# Valuing New Forest Sites over Time: the Case of Afforestation and Recreation in Denmark

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**Abstract**

We estimate changes in the total recreative value over a 20 year time period of a large newly established forest, using mixed specification of a random utility models and geographic information system. The models are estimated using data from two identical surveys in 1977 and 1997. We conduct three different spatial value transfers and test these on the new forest. Results suggest that the new forest increased the recreative value nearly 70 times over the 20 years, primarily due the maturing of the forest and changed patterns of behaviour. The value transfer to the new forest range between an underestimate of 57% and an overestimate of 349%, depending on the sampling of the choice set used as study sites in the transfer.

**Keywords**

recreation, random utility model, GIS

**JEL Codes:**

Q230, Q510

# 1. Introduction

Afforestation plans in Denmark are ambitious with a policy in place since 1990 to double the forest area over 80-100 years from around 11% in 1990 to 22% - 25% of the total area by 2090, corresponding to a annual increase of 4.000-5.000ha. (Miljøministeriet, 2002). The policy seeks to enhance the provision of goods and services produced by forests, including recreation, ground water and habitat protection, carbon sequestration and environmentally friendly production of wood and energy. The efforts to double the forest area are taken on by the State, through the Forest and Nature Agency, local authorities and private companies or people with the help of grants from the State and the EU.

Although privately led afforestation projects up to now account for the majority of new forests[1], these are generally small areas (8ha on average), located far from urban centres and provide limited recreational opportunities. Conversely, the Forest and Nature Agency and local authorities prioritise locations of new forests close to town and cities to enhance local recreation. These projects are therefore larger, on average 100ha.

On a national scale, the State has carried out afforestation on 5,115ha in 53 projects since 1993 compared to 12,000ha of private afforestation (Miljøministeriet, 2003, 2005). Despite the efforts over the last 15 years, the annual target of between 4.000 and 5.000 ha new woodland have not been met. Especially public afforestation, which is planned to account for half the efforts, representing approximately 210,000ha over the next 80 years, has lagged behind. State and local authorities are therefore likely to increase the current rate of afforestation.

As public afforestation projects focus on relatively large new forests established as urban fringe forests, policymakers and planners will increasingly need information on the value of new forests in terms of location and accessibility, substitution impacts between new and existing forests, and preferences in the population for different site characteristics. Predicting the value of a new forest is essential if policy-makers wish to use valuation of non-market goods to guide its priorities.

[1] Between 1993 and 2004, private afforestation represented 70% (12.003ha) of total afforestation area (Miljøministeriet, 2005 & 2003)

Transfers of recreational values from existing forests or study sites, where monetary valuation has already been carried out, to new sites or policy sites that are not yet created is one of the few ways of providing a future welfare measure. Although these transfers can perform no better than original studies available, they are considerably less cost and time consuming than original valuation studies, and are therefore frequently used in cost benefit analyses (See e.g. Hanley et al., 1999) and environmental regulation (e.g. WATECO 2003).

Value transfers are in most cases based on valuation studies that were not intended for transfers (Brookshire et al., 1992; Smith, 1992), causing basic problems such as non-similarity across sites and population (Boyle, 1992; Rosenberger et al., 2000). For instance, transferring values to a new forest that is very different from the study sites used for the transfer function is expected to cause large errors in transfers. Such 'outliers' may be important from a recreational perspective, but challenging from a value transfer perspective. Knowing under which conditions a transfer performs well is essential when choosing transfers from original valuation studies, but only relatively few studies have tested the reliability of transferring functions and welfare estimates across sites and those who have, found errors up to 475% of the policy site value (Brouwer, 2000; Loomis et al., 1995; Kirchhoff et al., 1997). A related issue is the impact on value transfers of the sampling of study sites in the original survey, as the original surveys, due to cost considerations, often do not sample all available sites. Therefore, despite the appealing properties of value transfer, the availability of studies and the characteristics of sites included in original studies, may result in diminished ability to predict values at policy sites successfully.

Another important aspect in valuing and assessing long term projects prior to the establishment of the new site is changes in values over time. Afforestation projects will only reach maximum welfare potential after 50 to 80 years and valuation of such projects should therefore take this time aspect into account. Time is frequently only represented implicitly in value transfers (e.g. using historic data to transfer present values) and estimated benefit measures from original studies or value transfers are extrapolated over long periods of time (e.g. 10 to 50 years, depending on the project). This is often made without knowledge about changes in the determinants of welfare (Loomis, 1989), such as marginal utility of income, family structures or transport behaviour.

Public afforestation in Denmark, primarily carried out through new urban fringe forests, could benefit from information on design of transfers and reliability of transferred values over space as well as evidence on how values of new recreation areas develop over time. Both pieces of information are essential when valuing the introduction of new forest recreation sites.

In this paper we provide a case study of how welfare of a large public afforestation project, called Vestskoven, changed between 1977 and 1997. The forest was established in the 1960s as an urban fringe forest in the western part of Copenhagen, and surveyed as part of a national on-site recreation study in 1976/1977 (Koch, 1980) and again in 1996/1997 (Jensen, 2003). We use the case study to evaluate the extent to which values can change over time and identify the main determinants. We conduct and test different function transfers based on 52 forests in North Zealand, the same region as Vestskoven, in order to test the extent to which we are able, today, to predict the value of a 30 year old forest. We also use the transfers to to make a systematic comparison of spatial transferability, useful for assessing new forest sites and to assess the importance of different sampling designs in conducting transfers. The transfer scenarios comprise the following three approaches: 1) transfer to Vestskoven based on preferences revealed when the transfer model is estimated for the remaining 51 forests; 2) transfer to Vestskoven based on preferences revealed when the most attractive forests or the least valued forests are excluded from the transfer model; 3) transfer to Vestskoven using only revealed preferences for other urban fringe forests in and around Copenhagen.
We test the reliability of transfers to Vestskoven by comparing the transfer value to the value estimated in the full model for all 52 forests and by making standard log likelihood tests for model transferability. To compare the relative performance of the Vestskoven transfers, we report results of the same 3 transfer approaches for the remaining 51 forests in the region.

