# Introducing accessibility analysis in mapping cultural ecosystem services

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## Abstract

In recent years, there has been an increasing interest in the study of the spatial link between service providing areas (SPA) and service benefiting areas (SBA). Understanding the spatial link between

SPAs and SBAs is essential when studying the ecosystem service delivery and the fulfilment of ecosystem service demand. However, far too little attention has been paid to the user movement related ecosystem services and where people should be geographically situated in order to benefit from these services. In the movement related services, benefiting areas are equal to providing areas and the spatial link from residential area to SPA is important. The spatial link is addressed through the concept of accessibility which determines the opportunity to move from the area where beneficiaries are located to areas where ecosystem services are produced.

This study presents an accessibility approach to the ecosystem services research. Accessibility analyses offer an opportunity to identify the gap between the ecosystems' potential to produce services and the actual usage possibilities of such services. We demonstrate the suitability of the method by using outdoor recreation and cultural heritage as examples of cultural ecosystem services that people actively want to reach. Accessibility was calculated using a Geographical Information System -based least-cost path analysis, which measures travel time by car between residential location and the nearest SPA via road network.

The examples highlight that accessibility varies according to the ecosystem service and depends mostly on population distribution and travel possibilities. Our results demonstrate that the density of the analysed ecosystem service opportunities is higher near urban areas than elsewhere. The accessibility of different ecosystem services also depends on how much time people are willing to spend for reaching these services. Our study emphasised that, from a population perspective, accessibility analyses provide a powerful tool for illustrating the utilisation possibilities of spatially distributed ecosystem services. The accessibility approach offers great potential to assess the potential use of SPAs and respond to the need to develop a practical tool for ecosystem service research. It effectively shows, for example, the areas where the risk of overuse of ecosystem services is increased. Knowing about the regional differences in ecosystem service usage also gives background information for the decision-makers for drawing conclusions about how much and where it is sensible to invest in the maintenance of ecosystem services.

# 1. Introduction

The Earth's ecosystems create the foundation for the well-being of all human beings (Haines-Young and Potschin, 2010). However, during the last few decades people have been altering ecosystems faster than ever before (MA, 2005; Garcia et al., 2014). Awareness of the importance of key ecosystems in sustaining well-being and economic wealth has increased the significance of the ecosystem service approach in contemporary science (Fisher et al., 2009; Seppelt et al., 2011). In general, ecosystem services (ES) are defined as benefits that humans directly or indirectly obtain from ecosystems (Daily, 1997; De Groot et al., 2002; MA, 2005).

Recently, researchers have shown an increased interest to study the spatial link between areas which provide ES and the areas where beneficiaries are located (Syrbe and Walz, 2012). This spatial link, defined as service connecting area (SCA) (see Syrbe and Walz, 2012), delivers goods and services from 'service providing area' (SPA) to 'service benefiting area' (SBA) (e.g. Rodrigue et al., 2006; Syrbe and Walz, 2012; Burkhard et al., 2014; Wolff et al., 2015), either passively through biophysical processes (e.g. air regulation) or through anthropogenic flow corridors, such as road networks (Villamagna et al., 2013) (Fig. 1). Especially in the case of spatial disconnection between SPA and SBA, this spatial link plays an important role to understand the actual service delivery and the fulfilment of ES demand (Wolff et al., 2015). Sometimes SPA and SBA may overlap (Syrbe and Walz, 2012), which means that people need experiential interaction with those SPAs to benefit from the ES (Fig.1).

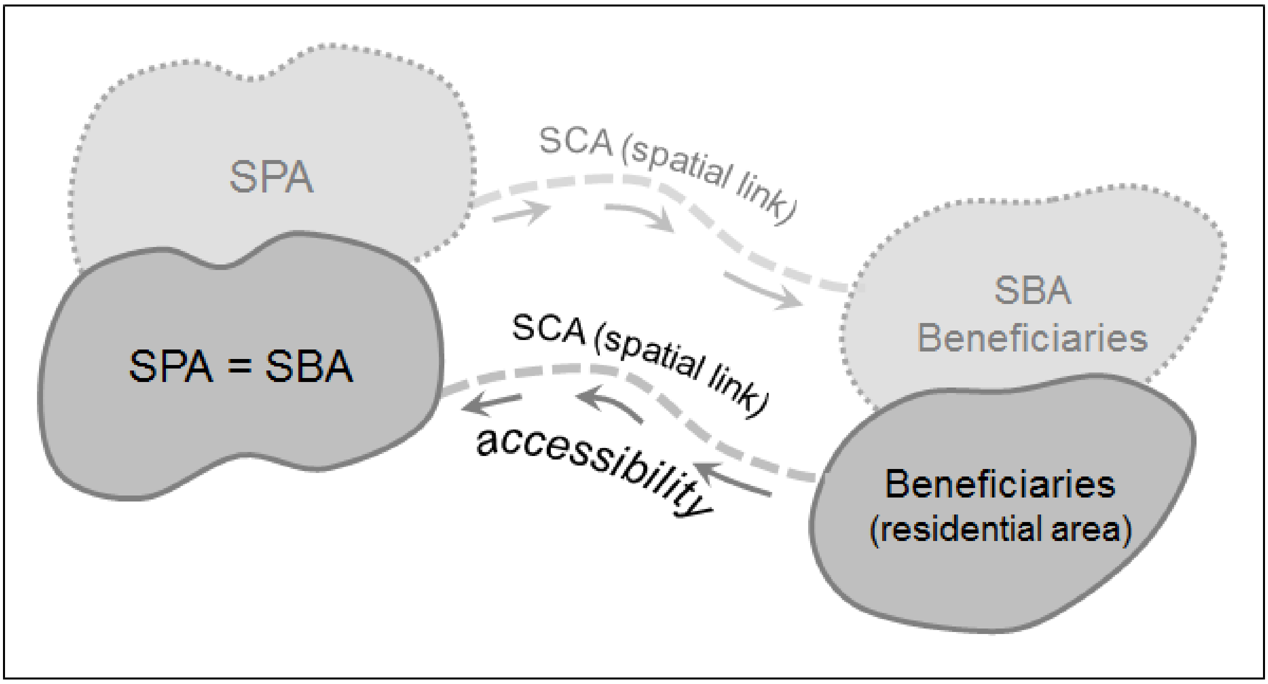



***Figure 1***. *Spatial relationship between service providing area (SPA) and service benefiting area (SBA) (according to Syrbe and Walz 2012).* ***The light grey*** *areas describe the situation in which service connecting area (SCA) (dash line in the figure) connect providing and benefiting areas and deliver goods and services from SPA to SBA (the arrows illustrate the direction of the movement of e.g. water or food products). In this case, SPA and SBA may be distant from each other.* ***The dark grey*** *areas describe the user movement related ecosystem services such as recreation, where benefiting areas (SBA) are equal or similar to providing areas (SPA=SBA) because people must be in the SPA in order to benefit from the ES. SCA, such as a road network, connects beneficiaries (residential area) to SPA. Accessibility describes the beneficiaries' possibility to reach SPAs via road network. This study utilised the latter (dark grey) situation.*

Accessibility is a key aspect in spatial linkage and determines the opportunity to move from the area where beneficiaries are located to areas where ES are produced (SPAs). The possibility for people to reach SPAs is also related to the studies of ecosystem functions. Recently, it has been emphasised that ecosystem functions (the potential of an ecosystem to provide a service) become a service (the actual use of potential ES) only if there are people who benefit from those ES (e.g. Fisher et al., 2009). Hence, the delivery of some of the ES is strictly dependent on the presence of people. Costanza (2008) has defined those services as "*user movement related services*", which commonly require traveling between the place of residence and the SPA (see Rodrigue et al., 2006). For example, recreation and many other cultural ES depend quite strongly on the flow of people; to benefit from such services, people must be able to actively reach them (see Paracchini et al., 2014). If people are unable to access the SPAs, there is no actual use of services (Science for Environment Policy, 2015). Unfortunately, there is a lack of information on the accessibility of SPAs, hindering the possibility to indicate how well people can actually benefit from them. However, it is evident that poor spatial accessibility reduces the use of ES.

