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Mapping of the forest recreation service in Lorraine: Applying high-resolution spatial data and travel mode information

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Abstract

Focus on ecosystem services and increased availability of spatial dataset describing ecosystems have generated a large interest in ecosystem service mapping. Maps of ecosystem services make the spatial heterogeneity in supply of demand for ecosystem services evident and they may serve as important tools for management and spatially targeted policies. In the present study we develop an approach for mapping forest recreation service based on high-resolution data and explicitly accounting for the visitors' choice of travel mode. The demand for forest recreation, including the demand for forest attributes is estimated, applying the travel cost method and using data from a web-based survey and from a GIS database describing forests and the access to forests. The approach is applied to data from a recent survey carried out in Lorraine. Compared to previous mappings of the economic value of forest recreation, the present study also accounts for visitors who are not going by car, i.e. we include people walking and biking to the forests. In Lorraine car-borne visitors represent only about half of the forest visitors. The results shows that the choice of travel mode depend on the access to forest, implying that the travel mode should be modelled as an endogenous variable in scenarios where access to forest changes. The proposed model framework allow for this.

Keywords: Ecosystem Services, Mapping, Forest Recreation, Travel cost method, Travel mode choice

JEL: Q51, Q230, Q570

Introduction

Recreation or physical and experiential interactions is a non-market cultural ecosystem service supplied by and demanded from forests (MA, 2005; Haines-Young and Potschin, 2012). Due to the public good characteristic of forest recreation, there is the tendency of undervaluation because of market failures (Bestard and Font, 2010). To address the market failures and to assess the economic value of forest recreation both the supply and the demand have to be taken into account (Schägner et al., 2013). Therefore the interaction of demand and supply regarding heterogeneity and substitution have to be considered on the ecosystem service assessment (Termansen et al., 2013, Abildtrup et al., 2013). On the supply side the attributes and geographical distribution of recreational sites have to be considered, as well as demand side related to the socioeconomic characteristics of recreationists and the heterogeneity in site selection preferences (Termansen et al., 2013). For this spatially inherent characteristic of the forest recreation, the mapping of recreation opportunities is essential in the assessment and valuation of the service (Schägner et al., 2013). Studies highlighting the importance of recreational forests spatial distribution have shown that forests more accessible and close to more populated areas have a higher service demand (Paracchini et al., 2014; Anderson et al., 2009; Brown et al., 2010; Natural England, 2011; Bestard and Font, 2010).

Schägner et al. (2013) made a comprehensive review of all the peer reviewed papers published before 2012 regarding ecosystem services monetary value mapping of supply and demand. 79 case studies out of 69 papers were reported, and recreation is the dominating, most often assessed ecosystem service, in a total of 50 case studies, followed by greenhouse gasses regulation in 41 records. The spatial scale range is highly variable: the smallest area is 550 ha and 5 assessments are global, although almost half of the papers assessed study areas between 1.000 to 100.000 Km^2, most often determined by political or administrative boundaries. Additionally, the most frequent number of ecosystem service assessed per case study is one, followed by 17 ecosystem services, due to the influence of the approach used by Constanza et al. (1997).

Still in the same literature review, the mapping the ecosystem services supply was divided in 5 different methodologies, as well as 4 methodologies for mapping service values. When mapping the supply, the following 5 methodologies were identified: *proxies* (LULC in most cases), *non-validated models*, in which the parameters are based on researches expertise or assumptions; *validated models*, calibrated by primary or secondary data; collected *representative data on the study area*; and *implicit modeling*, considering specific characteristics of every location when developing models. Since 84% of the case studies mapped ecosystem services using value transfer for at least one service, the authors used an analogy to the former method for defining the methodologies for assigning service monetary values spatially. The *unit value* designates constant values according to service supply; *adjusted unit values* uses intrinsic socio-economic variables that varies over space to specify different units values'; *value functions* are developed adding spatial variables to the function, accounting for individual units variation; and the *meta-analytic value function* uses regression estimation to adjust unit values'. However, many recreation case studies used mixed methodologies when mapping the service values, namely *validated models* with *unit values* or *value functions*; *non-validated* models with *unit values*; and *implicit modeling* together with *meta-analytic value functions*.

In the present study we are mapping the forest recreation service for Lorraine. The objective is to develop and to test a mapping approach applying spatially detailed data on the supply of forest recreation possibilities and econometrically estimated models for forest recreation demand. In the terminology of Schägner et al., (2013) we apply *value functions* based on *validated models*. Based on a survey of a representative sample of the population in Lorraine we have applied the travel cost method to estimate the demand for forest recreation. In particular, following the approach in Termansen et al (2013) Zandersen et al. (2007a, 2007b) we have applied a so-called site-selection model (e.g. Bockstael et al 1987) to estimate the population's preferences for the forest types and a trip demand model to estimate the demand for forest trips (annual number of recreational visits in forests). However, compared to previous studies, our approach includes all visits to forest – also visits that is not car-borne – and we model the travel mode choice explicitly. In Lorraine, about one half of the forest visitors goes by bike or walk to the forest. Difficulties in estimating alternative cost of time may be one of the reasons for ignoring visits that is not car-borne. Applying the travel cost method to visitors walking or biking hinge on a correct estimation of cost of the travel time. Another reason may be that the travel cost method as most often been used in an American context where, compared to Europe, a higher share of forest visits is car-borne. Finally, the present study provides a spatially high-resolution mapping, applying general available GIS dataset.

In the following section we describe the applied methodology, i.e. the econometric estimation of the site selection and trip demand models and the mapping approach. Then we describe the applied dataset and we provide some application of the mapping framework before concluding the paper with a discussion.

Methodology

Our approach to mapping of recreational services consists of 3 model components: First we apply a site selection model to estimate the preferences for forest attributes. We estimate a travel mode-specific model where the travel costs are conditioned on the travel mode. The site selection is used to estimate travel mode and location-specific specific values of a forest visit. Then, these values are used as explanatory variables in estimating trip demand model conditioned on travel mode. Finally, we use also the estimated travel mode and location specific values of a forest visits and a conditional logit model to estimate the probability of participating in forest recreation (visiting a forest at least one time) and the probabilities of the different travel modes. The three model components are used to calculate the number of visits, the value of a specific forest or the value of changing the recreative quality of a specific forest or of the forests in general. Combining the three model component allow to estimate the substitution effect between forest (the site selection model) and the effect on trip demand and travel mode of chancing quality or access to forests.

The mapping tool

First we apply the site selection model to assess the preferences for forest characteristics (Bockstael et al. 1989). The model is estimated using revealed preference data. The site selection model and data are previously documented in (Abildtrup et al. 2014) and will therefore only be discussed relatively briefly.

