lost agricultural output turns out to be the decisive factor in the ranking of NSB^{lim}.

Similarly, for NSB^{full} we find that both for the best and worst subset the substitution indexes are significantly different from the total sample. The index is lower for the best subset, whereas it is higher for the worst subset. This result emphasises the importance of the substitutes in our methodology. The population density and the share of older people do not significantly differ as most forest sites have partly overlapping origin zones. However, these variables are significant for estimating the visitor numbers from a single origin zone.

Table 5: Comparison of the costs and benefits[20] of the best and worst subsets to the average for the set of 32 sites

	NSB^{full} Best Subset	NSB^{full} Worst Subset	NSB^{lim} Best Subset	NSB^{lim} Worst Subset	Average
Lost agricultural production (€ per ha and year)	-2671	-2343	-3595**	-1232**	-2522
Lost manure deposition (€ per ha and year)	382	358	394	289	355
Recreation Value	51881***	4762***			32218
Population density (inhabitants/km^2)	1289	1545	-	-	1348
Proportion 55+	0.25	0.25	-	-	0.25
Substitution index (ha/minute)	16***	162**	-	-	81.11

** significant at 0.1, ** significant at 0.05, *** significant at 0.01*

[20] Data for each site separately can be found in Appendices A and B.

6. Conclusions

We show how a GIS-based cost-benefit analysis can be used as a decision support mechanism for afforestation projects. In our analysis the policy maker has a choice among a large number of subsets of new forest sites that respect the area constraint. The results suggest that our methodology is suited to select afforestation policies which are significantly better (or worse) than a random afforestion policy.

First, we find that the choice of a particular subset matters for a given area constraint. For NSB^{lim}, the benefit for the best subset is 1.5 higher than for the worst subset. For NSB^{full} there is a difference of factor 6 between the best and the worst subset. Second, the recreational value has an important effect on the net social benefit of afforestation projects. The best NSB^{full} is more than 8 times higher then the best NSB^{lim}. The worst NSB^{full} is still 2.5 times higher then the worst NSB^{lim}. Third, we show that the availability of substitutes has a significant effect on the recreation value of a forest. Hence, the substitutes also play a role in the ranking of subsets.

These results have important implications for the afforestation policy of suburban regions. The location choice is important with respect to substitutes and population centres. Afforestation at different locations leads to high variations in the net social benefits per hectare. The same € spent on afforestation can create different net benefits.

Nevertheless, the current methodology has some limitations. First, we made a once and for all analysis where all projects were decided and started at the same point of time. So the optimal timing problem still needs to be solved and this may become a very complex issue once one allows visitors to relocate endogenously. A second issue is the degree of decentralisation of the afforestation policy. Do we need public forests or can private forests do the job at lower costs? And what is the appropriate level of decision making: municipal, regional or central government? Third, the site characteristics have been neglected in the travel cost analysis. As there is only one base site study in Flanders, we are unable to test for variation in site characteristics. The major problem here is the size difference between the base site and the new forest sites. For other characteristics (such as type of deciduous trees, management, etc.) variation within the Flemish region is limited. Finally, our results may benefit from the translation of ecological benefits into monetary terms.

Acknowledgements

This research was financed by the Nature Development Research Program of Flanders (VLINA), the Fund for Scientific Research Flanders (FWO) and the Center of Expertise for Environmental Policy Sciences (CEEPS). We thank Hans Scheirlinck and the Flemish Forest Organisation (VBV) for their fruitful cooperation. We are grateful for the data and information provided by the foresters of Leuven, the 'Boerenbond' (farmers' union) of East Flanders, the Nature and Forest departments of the Ministry of the Flemish Community and, the National Institute for Statistics. We benefited from comments of participants of seminars at Paris I, the EAERE 2003 meeting in Bilbao and the ERSA 2005 conference in Amsterdam.