The concept of accessibility, which can be defined as how easily a location can be reached from another location (Rodrigue et al., 2006) or the possibility to reach spatially distributed opportunities (Paez et al., 2012), is a well-developed concept and serves as a common research framework within the field of transport geography (Rodrigue et al., 2006). More precisely, spatial accessibility measures the extent to which a land-use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) particular transport mode(s) (Geurs and Ritsema van Eck, 2001). However, this concept has rarely been applied in ES studies (see Brabyn and Sutton, 2013). In order for people to be able to reach different SPAs, more attention has to be paid to both the spatial distribution of ecosystems which provide services and accessibility properties, such as infrastructure (De Groot et al., 2010; Crossman et al., 2013; Paracchini et al., 2014), and the spatial structure of a population and its ability to reach such services. A recent study by Paracchini et al. (2014) suggested that accessibility via roads and related travelling time is one of the approaches to study the accessibility of ES. Additionally, Syrbe and

Walz (2012) have proposed that network analyses of roads give insight into the accessibility of service providing areas and have several utilizations for evaluating benefiting areas.

The purpose of this study is to introduce the methodology of accessibility to ES research. Especially, we analysed what kind of opportunities people have in reaching the user movement related ES at broad scale (e.g. from a regional scale up to a continental scale, and even in specific cases, a global scale). We used Geographical Information System (GIS) -based least-cost path analysis, which measures the time (or distance) between population settlements and SPA along a road network. In our work, accessibility is seen as the approximate travel time to different ES opportunities.

In this study, outdoor recreation and cultural heritage were selected to represent the cultural ES that people have to be able to actively reach in order to benefit from them. The used ES indicators (SPAs) are based on the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013). The study aim is to answer the following questions: (1) How accessible are the studied SPAs at a national scale in Finland? (2) What proportion of the population is able to reach SPAs given the different travel times? Overall, we evaluated whether the accessibility approach would offer a new and efficient way to measure the potential usability of "*user movement related ES*". Finland is an ideal choice to introduce the accessibility method at a national scale due to the availability of GIS data with a high degree of spatial accuracy concerning the transport network, population and several SPAs. This is one of the first studies to assess the accessibility of different SPAs with respect to the overall population using least-cost path analysis (see also Brabyn and Sutton, 2013).

# 2. Material and methods

## 2.1 Study area: key characteristics of the Finnish population and its travel habits

Finland is located in northern Europe by the Baltic Sea (Fig. 2). The total land area of Finland is 303 891 $km^2$, of which only about 30% is inhabited. The country had a population of 5.5 million (17.9 inhabitants / $km^2$) at the beginning of the year 2014. Although Finland is relatively sparsely populated compared to most of the European countries, a significant proportion of the population lives in urban settlements (Statistics Finland, 2014a; 2014b).

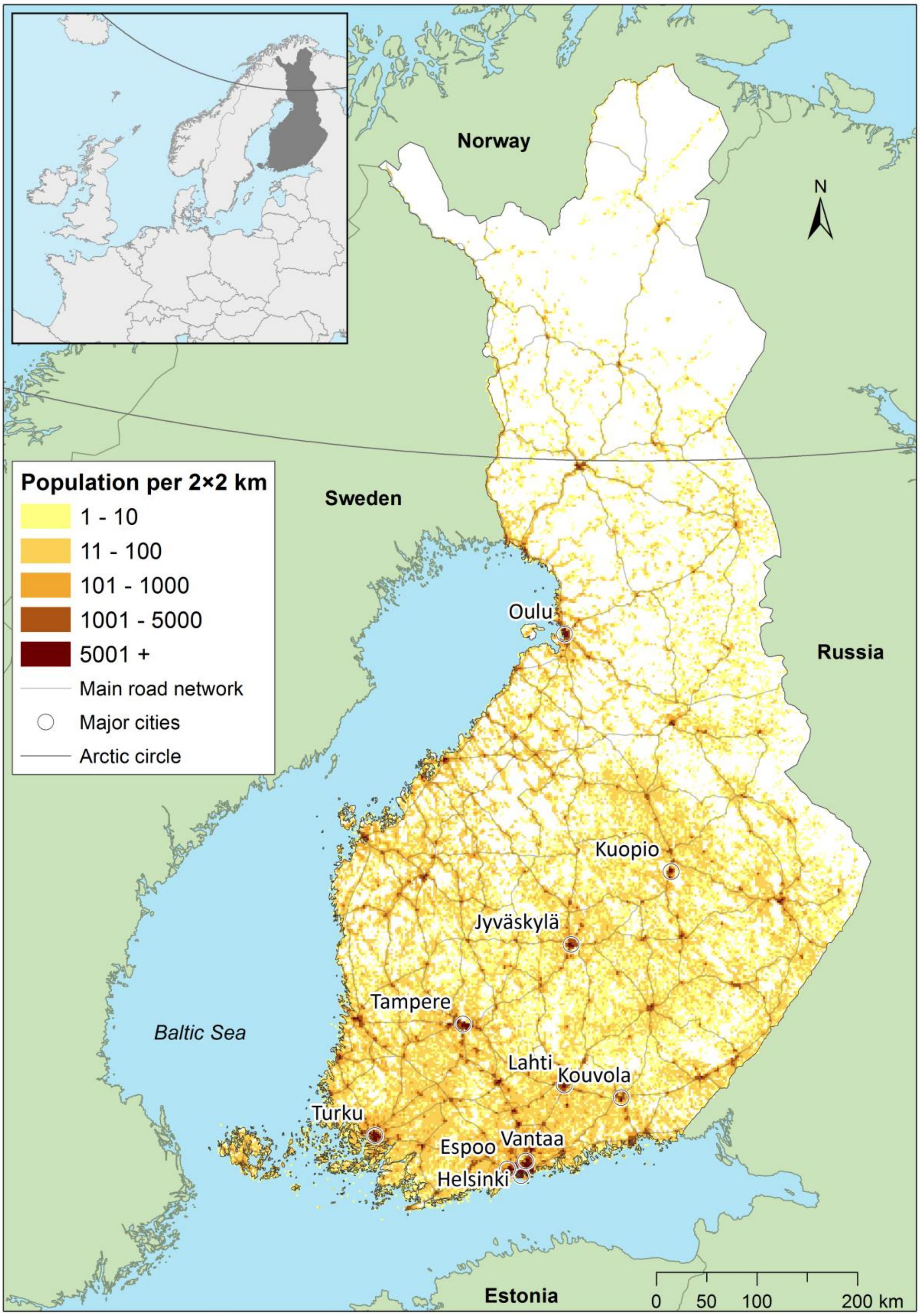
The road network of Finland is extensive and in a relatively good condition. In general, Finns have a good possibility to travel by car because most of the adults (84%) have a driving license (in 2013, two and a half million passenger cars were registered for traffic use) (Statistics Finland, 2013a). Indeed, Finnish traffic consists primarily of private cars, especially for short daily trips ranging from 1 to 150 km (National Travel Survey, 2010-2011). According to National Travel Survey results from the years 2010–2011, Finns made approximately two trips per day by car (total average length of the trips is 29.9 km during a day) and the average duration of each trip was approximately 21 minutes, depending on the area and the time of year (Table 1). Travel time is the total time a person has spent travelling from one place to another by car including all trip purposes (e.g. work and leisure-related trips). People make the longest trips in July, which is the general vacation season in Finland. During that month, each trip last on average 27 minutes, whereas the average travel time per trip takes 10 min less in December. The travel time information about the leisure trips made by car is not available.

Overall, 25% of trips have a recreational purpose and most of the trips start or end at home (National Travel Survey, 2010-2011). Finns take on average eight nature trips per year, of which the most are taken between May and September. In general, people will use about one and a half hours to travel to nature destinations (Table 1). Approximately 3% of nature trips have a hunting purpose and 26.7% are directed towards national parks. Nearly half of the trips to national parks take more than eight hours of travel time, while 38% of those taking hunting trips spend three to eight hours on the road (Sievänen and Neuvonen, 2011).

