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Mapping the intangible: Using geolocated social media data to examine landscape aesthetics

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ABSTRACT

The ecosystem services concept is increasingly gaining momentum in land-use policies and landscape planning. Yet, cultural ecosystem services often lack proper assessments. With this study, we use novel methodological approaches to map the cultural ecosystem service *landscape aesthetics* for its enhanced consideration in land-use policies. Our study uses expert-based participatory mapping and crowd-sourced (social media) photo data to examine the spatial distribution of landscape aesthetics in the Province of Barcelona, Catalonia. We distinguish the capacity and flow of landscape aesthetics. Landscape aesthetics capacity was assessed through spatial multi-criteria evaluation, consisting of a viewshed analysis and an expert-based selection and weighting of landscape features. Landscape aesthetics flow, i.e., people's actual appreciation of landscape aesthetics, was assessed by analysing a sample of 13,460 geolocated photographs from the social media platform *Flickr*. Our results uncover a substantial mismatch between landscape aesthetics capacity and flow. While landscape aesthetics capacity is widely distributed across the case study area, landscape aesthetics flow is (with few exceptions) mostly concentrated in urban and periurban areas. The main insights for land-use policies derived from our results are twofold. On one hand, landscape aesthetics flow seems less dependent on 'pristine nature' than experts and planners assume, while the complex integration of green and grey landscape features plays a critical role. On the other hand, urban and periurban landscapes as key landscape aesthetics providers should receive additional attention in land-use policies.

1. Introduction

Ecosystem service assessments are gaining momentum in informing land-use policies (MEA, 2005; van Zanten et al., 2016a; Wiedmann et al., 2015). Landscape aesthetics (LA)—and the wider concept of aesthetic appreciation (MEA, 2005; TEEB, 2010)—receives considerable attention in the growing literature on cultural ecosystem services (e.g. Andersson et al., 2014; Daniel et al., 2012; Dramstad et al., 2006; Frank et al., 2013; Marull et al., 2010; Tengberg et al., 2012). However, cultural ecosystem services (CES)—understood as the non-material and intangible benefits arising from multi-dimensional human-nature relationships, such as cultural heritage, place identity, spiritual enrichment, cognitive development and learning (Andersson et al., 2014; Chan et al., 2012a,b)—are widely lacking an appropriate, spatially explicit representation (Plieninger et al., 2013; Ungaro et al., 2016). The particularities of intangibility, subjectivity and lack of standardized assessment procedures that characterize many CES also make it difficult to systematically quantify and map LA and cause its poor appraisal within land-use policies (Daniel et al., 2012; Milcu et al., 2013; Schröter et al., 2014; UN, 2014).

According to the MEA, approximately 70% of the CES worldwide were degrading in 2005 (MEA, 2005), while similar figures were confirmed by IPBES' regional assessments in 2018 (IPBES, 2018a,b). In parallel, human societies' are assumed to increasingly depend on CES for their wellbeing (Guo et al., 2010). To alter the decline of ecosystem services, to safeguard Europe's cultural heritage and to better inform policy-making, EU-policies strongly encourage the mapping of CES (European Comission, 2013, 2011; European Environment Agency, 2014). In the early 19th century, Alexander von Humboldt (1808:321) laid the foundation for modern scientific assessments of aesthetics "in the description of biological organism in their local and landscape relations to the earth's surface". Put in modern terms, Humboldt believed aesthetics to be an important component in understanding the complexity of social-ecological systems and their embedded relationships.

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Aesthetics (from the Greek term “aesthesis” meaning sensory perception—originally dating back to Socrates) is mediated through people’s immediate and intuitive perceptions. It embeds historic and cultural identity (Nogué and Vicente, 2004) and reflects and forms people’s understanding and appreciation of landscapes. In other words, aesthetics can be understood as the spatial entities perceived by people that result from action and interaction of natural and/or human factors (European Landscape Convention, 2000). LA is supposed to enhance people’s awareness for the environment and is thereforecritically important to make the value of other ecosystem services more cognitively perceivable (Milcu et al., 2013). This can be assumed as fundamental for conservation policies and civic engagement in environmental stewardship action (Andersson et al., 2014). Stated differently, conservation policies might fail if LA and other CES remain under-considered.

Common approaches for assessing LA in the ecosystem services literature include economic valuation approaches, such as hedonic pricing (Cho et al., 2008; Jiao and Liu, 2010) and contingent valuation (Willis and Garrod, 1993), and social-cultural valuation approaches based on interviews and surveys (Frank et al., 2013), focus groups (Scolozzi et al., 2012), photo elicitation (Tveit, 2009; van Zanten et al., 2016b), participatory mapping (Brown and Fagerholm, 2015; Plieninger et al., 2013), as well as qualitative archival analysis of photographs, audio-visual recordings and transcripts of historical interviews (Thiagarajah et al., 2015). However, most of these methods provide limited spatial information and/or are limited to a small group of stakeholders expressing their subjective perceptions, as is the case for most participatory mapping exercises (Paracchini et al., 2014; van Zanten et al., 2016a). Larger scale assessments of LA mainly rely on expert evaluations based on the presence or absence of single landscape features that are supposed to enhance LA (Daniel et al., 2012). These common approaches for assessing LA reflect two major paradigms. On the one hand, the subjectivist or psychological paradigm assumes that LA is determined by peoples’ perceptions and preferences, which themselves are culturally, socially and psychologically shaped (e.g., Frank et al., 2013; Lothian, 1999). On the other hand, the objectivist or physical paradigm relates LA to biophysical landscape features. This paper treats both paradigms as complementary, with LA determined by not only the biophysical landscape, but also cultural and social context and individual preferences (Fry et al., 2009; Lothian, 1999; Plato and Aaron, 2013).