The basic idea in the RUM is that the individual chooses from a number of alternatives and selects the one that yields the highest utility level on any given choice occasion. Assume that a forest visitor, *n*, living in municipality, *i,* has a travel mode-specific choice set, $CS_i(m)$, of possible multi-attribute forest sites to choose from. The utility for visiting forest *j* conditional on travel mode *m* is given by:

$U_{inj}(m) = \boldsymbol{x}_j\boldsymbol{\beta}_n + \gamma_n p_{inj}(m) + \varepsilon_{inj}(m)$ for j=$CS(m)$ (1)

assuming a linear indirect utility function of visiting forest *j.* $\boldsymbol{\beta}_n$is a parameter vector specific for visitor *n*, $\mathbf{X}_j$ is a vector of variables describing the forest *j*, $p_{nj}(m)$is the individual's cost of visiting forest *j*, given travel mode *m* and $\varepsilon_{inj}(m)$ ε_{nj} is the stochastic element of utility. If the error terms are independently and identically distributed following an extreme value (Gumbel) distribution, the RUM model is specified as conditional logit (CL) for individual *n*. Taking preference heterogeneity in the population into account we apply an MXL model where we allow $\boldsymbol{\beta_n}$ and $\boldsymbol{\gamma_n}$ to vary over individuals defined by the distribution $f(\boldsymbol{\beta},\boldsymbol{\gamma}|\boldsymbol{\theta})$. This implies that the unconditional probability of choosing site *l* is defined as:

$$P_{nim}(l) = \int_{-\infty}^{\infty} \frac{e^{x_l\beta_n+\gamma_n p_{inl}(m)}}{\sum_{j\in CS(m)} e^{x_j\beta_n+\gamma_n p_{inj}(m)}} f(\boldsymbol{\beta},\gamma|\boldsymbol{\theta})d\boldsymbol{\beta}d\gamma \qquad (2)$$

Applying the estimated utility function in equation (1) we are can estimate the expected maximum utility of visiting a forest for an individual living in municipality *i* for a given choice occasion (see, e.g., Bockstael and McConnell 2006) conditioned on the travel mode *m* and on preferences, $\boldsymbol{\beta}$ and γ and assuming that the error terms, $\varepsilon_{inj}(m)$, are distributed independently and identically distribution type I extreme value:

$$V_{ni}(m|\boldsymbol{\beta},\gamma) = E\left[\max_{j\in J}\{\boldsymbol{x}_l\boldsymbol{\beta}_n + \gamma_n p_{inl}(m) + \varepsilon_{inj}(m)\}\right] = \ln(\sum_{j\in CS} e^{\boldsymbol{x}_l\boldsymbol{\beta}_n+\gamma_n p_{inl}(m)}) + C \quad (3)$$

where *C* is an unrecoverable constant and we condition on the parameter values $\boldsymbol{\beta}$ and γ. Using that the parameter on the travel cost parameter represents the marginal utility of income we can convert the expected maximum utility into a monetized utility per trip to a forest for an individual living in location *i*

$$WTP_i(m|\boldsymbol{\beta},\gamma) = \frac{\ln(\sum_{j\in CS} e^{x_j\boldsymbol{\beta}_n+\gamma_n p_{inj}(m)})}{-\gamma} + \bar{C} = \frac{I_i(m|\boldsymbol{\beta},\gamma)}{-\gamma} + \bar{C} \quad (4)$$

where $I_i(m|\boldsymbol{\beta},\gamma)$ is normally termed the inclusive value. Consequently, we can estimate the monetary value of changing the characteristics for the forest *j* from x_j to x_j^* which corresponds to the expected compensating variation for one trip

$$E\left[CV_i^m(x_j, x_j^*|\boldsymbol{\beta},\gamma)\right] = \frac{\ln(\sum_{j\in CS} e^{x_j^*\boldsymbol{\beta}_n+\gamma_n p_{inj}(m)})}{-\gamma} - \frac{\ln(\sum_{j\in CS} e^{x_j\boldsymbol{\beta}_n+\gamma_n p_{inj}(m)})}{-\gamma} \quad (5)$$

And we can estimate the expected compensating variation of closing forest, *k*, in the choice set for recreational visitors given the travel mode:

$$E[CV_i^m(k|\boldsymbol{\beta},\gamma)] = \frac{\ln(\sum_{j\in CS} e^{x_j\boldsymbol{\beta}_n+\gamma_n p_{inj}(m)})}{-\gamma} - \frac{\ln(\sum_{j\in CS-k} e^{x_j\,\boldsymbol{\beta}_n+\gamma_n p_{inj}(m)})}{-\gamma} = \frac{ln[1-P_{nim}(k|\boldsymbol{\beta},\gamma)]}{-\gamma} \quad (6)$$

The inclusive value which is not conditioned on the preference parameters, $\boldsymbol{\beta}$ and γ, is calculated:

$$I_i(m) = \int_{-\infty}^{\infty} I_i(m|\boldsymbol{\beta},\gamma)\, f(\boldsymbol{\beta},\gamma|\boldsymbol{\theta})d\boldsymbol{\beta}d\gamma \quad (7)$$

The inclusive value estimated in (4) can be considered as an indicator for each municipality the attractiveness of forests conditioned on the travel mode. We will in the present study use this value to explain the number of visits, and the decision to go or not to the forest, during twelve months. The inclusive value in monetary terms was interpreted as an price index of recreational visits in (Hausman, Leonard, & McFadden, 1995). The higher inclusive value the more likely it is that an individual will go to a forest and the higher is the expected number of visits. We use this approach as a pragmatic approximation, recognising that (Herriges, Kling, & Phaneuf, 1999) has shown that combining the RUM model and a trip demand model does not represent a consistent utility theoretic framework.

Before estimating the number of trips for an average individual in a given municipality we estimate the probability that an individual will go to the forest and the principal travel mode. We apply a conditional logit model in a simultaneous estimation of the choice to go to the forest and the choice of travel mode.

$$U_{in}(m^*) = \begin{cases} \delta_{car} I_i(car) + I_i(car)\mathbf{z}_{in}\boldsymbol{\delta}_{carz} + \varepsilon_{in}(car) \\ \delta_{bike} I_i(bike) + I_i(bike)\mathbf{z}_{in}\boldsymbol{\delta}_{bikez} + \varepsilon_{in}(bike) \\ \delta_{walk} I_i(walk) + I_i(walk)\mathbf{z}_{in}\boldsymbol{\delta}_{walkz} + \varepsilon_{in}(walk) \\ \varepsilon_{in}(home) \end{cases} \quad (8)$$

Where m^*={*car*, *bike*, *walk*, *home*} where *home* is indicating that an individual does not go to the forest during the last 12 months.

