

# Preserving natural habitat quality and/or recreational attractiveness? Spatial tools for management planning

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## Abstract

Despite the growing political attention paid to ecosystem services (ES), this concept remains underused to support practical decisions in conservation/development programs. One of the most important knowledge gap for a better consideration of ES in territorial decision-making is related to their spatial assessment and mapping. Yet, from a planning perspective, knowledge on non-market benefits derived from ES combined with geographic information systems (GIS) are potentially powerful analytical tools for public land managers. In this paper, we assess the management strategy of a Regional park in Eastern France, by assessing and mapping two major ES under issue in the study area: recreational attractiveness and natural habitat quality. Because the area under study is a large territory, primary valuations techniques would have been difficult to apply. We thus develop a methodology to characterise the recreation supply and demand in the area by basing predictions on a hedonic function of biophysical supply and a travel cost model, both fed by GIS. We further transfer the supply and demand functions in the whole territory covered by the park, allowing for the mapping of a recreational attractiveness index. To our knowledge this constitutes one of the first attempts of benefit transfer based on a travel cost method, and the process is reproducible for any other travel cost study. Habitat quality is computed with the InVEST module based on habitat suitability and pressures of different land use and land cover. Results of our spatial statistics analysis show that the territorial strategy is globally accurate according to the recreation strategy, however results are more ambivalent for habitat quality.

**Keywords:** Forest recreational attractiveness, Habitat Quality, InVEST, Travel Cost Method, Function benefit transfer, Regional Park.

**JEL codes:** Q26, Q51, R12, R58

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## 1. INTRODUCTION

Despite the growing political attention paid to ecosystem services (ES), the concept remains underused in the support of practical decisions with regards to conservation and development programs (Laurans et al, 2013). One of the most important knowledge gaps for a better consideration of ES in territorial decision-making is related to the accounting for spatial variability in environmental and economic analyses. Yet, from a planning perspective, knowledge on non-market benefits derived from ES combined with geographic information systems (GIS) are potentially powerful analytical tools for public land managers. By providing spatially explicit representations of ES, land managers have the possibility to broaden the goals that can be pursued in planning tools (e.g. environmental impact assessments, cost-benefit analysis) (Geneletti, 2016).

Yet, ES modelling and mapping in the context of planning has been receiving much attention in the environmental and economic research (Bateman et al. 2014, Burkhard and Maes, 2017). Refined techniques either to quantify or map the supply side (representing ES flows produced by ecosystems ecological functioning), the demand side (flows to beneficiaries) and different values associated to ES are developed (Tardieu, 2017). Still, the ES modelling and mapping exercise is not always readily feasible in local contexts as it requires a large amount of georeferenced data on ecosystems and beneficiaries which are not necessarily available.

In this paper, our primary focus is on the modelling and mapping of natural habitat quality and the recreational attractiveness of forests ecosystems. Several tools and models to spatially assess natural habitat quality are already made available. They are usually based on ecological indicators (Maes et al, 2012) or on ecological modelling such as Globio and Marxan (Alkemade et al., 2009; Chan et al., 2011), or InVEST<sup>2</sup> (Kareiva et al, 2011; Terrado et al., 2016 ; Sallustio et al., 2017; Salata et al., 2017). However the question is less investigated in the case of the outdoor recreation service. Conversely to other ES, in the literature the modelling of the demand side is much more developed than the supply side. Recreation demand is commonly assessed by modelling visits carried out in a site having a particular land-cover such as woodland (e.g. Jones et al, 2010; Binner et al, 2017), wetland (e.g. Shrestha et al, 2002) or benefiting from a specific protection status such as national parks (Martínez-Espiñeira and Amoako-Tuffour, 2008; Schägner et al, 2016) or regional parks (Bujosa Bestard and Riera Font, 2010). The modelling is usually done with the revealed preference method of travel cost or with the declared preference method of choice experiment, which are both based on individuals' surveys. For the travel cost method, recreational values are estimated based on individuals' consumer surplus derived from a recreation demand function, describing the number of trips undertaken to the site per year. Demand is determined by an implicit price (the travel cost) and set of other variables (distance, time available, income, other available sites as substitutes, visitors' socio-economic characteristics, etc.) (Parsons, 2003). Though, often produced results are (1) aggregated values that does not allow for a spatial differentiation of recreation trips, and (2)

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<sup>2</sup> Integrated Valuation of Ecosystem services and trade-offs from the Natural Capital Project. InVEST is an open-source software available at: <https://www.naturalcapitalproject.org/invest/>

individuals-driven, not enabling to specify preferences for different sites' biophysical characteristics of destination sites.

Some exceptions can be cited from the literature. Sen et al. (2014)<sup>3</sup> developed a model to predict visits, obtained from a national recreation survey, according to destination sites characteristics, outset locations' attributes and distance travelled by visitor to reach the site. They further apply the estimated model at the national scale (the United-Kingdom territory). Nevertheless, one can wonder if these types of models are applicable to more local territories, non-covered by a survey, and requiring more precise outputs data to develop accurate strategies at the local scale. Termansen et al. (2013) and De Valck et al. (2017) mapped respectively recreational values and site quality scores by site characteristics by transferring a function derived from a choice experiment study. In our case, we would like to rely on existing and observed (not declared) data to derive recreation demand functions. Finally, volunteered geographic information such as self-geotagged photographs directly filled out by visitors on web applications (e.g. Flickr®, Instagram®) may allow developing spatially sensitive recreation maps. However, to our knowledge, it is not used in this way at this point, and papers mostly produce aggregated predictions (e.g. Wood et al. 2013). One can suspect that such data may not be usable in a local context, holding potentially few observations, and that it could be subject to sample selection biases provided that applications are more likely to be used by young and well connected people.

This brings us to formulate several methodological questions:

- (i) How to model and map recreational attractiveness and habitat quality, in a spatially explicit way, at the local scale and from existing data?
- (ii) By which method can we analyse the articulation between supply and demand sides in the case of the recreation service?
- (iii) And finally, by which means can we evaluate the accuracy of a conservation or development strategy in a territory from the produced indexes?

This article presents objective GIS-based methods using readily available data, and discusses their interest to guide land managers at the local scale. We develop a methodology to predict, in a spatially sensitive way, the recreation supply and demand in a French Regional park case study. Predictions are based on a hedonic function of biophysical supply and a travel cost method for visitors' demand. We further transfer the supply and demand functions in the whole territory covered by the park, allowing for the mapping of a recreational attractiveness index. To our knowledge this constitutes one of the first attempts of function benefit transfer with a travel cost method. Habitat quality is computed with the InVEST module based on natural habitat suitability and pressures. The contribution of the paper is therefore twofold. The first contribution is a methodological one, as we develop a clear and original method to transfer the function of a travel cost model adjusted for biophysical attributes of destination sites and for geographical context of beneficiaries. This allows to analyse the articulation between demand and supply of ES, which is rarely done in the ES literature (Termansen et al., 2013). Second, the paper provides policy guidance for

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<sup>3</sup> This paper is mostly based on various seminal papers developing the use of GIS in travel costs techniques: Jones et al (2010), Brainard et al (1997 and 1999) and Lovett et al (1997).

the orientation of the studied park regarding the produced indexes for habitat quality and recreation attractiveness.