In line with this assumption, and with the ultimate goal to better inform land-use policy, we will here distinguish between *LA-capacity* and *LA-flow* (referred to as *LA-demand* by Yoshimura and Hiura (2017)). The LA-capacity is determined by the biophysical landscape and its features; the LA-flow by the actual realization of benefits through the appreciation of a landscape (*cf.* Villamagna et al., 2013). While land-use policies are classically based on LA-capacity assessments, capacity-flow comparison analyses of ecosystem services have shown to provide insightful information to land-use policy and planning (Baró et al., 2016; Schröter et al., 2014). For LA-flow assessments, novel methodological approaches based on geolocated social media data are recently gaining importance (Oteros-Rozas et al., 2017; Pastur et al., 2016; Plieninger et al., 2013; Richards and Friess, 2015; Tenerelli et al., 2016; van Zanten et al., 2016a; Yoshimura and Hiura, 2017). Geolocated social media data, and photos in particular, provide spatially explicit observations of people’s preferences and behaviour (Dunkel, 2015) and promise to overcome major limitations of classical subjectivist assessments at larger scales related to costs and time of data provision, and representativeness (*cf.* Tenerelli et al., 2016). Similarly, methods linked to the objectivist paradigm and the assessment of LA-capacity have also been improving. Combining viewshed analyses with multi-attribute models (inspired by multi-criteria decision-analysis theory) provides novel possibilities to systematically consider multiple landscape features and spatially weight them with regard to aesthetic preferences (Casado-Arzuaga et al., 2013; Frank et al., 2013).

With this study, we follow the overarching goal to make LA more tangible to land-use policies. Towards this goal, we conduct an examination of LA-flow by mapping people’s subjective landscape perceptions expressed in geolocated pictures placed on the photo-sharing platform *Flickr*.[1] We further aim at providing an improved objectivist assessment of LA-capacity by means of a spatial model of landscape features (considering regional experts’ and policy makers’ understanding of LA), to ultimately allow for a spatial comparison between LA-flow and LA-capacity.

2. Material and methods

2.1. Case study

This work used the Province of Barcelona, Catalonia (Europe), located at the North-Western Mediterranean coast, as a case study area. The Province of Barcelona (7726.4 km^2) is one of the most densely populated urban regions in Europe (717 inhab./km^2) with a total current population of 5.5 million people, mainly concentrated within and around the city of Barcelona (IDESCAT, 2016). Conducted in collaboration with the Barcelona Provincial Council (*Diputació de Barcelona*), our study was guided by the policy-makers’ advices and needs. In recent years, the Barcelona Provincial Council has shifted its land-use policies towards the maintenance of ecosystem services within a multifunctional green infrastructure network. Ecosystem services maps were developed and made available to support regional and local policymakers. To date, the maps include food provision, forest biomass provision, global climate regulation, erosion control, habitat for species, and recreation as the only CES; underscoring both the aforementioned lack of consideration of CES in policy-making and the need for an additional mapping of CES. Results on LA-capacity and flow derived through this study will help to close this gap and will be made available through the open and web-based spatial decision-support system, SITxell.[2]

2.2. Mapping landscape aesthetics flow

For the LA-flow assessment, Flickr was chosen as the data source rather than other photo-sharing platforms due to the higher number of active users in Spain, amounting to about 5.6 million (Graham et al., 2013). Although Panoramio and Instagram provide a similar coverage (van Zanten et al., 2016b) and could be valid sources, Instagram restricts research availability and Panoramio ceased operation after 2016. Flickr data is also the main data source for previous CES assessments (Dunkel, 2015; Gliozzo et al., 2016; Tenerelli et al., 2016; Thiagarajah et al., 2015; Yoshimura and Hiura, 2017). To use Flickr photos for the LA-flow assessment, it is hypothesized that people who take photos of landscapes (and upload them to the Flickr platform) consider those landscapes to be aesthetically pleasing. In other words, the landscape photo location is assumed to meet the photographer’s LA preferences. For the purpose of our study, we derived all photos within the boundaries of the Province of Barcelona that had been uploaded in 2015. Our query resulted in a sample of 131,507 photographs (see Fig. 1) by 4,356 different users. Apart from the photos’ geographical references (a geotag describing latitude and longitude), we derived the Flickr user ID, and the metadata added by the users (e.g., photo tags and descriptions).

The content analysis to determine the LA-flow was performed in two main steps: (i) a progressive visual content screening of a sub-sample of 13,460 photographs; (ii) a coding of the content of relevant photographs according to visible landscape features. The sample was derived randomly across the entire study area, in order to reflect quantitative