Then the probability of staying at home or going to the forest by travel mode *m* can be calculated:

$$P_{ni}(home) = \frac{1}{\sum_{m^* \in \{car,\ bike,\ walk, home\}} e^{\delta_m I_i(m) + I_i(m) z_{in} \delta_{m^*z}}} \quad \textbf{(9)}$$

And the probability of going to the forest by travel mode *m* is calculated:

$$P_{ni}(m) = \frac{e^{\delta_m I_i(m) + I_i(m) z_{in} \delta_{m^*z}}}{\sum_{m^* \in \{car,\ bike,\ walk, home\}} e^{\delta_m I_i(m) + I_i(m) z_{in} \delta_{m^*z}}} \quad \textbf{(10)}$$

The number of trips to a forest is estimated with a negative binomial model which account for the discrete nature of the trips to the forests and is a generalisation of the less general Poisson count data model. We estimate a trip demand model specific for the travel mode. In the estimation of the trip demand model we only include respondents who have visited a forest, since we do not know the travel mode for the non-respondent. This implies that the lowest number of trips observed is one. Therefore, we apply the truncated count model suggested by (Grogger & Carson, 1991) where the probability of t_n visits for by forest visitor *n* is defined

$$P_{ni}(t|t>0,m) = \frac{\Gamma\left(1+\frac{1}{a}\right)}{\Gamma(t+1)\Gamma\left(\frac{1}{a}\right)} (a\lambda_{ni}^m)^t [1 + a\lambda_{ni}^m]^{-\left(t+\frac{1}{a}\right)} [1 - F_{NB}(0)]^{-1} \quad (11)$$

Where $F_{NB}(\cdot)$ is the cumulative negative binominal distribution, $\lambda_{ni}^m = E[t|h_{ni}, m] = e^{(h_{ni}^m \vartheta_m)}$ is the unconditional mean number of visits, h_{ni}^m is the a vector variables describing the forest visitor and the municipality where the visitor lives given travel mode *m*. The vector h_{ni}^m includes the travel mode-specific inclusive variable $I_i(m)$. *a* >0 is a nuisance parameter to be estimated together with ϑ_m and $\Gamma(\cdot)$ is the gamma distribution.

To calculate the aggregate compensating variation over individuals and number of visits of changing the recreative quality of forests or the access to forest we follow (Creel & Loomis, 1992) where the welfare is calculated before and after the changes and the difference is measuring the compensating variation. However, we include in our study the potential change in travel mode as a result of scenario changes. The loss of value of closing site *k* for the population in municipality *n*

$$CV_{ik}^{total} = pop_i \sum_m \left[I_{ik}(m) e^{(h_{ni}^m \vartheta_{mk})} \left[1 - F_{NB}^k(0)\right]^{-1} P_{ni}^k(m) - I_i(m) e^{(h_{ni}^m \vartheta_m)} [1 - F_{NB}(0)]^{-1} P_{ni}(m) \right] \quad (12)$$

Where pop_i is the population older than 18 years in municipality *i.* Note that this an approximate to the true value as we ignore the constant of integration *C* in (4) following (Creel & Loomis, 1992).

To estimate the total value of closing a forest accounting for total population who consider visiting the forest (forest included in their choice set) is calculated

$$CV_k^{total} = \sum_i^I CV_{ik}^{total} \quad (13)$$

The welfare changes of changes the recreational quality of forest *k* from x_k to x_k^* for the population in municipality *i* is calculated:

$$CV_{ik}^{total}(x_k, x_k^*) = pop_i \sum_m \left[I_{ik}(x_k^*, m) e^{(h_{ni}^m \vartheta_{mk_{mk}}^*)} P_{ni}^{k*}(m) P_{ni}^*(m) - I_i(x_k, m) e^{(h_{ni}^m \vartheta_m)} P_{ni}(m) P_{ni}(m) \right] \quad (14)$$

And the total value of changing the characteristics of forest *k* for the population in Lorraine is calculated.

$$CV_k^{total}(x_k, x_k^*) = \sum_i^I CV_{ik}^{total}(x_k, x_k^*) \quad (15)$$

Data and survey implementation

The data for econometric estimation of the site selection, mode choice, and trip demand models are based on a survey carried out in July-August 2010. The survey will only briefly be described here as it is reported in detail in Abildtrup et al. (2014). The administration of our questionnaire was Web-based. An email was sent to an extensive list of email addresses of inhabitants in Lorraine. Based on previous experience, a response rate of two percent was projected by the company (*EmailingFrance*) that maintained the list used. Such a low response rate of course raises a serious concern about the representativeness. 53,000 people were sent an invitation e-mail and provided a link to the questionnaire on the Web. In total, 1837 respondents began to answer the online questionnaire (3.5%), and out of these, 1144 actually completed the questionnaire (2.2%). Compared to other surveys using the same panel, the response rate was relatively high (Bougherara et al. 2013), although compared to most other preference-eliciting surveys, in general, the response rate is considered very low. Furthermore, only 816 respondents out of the 1144 respondents actually lived in Lorraine, and out of these, only 526 had visited a forest and provided information about which specific forest they had visited. Hence, our final sample used for estimating the site selection model included 526 respondents.

The questionnaire had four main sections. The first section concerned basic socio-demographic variables such as age, gender and the municipality of the respondent's residence, and how many times he/she had visited a forest over the last 12 months. The municipality (*"commune")* is the most detailed information we could obtain from the respondents about their home address. The respondents were asked to provide their postal address in a pilot survey, but the majority refused to do so. Fortunately, French municipalities are relatively small and provide a rather precise spatial location. On average, a municipality covers an area of about 10 km^2 and, with very few exceptions, consists of one town or one village with its surrounding open space.

In the second section of the questionnaire, forest visitors were asked about their visits to the forest (motives, length of visit, mode of transport, etc.) and were asked to identify the forest they had most often visited over the last 12 months by clicking on it on an integrated and interactive map showing a satellite image of the Lorraine area.

The third section of the questionnaire included a choice experiment which has been analysed in (Abildtrup et al. 2013). Only the revealed preferences data have been used for mapping carried out in the present study.

To characterize the forests in Lorrain, we combined different GIS layers to establish a spatial database of forests (Thirion 2010). Variables describing tree species composition of the forest were obtained from the French National Forest Inventory (IFN). Data describing the presence of hiking trails were obtained from the French Hiking Association (Fédération Française de Randonnée Pédestre), whereas data concerning the presence of recreational facilities, lakes and rivers in forests were obtained from the French National Geographic Institute (IGN). Basically, forests are defined as continuous land with forest cover of more than five hectares. If a forest is very large (typically, greater than 1,000 hectares), it is divided into two forest units that are considered to be a unity in our analysis. The division of forests into units was, among other things, determined by existing structures in the forest, e.g., roads or rivers.