We conduct the valuation over time and spatial transfers using Random Utility Models (RUMs), which is one of the few tools capable of solving the problem of substitution and non-similarity across sites in value transfers (Brouwer, 2000) and link a count data model to the RUM in order to capture total demand for forest recreation in Northern Zealand. RUMs are based on the principle that the recreationist makes a choice among a set of available recreation sites, given a variety of site attributes, where the choice is between a finite number of mutually exclusive alternatives. The method can be used to value changes in specific site characteristics, value the benefits of introducing a new site or the losses from eliminating a site (Bockstael et al., 1987). Because of the inclusion of multiple site characteristics, a RUM can adjust for differences across sites in benefit transfers (Brouwer, 2000). We choose a mixed logit specification that accounts for heterogeneity in preferences across the population (Train, 1998).

We combine the RUM with the use of Geographic Information System (GIS), following the approach of Termansen et al. (2004). This captures a larger proportion of site heterogeneity with a spatially disaggregated representation of forest sites. Furthermore, it allows us to account for the spatial pattern of population density and other demographic characteristics.

Our logit model is based on data from a national visitor survey in forests from 1976/1977 (Koch, 1980) and 1996/97 (Jensen, 2003), where we focus on the regions of Copenhagen and Frederiksborg in Northern Zealand in Denmark. The surveys were carried out by the Danish Centre for Forest, Landscape and Planning and are directly comparable using identical questions and identical sampling sites and schedule.

The remainder of the paper is organised as follows: Section 2 describes the establishment of the new forest, Vestskoven, and data used to estimate the count and choice models for valuing recreational benefits over time. Section 3 specifies the theory, shows the resulting econometric estimation of the choice and count models and uses these to predict welfare measures for Vestskoven and the other 51 forests in 1977 and 1997. Section 4 outlines the benefit transfer approach and reports on tests of reliability and value transfer results. Section 5 discusses the findings of our analysis and concludes.

# 2. Data

### 2.1. Establishment of a New Forest - Vestskoven

Vestskoven is a large recreational area in the western part of Copenhagen that was introduced in the 1960s and expanded and developed up through the 1990s. The first plans to create Vestskoven as a forest park for recreation started back in 1936 but it was only in 1964 that the first 35ha of former agricultural land were donated to the state (Skovreguleringen 1974 & 1980). Later in 1967, the state, local and regional authorities agreed to an overall budget to buy up agricultural land for recreational use. Planners had for 40 years attempted to create a forest area on the flat, windy and forest-poor area west of Copenhagen. In addition, by the 1960s concerns were raised that the increasing movement of people north of Copenhagen, wanting to live in green areas, close to forests, would ultimately lead to serious urban sprawl. By 1972, a total of 821ha of primarily agricultural land was bought up followed by a further 418ha by 1980 and totalling 1361ha in 1997. Plans emphasised the combination of large open plains (400ha), lakes, streams and meadows with forested areas, with a majority of broadleaved species. Vestskoven is necessarily very different from other forests in the region with young tree stands and more open land as afforestation has been ongoing since the establishment. Also the design of the site differs from the average forest in the region with deliberately wide open spaces, high diversity in species, and a size three times larger the average size of forests in Northern Zealand. Table 1 summarises the development of Vestskoven in terms of size and other physical attributes and compares Vestskoven with the average characteristics of 51 other forests in the region.

### 2.2. On-site Survey Data

Our study is based a sub-sample of two national on-site recreation surveys from 1976/1977 and 1996/1997, where we focus on state-owned forests in the forest districts of Tisvilde, Frederiksborg, Kronborg, Jægersborg and Copenhagen in Northern Zealand, Denmark. State owned forests in this region represent 93% and total forest area, and attributes such as species, age and infrastructure are available in a comparable format across sites and time.

The surveys pertain only to day trips by car and were carried out during April 1976 to March 1977 and December 1996 to November 1997 on 22 random days. Questionnaires were distributed simultaneously on 321 locations within the 52 forests. The same routes within the forests were used at each sampling time and were designed to ensure that all cars visiting the forest during one ½ hour received the questionnaires. The identical sampling effort in the on-site survey implies a proportional random sampling where the population probabilities visiting individual sites can be assumed identical to the sample probabilities (Haab and McConnell, 2002).

The response rate was 53.7% in 1977 and 48% in 1997. For ease of computation and to ensure a relevant choice set of the sample population, we excluded visitors to the 52 forests who came from outside the regions of Copenhagen and Frederiksborg. The final samples retained for analysis amount to 6,580 questionnaires in 1977 and 6,987 in 1997.

We calculated the distance that people travelled from the origin of the trip to the the forest they visited using a 1:200,000 scale vector road map (Kort & Matrikelstyrelsen, 1995), assuming they used the shortest route, as well as the distance to each of the other 51 forests, which they could have visited. We use the average variable costs of travelling, including taxes but excluding car depreciation, which amount to €0.22 per km in 1977 (1997 prices) €0.187 per km in 1997 (Truelsen,1977; Vejdirektoratet, 2001).

### 2.3. Household Survey and Socio-economic Data

We use a national household survey dataset from 1994 to estimate visit frequency for the 1997 forest valuation model (Jensen and Koch,1997). 2,916 people between 15 and 76 years were randomly sampled from the national register during one year from November 1993 to October 1994 resulting in a response rate of 83.7%. We retained only questionnaires of people living in the regions of Copenhagen and Frederiksborg with complete questionnaires, totalling 283 people. We assume that the frequency of visits and underlying demand determinants in 1994, which we derive from the 1994 household survey, are not significantly different from 1997, where no such survey was carried out. Table 2 lists measurements and sources. Demographic data from 1997 were derived from a national digital dataset of 2,116 parishes with information on male and female population divided into 6 age classes. Population segments distributed on nodes in the road network were available from the Danish Centre for Forest, Landscape and Planning using an urban land use map (100x100m resolution). Data on average household income and car ownership were available from Danish Statistics on parish and local authority level, respectively.

For the 1977 forest valuation model, we calculated an average frequency of annual 18.25 car-borne trips per year per person, based on an average of 33 visits per person to forests per year and 55.3% of people travelling by car to forests in 1977 (Koch 1978). We use a fixed average, as the original data were not available. Population data for 1977 was available on a local authority level from Danish Statistics (2003).