***Table 1.*** *Statistics of the average travel times of Finns.*

| **Trips by car** | **Number of trips / day** | **Travel time (minutes)** | **Source** |
|---|---|---|---|
| *Total* | 1.7 | 21.4 | National Travel Survey (2010–2011) |
| *in July* | 1.6 | 27.4 | |
| *in December* | 1.5 | 18.9 | |
| **Nature trips** | **Number of trips / year** | **Travel time (minutes)** | **Source** |
| *total of all nature trips** | 7.7 (mean) | 90 | Sievänen and Neuvonen (2011) |
| *National parks*** | 2 (md) | > 480 (48.9% of trips) | |
| *Hunting trips*** | 2 (md) | 180 – 480 (38.0% of trips) | |

* Total number of 15–74 year olds in the population, including all kinds of nature trips (e.g. hunting, fishing, berry picking, boating, skiing). **Of those who took nature trips.




171 Map: University of Oulu, Finland. Data: Population, Statistics Finland; Digiroad, Finnish Transport Agency.

172 ***Figure 2.*** *Finland and its population distribution shown in 2×2 km grid cells.*

## 2.2 Identifying ecosystem service providing areas

Cultural ES are the ‘non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences’ (MA, 2005). This study uses outdoor recreation (SPAs: national parks, wilderness areas and wild game habitats) and cultural heritage (SPAs: nationally valuable landscapes) as an example of cultural ES (Table 2). The experience or use of the ES provided by these SPAs clearly depends on the flow of people, and accessibility is an important component for assessing such ES (Costanza, 2008; De Groot et al., 2010; Crossman et al., 2013; Paracchini et al., 2014). Recreation and cultural heritage areas were defined here as landscapes that have recreational or cultural heritage potential for people. To better illustrate the availability of SPA from the areas where beneficiaries are located, the opportunities for people to reach the nearest potential landscape sites were calculated.

***Table 2.*** *Types of ES analysed. Table identifies service providing areas to which the accessibility of the inhabited grid cells has been calculated.*

| **Section*** | **Division** | **Group** | **Class** | **Description** | **Data source** |
|---|---|---|---|---|---|
| CULTURAL | Physical and intellectual interactions with biota, ecosystems and landscapes | Physical and experiential interactions | RECREATION | | |
| | | | *National parks* | The nature reserves whose establishment and purpose have been prescribed by law. | Finnish Environment Institute |
| | | | *Wilderness areas* | Areas that have been established in northern Finland to protect wilderness areas. | |
| | | | *Wild game habitats* | Brown hare (*Lepus europaeus)* distribution indicates the potential | Natural Resources Institute |

| | | | | |
|---|---|---|---|---|
| | | | service providing area in Finland. | Finland |
| Intellectual and representative interactions | CULTURAL HERITAGE | | | |
| | | *area of nationally valuable landscapes* | Areas represent the important cultural landscapes of Finland. Their value is based on culturally significant natural diversity, cultivated agricultural landscape and traditional architecture. | Finnish Environment Institute |

* Based on Common International Classification of Ecosystem Services, CICES (Haines-Young and Potschin, 2013).

### 2.2.1 National parks and wilderness areas

For recreation purposes, natural ecosystems have an important role as places where people can go to refresh themselves (De Groot et al., 2002). According to Finnish National Outdoor Recreation Demand Inventory, people are especially attracted to forests and water environments (Sievänen and Neuvonen, 2011). Finland with nearly 200 000 lakes and forest cover of 67% (Statistics Finland, 2014a) provides a high level of recreation potential fairly homogenously throughout the country, even in the densely populated regions. For this reason, the areas which are clearly defined to have potential recreation status or natural state have been selected to represent as an example of outdoor recreation sites in this study. Recreational possibilities in nature throughout Finland were mapped based on GIS data (managed by the Finnish Environment Institute). The data contain twelve different recreation area classes, two of which (national parks and wilderness areas) were used in this study to demonstrate the applicability of accessibility measures in ES research. Used data contains 35 national parks and 30 wilderness areas. The size of national parks varies between 6.7 to 2859 $km^2$ and wilderness areas between 0.0005 to 2956 $km^2$.

### 2.2.2 Wild game habitats

The hunting of wild game for food can provide an intrinsic part of the human diet. Nowadays hunting can also be seen as a part of recreational activities or cultural traditions of a particular region (De Groot et al., 2002; MA, 2005). Depending on the definition, wild game can be categorised as belonging to either cultural or provisioning services (e.g. De Groot et al., 2002; Haines-Young and Potschin, 2011; Crossman et al., 2013). Following Haines-Young and Potschin (2013) we consider it to be a part of cultural services.

In order to hunt in Finland, each hunter must have a hunting card and hunting permit granted by a land owner or holder of hunting rights. Hunting rights belong to the land owner, or hunter can be a member of a hunting club which has leased areas for hunting. The game management fee was paid by 6% of the population in 2012, which is more than in other parts of Europe in proportion to the overall population size. Two-thirds of the hunters hunted at least once during the hunting season and nearly all of them hunted small game. The most important small game mammals are mountain hares (*Lepus timidus*), raccoon dogs (*Nyctereutes procyonoides*) and brown hares (*Lepus europaeus*) (Statistics Finland, 2013b; The Finnish Wildlife Agency, 2014). In this study, the brown hare is identified as the wild game indicator. Its distribution was used as an estimate of the potential of hunting areas at national scale, due to a lack of appropriate data of leased hunting areas. The potential availability of the brown hare in Finland was calculated based on the national monitoring of forest game (Lindén et al., 1996). Information on the brown hare populations are estimated every year with the help of game triangles (n = 1132), which are randomly situated in wooded landscapes in different parts of the country. To obtain information for the whole country (i.e. also for areas outside the triangles), we modelled the distribution of brown hare populations using generalized additive models (GAM) with standard procedures (Hastie and Tibshirani, 1990). The modelling was performed in R with the *mgcv* package (R Development Core Team, 2011).

We used four environmental variable groups (climate, topography, geographical location and land cover; see appendix A.1) in GAM to explain variation in brown hare distribution. All twelve explanatory variables, which did not suffer from multicollinearity (rs> |0.7|) and variance inflation factor, VIF < 10 (e.g. Kutner et al., 2004), were considered as potential explanatory variables. Brown hare distributions were described using binary data (presence/absence) of the populations. The calibration data set was created by randomly selecting 70% of the data, whereas the remaining 30% of data formed the evaluation data set. We used the Bayesian Information Criteria (BIC) (Schwarz, 1978) selection algorithm with a backward selection method in the development of the model. A smoothing spline with three degrees of freedom was used to fit the selected variables with brown hare observations. The modelling outcomes were assessed using the percentage of explained deviance ($D^2$) and the area under the curve (AUC) of a receiver operating characteristic plot (ROC). Following Swets (1988), the model's accuracy is excellent if AUC > 0.9, good if 0.9 > AUC > 0.8, fair if 0.8 > AUC > 0.7 and low if AUC < 0.7.

Based on BIC, growing degree days and cultivated field cover were selected as input variables in GAM. The model explained 40.7% of the deviance in brown hare data and the AUC values ranged from 0.898 (calibration) to 0.914 (evaluation). On the basis of the predicted brown hare distribution, probability values ≥ 0.5 were selected to represent an abundant occurrence of wild game in Finland. Based on these predicted distributions, national parks and settlements were removed to better describe those areas in which hunting is possible.

### 2.2.3 Nationally valuable landscapes

Cultural heritage, defined as nationally valuable landscapes or places which have high historical or cultural value on maintenance (De Groot et al., 2010; Hernandez-Morcillo et al., 2013), were officially inventoried in Finland in 1995 based on a decision by the Finnish Ministry of the Environment. The evaluation of such landscapes is based on regional variations in natural and cultural characteristics. The GIS data on nationally valuable cultural environments (managed by the Finnish Environment Institute) consist of data layer on culturally valuable natural diversity, traditional architecture and cultivated agricultural landscape polygons (n = 156 in total, the size of the areas varies between 0.005 and 4 $km^2$). Landscapes are protected by means of legislation and collaboration between environmental and cultural administrations.