## 2. MATERIALS AND METHOD

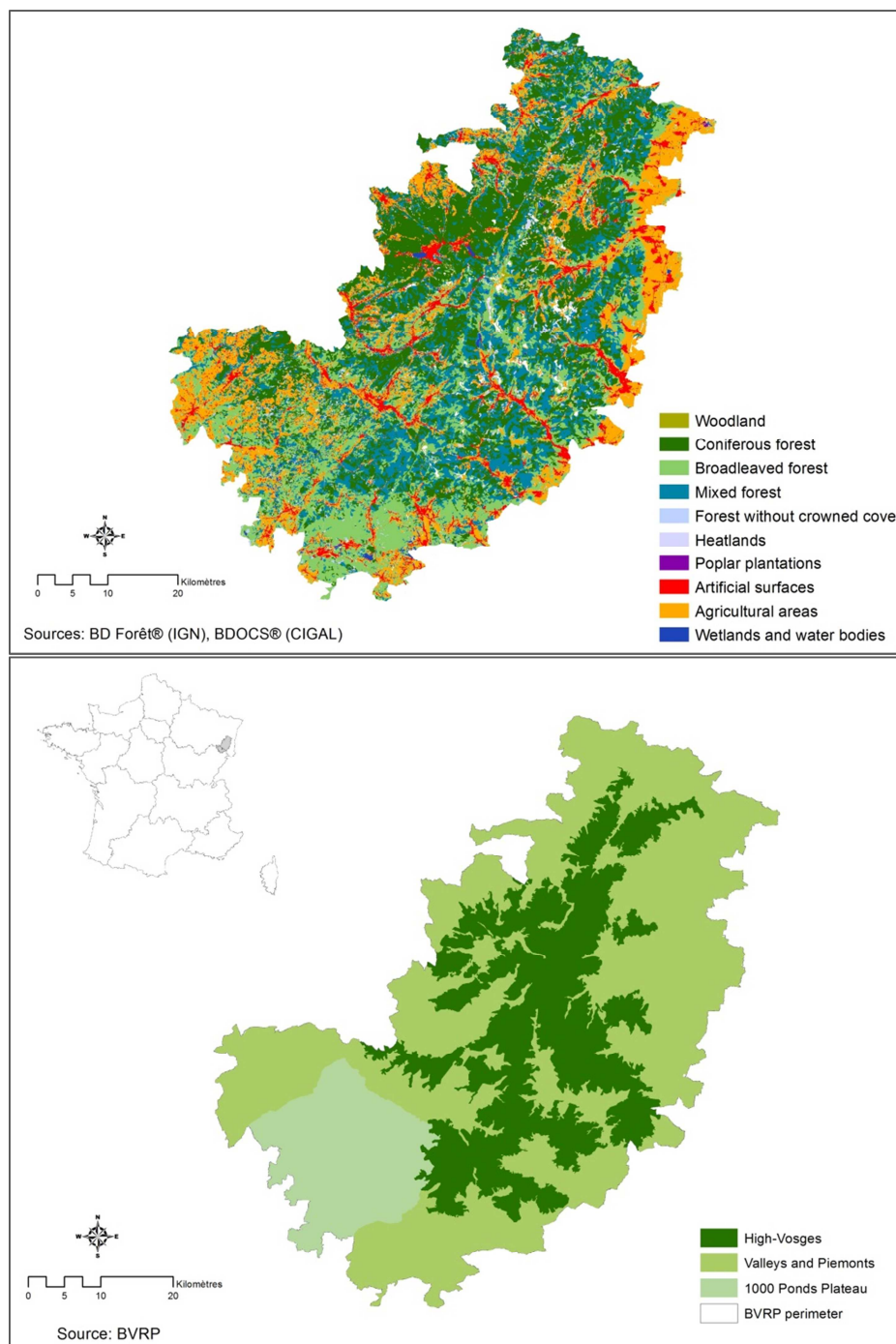
### 2.1. Case study: Ballons des Vosges Regional park, France

The Ballons des Vosges Regional park (BVRP) is a 2700 km<sup>2</sup> territory situated on two Regions of Eastern France: Grand Est and Bourgogne Franche-Comté. The forest covers about 61% of the total BVRP area and the remaining territory is covered by wetlands, lakes, agricultural areas and meadows (Figure 1). The mountainous relief gives a high diversity of natural habitats, governed by different bioclimatic stages. The *High-Vosges* are obstacles to oceanic disturbances coming from the west, giving heavy rains in the western part of the BVRP (more than 2 meters/year) to the crest line, and conversely about 50 centimetres/year in the eastern part, making this side of the area one of driest region in France. The third of the BVRP area is placed under remarkable natural site status and 22% under Natura 2000 conservation commitments. Few remarkable species are present in the site such as the *Tetrao urogallus* or the *Lynx lynx*, which are the subjects of particular conservation measures. In terms of recreation the BVRP is a landmark of outdoor recreation for its ski resorts and hiking paths. It is finally one of the largest and most populated French Regional park as it borders and includes partly several urban units as Colmar, Mulhouse and Belfort.

Natural Regional Park is a protection status in France. They are governed by a charter approved by the state and municipalities composing the area. The charter sets the development strategy in terms of maintenance/improvement of environmental and cultural heritage, and the means to implement it over a 15 years period. According to the charter the environmental strategy must be focused on three principal activities: (1) the forest production of wood and non-wood products, (2) recreational attractiveness, and (3) habitat and biodiversity conservation. To achieve this, land managers developed a management strategy, specified in the charter by 2024, for three different territories (Figure 1). First, in the *High-Vosges* territory, the objective is to conciliate the habitat conservation while maintaining a good recreational attractiveness. They rely more specifically on the European Charter for sustainable tourism<sup>4</sup>, and try to define tourists' attendance strategies. Second, the key challenge in the *Valleys and Piedmont* is to control urbanization and habitat fragmentation. Finally, the *1000 ponds plateau* benefit from exceptional habitat richness, however the industrial decline weakens attractiveness and farmlands activities. The objective in this area is thus to sustain its vitality.

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<sup>4</sup><http://www.europarc.org/library/europarc-events-and-programmes/european-charter-for-sustainable-tourism/>



**Figure 1** : The land-covers and the three main territories of the Ballons des Vosges Regional Park (France)

## 2.2. Snapshot of the methodological framework

The methodological framework can be divided in three steps (Figure 2). The first step is a recreation model described in the sub-section 2.3. The model is based on an initial survey conducted in Lorraine Region, further combined with spatial analysis. A hedonic function of supply attractiveness and a travel cost model are estimated to derive a combined attractiveness index. Simultaneously, a habitat quality model is computed by using the InVEST module (section 2.4). Results of the two models are detailed in Section 3. Finally, the

two indexes are analysed with regards to the BVRP orientation strategy to assess whether or not it is accurate and efficient in section 4.