Appendix A: Overview of characteristics of each of the 32 forest sites in the Gent region

Site number	Area (ha)	# subsets (max= 569242)	Population density (within 15 km)	Proportion 55+	Distance to closest substitute (in km)	Closest substitute (site number)	Maximum area of substitutes for each of the substitutes zones (ha)			
							0-2 km	2-5 km	5-10 km	10-15 km
1	28	264489	2025	0.27	3.82	2	0	84	140	224
2	20	276295	2246	0.26	1.97	30	26	130	156	312
3	104	152973	1682	0.26	2.75	29	0	858	429	1144
4	52	229013	2011	0.27	1.59	30	172	516	602	1032
5	71	200844	1722	0.26	2.00	4	75	450	750	825
6	26	243648	1346	0.25	2.29	29	0	182	156	208
7	285	14293	1327	0.25	2.50	5	0	2872	3231	3590
8	218	41872	1013	0.23	3.62	7	0	2358	3537	4323
9	83	183340	1372	0.24	4.04	7	0	690	1725	1035
10	57	221740	1523	0.26	2.51	15	0	876	2336	1314
11	193	58621	1030	0.25	1.84	17	274	1096	4384	2192
12	116	136787	905	0.23	3.42	13	0	912	1672	1672
13	54	226019	843	0.23	1.56	14	66	198	726	660
14	20	276295	713	0.23	1.56	13	48	144	432	432
15	137	110798	1262	0.26	2.28	25	0	966	1932	1771
16	350	3810	727	0.22	2.07	17	0	1290	5160	3870
17	28	264489	903	0.24	1.84	11	29	58	406	232
18	27	265715	440	0.21	2.73	19	0	32	192	288
19	97	163459	615	0.22	2.73	18	0	444	1332	1480
20	69	203771	2342	0.27	3.75	23	0	158	790	1343
21	245	27951	1292	0.25	3.47	22	0	912	2432	1520
22	22	273498	1329	0.25	1.75	26	36	180	180	432
23	23	271974	1556	0.27	1.20	24	39	273	117	663
24	22	273498	1467	0.27	1.20	23	46	138	138	345
25	40	246483	1382	0.26	1.56	24	70	420	560	980
26	26	267812	1184	0.25	1.03	27	72	144	216	288
27	38	248713	1092	0.24	1.03	26	38	152	266	228
28	307	9472	1398	0.24	7.29	1	0	0	390	1950
29	187	63196	1640	0.26	1.71	30	189	1323	945	2079
30	111	140246	1873	0.27	1.59	4	354	472	708	1298
31	38	250331	1399	0.24	1.22	32	40	0	40	240
32	190	60776	1467	0.24	1.22	31	191	0	191	1146
Average	**91**	**177257**	**1348**	**0.25**	**2.35**	**2**	**55**	**573**	**1133**	**1222**