## 2.3 Analysing the accessibility to ecosystem service providing areas with GIS

Accessibility approach was used to indicate people movement between origin and destination. It describes the spatial interaction between SPA and residential area over a geographical scale covering a wide variety of people movements (see Rodrigue et al., 2006). Accessibility is assessed as travel time estimates of the fastest routes between residential locations (origins) and the nearest SPA (destinations). Travel time via road network is one of the most common ways to approximate accessibility in geographical analyses of transport systems when considering the movement of people (Rodrigue et al., 2006; Paez et al., 2012). Several geographical models of a road network are applicable with GIS-based accessibility analyses as they have a routable topology and include speed limits as attributes (e.g. Nokia Here (2015); OpenStreetMap (2015)). In this study, a Finnish digital road network database (Digiroad) that includes accurate road geometry and speed limit data was used (Finnish Transport Agency, 2014). Origins and travel destination, as well as the road network, can be analytically considered as either a graph or a weighted graph when some attributes are added to the vertices connecting nodes (see Miller and Shaw, 2001). The least-cost path between the origin and destination can be calculated in a GIS, when the spatial data of travel speed and time, or other relevant travel cost estimates, for the graph model of a road network are available. In practice, route formulation in GIS relies mainly on Dijkstra's (1959) algorithm and its heuristic applications (ESRI, 2010). In this study, ArcGIS Desktop 10.2 and its network analyst extension was used to generate travel time estimates.

The residential pattern of the Finnish population was selected to represent the points of origin for travel to SPA. The population data used in this study was obtained from Statistics Finland's (2013c) population grid cell database for the year 2011. This is a raster layer of 250 × 250 m resolution representing the number of inhabitants per grid cell. The population data are based on national register that contains basic information from inhabitants of Finland and is free of estimation-related uncertainties. In comparison to populations related to administrative boundaries, the clear strengths of the grid cell-based population data include the ability to represent urban and regional structures and outline and ignore uninhabited areas with a high degree of spatial accuracy. However, the large number of observations (approximately 325 000 populated grid cells in total in this case) constituted a computational challenge for route solving when using desktop GIS. To prepare population data applicable for accessibility analysis, we aggregated data at a resolution of 2 × 2 km to achieve a functional amount of data (42 629 populated grid cells in total); the resolution of the data still represents the urban and regional structures with a high degree of accuracy at the state-level scale. Centroids of the grid cells were used as a spatial reference (origin) for the grid cells during accessibility analysis. Populated grid cells, relying on unscheduled coastal and inland maritime water transports, were omitted from the analysis as well as the settlements of the wilderness areas which are located more than 5 km from the closest point along the road network. Intersection points of the road network and SPA represents the destinations. All SPAs cannot, however, be reached directly by car (e.g. if the road network does not intersect SPA). In those cases, it was considered that road network which is located under 500 m from the SPA, can be reached in practice. A representative sample of the spatial accuracy of the data is presented in Fig. 3.

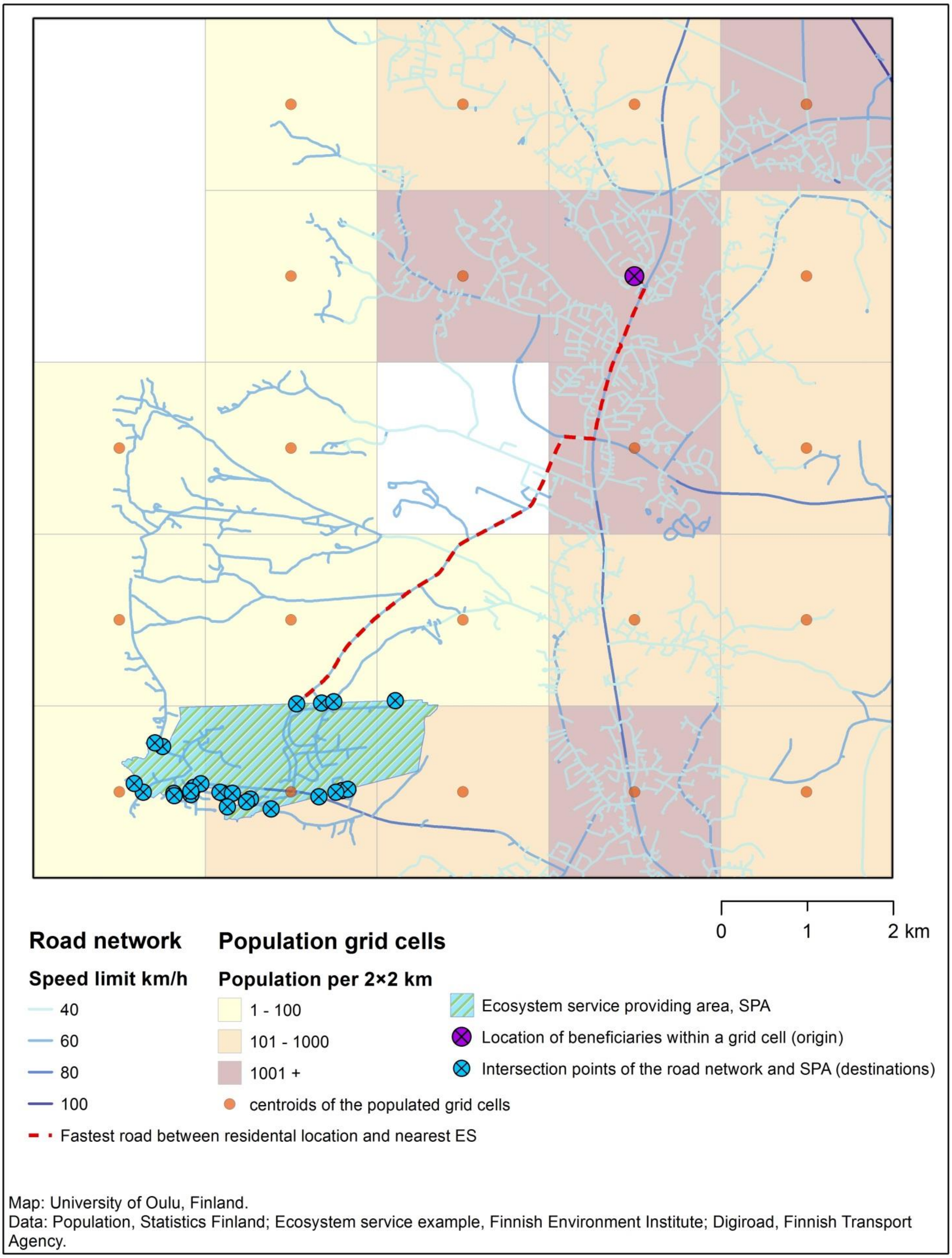



***Figure 3.*** *Example of the data used to calculate the quickest route from inhabited grid cells to the nearest service providing area (SPA).*

Travel time by private car was estimated according to the speed limit attributes and geometric information provided by Digiroad for the year 2012 (Finnish Transport Agency, 2014). On the basis of speed limits and turn penalties at road crossings, travel time by passenger car along the Finnish road network can be estimated and expressed quite accurately, as congestion problems are limited to a few urban cores and related mainly to the temporal patterns of commuting. The speed limit data included in the Digiroad database is available inclusively for primary and secondary roads as well as for streets. However, for local low-class road segments, which have no speed limit information available, an approximate speed of 30 km/h was used in populated areas and 50 km/h for roads outside of populated areas. In addition, the effect that turning had on travel times were estimated by applying time penalties of 12 seconds for right turns and 24 seconds for left turns (Spurr, 2005: 33). A few connections in the road network rely on scheduled ferry connections. To include areas connected by ferry links in the analysis, the travel speed of road ferry links was estimated at 20 km/h, except in the case of a few cable ferries for which the speed estimate was 10 km/h, and a time penalty of 15 minutes was included in the cost of ferry travel in order to take the waiting time into account. Even though travel time estimates based on speed limit and turn penalties will be quite accurate in the large majority of areas, temporal congestion patterns will increase travel times especially in urban cores, and particularly in the Helsinki metropolitan area (Helsinki, Espoo, Kauniainen and Vantaa, see Fig. 2) in southern Finland (Salonen and Toivonen, 2013).