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[1] www.flickr.com

[2] See http://www.sitxell.eu/en/default.asp

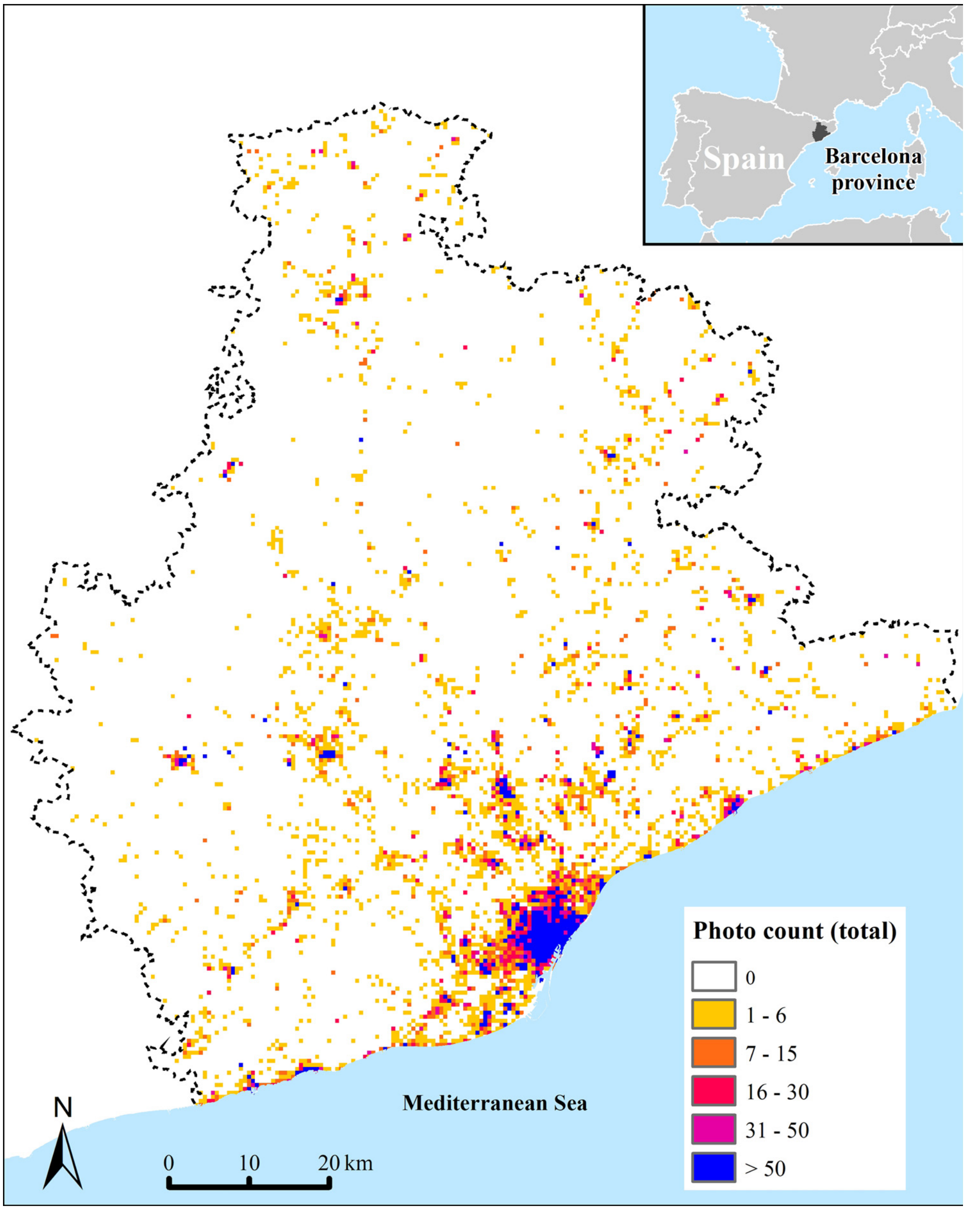

Fig. 1. Entire sample of 131,507 photos uploaded to Flickr in 2015 and considered in the LA-flow assessment. Location of the case study area (Province of Barcelona). Note: photos are grouped in pixels of cell size 500 × 500 m.

differences in the LA-flow at the Barcelona Province scale (*cf.* Richards and Tunçer, 2017). The sample size and coding relied upon rigorously applied guidelines, based on former studies (Pastur et al., 2016; Oteros-Rozas et al., 2017; Tenerelli et al., 2016) and further developed during this assessment (see Annex A). The guidelines stipulated that photos which do not represent landscape features as a main objective were discarded from the further analysis. In addition, we discarded all photographs with poor quality, wrong geographical references (verified with the help of the *Google Earth* program) as well as repeated photos, i.e., photos taken by the same user at same location with the same objects. This procedure led to final sub-sample of 1,262 relevant photographs, corresponding to about 1% of the entire sample, in line with descriptive studies of dichotomous variables for a confidence level of 99% with a marginal error of 2.06% (*cf.* Hulley et al., 2007). For geographical interpretations, all coded photos were mapped onto a 2.5 × 2.5 km resolution grid using ArcGIS 10.4 software based on the Eq. (1):

$$\mathrm{f_{i,tot}} = \sum_{\mathrm{i}} \mathrm{p_i} \tag{1}$$

where $f_{i,tot}$ is the flow in the cell i given by the sum of photos in the same cell, p_i.

With regard to the occurrence of each landscape feature shown in the photographs, we calculated a diversity indicator in order to relate LA-flow to landscapes complexity. The diversity was determined for each landscape feature as the average number of additional landscape features in the photographs depicting it. Finally, we examined the associations between the five broader classes of landscape features (see Table 1) by assessing their co-existence in the pictures through the following Eq. (2):

$$X_{ji} = \frac{\mathrm{Tot\ pj\ lfi}}{\mathrm{Tot\ pi\ lfi}} * 100 \tag{2}$$

where Tot pj $\mathrm{lf_i}$ are the pictures, among those representing the landscape feature i, also representing the landscape feature j; Tot $\mathrm{p_i}$ $\mathrm{lf_i}$ is the total amount of pictures representing the landscape feature i.

Table 1
Biophysical features as assessment criteria for the landscape aesthetic capacity in the Province of Barcelona.

Feature class	Landscape features (evaluation criteria)	Description
Landform features	Geological interest areas	Sites of importance for geodiversity (geology and geomorphology) such as limestone, conglomerate, marl, crags
	Scenic background (crest line)	Aesthetic value of horizon background features
	Point elements	Singular mountainous sites (Muntanya de sal, Montcau, Montserrat, Pedraforca)
	Mountain	Mountainous chain
	Beach	Coast line and coastal area
	Valley	Elongated depression between uplands, hills, or mountains
	Singular flat areas (e.g. Conca d'Odena, Pla de Bages, etc.)	Singular flat areas
	Hill (e.g. Serrat de Torello, Puigi Tur)	Landform that extends above the surrounding terrain
	Viewpoint	Observation points
Weather features	Foggy area	Frequently foggy area
	Transformation of shape and colours of vegetation	Seasonal effects on the natural landscape
Water features	Lakes, wetlands, reservoirs and ponds	Surface, inland and steady water lens
	River network	Surface, inland and dynamic water lens
	Sea	Open sea
Agro-forestry features	Agricultural land	Land used for agricultural purposes
	Agro-forestry mosaic	Contrasting pattern of agricultural close to forestry land
	Isolated crops within forestry matrix	Agricultural fields surrounded by forestry land
	Horticulture in linear structure in valleys	Linear agricultural patterns
	Forest and sea	Contrasting pattern of sea close to forestry land
	Cliff and vegetation	Green upland, hill or mountain
	Deciduous and evergreen forest	Seasonal contrasting pattern between vegetative species
	Singularities	Specific and unique natural or artificial elements in an agro-forestry context
	Repeating patterns	Repeating land-use patterns
Built- infrastructure features	Historic/cultural elements	Anthropic element with an historical or cultural value
	Water management systems	Water management network
	Representative sites	Representative and emblematic, natural or anthropic sites (Eixample, Montjuïc, Ciutadella, etc.)

Elaborated by the authors, based on landscape features assessed by The Landscape Observatory of Catalonia.