Appendix B: Non-constant costs and benefits

Site number	Agricultural production (€ per ha and year)	Manure (€ per ha and year)	NSB^{lim} (€ per ha and year)	NSB^{full} (€ per ha and year)			Recreation value (€ per ha and year)		
				Min	**Median**	**Max**	**Min**	**Median**	**Max**
1	-2573	475	5579	34876	45223	59821	29297	39644	54242
2	-1410	147	4744	39175	49175	64962	34431	44431	60218
3	-3191	441	6231	39424	48142	61767	33193	41911	55536
4	-2928	361	6048	26378	38842	55922	20330	32794	49874
5	-3183	316	6348	8672	23805	45833	2324	17457	39485
6	-329	14	3796	5612	16317	25798	1816	12521	22002
7	-2913	386	6008	9750	15242	39071	3742	9234	33063
8	-2658	344	5795	26070	29638	33874	20275	23843	28079
9	-2746	324	5903	11522	15748	25280	5619	9845	19377
10	-3849	431	6899	37386	45922	56879	30487	39023	49980
11	-1988	402	5067	39023	45147	54916	33956	40080	49849
12	-2752	399	5834	39444	50003	60291	33610	44169	54457
13	-2945	395	6031	41514	49824	61099	35483	43793	55068
14	-1188	183	4486	40249	50479	62284	35763	45993	57798
15	-1453	280	4654	55587	64642	74436	50933	59988	69782
16	-2167	404	5244	29245	31829	45073	24001	26585	39829
17	-2403	372	5512	37494	47324	61356	31982	41812	55844
18	-779	332	3928	35143	44141	61366	31215	40213	57438
19	-2323	428	5376	37026	46965	57893	31650	41589	52517
20	-2171	336	5316	38689	46703	55692	33373	41387	50376
21	-3088	357	6212	29432	34806	47478	23220	28594	41266
22	-2510	328	5663	21918	29075	38933	16255	23412	33270
23	-2749	366	5864	36835	46857	56733	30971	40993	50869
24	-3216	428	6269	35883	47958	60035	29614	41689	53766
25	-1655	197	4939	36251	45981	57483	31312	41042	52544
26	-3767	440	6808	45418	56121	68442	38610	49313	61634
27	-2850	353	5978	41428	54120	74336	35450	48142	68358
28	-3519	334	6666	32768	38037	44920	26102	31371	38254
29	-3417	417	6481	12836	17972	24518	6355	11491	18037
30	-3557	465	6573	6938	11904	26072	365	5331	19499
31	-980	458	4003	4477	8289	13477	474	4286	9474
32	-3434	436	6479	8203	15488	26373	1724	9009	19894
Average	**-2522**	**355**	**5648**	**29521**	**37866**	**50075**	**23873**	**32218**	**44427**

Appendix C: Distribution of subsets

We list all subsets meeting the area constraint consists of 2 to 16 forest sites.

Number of forests per subset	Number of subsets meeting the area constraint
2	1
3	27
4	354
5	2556
6	11742
7	35227
8	73261
9	109174
10	115469
11	90523
12	47993
13	55919
14	23032
15	3608
16	356
Total	**569242**

References

BATEMAN I.J., BRAINARD J.S., LOVETT A.A., LANGFORD I.H., POWE N. and SAUNDERS C. (1998), Transferring multivariate benefit functions using geographical information systems, paper presented at *The world congress of environmental and resource economists*, Isola di San Giorgio, Venice, Italy, 25-27 June 1998.

BATEMAN I.J., LOVETT A.A. AND BRAINARD J.S. (1999), Developing a methodology for benefit transfers using geographical information systems: modeling demand for woodland recreation, *Regional Studies* **33**(3), 191-205.

BATEMAN I.J., LOVETT A.A. and BRAINARD J.S. (2005), Applied environmental economics. A GIS approach to cost-benefit analysis, Cambridge, Cambridge University Press, 335.

BENSON J.F. and WILLIS K.G. (1993), Implications of recreation demand for forest expansion in Great Britain, Regional Studies, **27**(1), 29-39.

BERENSON M.L., LEVINE D.M. and KREHBIEL T.C. (2002), Basic business statistics. Concepts and applications, 8th edition, Upper Saddle River, Prentice-Hall International, Inc., 851.

BOSTEDT, G. and MATTSSON, L. (2006), A note on benefits and costs of adjusting forestry to meet recreational demands, Journal of Forest Economics **12**, 75-81.

BRAINARD J.S., LOVETT A.A. and BATEMAN I.J. (1999), Integrating geographical information systems into travel cost analysis and benefit transfer, *International Journal of Geographical Information Science* **13**(3), 227-246.

CARSON R.T., HANEMANN W.H. and MITCHELL R.C. (1986), Determining the demand for public goods by simulating referendums at different tax prices, Manuscript, University of Californa, San Diego.

CENTRUM VOOR LANDBOUWECONOMIE (2000), De rendabiliteit van het landbouwbedrijf in 1999 (boekjaar 1999-2000). Ministerie voor Middenstand en Landbouw, Bestuur voor Onderzoek en Ontwikkeling – DG6, 67.