### 2.4. Forest Data

A list of potentially important site attributes was added to the distance matrixes calculated based on the on-site survey data. To ensure comparability across forests, we use official forest data of the Danish Forest and Nature Agency from 1997 and 1977. Based on the forest inventories, we calculated Shannon indices as measures of species and age diversity. This takes into account species richness and evenness of species distribution (Shannon and Weaver, 1949). Fraction of broadleaf and conifer vegetation, size of forest, fraction of trees older than 60 years and water bodies within the forests were also extracted from the forest inventories. Measures of topography were available from Skov-Petersen (2002) and distance to coast from the land cover map “area information system, AIS” (Miljø & Energiministeriet / Danmarks Miljøundersøgelse, 2000). Table 3 lists the site attributes tested in the logit model.

# 3. Models & Estimation Results

Random utility models estimate the probability of visiting one site out of a choice of several mutually excludable alternatives where the probability is dependent on travel costs to and attributes of the sites (Haab and McConnell, 2002; Creel and Loomis, 1992; Kaoru et al.,1995, McFadden, 1974). The basis for examining the choice of site and hence the values of site attributes is the assumption that recreators make a choice to visit a site independently of previous visits (Yen and Adamowicz, 1993). This assumption of independence of trips necessitates a trip demand model be linked to the trip allocation model in order to estimate the total value of one site, rather than a value per visit. We start by describing the model that allocates choices of visit based on the random utility approach and report on the estimation results from 1977 and 1997. We then specify the trip demand model, explain the linkage to the trip allocation model and report on estimation results. Finally, we predict values and visits to Vestskoven in 1977 and 1997.

## 3.1. Trip Allocation

In discrete choice models the decision maker is assumed to choose the site that provides him with the greatest utility during one visit, based on a combination of travel costs and site attributes.

The 'true' utility function for the representative individual is specified as:

$$U_{nj} = V_{nj} + \mu_{nj} \quad \forall j \tag{1}$$

where $V_{nj}$ is the observed component of utility for forest visitor *n* visiting site *j* and $\mu_{nj}$ is the random component. Based on the joint density of the vector parameter $\mu_{nj}$, it is possible to make probabilistic statements of the choices of the decision makers (Train, 2003).

Our first specifications of standard conditional logit models clearly showed a violation of the "independence from irrelevant alternatives" (IIA) property in more than half the sites of the choice sets. As the unobserved portion of utility is correlated over alternatives, we specified mixed logit models with random coefficients and error components, that allows for the correlation of errors by introducing error components and preferences to vary over the population by specifying a distribution for the coefficients (Train, 2003). The 'true' utility function in the mixed logit specification is specified as:

$$U_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj} + \boldsymbol{\eta}' z_{nj} + \varepsilon_{nj} . \tag{2}$$

$\mathbf{\beta x}_{nj}$ is the representative utility component, where $\mathbf{x}_{nj}$ is a vector of observed variables relating to alternative *j*, $\mathbf{\beta}$ is a non-observed preference parameter vector specified according to a preference distribution function with density $f(\mathbf{\beta} \mid \mathbf{\theta})$, where $\mathbf{\theta}$ are the parameters of this distribution, such as the mean and variance. $\mathbf{\eta}' z_{nj} + \varepsilon_{nj}$ is the stochastic part of the indirect utility function is denoted, where $\mathbf{\eta}$ is a vector of random, non-observed terms with zero mean that varies over alternatives by $\sigma_{ec}$ and has density $g(\mathbf{\eta} \mid \mathbf{\delta}_{ec})$. $z_{nj}$ is the error component that allows for correlation in utility over alternatives and $\varepsilon_{nj}$ is the random error term, assumed iid type 1 extreme value.

The probability for individual *n* of choosing site *i* out of *J* sites in a mixed logit is the integral of standard logit probabilities over the density of parameters $\mathbf{\eta}$ and $\mathbf{\beta}$:

$$P_{ni} = \int_{\beta}\int_{\eta}\left(\frac{e^{\mathbf{\beta}'\mathbf{x}_{ni}+\mathbf{\eta}'\mathbf{z}_{ni}}}{\sum_{i\in J} e^{\mathbf{\beta}'\mathbf{x}_{ni}+\mathbf{\eta}'\mathbf{z}_{ni}}}\right) g(\mathbf{\eta} \mid \mathbf{\delta}_{ec}) f(\mathbf{\beta} \mid \mathbf{\theta}) d\mathbf{\eta} d\mathbf{\beta} \qquad (3)$$

The random utility models were estimated using GAUSS, adopting the routine developed by Kenneth E. Train[2].

Coefficients of variables, which can logically take either sign and which are of particular policy relevance for forest managers, such as species diversity, fraction of conifer trees, or fraction of open land in forests, were given an independent normal distribution with mean and standard deviation that are estimated. Other preference parameters such as size, slope, presence of water and distance to coast were given fixed specifications across the population. Finally, we gave the coefficient for travel costs an independent log normal distribution as costs are expected to have the same negative sign for all visitors, with only the magnitude differing over the sample population.

Table 4 lists variables and parameter estimates of the 1977 and 1997mixed logit models. Although parameters and variables appear similar in both sign and magnitude, the two models show significant differences in how preferences vary over the population in the case of species diversity, openness, and fraction of trees older than 60 year. Preferences appear stable and favourable towards coniferous forests, sloped terrain, presence of water bodies, larger forests, although with a marginal declining effect, and coastal forest sites. The error term on distance to coast in both 1977 and 1997 indicates a common substitutability between forests close to the coast.

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The GAUSS routine for mixed logit is available from K. Train's website.

### 3.2. Linked Trip Demand

The prediction of total demand of recreational trips to forests in 1997 is based on a zero-inflated Poisson count model to account for the large number of recreational trips not undertaken by car (Yen and Adamowicz, 1993; Haab and McConnell, 1996). The frequency of car-borne trips is modelled in two stages. The first stage is the inflation function which models the decision of mode of transport between a latent group A of individuals who never use the car for recreational trips, i.e. a zero trip frequency has a probability of 1, and a group B of individuals who sometimes uses a car, i.e. a positive trip frequency has a non-zero probability (Long, 1997). The second stage is the decision on the number of annual recreational trips given that the individuals belong to group B. As we find evidence of over-dispersion, we specify the second stage as a negative binomial, allowing the variance to exceed the mean.