The distance between a respondent and a given forest is the road network distance between the town hall of the municipality (*commune*) where the respondent had his/her residence (or the municipality where the respondent was temporarily residing when going to the most visited forest over the past 12 months) and the closest entry point to the forest. The road chosen when transport is by car was based on the road with the shortest distance in time. For people on foot, the road chosen was based on the shortest distance in kilometres. There is some uncertainty in the calculation of the distance since we did not know the exact place of residence of the respondent in the municipality nor which entry point to the forest was used by the respondent. We closest entry point to a forest was specific for visitors by car and warking or biking. The travel costs consisted of variable driving costs using a car (fuel and service costs) and alternative costs of time. The driving cost was based on information about the car type in the questionnaire and car type-dependent driving costs from the French Automobile Club[1]. When walking or biking to the forest, we used only alternative costs of time. We followed the standard approach in the literature where one third of the wage rate is used as the alternative cost of time (Cesario 1976)[2]. As a proxy for the hourly wage rate, we used the household revenue divided by the number of adults in the household and the average number of working hours per year. WE used average estimates of the direct costs per km for use of cars (fuel costs, etc.), but used the individual estimates of alternative cost of time. We used an average estimate of the direct costs, even though the questionnaire included questions on car type, because we do not know individual direct driving costs for visitors not going by car.

The sample and descriptive statistics

In Table 1, the main demographic and socio-economic characteristics of the effective sample used to estimate the site selection model are presented and compared with the total population of Lorraine. The share of female respondents is lower in the sample than in the population, and the 40-60-year-old respondents are overrepresented in the sample. The sample exhibits an overrepresentation of

[1] Budget of the French driver, June 2011 (www.automobile-club.org).

[2] The alternative cost of time is generally a source of discussion in the literature. Regardless of the assumption, it is true that individuals will consider a limited time budget and that the transport time will influence the choice of the forest to be visited. Even though we find this discussion to be relevant, it is beyond the scope of this paper.

people in high-income classes. The relatively high rates of middle-aged people and high-income groups in the sample are not unusual for Internet and mail surveys (Olsen 2009). Thus, even though the response rate might raise some concerns regarding the representativeness of the sample, the skewness of the sample for central socio-demographic characteristics does not seem to be much worse than similar surveys with much higher response rates.

Table 1. Sample (completed questionnaires) and population characteristics

	Sample	Lorraine
Gender distribution (% women)	39	52
Age distribution (%)		
20-39 years	24	34
40-59 years	53	37
60-74 years	21	18
75 years	1	11
Household income		
€0–9,400	5	25
€9,401–13,150	6	14
€13,151–15,000	5	8
€15,001–18,750	4	13
€18,751–23,750	10	11
€23,751–28,750	13	8
€28,751 -38,750	24	10
€38,75 –48,750	15	5
> €48,750	19	6

Source: Age and gender: INSEE – *Population estimations;* Income: Taxable income 2008. www2.impots.gouv.fr/documentation/statistiques/ircom2007/region/region.htm

The majority of the respondents (93%) had visited a forest at least once over the past 12 months and 90% had visited a forest more than once during the past 12 months, whereas 77% had visited different forests over the same period. Forest visitors had visited a forest an average of 27 times over the past year. A study carried out at the national level in France in the year 2000 (Peyron et al. 2002) estimated the average forest visits per household in France to be only nine times per year, though this only included car-borne visits. This study also found the percentage of respondents that visited a forest to be 44%. This relatively low percentage at the national level may be due to less accessibility to forests in some other regions in France and to the presence of other non-forest substitute sites.

Table 2 defines the forest attributes. Table 3 includes only variables that are kept in the final model presented in the next section.

Table 2 Descriptive statistics and variable definition

Variable	Variable definition	Mean	Std. Dev.	Min	Max
PATHONE	Is 1 if one marked hiking trail; otherwise 0	0.084	0.277	0	1
PATHMORE	Is 1 if more than one marked hiking trail; otherwise 0	0.027	0.162	0	1
FACIL_P	Is 1 if presence of parking or picnic places; otherwise 0	0.040	0.196	0	1
FACIL_PP	Is 1 if presence of parking and picnic places; otherwise 0	0.011	0.105	0	1
WATER	Is 1 if presence of lake or river	0.528	0.499	0	1
DIST	Distance to forest (km) - all forests	109	56	0	310
	Distance to visited forests, visitors driving	11.11	18.46	0.19	148
	Distance to visited forests, visitors biking	3.83	3.05	0.51	12.87
	Distance to visited forests, visitors walking	2.16	2.55	0.03	19.10
AREA	Log(Forest recreation unit (m^2))	13.0	1.6	10.4	17.8
PUBLIC	Percentage of publicly-owned forest*0.001	0.040	0.040	0	0.1
HIGHFOR	Percentage of forest with high forest*0.001	0.056	0.042	0	0.1
VAMY	Probability of finding blueberries	0.075	0.129	0.0	0.62
NATURRES	Is 1 if presence of a biological reserve; otherwise 0	0.010	0.102	0	1
FORROADS	Number of forest roads*0.001	0.014	0.033	0	0.488
CAR	Share of sample driving	51			
BIKE	Share of sample biking	10			

WALK	Share or sample walking	39

Results

Estimation of site selection model, transport mode model and trip demand model is first described. Secondly, we describe some applications of the developed mapping approach .

Econometric estimation

The estimation of site selection model is described in detail in Abildtrup et al. (2014). The definition of the choice set is travel mode-depended and was based on distance. The applied distances are 30 minutes driving time by car and 10 km and 11 km from the residential location for respondents walking and biking, respectively. These distance limits are estimated by searching for the minimum distance where at least 95% of the visited forests are inside the distance limits. Due to the high density of forests in Lorraine, the applied choice set was 20 forests sampled within the specified distance limits. We applied a strategic a strategic sampling strategy proposed by (Lemp & Kockelman, 2011) which in simulations have been shown to be less sensitive to violations of *the Independence of Irrelevant Alternatives* property when basing the estimation on sampled choice sets. A crucial assumption for the travel costs, when including the alternative costs of time, is the transport speed. For people going by car, the speed was based on the average speed for the different road types , and we assumed an average biking and walking speed of 11km/hour and 4 km/hour, respectively. These speeds are based on a sensitivity analysis and the chosen speeds give the highest log-likelihood when estimating the model.

Table 3 shows the results of the mixed logit estimation (equation 1) where we have conditioned on travel mode. The respondents have positive preferences for recreational facilities in forests, i.e., hiking trails, parking places and picnic places. They also prefer a forest with either a lake or a river, though this is not significant. Large forests are preferred to small forests. We use the logarithm of the forest size since this transformation resulted in better model fits than when directly using the size or using other transformations. Forests with a large share of old high forest are not significantly preferred to young forests or forests with coppice management, as expected from the focus group interviews. Forests with a large share of public ownership are preferred to forests with a large share of privately owned land. In the present sample of forests, we do not know if the private forest owner has closed the forest to the public, which may partly explain this revealed preference for publicly-owned forests. However, the majority of the private forests in Lorraine are open to public access. The presence of zones designated as biological reserves has a negative impact on utility. We found that the number of forest roads has a negative impact on the choice of a forest. This may indicate that visitors prefer forests that are not intensively managed. With both sampling schemes, we found that the travel cost variable is negative and highly significant. Considering the preference heterogeneity found in Table 3, we only found that the distribution of the distance variable has a significant standard deviation. The other variables (AREA, PUBLIC, FORROADS) with estimated standard deviations were kept in the model even if they were not (highly) significant because they were significant in initial estimations. The included alternative specific constants (ASCB and ASCW) were only significant for walking mode. This indicates that people walking to the forests have a positive utility of walking compared to going by car, beyond what is explained by the forest attributes.