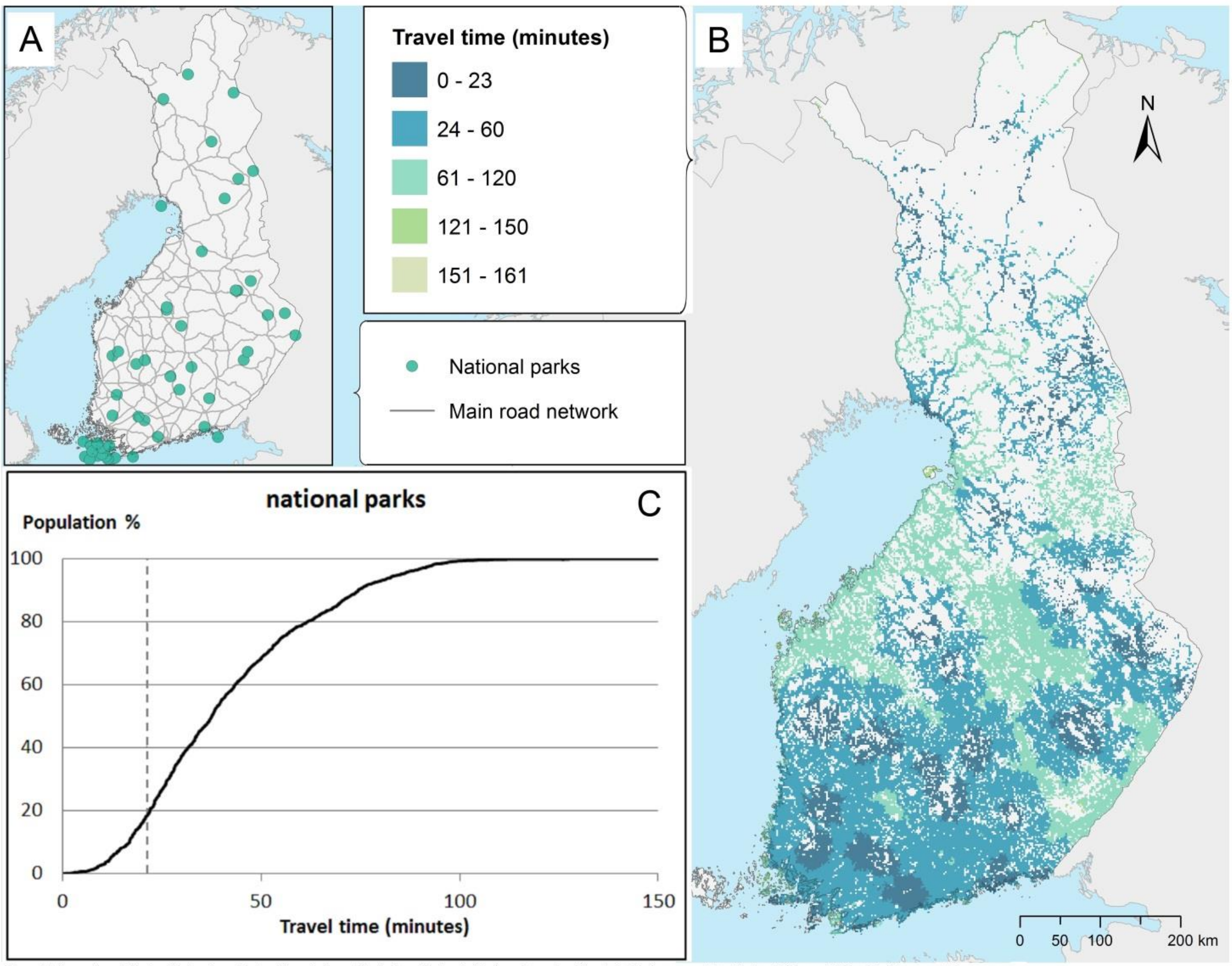
# 3. Results

To illustrate how SPAs (Figs. 4–7a) differs from their geographical accessibility, we mapped the travel time from each populated grid cell (2 × 2 km resolution) to the nearest SPA (Figs. 4–7b). The graphical illustration of travel time to the nearest SPA versus the cumulative percentage of population clarifies how well people can reach different SPA sites (Figs. 4–7c). In the graphs, the vertical dashed lines in the x-axis represent an approximate daily travel time (21 minutes) that has been used for one way trip (National Travel Survey, 2010-2011). The road network does not remarkably restrict the accessibility of ES. However, the number of inhabitants in the 2 × 2 km grid cells varies from one to more than thousands in Finland (see Fig. 2), which means that low travel times can either benefit only a few or several people depending on the population of the grid cells. To estimate the direction of the trips and the expected number of people who are able to reach each SPA, we made the maps of the national parks on the basis of the accessibility results in using different travel time thresholds (Fig. 8).

Our results show that the importance of the geographical distribution of population to the accessibility of SPAs is evident. National parks, for example, cover different regions of the country quite well (Fig. 4a) but are not very accessible. Only 18% of the population can reach them based on average daily travel time by car (Figs. 4b, 4c and Fig. 8). Despite the relatively poor accessibility of national parks on a daily basis, all Finns are able to reach their nearest national park if they are willing to travel at least eight hours (see Table 1 and Fig 8). Instead, wilderness areas are large but situated only in the northern part of the country. Thus, based on low travel times, only a few people (less than 1% of population) can benefit from the potential recreation ES they provide (Fig. 5).

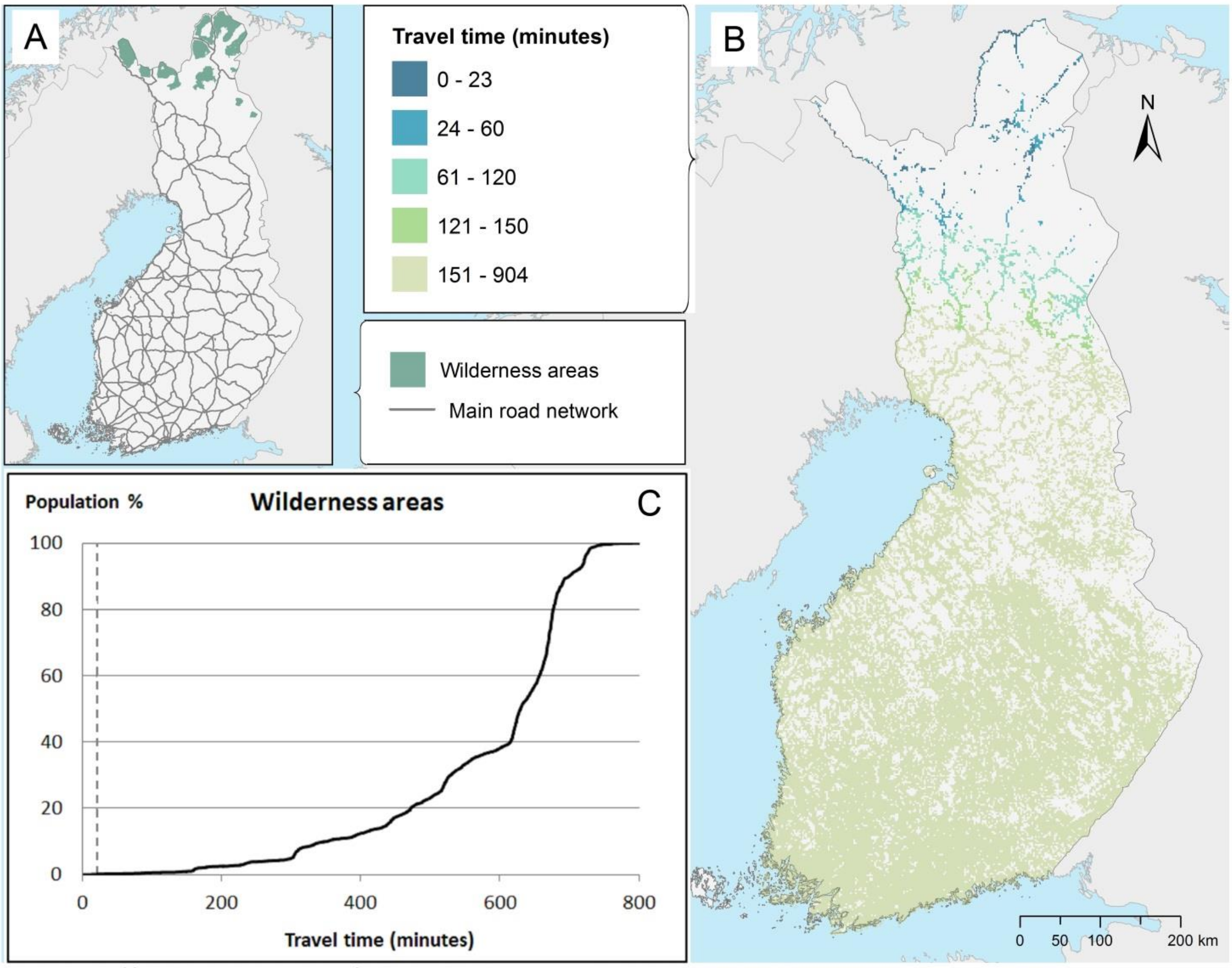
The distribution of brown hares (wild game habitants), for instance, is limited to the southern part of the country (Fig. 6a), and more than 65% of the population is able to reach the area in approximately 21 minutes (Figs. 6b and 6c). Even in December, when people use less time for traveling, approximately 60% of inhabitants have access to this SPA. If we compare the cumulative population accessibility to the travel time used for hunting trips (Table 1), we notice that more than 99% of the population can reach brown hare habitats at least once a year. The vicinity of the population to SPA is clearly evident in the short distances from the populated grids to the nearest brown hare areas in southern Finland, where the SPAs is extensively and easily available compared to northern Finland.