2.3. Mapping landscape aesthetics capacity

The LA-capacity assessment was conducted using a spatial multi-criteria approach, where landscape features were the evaluation criteria. The assessment also relied on an advisory panel, including four policy-makers from the Barcelona Provincial Council and two regional experts from the Landscape Observatory of Catalonia. The assessment was executed in four main steps: (i) selection of landscape features as evaluation criteria; (ii) expert weighting of the evaluation criteria; (iii) scoring of evaluation criteria (based on a spatial viewshed analysis, explained below); and (iv) the aggregation of criteria scorings through weighted summation. These four steps are briefly described as follows:

(i) Landscape features (Table 1) used as evaluation criteria were selected by the advisory panel due to their assumed impact on LA-capacity. The selection of evaluation criteria (as well as their subsequent weighting) relied on two assumptions. First, single landscape features were expected to have different levels of impact on the overall LA-capacity across the province. Second, the landscape features that determine LA-capacity were not the same across the entire study area; for example, the landscape feature 'beach' was considered a characteristic feature in coastal landscapes, but not in mountainous landscapes. The selection of evaluation criteria was thus conducted separately for seven landscape types (Fig. 2). Landscape types are an aggregation of landscape units, established planning areas used by the Barcelona Provincial Council, that share similar geographical characteristics (see Table 2). The advisory panel selected for each landscape type the eight most relevant landscape features determining the landscape type's LA-capacity.

(ii) Criteria weights were determined as the impact of single landscape features on the LA-capacity of a specific landscape type. For the criteria weighting, an online survey (available online: http://goo.gl/forms/z7sFH6hlQOjyNQeY2) was developed and distributed among 20 landscape planning experts proposed by the advisory panel (including public administration, scientists and civil society organizations and private companies). Six completed surveys were returned. The online survey used a so-called ELECTRE type method (ELimination and Choice Expressing REality), including a revised Simos' procedure (see Figueira and Roy, 2002). Respondents were requested to order the eight landscape features (selected in the first step) with regard to their importance for the LA-capacity of each of the seven landscape types.

(iii) The scoring of evaluation criteria was built on the assumption that the LA-capacity increased with the visibility of the landscape features. We thus modelled the visibility of landscape features using the *Viewshed* tool in ArcGIS. As input data, we used point, line or polygon representations of landscape features, as well as a digital elevation model of the Province of Barcelona. The scoring, i.e. the visibility, of each landscape feature was ultimately described by an output raster set in a 100 × 100 m grid (1 = visible; 0 = not visible).

(iv) Finally, an aggregation of criteria scores was conducted to determine an individual value of the LA-capacity in a 2.5 × 2.5 km raster grid. The aggregation was conducted through the summation of criteria scores under consideration of criteria weights. Thereby we applied different evaluation criteria and weights for each landscape type projected on the raster grid (Eq. (3)):

$$C_{i,tot} = \sum_{n}^{N} (v_{n,i} \times w_{n,lt}) \tag{3}$$

where $v_{n,i}$ is the visibility of the landscape feature n in grid cell i; N is the total number of landscape features present in a grid cell; $w_{n,lt}$, is the weighting factor (normalized according to Figueira and Roy (2002) through a unity-based approach into a 0–1 range) assigned to landscape feature n, depending on the landscape type lt in which the cell i is located. Eq. (3), thus, expresses an aggregated value of the LA-capacity for each (observation point) grid cell i.

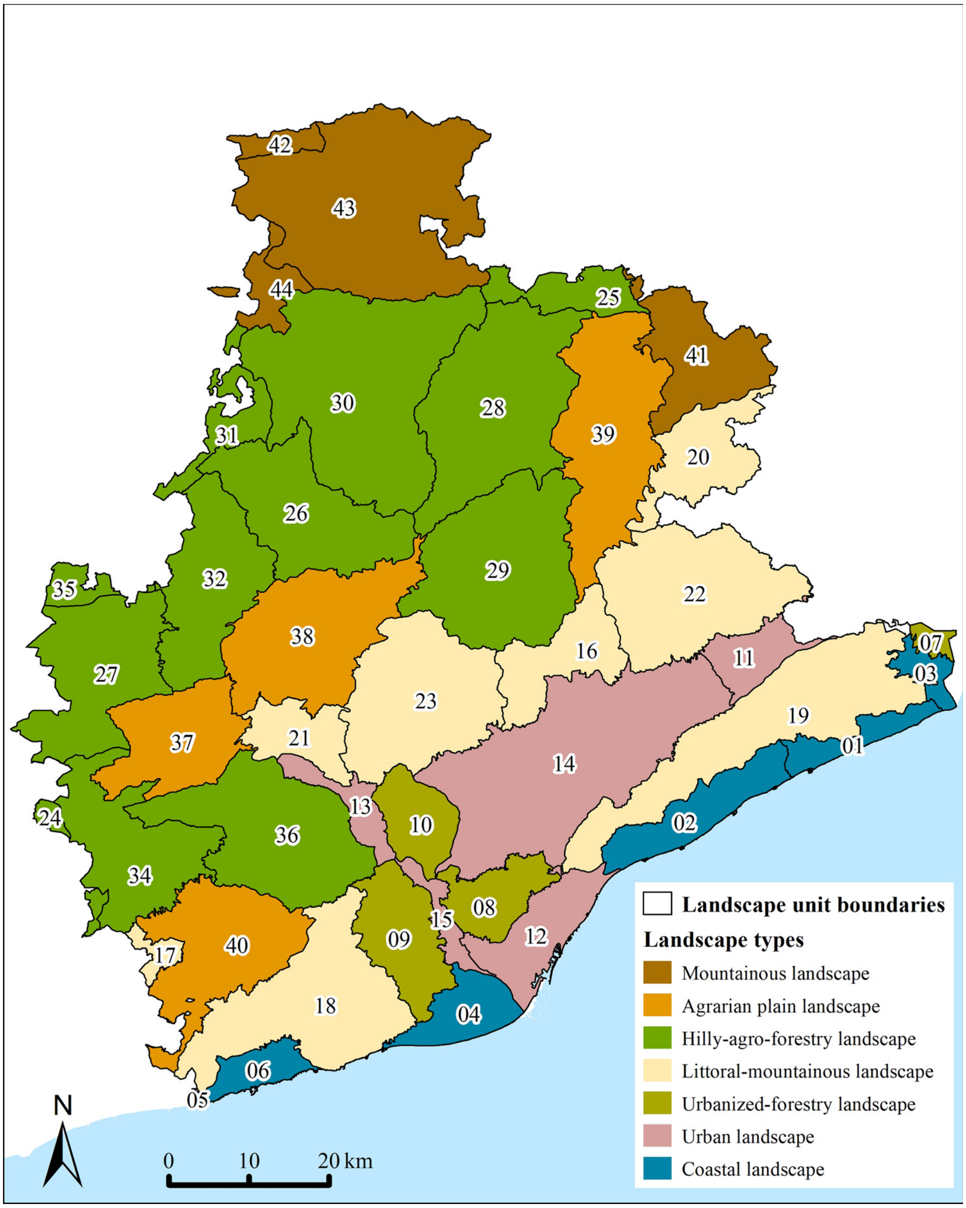

Fig. 2. Distribution of landscape types and landscape units in the Province of Barcelona. Labels indicate the code of each landscape unit (see table below).