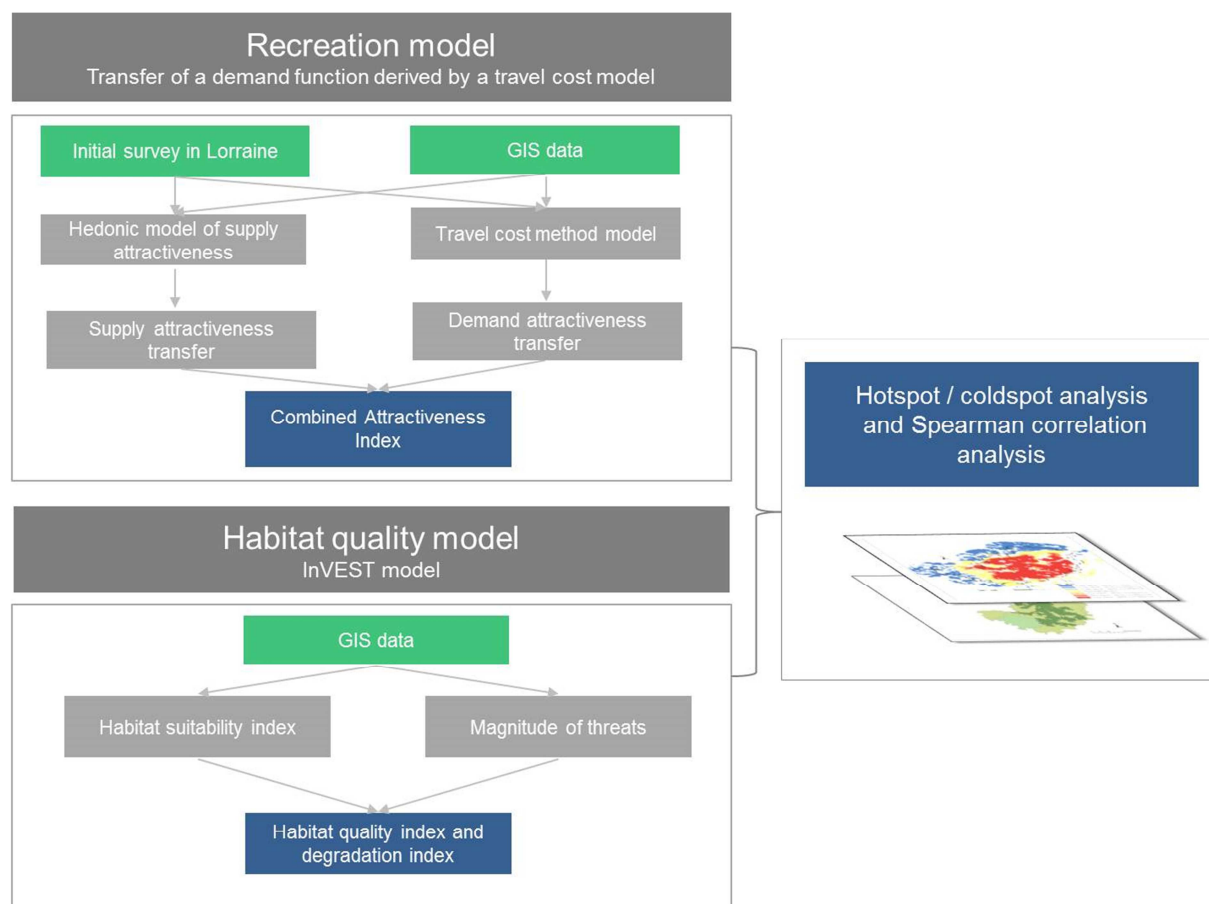


Figure 2 : Snapshot of the methodological framework

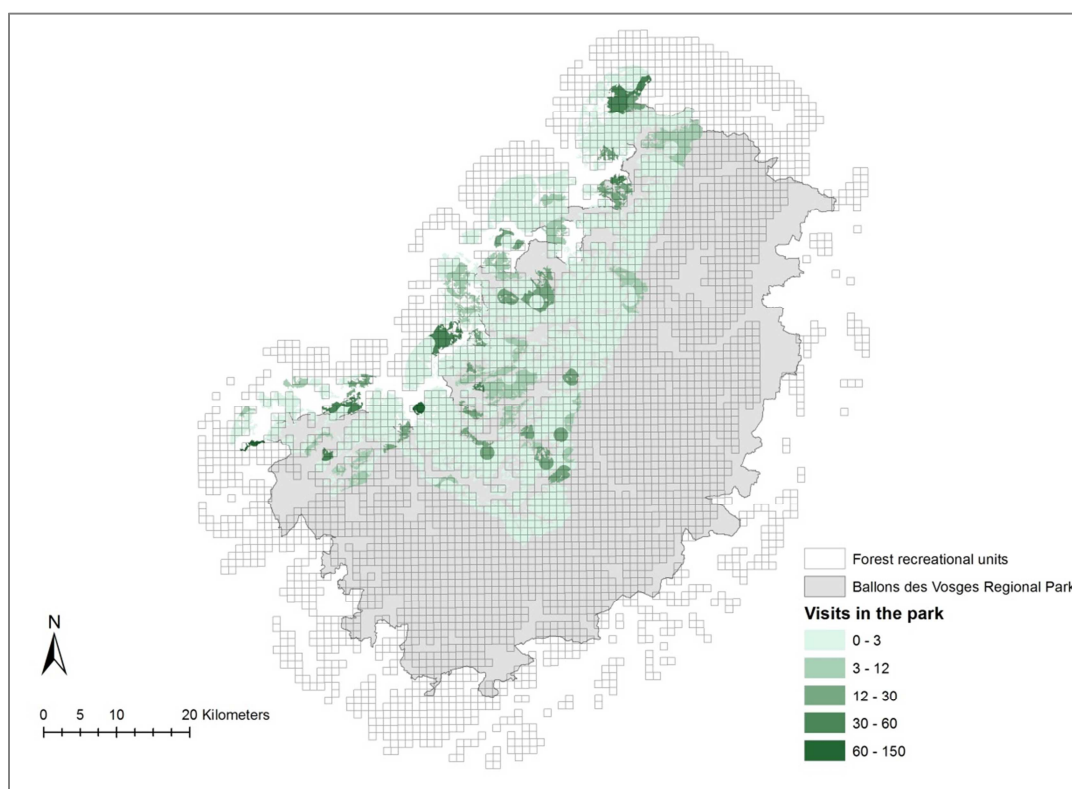
## 2.3. Recreation Model

### 2.3.1. Original survey and scales of analysis

We rely on an online survey initially applied in the former Lorraine Region (now region Grand -Est), covering one third of the BVRP territory (Figure 3). This survey had been used in different application cases to study local recreation: Abildtrup et al. (2015a and 2015b). It was carried out between July and August 2010 by emails survey in the former Lorraine Region. 1144 respondents completed the questionnaire, and 526 had visited a forest and provided information about which specific forest they had visited on the last 12 months. Only the most visited forest had been retained. All the survey details are reported in Abildtrup et al. (2015a and 2015b).

In the initial survey, Lorraine's forests were divided into "forest units" representing relevant recreational units greater than or equal to 5 ha. A total of 5568 forest units were delineated in the initial survey. From this total sample we selected forest units included in the BVRP, which are in the Vosges department in Lorraine region, resulting in 256 forests units. In total 1236 visits have been recorded in 94 forests units, over 256, and are distributed in the entire area

of the BVRP surrounded by a buffer zone of 10 kilometers<sup>5</sup> (Figure 3). Our recreation model is thus developed based on those forest units. However, because we had no clear rules to define forest units in the rest of the BVRP area, we defined recreational units through a raster divided in 100 ha cells (1km<sup>2</sup>), distributed homogeneously according to a kilometric mesh. Based on the Forest French database (BD Forêt®, IGN), we assign to each mesh the surface of forest areas. Only the meshes including at least 50% of closed forest are considered as forest recreational unit in this work. Meshes cover the entire area of the park increased by a buffer zone of 10 km around its perimeter in order to take into account for possible visitors leaving outside and therefore avoid border effects. In the end we obtain 3774 forest recreational units over the entire BVRP (Figure 3). These recreational units are used for the transfer of the recreational functions.



**Figure 3 :** Area covered by the initial survey in the BVRP, Forest units visited, and kilometric mesh used for the transfer

### **2.3.2. Supply attractiveness model**

In a usual travel cost model, visited sites are revealed directly by visitors during the survey. However, in this paper such locations are unknown in a large part of the BVRP and have to be predicted. The supply attractiveness model characterises the supply of recreational forests in the area with a hedonic function of biophysical characteristics and forecasts the most interesting ones. The prediction model achieves this by taking information on the number of visits on destination sites from the initial survey, and observes how it is related to

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<sup>5</sup> We considered this buffer zone because forest units are sometimes juxtaposed with the BVRP territory or very close to the limits of the BVRP.