Table 3 Estimation of site selection model conditioning on travel mode *m*:

Variable	Coefficient	s.e.	P[|Z|>z]
PATHONE	0.42	0.145	0.008
PATHMORE	0.48	0.192	0.026
FACIL_P	0.36	0.164	0.109
FACIL_PP	0.79	0.222	0.004
WATER	0.35	0.137	0.027
AREA	1.00	0.101	0.000
PUBLIC	9.94	2.693	0.004
HIGHFOR	3.36	2.343	0.245
VAMY	1.73	1.090	0.214
NATURRES	-1.14	0.524	0.099
FORROADS	-7.90	1.920	0.001
TC ($-\gamma$)	-1.11	0.061	0.000
Derived standard deviation of parameter distribution			
AREA	0.28	0.20	0.188
PUBLIC	2.38	13.72	0.854
FORROADS	5.71	3.54	0.129
TC	1.11	0.06	0.000
McFadden Pseudo R-squared	0.40		

Applying the estimated utility function reported in Table 3 the travel mode-specific inclusive value is calculated using equation (7) for each of the municipalities. We see that the largest standard deviation concerns the inclusive value for people walking. This is because visitors who have decided to walk are more sensitive to having local access to attractive forests while visitors going by car have lower cost per km and are therefore more flexible with respect to finding attractive forests according to their preferences. This variation in the inclusive value over municipality is a key variable in estimation of the conditional logit model of travel mode choice (equation 8) and is reported in Table 6. We see that for people walking and going by car the inclusive value are significant in explaining the choice. However, the inclusive value conditioned on biking was not significant. This indicate that biking visitors was not really considering the access to forest when deciding to bike to a forest. It should be noted that only a relative low share of the respondent in the survey did go by bike and the number of observations may be too low to find a statistical significant effect of this variable. We did also find that the effect of inclusive value for people going by car increased with the age of the respondents.

Table 5 Travel-specific inclusive values, descriptive statistics

Inclusive value	mean	s.d.	Min	max
$I_i(car)$	22.33	0.90	20.31	24.77
$I_i(bike)$	20.91	1.20	18.04	24.15
$I_i(walk)$	18.66	1.85	12.78	22.99

Table 6 Conditional logit of decision to go to forest and of travel mode

Variable	Coefficient	s.e.	z	P[|Z|>z]
$I_i(car)*age$	1.488	0.787	1.890	0.059
$I_i(car)$	0.128	0.009	13.900	0.000
ASC(*bike*)	0.635	0.361	1.760	0.078
$I_i(bike)$	-0.016	0.025	-0.650	0.519
ASC(*walk*)	-0.326	0.175	-1.860	0.063
$I_i(walk)$	0.146	0.012	11.980	0.000
N	818			
Log likelihood	-892.37840			

In table 7 we have reported the truncated trip demand models for the three travel modes. We find that the inclusive value has a statistical significant positive effect on the number of annual visits to a forest as expected. Age has a statistical significant effect on the number of visits. For visitors going by car, the annual number of visits decreases by age while it increases for visitors biking or walking. Female visitors go less often to the forests for all three travel modes. For visitors going by car the length of residence in the same municipality increased the number of visits while the number of visits decreased by biking visitors having only a basic education.

Table 7 Mode-specific truncated trip demand model

Variable	parameter	s.e.	*z*	P[|Z|>*z*]
Car trips				
I_i(*car*)	0.233	0.086	2.720	0.006
Age3	-0.467	0.172	-2.710	0.007
Age4	-0.938	0.475	-1.970	0.049
Female	-0.724	0.144	-5.020	0.000
Residence	0.011	0.005	2.280	0.023
Constant	-2.035	1.901	-1.070	0.284
alpha	1.883	0.227		
N=400	Log likelihood = -1627.3291			
Bike trips				
I_i(*bike*)	0.082	0.087	0.940	0.347
Edu0	-0.484	0.297	-1.630	0.103
Female	-1.327	0.286	-4.650	0.000
Constant	1.876	1.790	1.050	0.295
alpha	0.864	0.180		
N=69	Log likelihood = -284.7139			
Walk trips				
I_i(*walk*)	0.096	0.038	2.550	0.011
Age2	0.823	0.205	4.020	0.000
Age34	0.591	0.256	2.310	0.021
Female	-0.272	0.171	-1.590	0.112
Constant	0.958	0.708	1.350	0.176
alpha	1.934	0.263		
N=291	Log likelihood = -1246.3073			

Mapping of baseline and scenario[3]

Below we show some applications of the mapping approach presented above. Figure 1 show the number of visits per ha where the spatial units are the forest recreational units used in the site selection model. We see, as expected a high variability in the number of visits per ha. Comparing with the map in figure 2, the population of the municipalities in Lorraine, we see that the highest number of visits is found close to the urban agglomerations. The same patterns are seen when we have calculated the loss in WTP (compensating variation) of closing individual forests (equation 13) and mapped in figure 3. This is carried out one by one, i.e. that we consider that the visitors can still go to the 5268-1 forests. The loss per forest is between less than one Euro to more than 2 million Euros per year. Besides being close to an urban agglomeration the size of the forest has an effect on this measure. In figure 4 we measured the loss of closing a forest in CV per ha and year and shows that the distance to urban agglomerations are the dominant determinants of the loss estimates. In figure 5 we have mapped the benefit of introducing a picnic and parking place in forests not already having such facilities. Again the map shows the value of introduction only picnic and parking places in one forest at the time. Again access to urban agglomerations and forest size is important determinants

[3] In the present version of the paper the estimates are only based on the 552 municipalities that were represented in the survey of the population's recreation use of forests in Lorraine. These represent about two third of the population in Lorraine. Updating with all municipalities is ongoing.