Linking the trip demand model to the model specifying the choice of alternative needs to accommodate the fact that not only changes in travel costs but also changes in site attributes and access alter the frequency of visit as well as the choice of site. Our approach follows the work of Bockstael et al. (1987), where we link the participation function to the site choice decision by including the post-change inclusive value, calculated in the trip allocation model, in the regression of the trip demand model. The inclusive value represents the value of different alternatives weighted by their probabilities of being chosen (Bockstael et al., 1987). It is calculated as:

$$IV = \ln \sum_{j=1}^{J} \exp\left(\mathbf{v}_j\right)$$

The link ensures that, for instance, an increase in an attractive attribute or an inclusion of a new site increases both the probability of visiting this site and the probability of participating on any given choice occasion, hence increasing the total number of visits (Yen and Adamovicz, 1993).

The parameter estimates and z-values of the trip demand model are outlined in Table 5. The inflation function, which estimates the probability of a zero count, confirms that owning a car and increased distance to the nearest forest in the choice set also increases the probability of travelling by car to forests. The negative binomial shows that the amount of car-borne trips taken increases with income and for people older than 39 years. The parameter of the inclusive value is positive but only significant at the 10% level. It indicates that trip frequency rise with increasing overall utility of visiting forests in the choice set.

### 3.3. Value of Access to Vestskoven, 1977 & 1997

The indirect utility function is the basis for welfare calculations in random utility models and provides a direct means for estimating welfare impacts of changes in site characteristics or access. The expected maximum utility that we seek to estimate is given by:

$$E\{max(U)\}=\ln\left(\sum_{j\in J}\exp(\mathbf{v}_{\mathrm{nj}})\right) \quad (3)$$

where the indirect utility function of individual *n* choosing site *j* is $v_{nj} = v(y - c_{nj}, \mathbf{q}_j)$, y is income, $c_{nj}$ is the cost for individual *n* to visit site *j* and **q** is a vector of site attributes

$$WTP_n = \frac{\ln\left(\sum_{j\in J}\exp(v_{nj}*)\right) - \ln\left(\sum_{j\in J}\exp(v_{nj})\right)}{\beta_c} \quad (4)$$

The value of access to a site is calculated by increasing the cost of travel to infinity, which drives the probability of visiting a site to zero. Simulation over the total population in the region was performed using 500 random draws for each node in the road network in 1997 and 1977. The difference in welfare measures between 500 draws and 1000 draws is non-significant.

Results suggest that the value of Vestskoven has increased dramatically from an annual value of approx. €44.600 to €3.6mio. between 1977 and 1997 (both values in 1997 prices). Predicted yearly number of car-borne visits increased from approx. 9.700 to 1.3mio. The popularity of the new forest has thus advanced from a ranking as the second least popular site to the 3rd most attractive site of forests in the choice set. Despite the general increase in value, 22 forests actually lost in value over the period. The reduced values generally occurred in relatively remote coastal sites towards the north in the region whereas benefits of forest recreation have increased at a higher rate the closer sites are located to Copenhagen. Vestskoven is by far the site that has gained the most in relative terms in attractiveness over the 20 year time period. Figure 1 shows the spatial distribution of changes in value over 20 years across the 52 forests.

# 4. Value Transfer Approaches & Results

The previous section showed how a relatively young forest increased its value nearly 77 times in 20 years from one of the least popular to one of the most attractive forests in the region. This section investigates to what extent transfers are capable of predicting the value of a relatively new forest with significantly different attributes from other forests in the region. It also assesses the influence on transferability of choosing different sampling designs, for instance, the effects of not sampling in attractive or unattractive sites, or the effects of reducing the sample based on geographic location of sites.

The first scenario transfers a value function based on 51 forests to Vestskoven. This gives us the best possible variety of sites, including size, and other attributes, deemed ideal in value transfers. In order to compare the performance of the Vestskoven transfer, we also report on transfers of each of the remaining 51 forests.

The second scenario tests for sampling implications. We assume that the study planner excludes certain sites in order to reduce the sampling effort and then transfers the value function to Vestskoven. We have chosen to exclude the five and ten least attractive sites and test the performance of the value functions in predicting the value of Vestskoven[3] and repeat the exercise for the five and ten most attractive sites. We expect the extreme sampling to reveal information about error structures in value transfers.

The third and final value transfer approach is based on a geographically limited sample. We restrain our choice set the urban forests in and around Copenhagen and transfer the value function to Vestskoven. This constitutes a sample of 14 sites. The reason for the geographic sampling is related to the development of forest recreation values since the 1970s, where forests closer to Copenhagen have clearly gained and forests further away have lost recreational values based on car-borne recreation. By using other urban fringe forests, with a similar recreation trend over time, this transfer may be superior to the two previous scenarios.

## 4.1. Value Transfer Function based on 51 Forests

The first scenario conducts a value transfer to Vestskoven based on preferences for the remaining 51 forests. The trip allocation component of the value transfer function is estimated

[3] Vestskoven is removed from the choice set along with the five and ten least attractive forests.

after removing respondents who were sampled in Vestskoven in 1997 and excluding Vestskoven as an alternative in the choice set. We then adjust the inclusive value in the trip demand model and calculate the total yearly welfare measure for Vestskoven. The transfer value of Vestskoven is compared to the true value, mentioned in Section 3.3 and the difference makes out the 'transfer error'. We test for equivalence between true and transfer models with a standard log likelihood ratio. To ensure identical sample sizes, we compute a ratio between the log likelihood of the transfer model coefficient estimates and the log likelihood of the full model coefficient estimates, both computed over the full sample. In order to assess the performance of the Vestskoven we repeat the tests and transfer for each forest in the choice set.

The log likelihood test was not performed on the Vestskoven transfer model as the specification of the transfer trip allocation model differed substantially from the full model. Fraction of water and open land appeared no longer significant, indicating the outlier properties of Vestskoven. As a result, Vestskoven was overestimated by 346% from the true value, representing a difference of €10.5mio. In comparison with the other forests in the region, the Vestskoven transfer performed the worst. The 51 other transfers were on average underestimated by 4%, ranging from –86% to +251%. The largest transfer errors are generally those, where the specification of the transfer trip allocation models differ from the full model. Nevertheless, transfers of only two forests proved to have statistically equivalent models with the full model. These produced transfer errors of 3% and 9%. For the remaining models that failed the equality test, 34 had a log likelihood ratio between 47 and 100[4] and transfer errors ranging between -47% and +18% and 36 of the 52 transfer models performed within an error range between –20% and +20%. Table 7 shows average error margins of the full choice set and errors of the Vestskoven transfer and Figure 2 ranks the error margin in ascending order. Vestskoven appears as the extreme point.