(i) the forest structure characteristics, (ii) the amenities available at the site, (iii) the distribution of population around the site (Table 1). Expectations concerning these variables are that elevated, broadleaved and mixed forests, holding water surfaces, are more attractive, as well as sites strongly endowed with amenities. Population living at 2km around the forest represents the forest accessibility. We expect that when the accessibility is important the more attractive the forest is. These variables were not present in the initial survey and have been reconstituted for the purpose of the paper.

**Table 1** : Variables description for the supply attractiveness model

Variable	Description	Data source	Descriptive statistics		
			Mean	Median	Std. err.
Population at 2 km	Population included in a 2 km buffer zone of the mesh	Census data, INSEE	2165	1827	1472
Share of forest types	Share of coniferous forests at site	GIS calculation from the Forest French database (BD Forêt®, IGN)	0.41	0.43	0.22
	Share of broadleaved forest at site		0.17	0.09	0.15
	Share of mixed forests at site		0.27	0.25	0.14
Hiking path	Hiking path density (in meters) including biking paths	BDTOPO®, IGN- paths, roads	11369	6998	14781
Natural and cultural points of interest	Number of natural and cultural points of interest in the mesh	BDTOPO®, IGN – nature and culture	0.3	0	0.86
Water courses, water surfaces	Share of water courses in the mesh with a buffer zone of 200 meters around the courses	BDTOPO®, IGN - water surfaces	0.09	0.06	0.14
Elevation	Altitude in meters	BD Alti®, IGN	669	630	177

Supply attractiveness of each recreational unit is predicted with a count data model. These models are particularly accurate when the dependent variable is an integer taking few values as the visitors' trips taken to a destination site (Shaw, 1988; Englin and Shonkwiler, 1995; Baerenklau et al, 2010, Roussel et al, 2016). Many pixels are however not visited. We approached this issue by using a zero-inflated count data, where the probability of participation is simultaneously estimated with the visit function (Gurmu and Trivedi, 1996). Zero-inflated count data models are more general than general count ones in that they relaxes the restriction that an identical process generates both the zeros and the positive integers. Non participation in our case represents the pixels that are not visited by the surveyed respondents. As Englin et al. (2003) argue, zero trips can be generated by both a binomial process (for people not in the market *i.e.* not visiting any forests) and a Poisson process (for people in the market who took zero trips *i.e.* surveyed visitors that did not took a trip to the forest during the year preceding the survey).

### 2.3.3. Demand attractiveness model

The demand attractiveness is derived from the initial survey by applying a travel cost model. It aims at further predicting the number of visits that will occur in each forest recreational unit from any given outset area. To let the trip function be transferable, we limited the number of variables to the ones that can be reconstituted in the entire area covered by the BVRP.



Nevertheless, as Bateman et al. (2011) suggest, this type of parameterisation is recommended because of the multiplicative role of coefficients resulting major transfer errors in over-parametrized models. We derive a recreation demand function from the travel cost model determined by an implicit price (the trip cost) and set of independent variables (socioeconomic and demographic characteristics of the individual and the availability of potential substitute sites).

The trip cost is a combined cost between trip costs for individuals using motorised means of travel and an opportunity cost of time. The trip cost is computed as follow:

$$TC = 2 \times \left( \frac{(D \times KMC)}{P} + OCT \right) \quad (1)$$

With  $TC$  the trip cost,  $D$  the distance between the outset location and the site in kilometers.  $KMC$  is a kilometer cost based on the vehicle fiscal power published annually by the fiscal administration. Because we do not have this information we made the assumption that vehicles have a mean fiscal power of 4 fiscal horsepower corresponding to a 0.493/km cost<sup>6</sup>. This cost takes into account for the vehicle depreciation, maintenance costs, tire expenses, fuel consumption and insurance premiums.  $P$  is the number of individuals in the group. The costs are multiplied by two in order to consider the entire round trip. We did not considered foot and cycle travels, even if some studies considered the material depreciation as cycle or trekking shoes (e.g. Bertram et al., 2017).  $OCT$  is the Opportunity Cost of Time. An individual who visits a recreation site has an opportunity to use his time differently (working for example) and is therefore subject to an opportunity cost. This relies on the assumption of individual's trade-off between labour and leisure.  $OCT$  characterises the cost of time whilst traveling to and from the site, and eventually the time spent in the site<sup>7</sup>. However, we chose to not consider an  $OCT$  for two reasons (1) because we rely on very local recreation implying short trips to forests, (2) because this approach assumes individuals have flexible jobs and are able to substitute work for leisure time at the margin, and this assumptions is rarely verified.

As in the supply attractiveness model, visits are predicted with a count data model where the dependent variable is the number of observed visit in each forest unit. Observations come from the initial survey. Dependent variables are recomputed to serve our trip function transfer and are described in Table 2. Expectations regarding these variables are that the trip cost between the respondent outset location and the visited site decreases visit demand as well as the availability of substitutes around the outset location, and that the income increases recreation demand.

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<sup>6</sup>  $KMC$  takes into account the vehicle depreciation, maintenance, fuel and insurance costs and is published annually by the fiscal administration in France:

[https://www3.impots.gouv.fr/simulateur/calcul\\_impot/2017/pdf/baremekm.pdf](https://www3.impots.gouv.fr/simulateur/calcul_impot/2017/pdf/baremekm.pdf)

This inclusion of the vehicle depreciation is usual in the TCM (see Parsons, 2003). However, this inclusion has been discussed in the literature (see Earnhart, 2003) because individuals may not perceive explicitly these types of costs.

<sup>7</sup> For a discussion on the  $OCT$ , refer to Roussel et al, (2016).

**Table 2 :** Variables used in the demand attractiveness model and in the transfer

Variables	Description	Data source	Descriptive statistics		
			Mean	Median	Std. err.
Visits	Declared visits by visitors in the year preceding the survey	Survey	15.63	6	23.5
TC (Trip cost)	<i>Initial survey</i>				
	Calculated from the centroid of the visitor's IRIS <sup>8</sup> ) to the recreational unit centroid	GIS calculation, ESRI ArGIS	16.20	10.46	23.93
Income	<i>Reconstituted variable in the transfer</i>				
	Calculated from each IRIS centroid to each recreational unit centroid with equation 1				
	<i>Initial survey</i>				
	Median income in different income classes	Census data INSEE	33007	33750	14581
	<i>Reconstituted variable in the transfer</i>				
Availability of substitutes	Median income at the IRIS level				
	<i>Initial survey</i>				
	Share of other types of land uses around a 5km <sup>9</sup> buffer around the visitor's IRIS centroid	GIS calculation (ESRI ArGIS) from Corine Land Cover (2012)			
	% Urban areas (CLC1)		0.38	0.25	0.34
	% Agricultural areas (CLC2)		0.25	0.24	0.27
	% Wetland (CLC4)		0.001	0	0.008
	% Water bodies (CLC5)		0.008	0	0.014
	% Coniferous forests (CLC311)		0.19	0.14	0.18
	% Broadleaved forests (CLC312)		0.05	0	0.15
% mixed forests (CLC313)		0.04	0	0.11	
	<i>Reconstituted variable in the transfer</i>				
	Share of other types of land uses around a 5km buffer around the IRIS centroid				

### 2.3.4. Benefit transfer and construction of the combined attractiveness index

Two transfer functions are completed in order to map the Combined Attractiveness Indicator (CAI) of the BVRP forests:

- (1) A transfer of the function developed in the supply attractiveness model that leads to the development of a Supply Attractiveness Index (SAI);
- (2) A trip transfer function predicting the visits in the BVRP territory, allowing to develop the Demand Attractiveness index (DAI).