Access to nationally valuable landscapes is easy for a large share of the population (Fig. 7). Nearly 80% of people can reach some form of valuable landscape within daily average travel time, and most of the people (nine out of ten) can easily reach them in July given the average travel time during this typical summer holiday month (see Table 1). Compared to national parks, the nationally valuable landscapes are located closer to the settlements and can thus be reached more easily. In general, our results suggest that Finland is able to offer its citizens reasonably convenient access to the analysed SPAs except for wilderness areas.



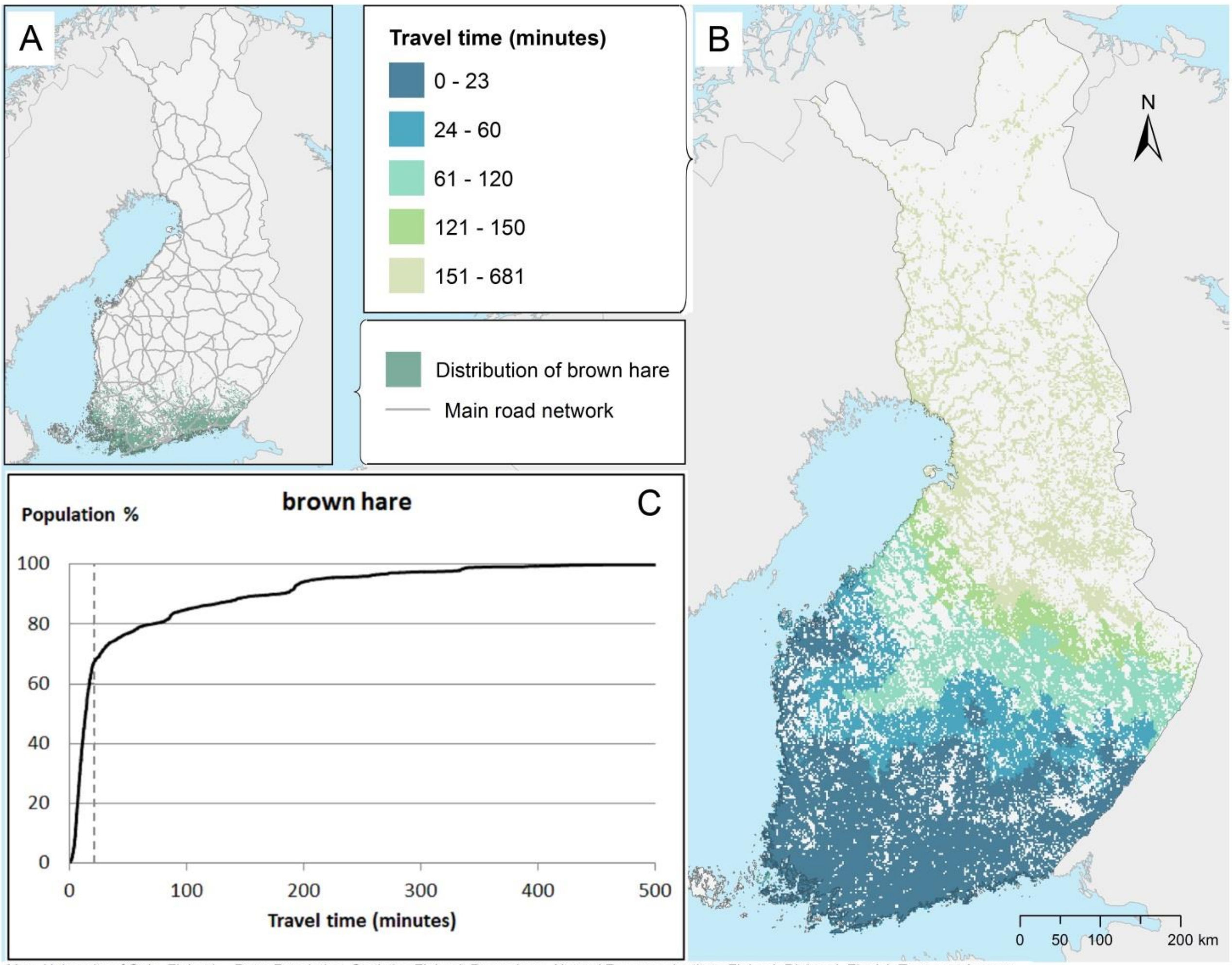
Map: University of Oulu, Finland. Data: Population, Statistics Finland; National parks, Finnish Environment Institute; Digiroad, Finnish Transport Agency.

***Figure 4.*** *Potential accessibility to national parks by car. A: service providing areas (SPAs) locations, dots represents the centroids of national parks; B: travel time from each populated grid cell to the nearest SPA; C: cumulative percentage of population (y-axes) in relation to travel time to nearest SPA (x-axes). The vertical dashed line in the x-axis represent an approximate daily travel time (21 minutes) that has been used for one trip (National Travel Survey, 2010-2011).*