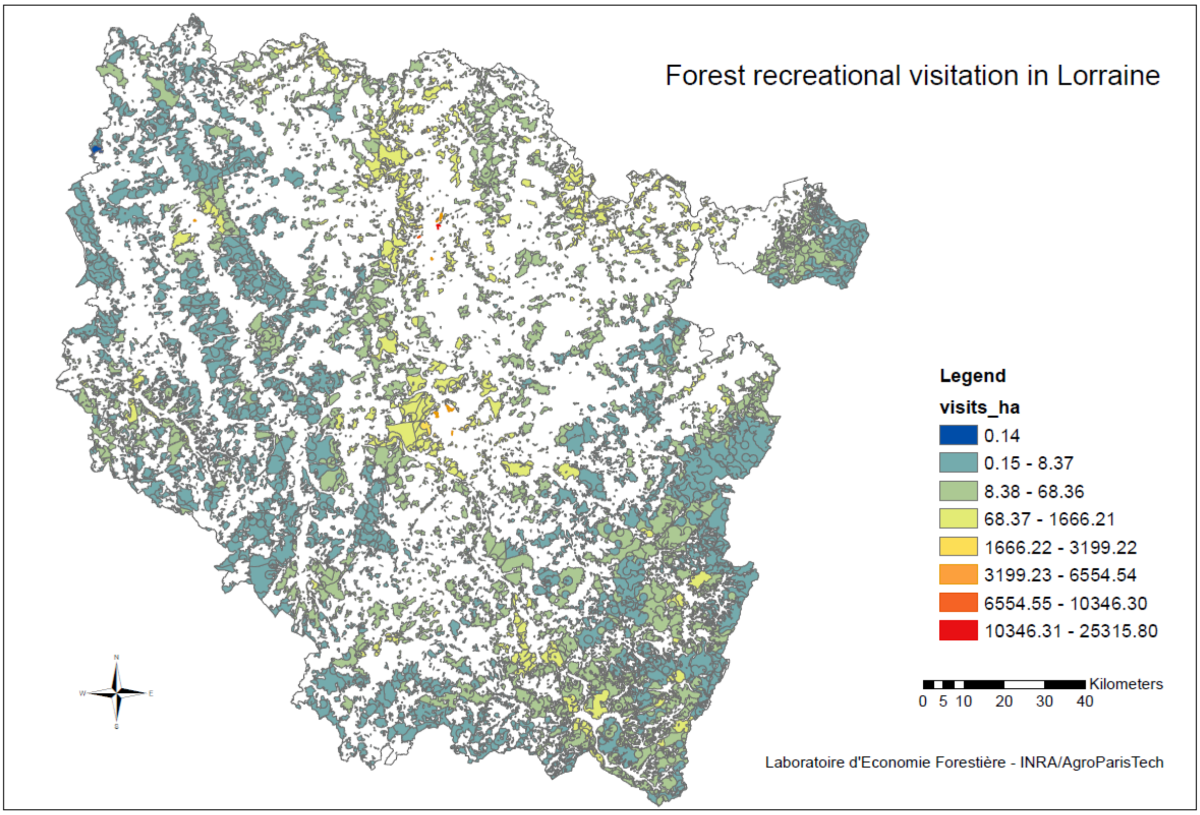

Figure 1 the estimated number of visits per ha per year.