### 4.2. Value Transfer Function based on Attractiveness

The second scenario transfers values to Vestskoven based on four different sampling of the study sites that excludes five and ten of the most attractive predicts and five and ten of the least popular sites. Attractiveness is measured as the predicted values of the full model. We aim at finding out to what extent excluding the most attractive sites impacts the predictive power of the transfer model compared to excluding the least attractive forests. We expect that

[4] $\chi^2$ distribution and 11 degrees of freedom. The critical value of P=0.001 is 31.26

excluding the most attractive forests will lead to large transfer errors and highly significant differences between transfer and full models. Likewise, we do not expect the true model to be significantly different from the transfer models of the least popular forests; neither do we expect the transfer values to be very different from the true model results.

We first exclude five forests and respondents from of the most valuable sites from the sample and the choice set and estimate a new set of coefficients of the trip allocation model. We conduct the transfer by applying the new trip allocation model on the full sample to calculate the willingness to pay. We repeat this with a transfer of the 10 most popular sites. The same set up is followed in the benefit transfers based on the five and ten least valuable forests. As previously, we calculated the transfer error margin and the standard log likelihood ratio test, to test for model transferability. We tested for transferability using the log likelihood ratio with a $\chi^2$ (11) distribution. The four transfer models strongly reject the $H_0$ that the sets of coefficients are the same. As expected, excluding the five and ten most valuable forests from the trip allocation model result in larger and more non-significant likelihood ratios (812.40 and 250.7, respectively) than when excluding the five and ten least attractive sites (128.5 and 48.6, respectively). Excluding five rather than ten attractive or unattractive sites produce larger log likelihood ratios.

Results of transferring value functions where sampling is limited based on attractiveness of study sites suggest that removing the least popular sites from the sampling induces lower transfer errors than when we limit the sampling of the study sites for the most popular sites. Errors in the Vestskoven transfer when excluding the least attractive sites are found to be between 36% and 31%, depending on how many sites are excluded from the sample compared to between 55% and 330% when excluding the most popular sites. In general, it is surprising to find than excluding fewer sites produce higher transfer errors than transfers excluding more sites in both popular and non-popular samplings. Table 7 lists the error margin of Vestskoven and summary statistics of the full choice set.

### 4.3. Value Transfer Function Based on Urban Fringe Forests

The third and final transfer uses only urban fringe forests as study sites. We identified 14 forests that are located in Copenhagen or spatially linked to the city and estimated the trip allocation model based on the revealed preferences observed in these forests.

The transferability test was not performed as the full model and the geographically limited transfer model have different significant variables explaining preferences. The variables Shannon species index, fraction of water bodies and distance to coast did not contribute significantly to the model and were removed. Also a fixed parameter model seemed more adequate for modeling the preferences of fraction of coniferous forests in transfer model.

Results suggest that such a design would underestimate the true value of Vestskoven by 57% or by €1.7mio. The sampling also underestimates the true values of the other forests in the region. Table 7 shows the average results of this transfer.

# 5. Discussion & Conclusion

In this paper, we have sought to shed more light on the development of values over time and on the properties of spatial transfers in relation to the establishment of new forest sites for recreational use. The Danish Government and local authorities pursue an ambitious afforestation plan over the next 80 years to create additional 210.000ha. Much of the public forest expansion is likely to be carried out as new urban fringe forests, creating green belts around towns and cities, much like Vestskoven in the 1970s. A recent example of the efforts made by the State and local authorities to enhance access to forests for city-dwellers are eight strategically located new forests around Aarhus, the second largest urban area in Denmark. Between 1988 and 2005, close to 1,000ha was afforested, creating a 'green belt' around the city (Aarhus Kommune, 2005).

The current forest cover in Denmark is relatively sparse with 11% of the land area afforested corresponding to 486.000ha and with only 0.1ha available per capita. This is low compared to other Nordic countries (2.2ha) or Europe (0.3ha) (Miljøministeriet, 2002). Because competition for land is high in Denmark between agriculture, industry and urban areas, attaching a value to where and how new forests should be established is important for making informed decisions about developments in land use.

The valuation of carborne recreation in Vestskoven in 1977 and 1997 suggests that benefits have increased nearly 77 times over 20 years from one of the least attractive to one of the most attractive sites in the region. This sharp increase in benefit is unmatched in the region. Although Vestskoven was expanded by some 10% over the period, the continued afforestation efforts, decreasing open land and increasing species diversity, are far more accountable for the trend.

In general, also other urban fringe forests around Copenhagen appear more popular since the 1970s while sites further away from the population centre now provide significantly reduced welfare. The main determinants for this development can be found in a pronounced shift in mode of transport and a general change in recreation patterns in forests. Although the average yearly number of visits to forests increased by 15% at the national level, the number of car-borne trips to forests decreased over the period. This is primarily due to more people travelling by other means of transport than by car (Koch, 1978; Jensen and Koch, 1997). As a consequence, the time spent on-site and the average travel distance have dropped. Because recreationists now prefer to travel shorter distances and more often, forests far away from Copenhagen have received less visits and urban fringe forests have become more popular to visit by car. Both the changes in attributes as Vestskoven matures and the preference for urban forests have contributed to the increased welfare derived from Vestskoven.

Tracking changes in behaviour illustrates the core challenge in discrete choice modelling when predicting future benefits of new sites. Zandersen et al. (2005) transferred recreation value functions from 1977 to 1997 in the same region and found that updating the transfer model with present demand for forest recreation improves the transfer errors by an average of 182% compared to transferring both demand and preferences from 1977 to 1997.

Not only demand for forest recreation and wider societal influences on recreation behaviour play a role in valuing sites over time. Also changes in preferences of site attributes may have a significant effect. Commonalities of preferences over time suggest that people's positive attitude towards coniferous forests in this region of Denmark has remained stable, although national studies indicate the opposite (Koch and Jensen, 1988; Jensen and Koch, 1997). This is primarily due to the above average preponderance of broadleaf forest in Northern Zealand. Other commonalities that appear to stay constant include preference for large rather than small forests, sloped terrain and coastal proximity. Differences over time are found in preferences towards species diversity and openness of forests. In 1997, 62% of the population appear to prefer a species rich forest and 76,2% a dense forest whereas the 1977 model does not show significant evidence of heterogeneity of these preferences. Preferences for forests with trees older than 60 years appear to vary over the population in 1977 with 81.6% finding older trees more attractive, but showed no significant evidence of variance in preference across the population in the 1997 model. Although a few benefit transfer studies have applied random utility models to transfer value functions (e.g. Feather and Hellerstein, 1997; Parsons and Kealy, 1994), we are not aware of any examples that transfer heterogeneous preferences.