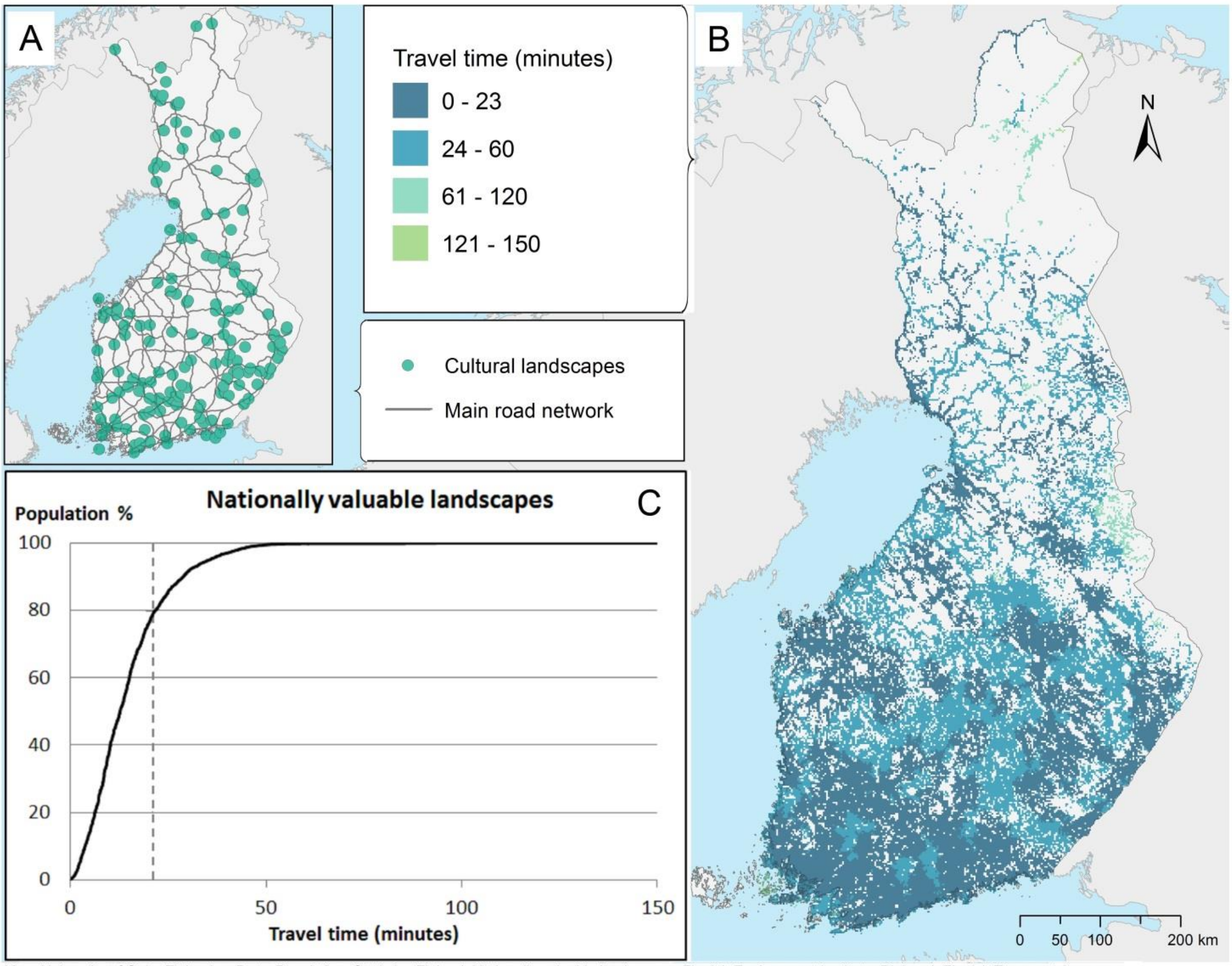

Map: University of Oulu, Finland. Data: Population, Statistics Finland; Wilderness areas, Finnish Environment Insitute; Digiroad, Finnish Transport Agency

***Figure 5.*** *Potential accessibility to wilderness areas by car. A: service providing areas (SPAs) locations; B: travel time from each populated grid cell to the nearest SPA; C: cumulative percentage of population (y-axes) in relation to travel time to nearest SPA (x-axes). The vertical dashed line in the x-axis represent an approximate daily travel time (21 minutes) that has been used for one trip (National Travel Survey, 2010-2011).*



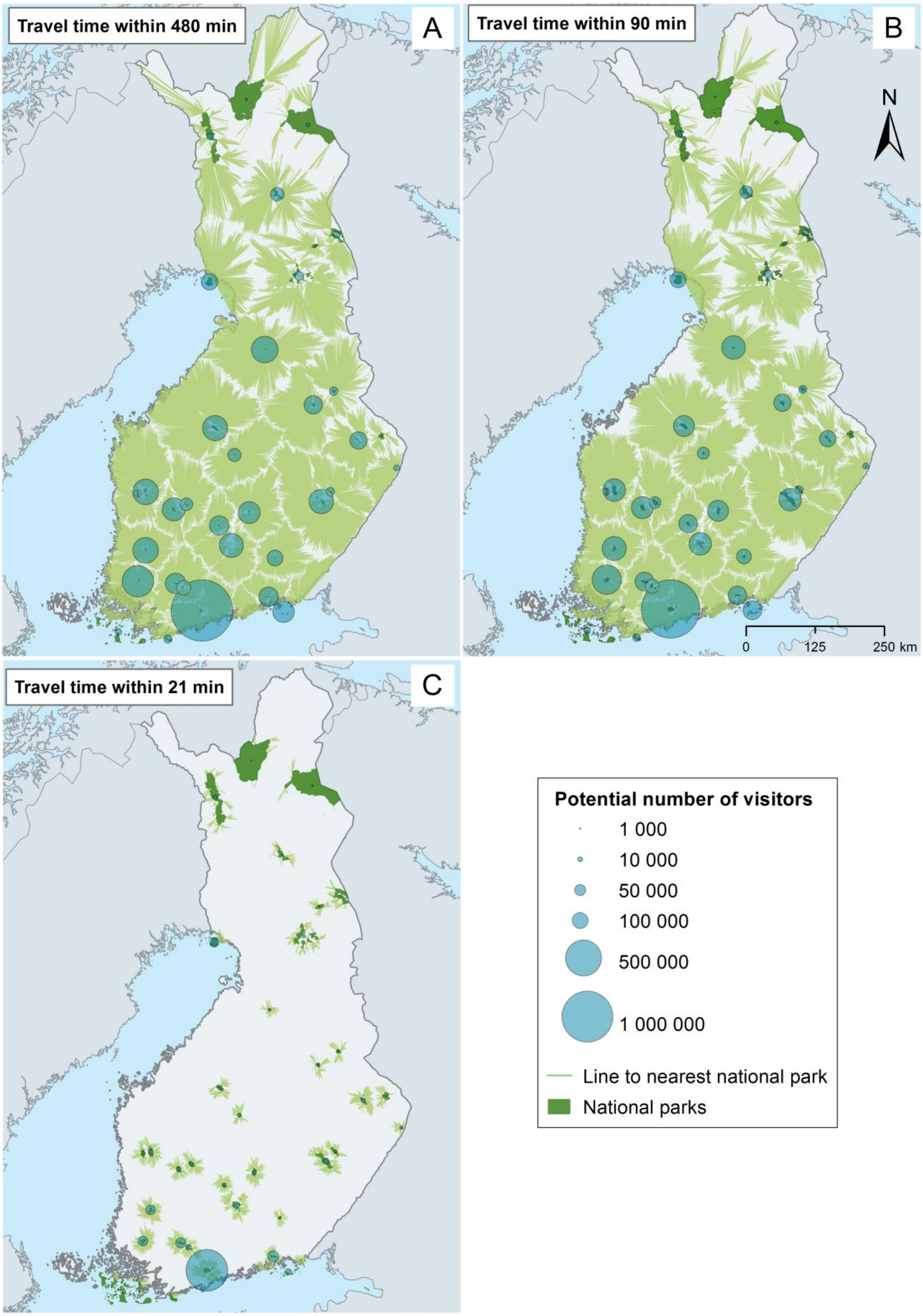

Map: University of Oulu, Finland Data: Population, Statistics Finland; Brown hare, Natural Resource Institute Finland; Digiroad, Finnish Transport Agency.

***Figure 6.*** *Potential accessibility to wild game habitats by car. A: predicted distribution of brown hare populations (service providing areas, SPAs), where settlements and nature reserves were removed; B: travel time from each populated grid cell to the nearest potential hunting area; C: cumulative percentage of population (y-axes) in relation to travel time to nearest SPA (x-axes). The vertical dashed line in the x-axis represent an approximate daily travel time (21 minutes) that has been used for one trip (National Travel Survey, 2010-2011).*




Map: University of Oulu, Finland. Data: Population, Statistics Finland; Nationally valuable landscapes, Finnish Environment Institute; Digiroad, Finnish Transport Agency.