In the case of the supply attractiveness model, significant coefficients derived from supply attractiveness model are applied to each 1km<sup>2</sup> mesh of recreational units in the park. The result, after normalisation, gives the SAI based on characteristics sought by visitors. The SAI for each cell  $i$  varies between [0; 1] and is calculated as follow:

$$SAI_i = \frac{SA_i - SA_{Min}}{SA_{Max} - SA_{Min}} \quad (2)$$

With

<sup>8</sup> IRIS is the smallest French national statistics level, and it includes approximately 2000 persons.

<sup>9</sup> The 5 kilometers buffer was chosen after Sen et al. (2014) which tested different radius (1km, 2.5km, 5km, and 10 km). 5 km was the best fitting one according to the Akaike Information Criteria (AIC).

$$SA_i = \exp(\beta sv_i), \forall i \quad (3)$$

$SA_i$  is the recreational supply attractiveness score of the recreational cell  $i$ , with  $i \in \{1, \dots, I\}$ ; before normalisation.  $sv_i$  is a vector of supply independent variables (the same variables that the ones described in Table 1) describing the recreational forest unit  $i$  in the entire Park and  $\beta$  is a vector of estimated parameters associated to the vector  $SV$  in the supply attractiveness model (specified as a zero-inflated Poisson, this is why the functional form of the equation is a semi-logarithmic form).

Further, the demand function is applied to construct the Demand Attractiveness Index (DAI) applied to the variables described in Table 2.

$$DAI_i = \frac{DA_i - DA_{Min}}{DA_{Max} - DA_{Min}} \quad (4)$$

With

$$DA_{ij} = \exp(\gamma TC_{ij} + \sigma dv_j), \forall i, \forall j$$

And

$$DA_i = \sum_{j=1}^J DA_{ij}, \forall i, \forall j \quad (5)$$

$DA_i$  is the demand attractiveness of recreational cell  $i$  from a series of outset locations present in the BVRP, with  $i \in \{1, \dots, I\}$ ; before normalisation. As in the common travel cost it also denotes the number of visits in cell  $i$ .  $DA_{ij}$  is the demand attractiveness for cell  $i$  from a given outset location  $j$ , with  $j \in \{1, \dots, J\}$ .  $dv_j$  is the vector of demand independent variables describing visitors and the outset area  $j$  characteristics i.e. the percentage of various land uses within a set radius of the outset location.  $TC_{ij}$  is the travel cost between the recreational cell  $i$  and the outset  $j$ . All the variables are described in Table 2.  $\sigma$  and  $\gamma$  are the vector of parameters associated to the trip cost and other variables estimated in the demand attractiveness model.

Finally the Combined attractiveness Index (CAI) is attributed to each recreational unit cells  $i$ , by computing the geometric mean of the two indexes, as follow:

$$CAI_i = \sqrt{SA_i \times DAI_i} \quad (6)$$

Using a geometric mean allow for considering a non-compensation between the two indexes. That is to say that the SAI and the DAI cannot totally compensate each other in the CAI if the SAI is strong and the DAI weak, or vice-versa. A strong combined index reveals therefore strong supply attractiveness combined with a strong demand index (and this is symmetrical for a low CAI).

## 2.4. Habitat quality index

We use the InVEST model based on land-use/land-cover and threats distribution. InVEST defines habitat quality as “*the resources and conditions present in an area that produce*

occupancy – including survival and reproduction – by a given organism” (Hall et al., 1997:175). The aim is thus to estimate habitats’ quality in spatially explicit terms by measuring the appropriate conditions for the survival and reproduction of species generally based on the potential threat and degradation of natural habitats (Tallis et al., 2013). This approach appears relevant to analyse the habitat quality index within the BVRP.

Land-use/land-cover is composed by seven categories extracted from Corine Land Cover database (CLC, 2012): Artificial areas (CLC1); Agricultural areas (CLC2); Coniferous forests (CLC311); Broadleaved forests (CLC312); Mixed forests (CLC313); Scrub and/or herbaceous vegetation associations (CLC4); Open spaces with little or no vegetation (CLC5). Only forests are thus considered and more precisely identified (*i.e.* three categories of forest land-covers) as our analysis is based on the habitat quality in forest areas.

Habitat quality/degradation is a function of threats coming from different sources *e.g.* artificial areas, agricultural land, main roads, secondary roads, trails. Artificial areas and agricultural land are included as sources of landscape fragmentation and habitat degradation (Girvetz et al., 2008). In addition, few studies revealed the important impact of forest roads on biodiversity and forest habitat (*e.g.* Marcantonio et al., 2013). Consequently, the analysis of the road networks according to its categorization (primary, secondary and trails, derived from the BDTOPO®) is critical to better understand the role of linear infrastructure on habitat loss, fragmentation, and degradation (Underhill and Angold, 2000; Von Der Lippe and Kowarik, 2008).

Based on these different factors, the threat level  $D_{xj}$  is defined as follows:

$$D_{ij} = \sum_{r=1}^R \sum_{y=1}^{Y_r} \left( \frac{W_r}{\sum_{r=1}^R W_r} \right) r_y x_{rxy} S_{jr} \quad (7)$$

With  $y$  a mesh of the threat raster  $r$ ,  $Y_r$  all the meshes of the raster  $r$ ,  $W_r$  the relative weight of the impact of the threat  $r$ ,  $x_{rxy}$  the impact of threat  $r$  that originates in grid cell  $y$ , on the habitat in grid cell  $i$  (function of the distance, Max. D) and  $S_{jr}$  the sensitivity of the habitat  $j$  to the threat  $r$ .

The habitats quality  $Q_{xj}$  is defined as follows:

$$Q_{ij} = H_j \left( 1 - \left( \frac{D_{ij}^z}{D_{ij}^z + K^z} \right) \right) \quad (8)$$

The  $H_j$  is ranged from 0 to 1, where 1 indicates LULC classes with the highest suitability for species and  $K$  is the saturation constant. Thus, the higher the degradation index  $D_{ij}$ , the lower the quality of habitats  $Q_{ij}$ .

Information’s required for the threats analysis are the impacts weights (*i.e.* the impact of each threat on habitat quality, relative to other threats, ranging from 0 to 1), distances (*i.e.* maximum distance, in km, over which each threat affects habitat quality)<sup>10</sup>. We used the

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<sup>10</sup> The distance decay is defined as exponential by the InVEST model.

literature to calibrate our input data (Salata et al., 2017; Sallustio et al., 2017; Terrado et al., 2016). Inputs are presented in Tables 3 and 4.

**Table 3:** the characteristics of the threats to habitat quality in the BVRP

Type of threat	Maximum distance	Impact weight
$r$	$Max.D$	$Wr$
Urban cover	1.5	0.9
Agricultural cover	1	0.56
Main roads	1.5	0.9
Secondary roads	1	0.7
Trails	0.3	0.35

**Table 4:** Habitat suitability and the sensitivity to each threat in the BVRP

	Habitat suitability	Urban	Agriculture	Road1	Road2	Trail
Forest cover	$Hj$			$Sjr$		
Broadleaved forest	0.9	0.8	0.5	0.8	0.6	0.4
Coniferous forest	0.8	0.72	0.45	0.72	0.54	0.36
Mixed forest	0.9	0.8	0.5	0.8	0.6	0.4

### 3. RESULTS

#### 3.1. Recreation model

##### 3.1.1. Supply attractiveness model

We estimated four count data model: a Poisson model, a zero inflated Poisson, a negative binomial and a zero inflated negative binomial. However the likelihood ratio test on alpha, the dispersion parameter, show that our dataset is not over-dispersed justifying the use of a Poisson compared to a Negative binomial. The Vuong test shows that the zero inflated Poisson has to be preferred compared to a standard Poisson model ( $z > 2$ ). The model is a count data model with two regimes. First regime explains the participation, that is visits performed on sites, and the second regime explains the non-participation.