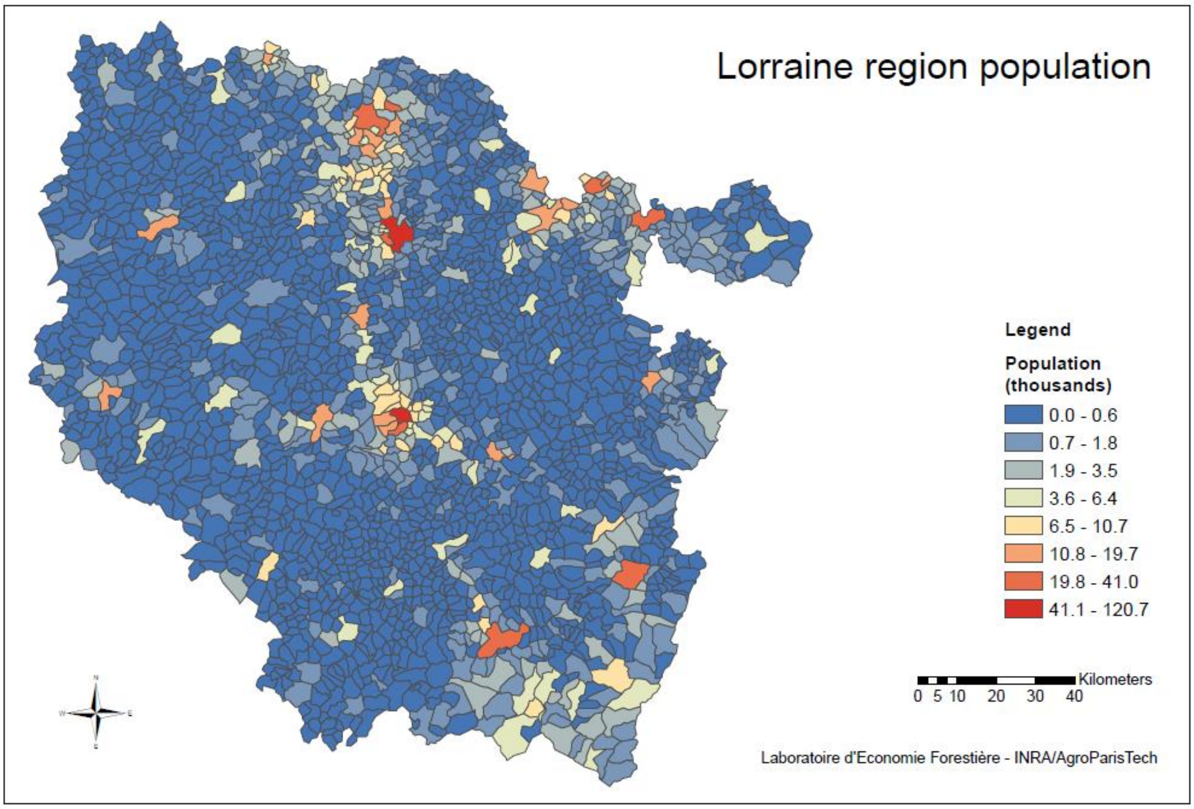

Figure 2. Population in municipalities of Lorraine

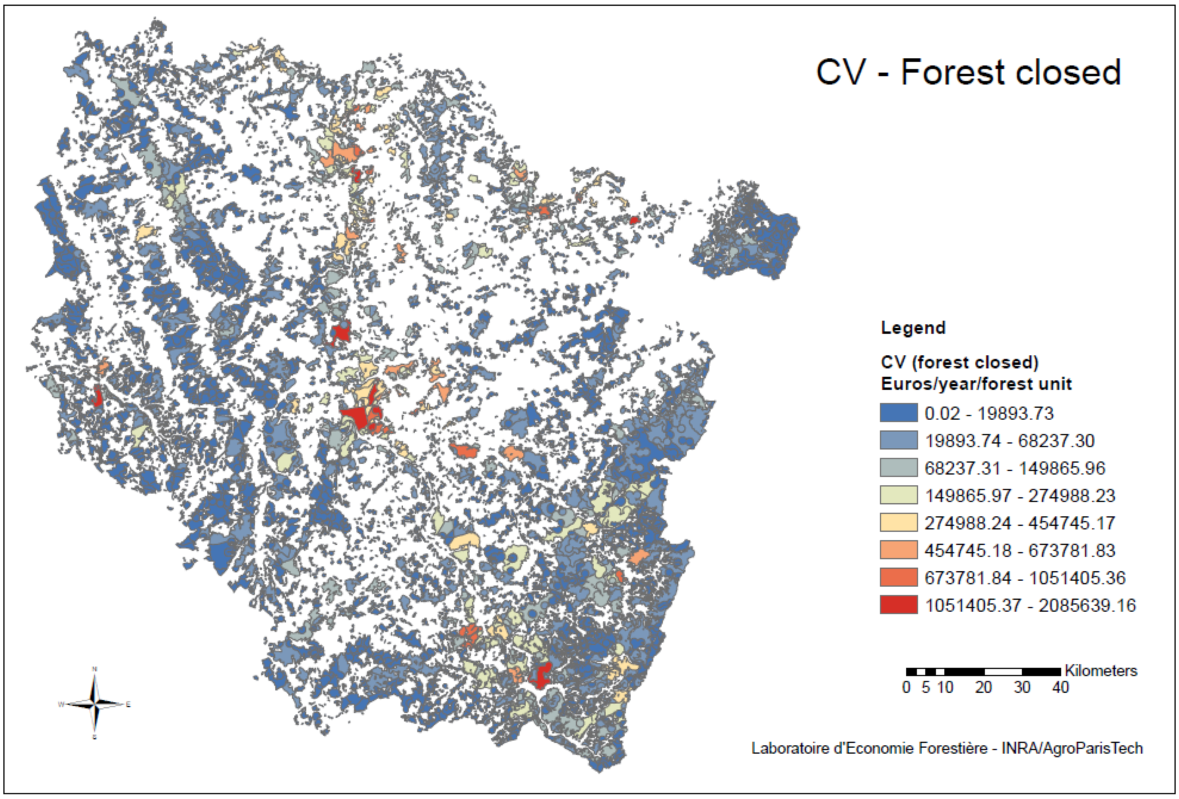

Figure 3 The compensating variation (CV) of closing the assess to forest units

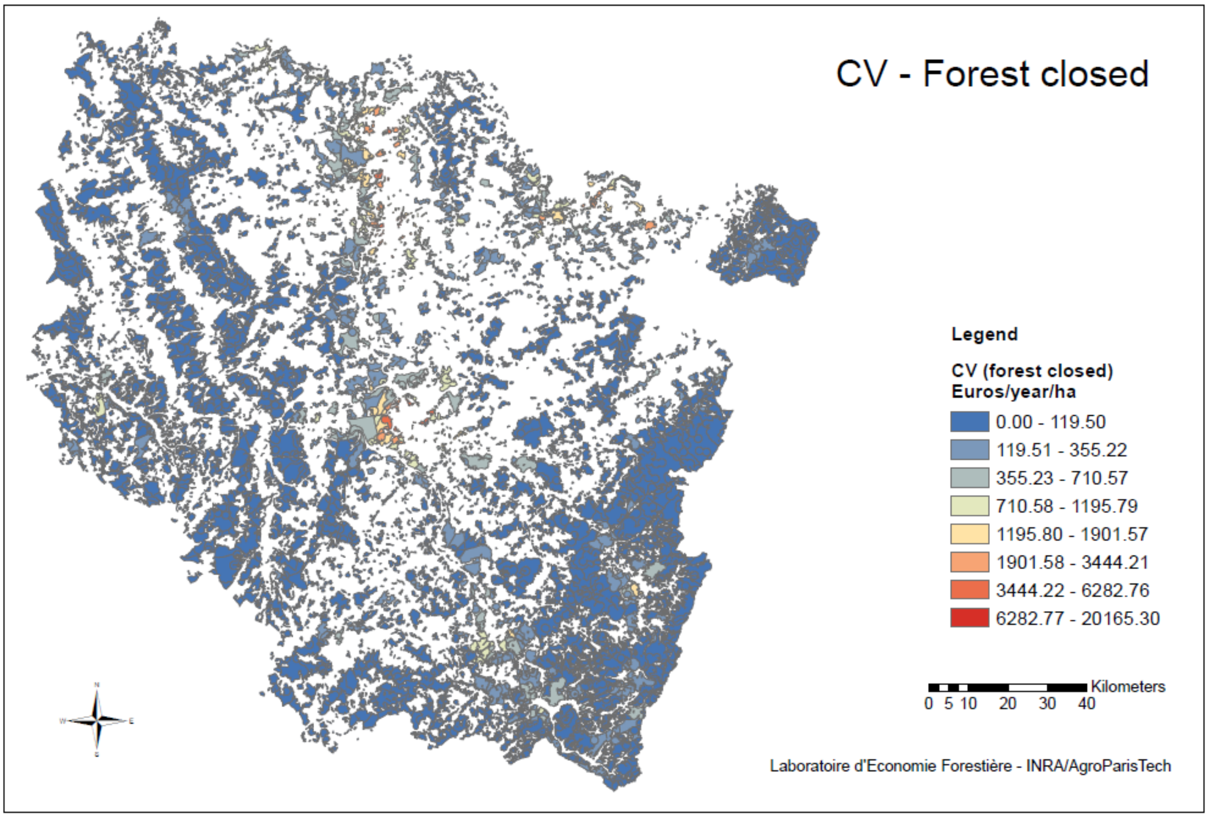

Figure 4 The compensating variation (CV) of closing the assess to forest units in Euros per year per ha