2.4. Comparison between landscape aesthetic capacity and flow

Finally, the spatial distribution of LA-capacity and LA-flow were compared. The comparison was undertaken at the landscape unit (LU) level to enhance its consideration in policy-making in the Province of Barcelona (see Fig. 2).

Therefore, we related the LA-flow to landscape units, following Eq. (4):

$$f_{lu} = \frac{mean(\sum_{lu} p_{i,lu})}{A_{lu}} \tag{4}$$

Table 2
Landscape units included within each landscape type.
Source: Landscape Observatory of Catalonia, relying on the European Landscape Convention (European Landscape Convention, 2000).

Landscape types	Landscape units
Coastal landscapes	Alt Maresme (01), Baix Maresme (02), Baixa Tordera(03), Delta del Llobregat(04), Litoral del Penedès(05), Plana del Garraf (06)
Urbanized-forestry landscapes	Ardenya-Cadiretes (07), Collserola (08), Muntanyes d'Ordal (09), Xaragalls del Vallès (10)
Urban landscapes	Baix Montseny (11), Pla de Barcelona (12), Pla de Montserrat (13), Plana del Vallès (14), Vall Baixa del Llobregat (15)
Littoral-mountainous landscapes	Cingles de Berti i Gallifa (16), El Montmell (17), Garraf (18), Serra de Marina (19), Guilleries (20), Montserrat (21), Montseny (22), Sant Llorenç del Munt i l'Obac - El Cairat (23)
Hilly agro-forestry landscapes	Alt Gaià (24), Alt Ter(25), Conca Salina (26), Costers de la Segarra (27), Lluçanès (28), Moianès (29), Replans del Berguedà (30), Replans del Solsonès (31), Rubió – Castelltallat-Pinós (32), Serres d'Ancosa (34), Vall del Llobregós (35), Valls de l'Anoia (36)
Agrarian plain landscapes	Conca d'Òdena (37), Pla de Bages (38), Plana de Vic (39), Plana del Penedès (40)
Mountainous landscapes	Cabrerès – Puigsacalm (41), Cadí (42), Capçaleres del Llobregat (43), Port del Comte – Valls de Lord (44)

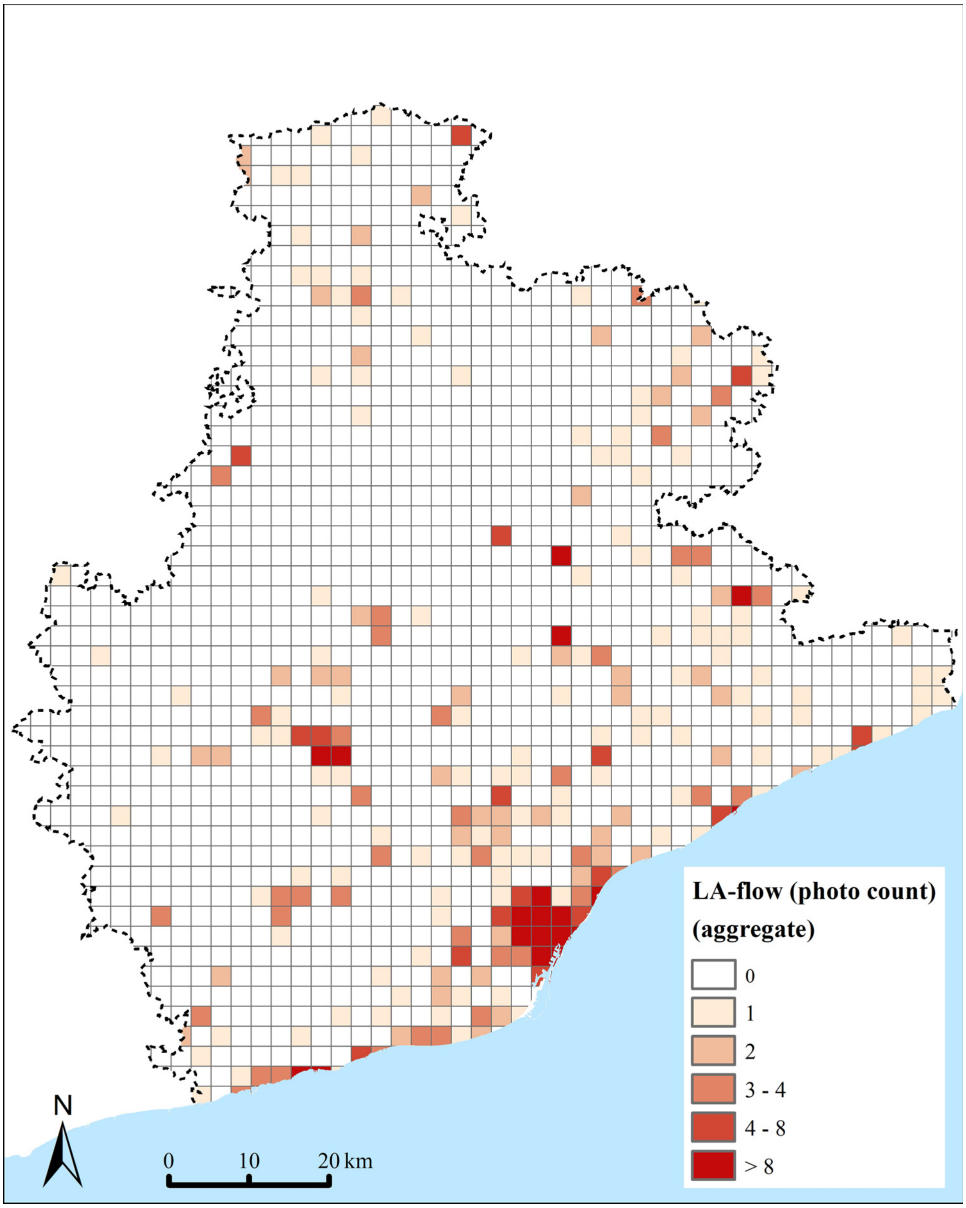

Fig. 3. Landscape aesthetic flow, Province of Barcelona. *Sum of photographs at the pixel level (2.5 × 2.5 km).*

where f_{lu} quantified the LA-flow in the LU (lu) as an average amount of photos per LU normalized by the landscape units surface area, A_{lu}.