We tested various model specifications including the following:

- Hiking path in number of paths instead of meters;
- Water courses and forests surface instead of coverage share variables;
- Public *versus* private forests;
- The distance to the nearest forest;
- Different variables explaining non-visited forests.

We present the best-fitting model, according to the AIC and BIC model selection criterions, in Table 5.

**Table 5** : Zero inflated Poisson for the supply attractiveness model based on destination sites

<b>Variables</b>	<b>ZIP coefficients</b>	<b>Std. Err.</b>
<b>Participation</b>		
Population around 2km at site	-4.87e-05	(3.18e-05)
Log (% of broadleaved forests at site)	-0.100***	(0.0287)
Log (% of mixed forest at site)	0.0807**	(0.0390)
Natural and cultural points of interest at sites (number of points)	0.521***	(0.0457)
Water courses, water surfaces (% of the surface)	0.996**	(0.416)
Elevation	-0.00646***	(0.00138)
Squared Elevation	7.88e-06**	(9.66e-07)
Hiking path density (in meters)	-1.16e-05	(7.32e-06)
Squared Hiking path density (in meters)	0	(1.29e-10)
Constant	5.608***	(0.448)
<b>Non-participation</b>		
Hiking path density (in meters)	-5.84e-05**	(2.48e-05)
Squared Hiking path density (in meters)	7.41e-10*	(4.02e-10)
Constant	0.917***	(0.237)
Log likelihood	-1038.1072	
LR chi <sup>2</sup> (9)	268.85377	
Prob > chi <sup>2</sup>	0.000	
AIC	2098.2144	
BIC	2135.9372	
Number of zero observations	162	
Number of non-zero observations	94	
Total observations	256	

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Vuong test of zip vs. standard Poisson:  $z = 5.76$   $Pr>z = 0.0000$

Alpha test on ZINB = 1.948269  $Pr>z = 0.286$

Coniferous forests are set as the base case coverage share

We can see that the most powerful predictors are the elevation first, followed by the presence of water and the presence of natural and cultural points of interests at site. This is also observed on some studies based on declared preferences (*e.g.* Abildtrup et al, 2013; Termansen et al, 2013 and De Valck, 2017). Forest types are integrated as logarithms, and can thus be interpreted as elasticities. Mixed forests exert the greatest attraction compared to coniferous and broadleaved forests respectively. These types of forest characteristics are, to our knowledge, rarely integrated in models explaining recreational visits, making difficult the comparisons. However, some studies did integrate some of them in the regressions, for instance, Sen et al. (2014) found a positive relation between visits and the presence of woodland (they don't separate forest types), Termansen et al. (2013) a preference for broadleaved forest and Schägner et al (2016) found no effect of the forest type.

Nor the presence of population at 2 km around the site, neither the density of hiking path has an impact on the site attractiveness. This goes against our first intuitions and literature findings (*e.g.* De Valck et al., 2107) but this is maybe due to the case study including many hiking paths, so that the variable does not discriminate between different supply units. Further, elevation has a negative effect on attractiveness. Nevertheless, the square of elevation has a positive impact, giving an overall non-linear effect of elevation variables. Graphically, the effect of elevation on supply attractiveness has a convex curve, that is elevation has low effect on attractiveness until a certain point at which it plays a major role

(823m in our case). This makes sense in a mountainous environment, like the BVRP, indeed it shows that individuals are more attracted by forest with low elevation and high elevation and have lower preferences for forests situated in medium mountain. Non-attractiveness is only slightly explained by hiking paths density. Sites with less hiking paths are less attractive. However the predictor is weak to explain non-participation.

### 3.1.2. Demand attractiveness model

As for the supply attractiveness model, we estimated four count data model. But for the same reasons, we finally relied upon Zero Inflated Poisson (ZIP) to explain demand attractiveness. Results are presented in Table 6. Other variables have been included to explain non-participation however any of them were significant.

**Table 6:** Zero inflated Poisson for the demand attractiveness model based on outset locations

<b>Variables</b>	<b>ZIP coefficients</b>	<b>Std. Err.</b>
<b>Participation</b>		
Trip cost	-0.0188***	(0.00215)
Income	3.82e-05***	(8.22e-06)
Squared income	-5.57e-10***	(1.30e-10)
Log (% Urban substitutes availability)	-0.0702***	(0.0231)
Log (% Agricultural substitutes availability)	-0.0460**	(0.0185)
Log (% Wetland substitutes availability)	0.237***	(0.0778)
Log (% Water bodies substitutes availability)	-0.0683***	(0.0181)
Log (% Broadleaved substitutes availability)	-0.139***	(0.0221)
Log (% Mixed forest substitutes availability)	0.0359**	(0.0172)
Constant	1.877***	(0.146)
<b>Non-Participation</b>		
Trip cost	-38.23	(11,902)
Constant	3.988***	(0.583)
Log likelihood	-1063.1648	
LR chi2(9)	264.00	
Prob > chi <sup>2</sup>	0.000	
AIC	2148.3295	
BIC	2187.3265	
Number of zero observations	162	
Number of non-zero observations	94	
Total observations	256	256

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

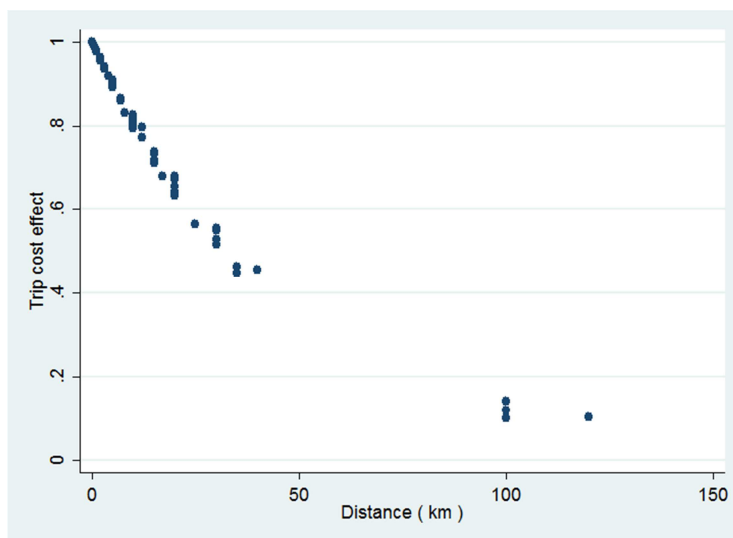
Vuong test of zip vs. standard Poisson: z =2.46 Pr>z = 0.0069

Alpha test on ZINB= 1.082131 Pr>z =0.580

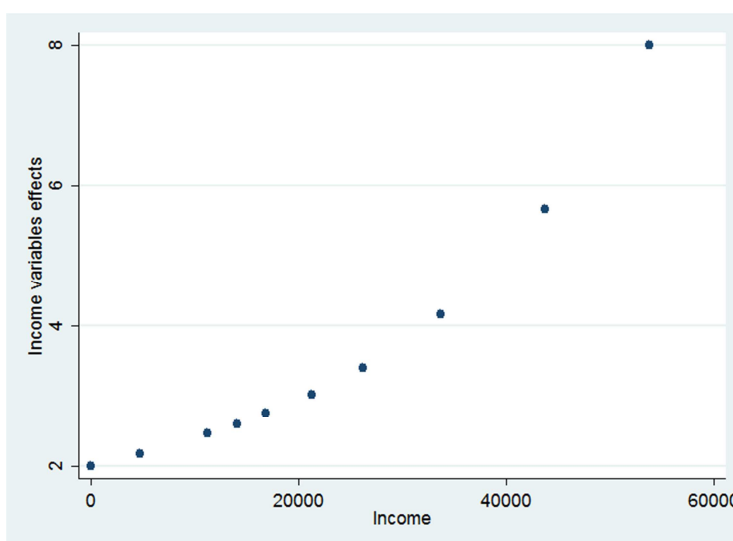
Coniferous forests are set as the base case coverage share