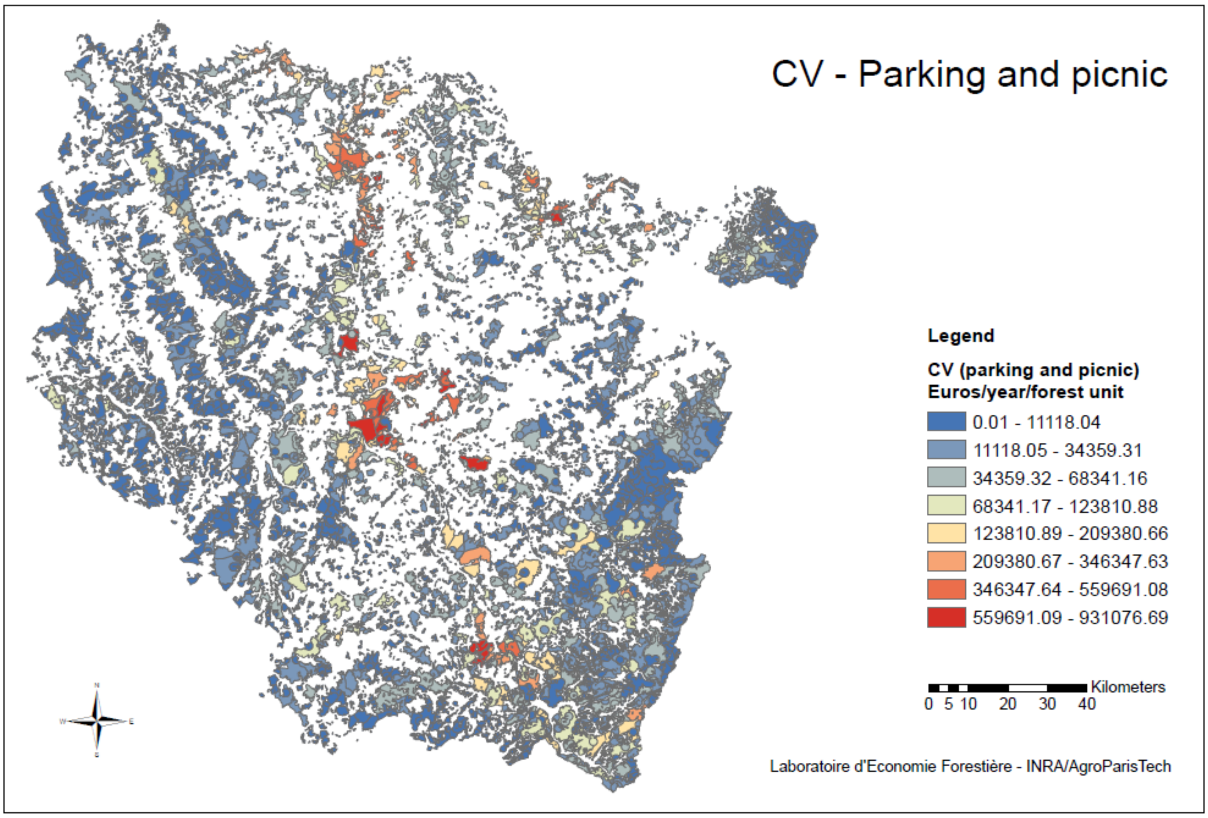

Figure 5 The compensating variation (CV) of adding one picnic and parking place to a forest unit where not already a picnic and parking place.

In table 8 we have summarized the data behind Figure 5. First we show the probabilities of travel modes and of no visits for the baseline and the scenario where there is introduced a picnic and parking place there these facilities are not present today. Note first that the differences in mean values between baseline and scenario is very small. This is partly because the mean is calculated by averaging over all municipalities (552) and for most municipalities there is no change in probability of introduction the facilities in a given forest as the forest is too far away to be considered by a visitor. Therefore, it makes more sense to look at the effect on the minimum and maximum values of the different variables. It should be noted that there are two effects of improving the recreational quality of a forest. First it may reduce the probability of staying at home. Furthermore, it may change the travel mode. If a forest close a visitor is improved, it is more likely that the forest is visited by walking as the inclusive value is more sensitive to the distance to attractive forests for visitors walking than going by car. The table shows also the average number of visits by different travel modes. We see that the number of visits between municipalities varies significantly. The maximum number of visits is more than two times the minimum number of visits. And when accounting for populations in the municipalities the variation in the total number of visits per municipality varies even more. We find that the average compensating variation of introducing a picnic and parking place in a forest is 32 Euros per year. The maximum value is 510000 Euros per year. Note this is value adding picnic and parking place to only one forest while the other are kept as before (with or without a picnic an parking place).

Table 8 Probability of going to forest and of the travel mode and number of visits in baseline and by introducing a picnic and parking place in all forest one by one and the compensation variation.

		N	mean	min	max
$P_{ni}(car)$	baseline	2907936	0.6002698	0.5178231	0.7595483
$P_{ni}(car)$	scenario	2907936	0.6002709	0.5103074	0.7611112
$P_{ni}(bike)$	baseline	2907936	0.0457176	0.0278158	0.0731477
$P_{ni}(bike)$	scenario	2907936	0.0457163	0.0275708	0.0731477
$P_{ni}(walk)$	baseline	2907936	0.3207451	0.1502334	0.4064574
$P_{ni}(walk)$	scenario	2907936	0.3207462	0.1495055	0.4185802
$P_{ni}(home)$	baseline	2907936	0.0332674	0.0212941	0.051115
$P_{ni}(home)$	scenario	2907936	0.0332666	0.0211264	0.051115
Visit car/individual	baseline	2907936	10.1161	6.8891	15.7132
Visit car/individual	scenario	2907936	10.1165	6.8534	16.1766
Visit bike/individual	baseline	2907936	0.6198	0.3990	0.8813
Visit bike/individual	scenario	2907936	0.6198	0.3939	0.8848
Visit walk/individual	baseline	2907936	8.1588	2.2409	16.0784
Visit walk/individual	scenario	2907936	8.1590	2.2321	16.0995
Total visits/municipality	baseline	2907936	37269	437	1326351
Total visits/municipality	scenario	2907936	37270	437	1342984
Total compensating variation	scenario	2907936	31.9	0.0	518922.7

Based on 552 municipalities representing 2/3 of population in Lorraine. N=5268 forests*552 communes.

Discussion

We show that the spatial variation in the value of forest recreation is very high. This implies that spatial targeting of projects improving the recreational quality of forests in Lorraine would improve the efficiency of such measures. We show that combining survey data, travel costs methods and high-resolution GIS data on population location and forest characteristics allow a high-resolution mapping of recreative values of forests in Lorraine. We also show that is possible to include visitors that are not car-borne and accounting for the travel mode decision.

The econometric models estimated for developing the mapping approach is based on a survey in 2010 which had a relative low response rate. This raises some questions about the representativeness of the sample and should be addressed in future analyses.

Future research should compare the results with and without explicit modelling of travel mode to evaluate the potential mapping error induced by ignoring the travel mode decision. In other words, is the increased complexity of including the travel mode decision worth the effort?

A potential improvement of the current system would be to model the site selection and travel mode decision simultaneously as suggested in Abildtrup et al. (2014). Furthermore, one could also consider integrating the trip demand model with the travel mode and/or the site selection model applying the endogenous multiple discrete-continuous selection system proposed by (Bhat et al., 2014; Bhat & Pinjari, 2014).

Considering the travel mode could also be relevant from a population health perspective. Does improved access to forest increase physical activities? On one hand, the improvement in access to local forests could make more people bike or walk to the forest – and go more often to the forests and therefore increasing physical activities. On the other hand, visitors that would in any case walk or bike would go less far per visits (less physical activity) if local forest get more attractive and therefore more often chosen as site for outdoor recreation. The proposed approach could be used to get insight into these issues. Of course the activities in the forests and the time in the forests may also depend on distance travelled to the forest and the quality of the forests. This should also being taken into account considering the link between access to forests and physical activities.

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