***Figure 7.*** *Potential accessibility to nationally valuable landscapes by car. A: service providing areas (SPAs) locations, dots represents the centroids of valuable landscapes; B: travel time from each populated grid cell to the nearest SPA; C: cumulative percentage of population (y-axes) in relation to travel time to nearest SPA (x-axes). The vertical dashed line in the x-axis represent an approximate daily travel time (21 minutes) that has been used for one trip (National Travel Survey, 2010-2011).*




394 Map: University of Oulu, Finland. Data: National parks, Finnish Environment Institute

***Figure 8.*** *Location of the nearest national park (service providing area, SPA) form each 2x2 km populated grid cells. Straight lines are drawn between origin (populated grid cell) and destination (the nearest SPA). The figure illustrates the geographical areas (light green) from which population has an opportunity to reach the nearest SPA within given time (A: travel time to National parks, 480 min; B: travel time to nature destinations, 90 min and C: daily travel time, 21 min; see Table 1) and how many people i.e. potential users (blue circle) reside in those areas. Note that the studied accessibility has been calculated from each populated grid cell to the nearest SPA. The straight lines are based on the accessibility analyses along the road network but to clarify the link between origin and destination the connections has been drawn as a straight line.*

# 4. Discussion

The aim of the study was to explore the applicability of accessibility measures in ES research. This study demonstrated that the used approach is well-suited to model the user movement related ES that require a direct interaction with people, as is the case in the studied SPAs. In general, mapping has become a powerful tool for illustrating and quantifying the spatial disparity between SPAs and SBAs (see Burkhard et al., 2012; Crossman et al., 2013). For user movement related ES, benefits are commonly experienced in the area where the service is provided (Fig.1). Thus, it is fundamental to evaluate the accessibility of SPA from residential areas to better understand the usage of these ES. Hence, quantifying only the location of SPAs is not an appropriate indicator when evaluating the use of the ES. In this study, least-cost path analysis was used to investigate the potential movement of people between residential areas and SPA. Instead of focusing only on mapping the spatial distribution of SPAs, residential areas and the spatial link between them, accessibility analyses were used to effectively reveal the areas where people do not adequately have opportunity to reach SPAs.

The results showed that the accessibility of different SPAs varies widely in Finland. More precisely, travel times to the nearest SPA in densely populated areas were lower than in sparsely populated areas. On the one hand, it is good that the density of SPA is higher closer to urban than to peripheral areas, because it increases people's opportunities to reach SPA (see Páez et al., 2012). On the other hand, SPA close to urban areas may be subject to deterioration if large numbers of people actually use these ES (e.g. Turner et al., 2014). Based on this accessibility analysis, the SPAs in the Helsinki metropolitan area, for example, can potentially receive more people than the services which are located in the sparsely populated areas, increasing the risk of the overuse of ES (see Fig. 6). Increasing pressure from anthropogenic drivers, such as overuse or congestion in SPAs close to urban areas, may have impacts on biodiversity, which in turn can directly or indirectly affect ESs (e.g. Mace et al., 2012; Maes et al., 2012; Science for Environment Policy, 2015 and references therein). This kind of accessibility analyses of SPAs using visual maps provide improved guidelines for policy actions, as the findings can effectively show the areas in which conservation of services must be improved or where it is worthwhile to invest in and restore new ES sites (e.g. in case of potential overuse of ES). In addition, the method reveals the residential areas where no SPAs are available in reasonable travel time or where the ES are potentially underutilized. Moreover, if residential data includes basic information on inhabitants (e.g. age), it is possible to get statistics about the potential users of each SPA. This kind of information is important when a SPA network is estimated for national or even at global level.

Our study showed that private cars are needed in order to guarantee the flow of the people to the analysed SPAs. In reality, the use of different means of transport during the trip influence travel times (National Travel Survey, 2010-2011). Also, the amount of the traffic and the condition of the road network has an influence on the travel time. Additionally, the available means of transport or the lack thereof may even constrain the final decision about the use of SPAs. In Finland, nearly all

(85%) trips between 20 and 150 km and even 90% of nature trips are made by a private car (National Travel Survey, 2010-2011; Sievänen and Neuvonen, 2011). Thus in this study, significant attention is not paid to other forms of travel.

This analysis focused on the accessibility of the nearest SPA as an indicator of people's movement. However, accessibility can differ from one person to another. The travel and destination choices of where people actually go are driven by various individual factors, such as personal preferences, available time, funds or even the weather. Also the time of the day and the season have an influence on travel time. Especially in cities, traffic congestion varies during the day, affecting the availability of SPAs for people who live in urban areas. Furthermore, the amount of time that people are willing to use to travel to different SPA varies throughout the year. People have more time to travel during the vacation season, which means that SPAs are more available during those times. Also, the supply of some ES may be seasonally restricted. For example, wild game SPAs, such as those harbouring large brown hare populations, will be used only during the hunting season, while the majority of nature trips will be made in the summer time (Sievänen and Neuvonen, 2011).

Páez et al. (2012) consider that normative accessibility measures, characterising opportunities of spatial accessibility by means of travel, can also be used in a positive research framework, when the characteristics of travel behaviour are included in the interpretation of the results. In general, normative accessibility is a measure of potential mobility and does not take actual travel behaviour into account. The analysis results based on normative accessibility do not reflect how far people are willing to travel. Thus, normative accessibility is uniform between individuals and it describes how far people should travel, not how far people actually travel (see Páez et al., 2012 and references therein). In this study, we have taken actual travel behaviour (positive accessibility approach) more into consideration by reflecting actual daily and seasonal travel times reported on travel surveys (see Table 1) to measure opportunity to move from one place to another. In general, the travel time serves as highly applicable indicator in evaluating access to SPA between regions, or more specifically in geographic space.

Accessibility approach offers an innovative opening to assess the potential opportunity to use SPAs and responds to the need to develop a practical tool for ES research and decision making. The accessibility analysis is, in principle, ready to be applied in various types of areas and at different scales (from a regional up to global scale), as network analyst tools and accurate GIS data, at least for road networks, residential locations and SPAs are already available. Generally, the method can be used to identify the areas where people have a weak possibility to use SPAs. The analysis effectively shows that two different locations with the same importance in term of potential SPA might have different accessibilities. Hence, the accessibility measures presented here offer a good indicator which considers not only the location but also inequality conferred by distance more accurate than simple geographical or Euclidean distance based comparisons. Our study well demonstrates that all SPAs are not equal in terms of ES use because some are more accessible than others.

# 5. Conclusion

In this study, we analysed the accessibility of four cultural SPAs to illustrate the applicability of least-cost-path analysis for ES research. Based on the results, we draw two main conclusions. First, the approach can be used to indicate areas where people have limited possibilities to reach the analysed SPAs within a reasonable amount of travel time. The results have shown that in Finland, where SPAs are available on a fairly homogenous basis throughout the country, the extent to which they are used depends on the population distribution and travel possibilities. Moreover, the accessibility approach provides a powerful tool for surveying regional differences in SPAs from a population perspective. Second, the accessibility method provides a more accurate picture of the potential utilization rate of SPAs and suggests new opportunities for ES research to map the movement of people to the SPAs with a higher detail. This type of information offers decision-makers further insight on how much and where is it sensible to invest in the maintenance of ES. Place-based information on the accessibility of SPAs provides an opportunity to add information about spatial distribution and the potential use of particular services, which will help, for example, planners to achieve the targets of the European Union's Biodiversity Strategy 2020 and better assess and map user movement related ES (see European Commission, 2011, Action 5).

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# Appendix A.

***Table A.1****.List of environmental variables used in modeling the distribution of brown hare. Italics indicate those variables which were derived by Bayesian information criteria (BIC) to final model.*

| Environmental variables | Unit | Source |
|---|---|---|
| **Climate** | | |
| *Growing degree days* (> 5 °C) | GDD | |
| Sum of the mean temperatures of the days at growing period (days of which temperature exceeds +5 °C) | | Finnish Meteorological Institute |
| Water balance | mm year -1 | Finnish Meteorological Institute |
| **Topography** | | |
| Elevation (std) | m | Digital elevation model |
| Slope angle (std) | ° | Digital elevation model |
| **Geographical location** | | |
| X-coordinate | | |
| **Land cover** | | |
| Built-up area | $m^2$ | CORINE land cover classification |
| *Cultivated field* | $m^2$ | CORINE land cover classification |
| Water | $m^2$ | CORINE land cover classification |
| Wetland | $m^2$ | CORINE land cover classification |
| Deciduous forest | $m^2$ | CORINE land cover classification |
| Coniferous forest | $m^2$ | CORINE land cover classification |
| Mixed forest | $m^2$ | CORINE land cover classification |