We illustrated the importance of how study sites are selected in a transfer using multiple sites by choosing three scenarios based on i) a large number of sites, ii) a restricted sampling excluding extreme attractive or not attractive sites, and iii) a sampling that only includes sites from a geographically very limited area.

The value transfer based on 51 forests shows the complexity of selecting study sites. Transfer errors, using this sampling, range from –84% to 346% although with a large majority (36 forests) producing a transfer error of ± 20%. Vestskoven, as an outlier in the region, performed the worst (346%), suggesting that transfers without a range of study sites, which cover similar characteristics as the policy site, fare poorly.

Results of the value transfers that exclude extreme sites, be they attractive or of little interest, indicate a complex relationship between which sites are included as study sites and the resulting transfer performance. The most extreme transfers where the five most valuable and least valuable sites are excluded perform generally worse than transfers of the ten most and least interesting sites. Transfers to Vestskoven appear fairly decent when excluding least valuable sites (31%-36%) whereas excluding the five most popular sites leads to nearly as large an error as the transfer based on 51 study sites (330%). The non-linearity of the sampling effect on willingness to pay is confirmed with a relatively good transfer to Vestskoven (28%) when as many as ten popular sites are excluded.

The transfer using only urban fringe forests illustrates the importance of designing sampling with a sufficient variety in distances in order to estimate the marginal utility of income. If the specification of the choice set does not allow the researcher to reveal the trade off between travelling further to an attractive site or visiting a local non-attractive forest, the recreation model may not be able to predict the true variance in preferences and will eventually not properly account for the fact that some forests are too far away and therefore have a low probability of visit. Estimating total willingness to pay is bound to underestimate the true value as the people who are willing to travel far are excluded. Our transfer therefore produces an underestimate of values of all forests in the choice set. The transfer to Vestskoven produces near average results. Termansen et al. (2004) finds positive cost coefficients when specifying the choice set too narrowly and recommends that the impact of the choice of the size of spatially defined choice sets on parameter estimates is tested before choosing a particular choice set size. The effect on the narrow choice set size can be detected in the travel cost coefficient of the transfer model, which appears slightly reduced to mean -2.44 standard deviation 0.8055 from mean –2,48 and standard deviation 1.020 of the full model specification.

The log likelihood ratio test of statistical equality of models is one of frequently used tests in the benefit literature stating that if transfer and true model are not statistically identical, the transfer is not valid (Loomis, 1992; Bergland et al.,2002, Downing and Ozuna, 1996). Applying the stringency of this test to this study would mean that only two transfers in the scenario based on 51 forests should be carried out. Despite the poor performance of the transferability test, we find a relatively clear link between the level of significance of the log likelihood ratios and the level of transfer errors. For instance, we find that forests in the transfer scenario based on 51 sites with log likelihood ratio scores between 48 and 65 (which is significant at the 0.1% level) all have transfer errors between $\pm 20\%$ while forest transfers performing worse have either a far higher significance level or a differently specified trip allocation model altogether. A similar link between transfer errors and log likelihood ratios can be detected in the transfer based on attractiveness. Here, the log likelihood ratios of the transfer models with most extreme exclusions have far higher significance levels and higher transfer error than models excluding either 10 of the most popular or least popular forests. Downing and Ozuna (1996) conclude in their value transfer study that although the transfer model may be statistically equivalent with the true model, the same is not necessarily so for the willingness to pay measures. Complementary to this, we find that, although the set of coefficients of the transfer models are not equivalent to the full model, transfer results may still perform within reasonable limits, e.g. $\pm 20\%$. It should be noted though, that these errors appear in the case of benefit transfers within one region where the maximum distance to one of the forests by the sample population is 156km. The total value of access of the transfer models is estimated over the same population and the recreation opportunities are constant across the transfers (with the exception of the study-site(s)). These are very favourable conditions for a benefit transfer, not normally the case in benefit transfers.

This study has exemplified a number of issues necessary to take into account when valuing new forest sites, including capturing changes in preferences over time, tracking changes in recreational behaviour and dealing with the complexity of selecting the right choice set in terms of size, location and attributes. The study and results have only been made possible through the availability of a unique data set, repeated twice over a long time period. Combining this data set and valuation of new afforestation sites spurred by the expansive Danish forest policy should be a must.

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# 7. Tables

**Table 1 Site Characteristics of Vestskoven 1972-1997 & Average Attributes of Other 51 Forests**

| *Site Characteristics* | *1972* | *1977/80* | *1997* | *Average 51 Forests 1997* |
|---|---|---|---|---|
| Total Area (ha) | 821 | 1239 | 1361.24 | 445.453 |
| Afforested (ha) | 269 | 535 | 665.74 | 375.4 |
| Open land (ha) | 552 | 704 | 695.5 | 70 |
| Fraction broadleaf (%) | 74% | 74% | 70% | 0.745 |
| Open land (%) | 53% | 86% | 51% | 16% |
| Shannon species index | 0.997 | 0.879 | 1.747 | 1.270 |
| Shannon age index | n/a | 0.163 | 0.636 | 1.752 |
| Fraction of trees older than 60 years | n/a | 0.005 | 0.002 | 0.424 |

**Table 2. Count Model Variables**

| VARIABLE | MEASUREMENT |
|---|---|
| Income[1] | Yearly gross income at parish level |
| Age[2] | Year of birth |
| Car ownership[1] | Dummy variable. 1= owing at least one car in the household; 0 otherwise |
| Distance[3] | Shortest Euclidian distance through road network from home address of respondents to the nearest of the 52 forests in the choice set. |
| Visit frequency[4] | Total number of car-borne forest visits per year |

Source:
[1]Statistics Denmark (2004)
[2] Jensen and Koch (1997)
[3] Kort & Matrikelstyrelsen (1995)
[4] Own calculations, based on Jensen and Koch (1997)