As expected the trip cost plays negatively on demand attractiveness, as shown in Figure 4, following expectations. The income variable plays as a U-shaped curve, having low effect on demand attractiveness in the first classes of income and then increasing exponentially demand for higher classes (see Figure 5). This result is unusual in travel cost models, as income is commonly non-significant in explaining visitors' trips (Shrestha et al., 2002; Parsons,

2003; Martínez-Espiñeira and Amoako-Tuffour, 2008; Garcia and Jacob, 2010, Roussel et al., 2016). Substitute's availability around a potential outset location also influences visits numbers and this is common to recreation models (Sen et al., 2014; Schägner et al., 2016). The presence of urban, agricultural, water bodies and broadleaved forests influences negatively visits and the presence of mixed forests and wetlands influences positively visits.



**Figure 4:** Effect of the travel cost on demand attractiveness



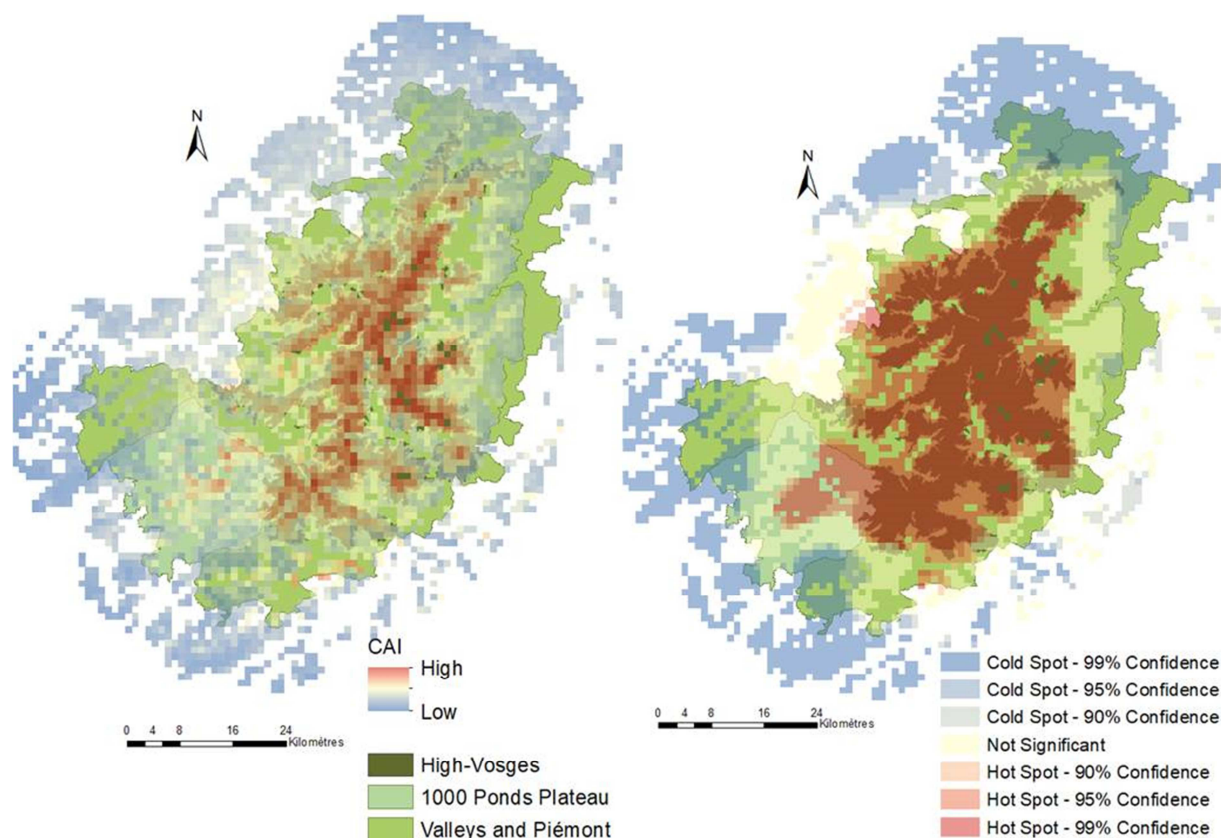
**Figure 5 :** Effect of income on demand for forests (income are represented by medians in different income classes)

### 3.1.3. Combined Attractiveness Index (CAI)

The CAI is finally computed and mapped in the BVRP as shown in the left side of Figure 6. Graphically, we can see that the attractiveness is principally concentrated in the center of the BVRP, which is also the most elevated part of the area. A hotspot analysis settles statistically this graphical insight (right side of Figure 6). Hotspot areas are characterised by high density clusters of the CAI and surrounded by low density clusters of CAI referred as a coldspot. The



hotspot analysis is done by applying a combination of statistical analysis and spatial procedures using the High/Low Clustering<sup>11</sup>.



**Figure 6 :** Spatial distribution of the combined attractiveness index (left) and hotspot analysis (right)

Results thus let us presume a high influence of elevation. This is confirmed by Pearson correlations presented in Table 7. Correlations show that the CAI is primarily determined by the supply index SAI, which in turn is highly influenced by elevation, and in a lesser extent by DAI even if the correlation is also strong. This means that biophysical attributes are particularly critical to take into account for in outdoor recreation models.

**Table 7:** Pearson correlation of CAI, SAI and DAI indexes

	Supply Index - SAI	Demand Index - DAI	Combined Index - CAI
Supply Index - SAI	1.0000		
Demand Index - DAI	0.3926***	1.0000	
Combined Index - CAI	0.9538***	0.6224***	1.0000

Moreover, we can see that the demand and the supply are significantly correlated but not very strongly. This confirms the fact that individuals' driven-models may have a truncated view of recreation as the analysis of both side of this ES flow reveal different and potentially complementary information.

### 3.2. Habitat Quality

<sup>11</sup> This is done with the command Getis-Ord General G from the ESRI ArcGIS© software package of spatial statistics.

InVEST outputs, degradation and suitability index, are presented in Figure 8. Degradation can be interpreted as a relative level of habitat degradation on the current landscape. A high score in grid cell means that habitat degradation in the cell is high relative to other cells. The same reasoning can be applied to habitat suitability, where a high level could be interpreted as a better habitat quality vis-a-vis the distribution of habitat suitability across the rest of the BVRP (Tallis et al, 2013).

We can observe in Figure 8 a spatial heterogeneity in terms of quality across the study area. The BVRP seems separated in two parts negatively correlated. The eastern and southern parts show the highest quality index of habitats, and inversely the lowest index appear in the eastern and northern parts of the site.