To allow for comparison with the LA-flow assessment, we related LA-capacities to the same LU, following Eq. (5):

$$C_{lu} = \frac{mean(\sum_n^N (v_{n,i} \times w_{n,\mathrm{lt}}))_{lu}}{A_{lu}} \tag{5}$$

As for the flow, we averaged the capacity values corresponding to the cells located in each LU and normalized per m^2 of LU.

Finally, LA-capacity and LA-flow were divided into low and high values; the average across all values determined the distinction between low and high. Combining LA-capacity and LA-flow thus results in a spatial representation of four possible combinations (high-high, high-low, low-high and low-low).

3. Results

3.1. Landscape aesthetics flow

The LA-flow assessed in this study showed a strong inbalance across the Province of Barcelona (see Fig. 3), with very high levels of LA-flow (expressed by a high concentration of relevant photos) in the Pla de Barcelona (nº 12 in Fig. 2). Complex landscapes appear to enhance LA-flow, as multiple landscape features were generally present in most photos; in average there were 3.8 landscape features in each photograph (see Annex B). Buildings were present in 41.4% of the coded photographs, making them the most common feature. In comparison, forest and sea elements were the second and third largest representations, captured in 28.8% and 28.6% of the photos, respectively. Aggregately, built-infrastructure features, which include buildings, were represented in 57.0% of the photos, agro-forestry features were found in 50.6%, water features in 36.7%, landform features in 39.5% and weather features in 7.4% of the photographs. Built-infrastructure in general, and buildings especially, commonly appeared in association with other landscape features. This observation is also confirmed by the

Table 3
Co-existence between (classes of) landscape features in Flickr photos, Province of Barcelona (2015).

	Landform features (%)	Water features (%)	Agro-forestry features (%)	Weather features (%)	Built infrastructure(%)
Landform features	100.0	15.6	24.4	3.6	22.4
Water features		100.0	1.41	2.8	26.1
Agro-forestry features			100.0	3.6	50.9
Weather features				100.0	3.5
Built infrastructure					100.0

Percentage of the pictures depicting combinations of landscape features across all categorized pictures.

co-existence analysis (Table 3) showing that built infrastructure occurs – more than any other feature class – together with landscape features from other classes. Landform features, water features and agro-forestry features (especially croplands) showed slightly higher 'stand-alone' capacities to sustain LA-flows. In particular, photos representing agro-forestry, landform and water features were distributed more evenly across the entire Province of Barcelona, while built infrastructure features were mainly found in photographs from the city of Barcelona and its urban surroundings.

3.2. *Landscape aesthetics capacity*

The LA-capacity investigated was found to be widely distributed across the Province of Barcelona (see Fig. 4). Our study indicates viewpoints, agricultural land, and historic/cultural elements to be the landscape features that influence LA-capacity the most (see Annex C). The LA-capacity in most landscape types showed to be especially related to one or two specific landscape features. For example, LA-capacity in littoral-mountainous landscapes is mostly determined by forest and sea elements; in urban landscapes, LA-capacity is mediated by hills and river-networks; and in mountainous landscapes the scenic background (crest line) is critical. In urban landscapes, built-infrastructure features were observed to have an especially strong impact. Water features showed a geographically limited influence on LA-capacity; present in coastal landscapes, some mountainous landscapes of the Pyrenees, and in some urban landscapes.

3.3. *Comparison between landscape aesthetics capacity and flow*

Our comparison revealed several similarities between the landscape features determining LA-capacity and LA-flow (see Annex D). The spatial comparison provides further differentiations in the information. Obvious is the high LA-capacity-flow in urban landscapes in and around the capital city of Barcelona and in urban-forestry landscapes, such as in the LU of Collserola (nº 08 in Fig. 2), which is the largest periurban, natural park of the Barcelona metropolitan area (Fig. 5). Yet, the high LA-flow in the 'Pla de Barcelona' (n° 12) seems rather exceptional and does not reflect other urban landscapes. High LA-capacity and high LA-flow could also be observed for littoral-mountainous landscapes. The highest LA-capacities were observed for the LU of Montseny (n° 22), but also for Muntanyes d'Ordal (n° 09) and Montserrat (n° 21). The peculiar sedimentary rock formations of Montserrat, a touristic and highly frequented landscape, rendered the highest values of LA-flow. In addition, high LA-capacities and LA-flows were also observed for all coastal landscapes and some of the mountainous landscapes of the Pyrenees and Pre-Pyrenees in the North of the Province of Barcelona. In contrast, most inland hilly-agro-forestry landscapes, agrarian-plain landscapes as well as urban landscapes (apart from Barcelona) were found to provide a rather low LA-capacity and LA-flow. Of high interest for policy-makers was the detection of several landscapes with high but unused LA-capacity, such as the western mountainous and western and centre agrarian plain landscapes, as well as some of the urbanized-forestry landscapes. LA-flow appeared to be especially low in the hilly-agro-forestry landscapes in the Northern inland of the Province.

4. Discussion

4.1. *Built infrastructure as part of the landscape complexity*

A key finding from our analysis was that the interplay between built infrastructure and other more 'natural' landscape features was generally rendering high levels of LA-flows, especially in urban landscape types. At the same time, we observed an underestimation of LA-capacities with regard to built infrastructure features by the expert panel. This underestimation might be due to a bias in the selection of experts, most of which were biologists or ecologists, who might have an individual preference towards more 'natural' landscape features. However, the landscape feature weights followed a common assumption in the literature that natural features are crucially determining LA (*cf.* Daniel et al., 2012; van Zanten et al., 2016a). This might thus be an inherent bias in classical LA assessments; to the contrary, our examination of social data from Flickr indicates that for many (non-expert) users built infrastructure does not seem to negatively affect LA, and might even enhance it; thereby confirming previous findings by Gliozzo et al. (2016). Our analysis shows that this is not only true for historic/cultural elements, water management systems, and representative sites, for which experts in our study assumed some positive influence on the LA-capacity, but also for modern built infrastructure, including bridges, streets, railways, and especially buildings (confirming previous findings by Richards and Friess (2015)).

