48 Modelling visitors' movements of nature-based tourism from social media data

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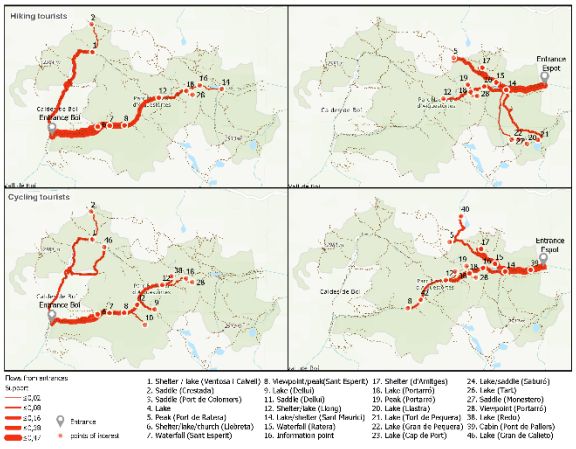
Trails are an important resource for recreation and tourism in protected areas. They enable visitors' access to the main points of interest within a protected site and help preserve the protected ecosystems by restricting the visitors' dispersion. However, the increase in the use of trails can lead to negative impacts on natural resources. For example, soil erosion and vegetation loss are amongst the typical impacts of intensive use of trails.

Thus it becomes necessary to identify and measure visitors' behaviour on trails. The conventional way of measuring use intensity is through surveys and counters. The dissemination of GPS devices has open opportunities to collect precise and complete data on how visitors move and their itineraries.

More recently, the rise of smartphones together with web 3.0 has allowed the abundant production of GPS tracks that users from all over the world regularly share on specialized social networks such as those dedicated to outdoor activities. Among these networks, the Spanish platform Wikiloc stands out, bringing together about 20 million routes in 2020.

These new data sources have advantages for studying visitor movement within trails because of their granularity in terms of spatial and temporal scale. In addition, the large amount of data that users upload provides opportunities to analyze visitor behaviour in places where data is scarce or non-existent.



This study uses GPS data from the route sharing site, Wikiloc, to identify and map the visitors' movement within the trail network of a protected area. Using the Aigüestortes i Estany de Sant Maurici National Park as a case study, we aim to answer the following research questions:

1. Where most visitors go?
2. Which are the trails that attract most visitors and which are neglected?

The Aigüestortes I Estany de Sant Maurici National Park was created in 1955 and is located in the Catalan Pyrenees, in Spain. The park has 14,119 hectares and constitutes the most important lake area in the Pyrenees. For this reason, water is the main protagonist of this space and its sign of identity since it has more than 200 lakes or ponds. The park receives an average of 550,000 visitors per year, and it is the 5th most visited park of the Spanish national network.

This research purpose is to identify movement patterns of adventure visitors within a protected area. There are different methods for analyzing movement within GIS which can be used on geotagged data. We applied a method that combines spatial statistics and tracking analysis to identify: Trail use density, Flows from main entrances and general sequence patterns.

The first step of our methodological approach was to colled the data from Wikilok. GPS tracks of Aigüestortes National Park were downloaded from the Wikiloc site in January 2019. We used the park's name in English and Spanish as keywords to search for all available tracks. To visualize and analyze the tracks, we converted the gpx files into point feature classes using ArcGIS 10.6 software. An early exploration of the converted tracks allowed for the identification and removal of inconsistent tracks. After data depuration, we used the timestamp and XY coordinates of the track points to calculate the tracks' movement vectors. Movement vectors are derived from GPS data by computing the speed, direction, duration and distance between a consecutive pair of GPS records (Moreira et al. 2010). In order to identify

Activity	*# tracks*	*Duration (min) average*	*Duration (min) maximum*	*Duration (min) minimum*	*Distance (Km) average*	*Distance (Km) maximum*	*Distance (Km) minimum*	*Speed (km/h) average*
Hiking	320	337	718	22	12	24	1,1	3,33
Cycling	190	296	1060	15	12	51	0,8	6,71
Total (mean over total)	510	317	889	19	12	37,5	1,0	5,02

and measure the visitor flows from the park entrances, we built a flow map based on the first point where the visitors started their track and the stops they made during the tracks.

The local statistics of a set of movement vectors can identify spatial clusters of low-speed values. To identify the places where visitors stopped from the GPS points, we calculated Moran's local spatial autocorrelation Index to the points and selected the low-low clusters as the stops. Then we performed a Kernel density analysis on the LL clusters to select areas with higher density and overlay these areas with a POIs from the park to extract only the ones where people stopped.

The next step was to extract the GPS Points from every track within the high density areas. From these points, we calculated the order in which each site was visited based on their timestamp. Finally, we counted the number of tracks per each segment between the stops. The result was a line layer with the trail density per segment that allows us to build a flow map and a density map.

General Results

Tracks uploaded by month show a seasonal visitation pattern, which is in line with official visitors' numbers of Aigüstortes national park. Cycling routes were found on more trails than hiking routes. Both maps showed a differentiated behaviour of the two types of visitors analyzed, hikers and cyclists. Visualization of hiking and cyclist flows allows identifying which trails are the most used and which are neglected by the visitors.