CIEMAT (1999), Externalities of Energy. Volume 10: National Implementation, Luxembourg, European Commission DGXII, Science, Research and Development.

DESVOUSGES W.H., NAUGHTON M.C. and PARSONS G.R. (1992), Benefit transfers: conceptual problems in estimating water quality benefits using existing studies, *Water Resources Research* **28**(3), 675-683.

DIENSTENCENTRUM VOOR BOSBOUW (2000), Vergelijkende studie met betrekking tot de bosrentabiliteit in productiegerichte, multifunctionele bossen en natuurgerichte multifunctionele bossen. Vlaams Syndicaat van Boseigenaars.

DRAKE L. (1992), The non-market value of the Swedish agricultural landscape, *European Review of Agricultural Economics* **19**, 351-364.

FAO (2006a) http://faostat.fao.org/faostat/form?collection=Crops.Primary&Domain=ProducerPrices&servlet=1&hasbulk=&version=ext&language=EN, last checked March 2006.

FAO (2006b), http://faostat.fao.org/faostat/form?collection=Livestock.Primary&Domain=ProducerPrices&servlet=1&hasbulk=&version=ext&language=EN, last checked March 2006.

GARCIA QUIJANO J., DECKMYN G., MOONS E., PROOST S., CEULEMANS R. and MUYS B. (2005), An integrated decision support framework for the prediction and evaluation of efficiency, environmental impact and total social cost of domestic and international forestry projects for greenhouse gas mitigation : description and case studies, *Forest Ecology and Management* 207, 245-262.

LOOMIS J.B. (1992), The evolution of a more rigorous approach to benefit transfer: benefit function transfer, *Water Resources Research* **28**(3), 701-705.

LOOMIS J.B. and WALSH R.G. (1997), Recreation economic decisions: comparing benefits and costs. 2nd edition, Pennsylvania, Venture Publishing, Inc. 440.

LOVETT A.A., BRAINARD J.S. and BATEMAN I.J. (1997), Improving benefit transfers demand functions: a GIS approach, *Journal of Environmental Management* **51**, 373-389.

MITCHELL R.C. and CARSON R.T. (1989), Using surveys to value public goods: the contingent valuation method, Washington, Resources for the Future, 463.

MOONS E., EGGERMONT K., HERMY M. and PROOST S. (2000), Economische waardering van bossen – een case-study van Heverleebos-Meerdaalwoud, Leuven, Garant, 356.

NIS (2000a) , Landbouwstatistieken, Landbouw- en Tuinbouwtelling op 15 mei 1999.

NIS (2000b), Werkelijke bevolking per gemeente op 1 januari 2000.

PEARCE D.W. (1994), The environment: assessing the social rate of return from investment in temperate zone forestry, in LAYARD R. and GLAISTER S. (Eds.) *Cost-benefit analysis*, 464-490, Cambridge, Cambridge University Press.

ROSENBERGER R.S. and LOOMIS J.B. (2000), Benefit transfer of outdoor recreation use values: a technical document supporting the FY2000 RPA values, Draft report for the USDA Forest Service under Research Joint Venture Agreement #RMRS-98132-RJVA: Objective #4, "Theories and methods for measuring environmental values and modelling consumer and policy decision processes".

SCARPA, R., CHILTON, S.M., HUTCHINSON, W.G. and BUONGIORNO, J. (2000), Valuing the recreational benefits from the creation of nature reserves in Irish forests, *Ecological Economics* **33**(2), 237-250.

STAVINS R.N. (1999), The costs of carbon sequestration: a revealed preference approach, *The American Economic Review* **89**(4), 994-1009.

ZANDERSEN, M., TERMANSEN, M. and JENSEN, F.S. (2005), Benefit transfer over time of ecosystem values: the case of forest recreation, Working Paper FNU-61.