A common assumption in the literature is an emergence of LA linked to landscape complexity, including multiple and diverse landscape elements (e.g. Casado-Arzuaga et al., 2013; Tenerelli et al., 2016; van Zanten et al., 2016a). Usually this assumption has implicitly excluded built infrastructure, which was rather considered as a disturbance to LA. The LA-flow analysis conducted in this study indicates the assumption that LA emerges from combination of landscape features. Yet, our findings also indicate that attractive landscapes can consist of built infrastructure and 'natural' landscape features alike. Mediterranean landscapes such as those of the Province of Barcelona have been shaped by humans during centuries (Gómez-Baggethun and Ruiz-Pérez, 2011) and LA values seem to be associated to both nature and built features, including modern ones. This finding is novel and might be of crucial consideration in future land-use policies because it implies that – at least for a broader non-expert part of the society – natural landscapes do not lose their LA value in the presence of built infrastructure. This outcome, if confirmed in future studies, has the potential to shift the weight in land-use policy to more systemic considerations, including ecological connectivity and functional complexity, sustaining other critical ecosystem services, while reducing the importance of impacts on LA.

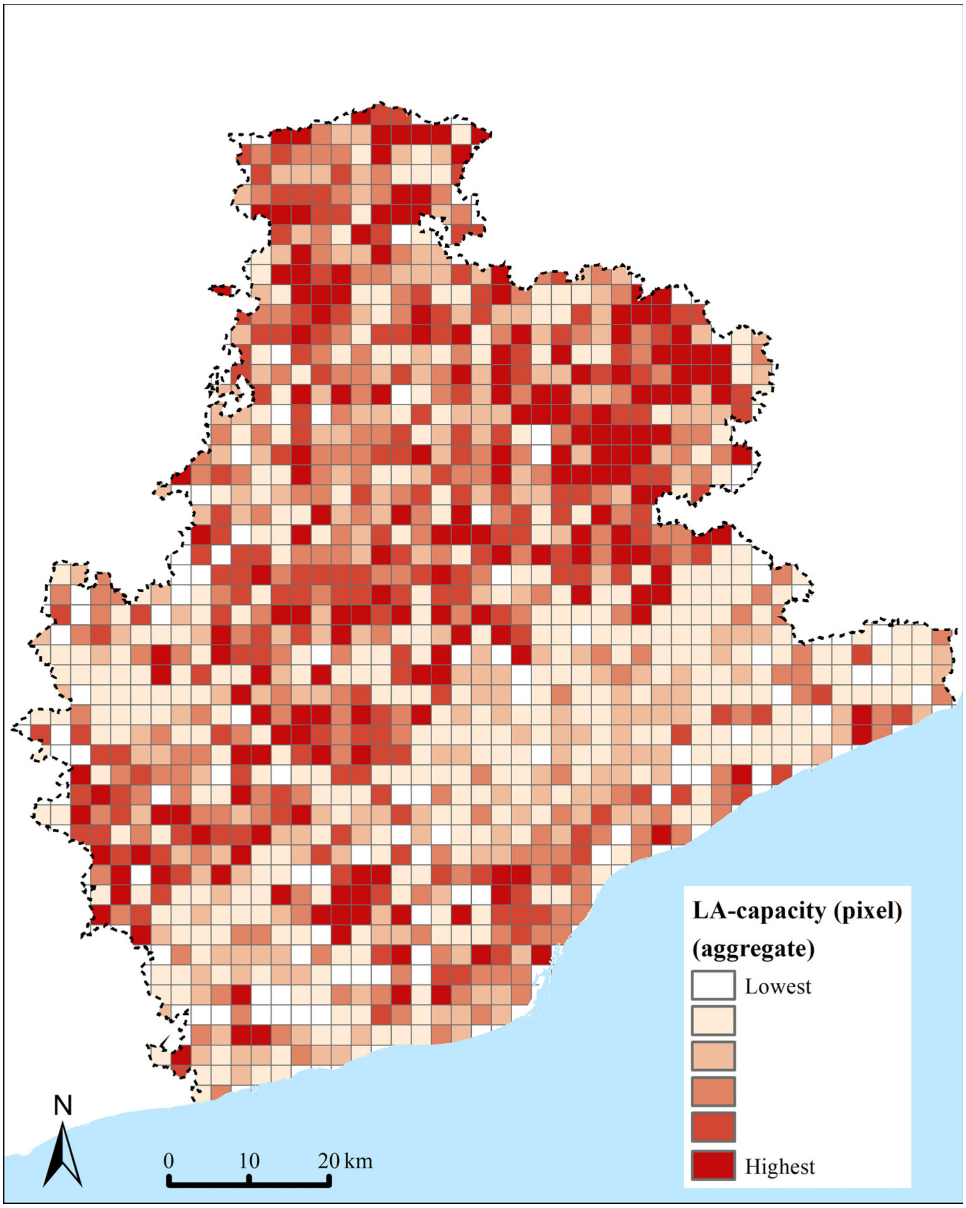

Fig. 4. Aggregated LA-capacity in the Province of Barcelona. *Viewshed analysis and expert weighting computed on a 2,5 × 2,5 km pixel grid.*