**Table 3. Site Attributes.**

| VARIABLE | MEASUREMENT | Data Source |
|---|---|---|
| Travel distance | Shortest distance through road network from the origin of the trip given by the respondents to the sites. The travelled distance is measured to the visited site and back to trip origin. The distance to the alternative sites are measured to the representative survey location. | Koch, N.E. (1980); Jensen, F.S. (2003)<br>Kort & Matrikelstyrelsen (1995) |
| Forest area | Size of the forest | Danish Forest and Nature Agency (1977/1997) |
| Distance to coast | Euclidian distance from aggregate site to nearest coastline | Miljø & Energiministeriet and Danmarks Miljøundersøgelse (2000) |
| Slope | The average slope index of the 1 km by 1 km area around the aggregated sites. | Skov-Petersen (2002) |
| Distance to View point | Euclidian distance from aggregate site to nearest view point | Kort & Matrikelstyrelsen, (1995) |
| Planting Year | Shannon diversity index;<br>% trees older than 60 years | Danish Forest and Nature Agency (1977/1997) |
| Species (family level) | Shannon diversity index;<br>% broadleaf;<br>% coniferous | Danish Forest and Nature Agency (1977/1997) |
| Water presence | Continuous variable. Fraction water within forest area | Danish Forest and Nature Agency (1977/1997) |
| Open Space (landscape type) | % afforested area within forest | Danish Forest and Nature Agency (1977/1997) |

**Table 4. Mixed Logit Model of Car-borne Forest Recreation in 1977 and 1997 (1997 prices, DKR)**

| | | Mixed Logit 1977 | | Mixed Logit 1997 | |
|---|---|---|---|---|---|
| VARIABLES | | Estimates | asymptotic z- | Estimates | asymptotic z- |
| Travel cost | Mean of ln(coefficient) | -2,967 | 129.0 | -2.476 | 106.579 |
| | Std. Dev. of ln(coefficient) | 1.092 | 35.226 | 1.020 | 37.449 |
| Shannon species index | Mean of coefficient | 2.461 | 16.085 | 1.116 | 6.409 |
| | Std. Dev. Of coefficient | | | 3.639 | 12.951 |
| Fraction of open land | Mean of coefficient | -1.692 | 8.096 | -4.192 | 12.012 |
| | Std. Dev. Of coefficient | | | 5.880 | 13.665 |
| Fraction of trees > Age60 | Mean of coefficient | 3.279 | 15.689 | 3.902 | 16.040 |
| | Std. Dev. Of coefficient | 3.641 | 10.709 | | |
| Fraction coniferous | Mean of coefficient | 0.538 | 3.611 | 0.831 | 4.737 |
| | Std. Dev. Of coefficient | 1.833 | 5.120 | 2.000 | 3.569 |
| Log(size) | Mean of coefficient | 0.915 | 48.158 | 1.295 | 38.684 |
| Log (coast) | Mean of coefficient | -0.565 | 17.656 | -0.539 | 10.789 |
| Slope | Mean of coefficient | 0.158 | 3.762 | 0.279 | 6.725 |
| Fraction of water bodies | Mean of coefficient | 2.316 | 6.598 | 2.752 | 9.998 |
| Coast Error component | Std. Dev. Of coefficient | 1.288 | 7.951 | 1.360 | 5.329 |
| Mean Log-likelihood | | -2.563 | | -2.304 | |
| Sample size | | 6580 | | 6987 | |
| Choice set size | | 52 | | 52 | |

**Table 5. Count Data Model Results**

| | | | | | |
|---|---|---|---|---|---|
| Inflation model | = | normal | Number of observations | = | 283 |
| Log likelihood (Zinb) | = | -649.85 | Nonzero obs | = | 122 |
| Log likelihood (Poisson) | = | -7305.12 | Zero obs | = | 161 |

| | Variable | Coefficient | Asymptotic-z |
|---|---|---|---|
| Negative binomial | Constant | -3.059 | 0.058 |
| | income | 0.02 | 0.001 |
| | Age 25-39 | -1.078 | 0.01 |
| | Inclusive value | 0.0874 | 0.084 |
| Dispersion parameter | Alpha | 2.986 | 0.00 |
| Inflation Function | Constant | 2.629 | 0.00 |
| | Car owner | -1.954 | 0.00 |
| | distance nearest forest | -0.313 | 0.00 |
| Vuong Test of Zinb vs. Neg. Bin: Std. Normal | | 5.065 | |

**Table 6. Predicted Number of Car-borne Visits and Values of Site Access**

| *Economic Measure* | *1977** | *1997* |
|---|---|---|
| ***Vestskoven*** | | |
| Compensating Variation (*€/year/site)* | $44.6*10^3$ | $3*10^6$ |
| Total Value of Car-Access per ha (*€/year)* | 36 | 2.201 |
| Number of car-borne visits *(site)* | $9.7*10^3$ | $1.2*10^6$ |
| ***All 52 Forests*** | | |
| **Compensating Variation (*€/year/site)*** | | |
| Minimum | $13.9*10^3$ | $12.2*10^3$ |
| Maximum | $6.3*10^6$ | $10.4*10^6$ |
| Average | $7.1*10^5$ | $7.5*10^5$ |
| **Total Value of Car-Access per ha** (*€/year/ha)* | | |
| Minimum | 14 | 26 |
| Maximum | 9.233 | 22.437 |
| Average | 500 | 1.630 |
| **Number of car-borne visits***(site)* | | |
| Minimum | $3.7*10^3$ | $3.4*10^3$ |
| Maximum | $1.87*10^6$ | $2.9*10^6$ |
| Average | $1.2*10^5$ | $2.2*10^5$ |

Note: EUR are converted to real 1997 prices

**Table 7 Error Margins of Three Transfer Scenarios**

| Transfer Scenario | | | Error Margin |
|---|---|---|---|
| Transfers based on Least Attractiveness | 5 Forests excluded | average | 26% |
| | | min | -28% |
| | | max | 169% |
| | | Vestskoven | 36% |
| | 10 Forests excluded | average | 21% |
| | | min | -32% |
| | | max | 154% |
| | | Vestskoven | 31% |
| Transfers based on Most Attractiveness | 5 Forests excluded | average | 55% |
| | | min | -49% |
| | | max | 330% |
| | | Vestskoven | 330% |
| | 10 Forests Excluded | average | -8% |
| | | min | -191% |
| | | max | 55% |
| | | Vestskoven | -28% |
| Transfer based on 51 forests | | average | -4% |
| | | min | -86% |
| | | max | 349% |
| | | Vestskoven | 349% |
| Transfers based on Urban Forests | | average | -66% |
| | | min | -99% |
| | | max | -19% |
| | | Vestskoven | -57% |