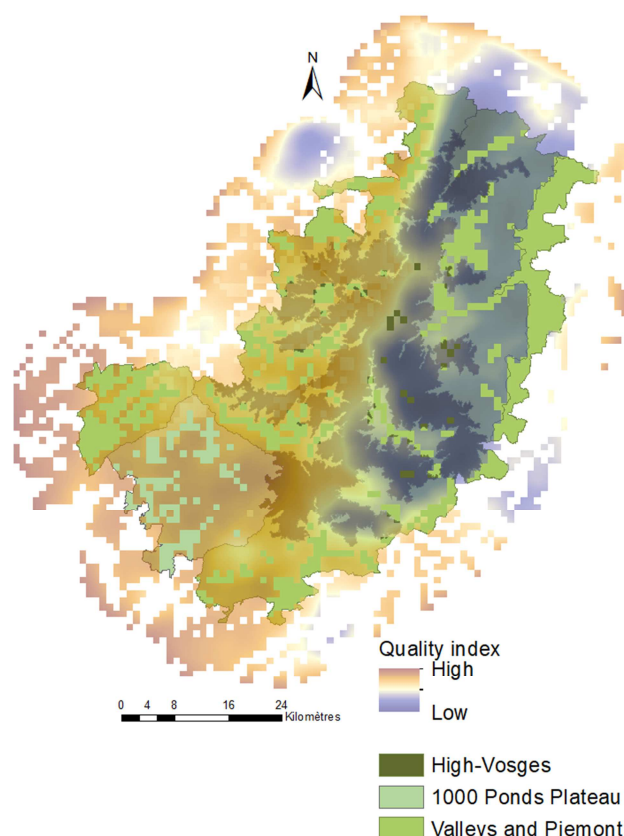


Figure 7 : Habitat quality in the BVRP

#### 4. DISCUSSION IN TERMS OF PUBLIC POLICY IMPLICATIONS

Relationships between habitat quality and the recreation attractiveness indexes can be analysed with Spearman correlations, as well as their coherence or incoherencies with the strategies formulated for three territories presented in Section 2.1. Statistical results are presented in Table 8.

First, as expected, a negative but low correlation appears between the attractiveness index and the habitat quality. This predictable result shows statistically that a strong recreational attractiveness is opposed to a good quality of the habitats in the PNBV. In terms of spatial repartition, the BVRP is clearly divided in two territories, an attractive part in the eastern side, and a “friendly” natural habitat part in the western side.

Regarding the BVRP managers' strategy, Spearman's statistics tend to validate the choices made by the BVRP in terms of recreation; however results are more ambivalent with regards to habitat quality.

In the *High Vosges*, the objective is to conciliate biodiversity conservation with recreational attractiveness. Our results on recreational attractiveness show that this territory is effectively the most attractive one in the area, if it is not the sole, the other two territories showing a negative correlation with our attractiveness index. Overall, the habitat quality is however negatively correlated with the territory, even if habitat quality seems high in the western part of the *High-Vosges* (see Figure 7). The conciliation between the two objectives is thus not achieved, and recreation seems to be privileged to the detriment of habitat quality (a Spearman test between quality and attractiveness confirms the correlation of the two variables in the territory). The goal pursued by managers seems therefore accurate for the *High Vosges*;

Regarding the *1000 Ponds Plateau*, the charter objective is to preserve habitat quality and limit the decline of the agricultural/industrial activity. We can see that in terms of habitat quality the territory effectively beneficiate from a high habitat quality. Again, this is the sole territory showing a positive correlation with the index. The goal, again, seems relevant here, even if it doesn't give the impression to be ambitious as it aims at preserving the strength of the area, and not to ameliorate a weakness. Limiting the decline of the territory could be achieved by developing a real recreation policy around the agricultural industrial/products and by developing a better communication plan around the habitat richness of the area. We can see in the CAI map (Figure 6) that the hotspot of attractive forests covers a good part of this territory. Individuals' preferences for a good habitat quality can also be tested in our model to further simulate the expected effect of such policy on expected visits in the area;

Finally, the BVRP managers' aim in the *Valleys and Piemont* area is to control urbanization and habitat fragmentation. The habitat degradation index, being also an indicator of habitat fragmentation, shows that the objective tends to not be reached in this territory, the correlation with fragmentation being positive even if the coefficient is low. This confirms that the goal is relevant in this territory.

**Table 8:** Spearman correlations between recreation, habitat quality indexes and territories

	Recreation	Habitat quality	
	CAI	Suitability	Degradation
CAI	1.0000		
Suitability	-0.0607***	1.0000	
Degradation	<i>n.s.</i>	-0.9747***	1.0000
<i>High Vosges</i>	0.6373***	-0.2393***	0.2114***
<i>1000 Ponds Plateau</i>	-0.1606***	0.5203***	-0.5147***
<i>Valleys and Piemont</i>	-0.5534***	-0.1106***	0.1358***

\*\*\*p<0.01

*n.s.* : non significant

Overall, we can conclude that the strategy is consistent to tackle the different issues raised in the three territories under study. However two points could be enhanced (1) the strategy pointed in the *High Vosges* should take into for the dichotomous aspect of the territory; and (2) the policy approach is intended to preserve the strengths present in the area more than to enhance weaknesses *e.g.* enhancing the recreational attractiveness of the *1000 pounds*

*plateau* should be a notable enhancement. The developed method may allow testing the effect of different forest policy schemes on the attractiveness of the BVRP. This will be done in a further version of the paper, notably in order to orient decisions in the development of the territorial forestry charter<sup>12</sup>, in which the results produced here are already planned to be used.

## 5. CONCLUSION

In this paper we study the habitat quality and recreational attractiveness potentials in a French Regional Park. To do so, we use the InVEST module to assess habitat quality and we developed an inventive method to evaluate the recreation attractiveness potential. The method is based on two count data models estimated based on a previous survey comprising a part of the studied area, fed by GIS information, to produce a recreation function. The function takes into account both the biophysical aspects of recreation sites and agents' preferences in terms of distance, substitute sites, etc. The function is further transferred in the whole area covered by the BVRP, which allows us to predict visits in a spatially explicit way accordingly to the supply and demand characteristics potentially pursued by visitors. The indexes developed are finally statistically compared with the planning strategy (by using Spearman correlations) that allows highlighting strengths and weaknesses of the goals followed by land managers.

Three principal refinements of the study are possible to provide better policy orientations. First, the recreational attractiveness index developed is only valid for local population, that is the population living in and around the BVRP. Even if a large part of the area is visited by local people, 86% of the French people visiting the park come from the Grand Est and Bourgogne Franche-Comté regions (ORTA, 2011), a significant part of recreationists, roughly 35%, are tourists coming from other countries (principally Germany and Belgium). Their preferences should also be studied in order to complete the recreational attractiveness index. Second, we consider only motorised trips, and this is usual in travel cost studies. Even if 84% of visitors visit forests by using their car (ORTA, 2011), the remaining part of visitors should be accounted for in an ameliorated version of the model. Third, the habitat quality model should benefit of a better calibration of treats and suitability variables. This can be done first by using a more precise typology of habitats (*e.g.* by using the BDOCS® instead of the Corine Land Cover typology) and second by calibrating the impact weights with expert knowledge through a focus group for instance (*i.e.* with foresters, the BVRP managers, environmental associations, ecologists etc.). This will be organised in the coming months even though first feedbacks from the BVRP managers were positive regarding the calibration used.

The method developed in this paper for the recreational service mapping is reproducible to any extrapolation of single site or multiple sites travel cost model, allowing for a better apprehension of the spatial repartition of the service. Indeed, land planners rely now principally in GIS technology for the definition of planning strategy. Producing spatial

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<sup>12</sup> The territorial forestry charter brings together all the actors of a territory to define a program of actions to enhance their forest areas. It takes into account all the forests uses in a territory: economic, environmental and social.

information appears thus particularly critical for ES being accounted for in day-to-day decision making.

We will conclude on directions that can be taken in future research. Here we evaluate a state of the art of the recreational service and habitat quality, in a positive analysis. An interesting extension would be to adopt a normative analysis and thus to optimally allocate different services with spatial optimisation modelling. This would allow highlighting areas benefiting from comparative advantages in the provision of different ES. The spatial assessment of wood production will be necessary to analyse trade-offs, and the functions developed in this paper will serve as inputs in the optimisation model.

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