# 8. Figures

**Figure 1. Changes in Forest Recreation Values over Time**

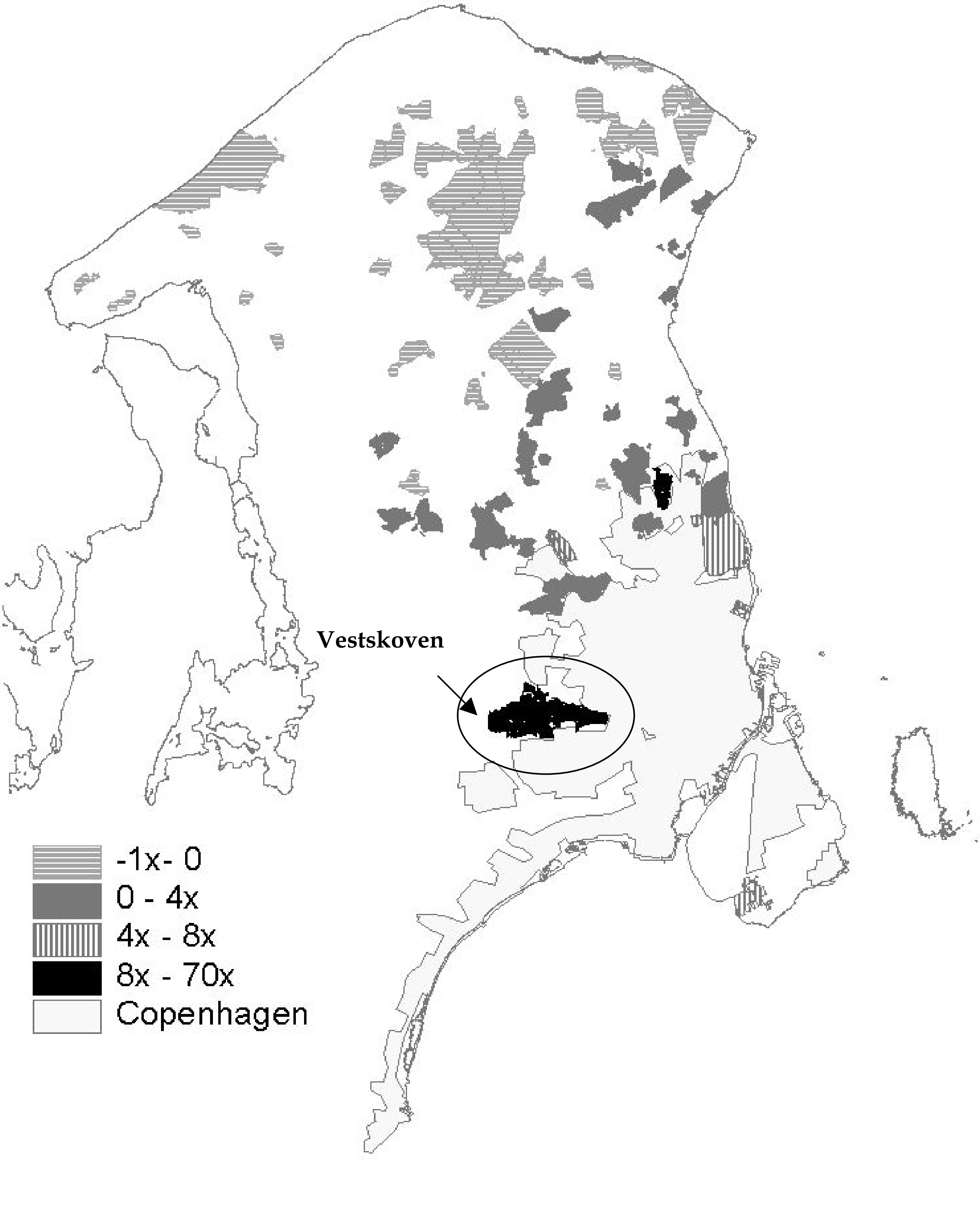
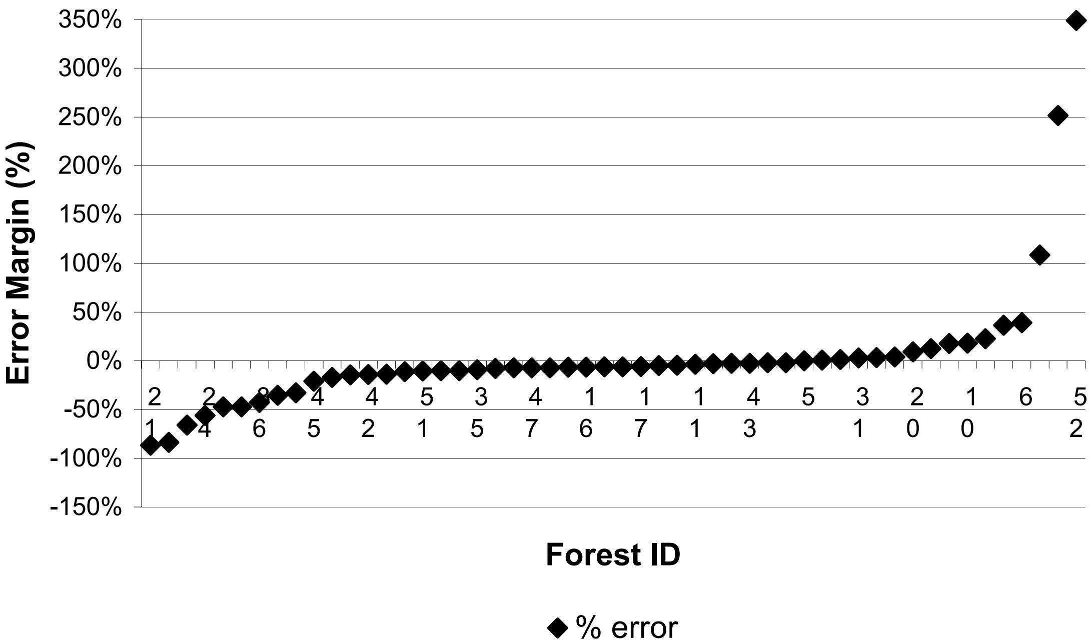


**Figure 2 Benefit Transfer Results of one forest at a time, all forests**



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