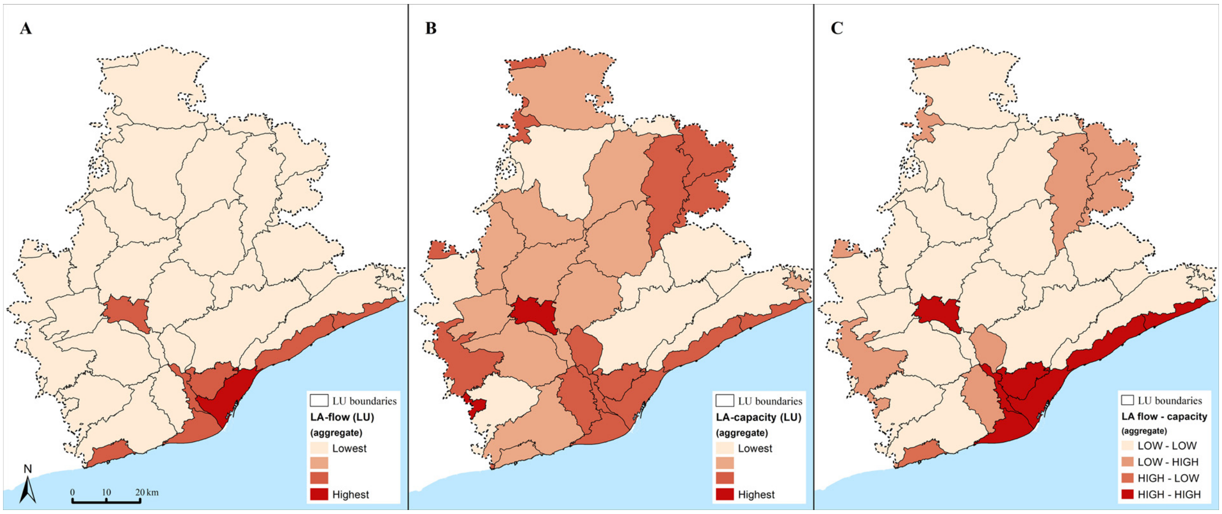

Fig. 5. Comparison between LA-capacity and LA-flow. *Based on natural breaks.*

4.2. The importance of accessibility

We assume the strong mismatch between LA-capacity and LA-flow is not exclusively related to a potential expert bias towards ‘natural’ landscapes (described above), but also profoundly bound to the accessibility to places where LA can be experienced. The spatial distribution of LA-flow reveals that LA is mainly experienced in coastal, urban-forestry, and urban landscapes, thus close to the areas where most people live. Population density and transport network are critical factors for the accessibility of a given area and seem to explain much of the LA-flow; distant locations with poor transport networks, such as the hilly agro-forestry inland landscapes, are less accessible and thus render the lowest LA-flow (see also Ala-Hulkko et al., 2016). Only a few landscapes more distant from urban areas are motivating people’s travel to enjoy LA benefits (i.e. they render high LA-flow), particularly the (pre-) littoral-mountainous landscape of Montserrat which has high LA-capcity and good accessibility by public and private transport. Based on these results, we claim that policies intended to sustain or enhance LA-flow need to focus especially on green and blue infrastructure in the urban fringes. Remote areas may have high LA-potentials, and to some individuals might be the most important spots for experiencing LA; however, the nearby landscapes are frequently far more relevant for most people. Perhaps the most representative example of accessibly and LA-flow is the urban forestry landscape of Collserola (LU nº 08 in Fig. 2). This landscape, protected as a Natural Park, has previously been described as a key green infrastructure area for supplying Barcelona city with ecosystem services, including urban cooling, air purification, flood regulation and recreation (Baró et al., 2016; Depietri et al., 2016). Our study adds LA to this list of ecosystem services. However, the high accessibility of Collserola, and the corresponding high LA-flow, may be problematic for land-use policy due to potential trade-offs between ecosystem services. Turkelboom et al. (2017) describe trade-offs in Collserola between provision and recreational ecosystem services and conservation goals like biodiversity maintenance. Similar trade-offs could be expected between LA and conservation, a relationship that merits future exploration and compromise in land-use policy and design (*cf.* Allan et al., 2015; Casalegno et al., 2013; Goldberg, 2015; Pastur et al., 2016).

4.3. Strengths and shortcomings in using social media data to assess landscape aesthetics

The comparison between LA-capacity and LA-flow showing both geographical and quantitative differences highlights the importance of LA-flow analyses alongside the classical LA-capacity assessments to allow for thorough land-use policies. The analysis of social media data has demonstrated a useful approach to examine LA-flow that complements expert-based LA-capacity assessments. Social media networks are already used by large parts of the society, and Flickr is assumed to include a broad social diversity in user groups (Dunkel, 2015; Tenerelli et al., 2016). The more users and sample photographs, the more accurate the estimation of LA-flow will be from a broad societal perspective. However, with limited knowledge on the users’ profiles we cannot exclude a bias towards specific user groups (e.g., intuitively we would assume to miss the preferences of elders and small children who are less likely to use social media platforms). This limitation requires careful further research. An examination of user-added metadata, such as title, tags, and descriptions, could allow for studying differences in aesthetic preferences across demographic, ethnic or other social groups (see Stamps, 1999; Tenerelli et al., 2017; van Zanten et al., 2016a), accounting for the influence that knowledge and cognitive processes have on landscape perception (Gobster et al., 2007). Further, a combination of social media data analysis and on-site surveys might enhance the accuracy of LA-flow assessments and provide evidence on potential biases associated to social media based CES assessments (see Thiagarajah et al., 2015; Upton et al., 2015).

However, the use of social media data involves several advantages with regard to classical survey approaches to study people’s preferences. First of all, it is not biased by the researchers’ personal interaction with responders (Dunkel, 2015). Furthermore, the data is often easily and freely accessible and abundantly available on the web. For this study, we derived more than 130,000 photo samples from Flickr in the year 2015 alone; it seems more than likely that these figures expand as more and more people use social media. Using geo-located social media data has helped broadening the—so far mainly expert-based—assessment of LA. This novel approach allows for the consideration of multiple observations to estimate the LA-flow in a spatially explicit form and across larger scales. Using social media data, as from Flickr, provides comparable data sets and permits studies in different regions around the globe (Pastur et al., 2016; Tenerelli et al., 2016; Yoshimura and Hiura, 2017). This will allow for comparable studies across multiple types of landscapes and will likely make LA better understood and more accessible for land use policy. In future research, it will eventually be possible to observe changing LA preferences over different temporal scales (seasonal, annual). In addition, other social media platforms (e.g., Instagram) provide similar content and might provide complementary information (*cf.* van Zanten et al., 2016a). Future research will also utilize computer algorithms for semi-automatic analysis of photo content, whereby computer programs are ‘trained’ by manual photo-sighting, such as conducted in our study (Richards and Tunçer, 2017; Kennedy et al., 2007). This will allow for the analysis of much larger photo samples and thus provide a comprehensive database for the assessment of LA-flow. Finally, considering that LA experiences can be mediated by other sensory inputs than just sight (Gobster et al., 2007), a comparison with maps reporting the spatial distribution of sensory and acoustic perceptions (see Aiello et al., 2016; Quercia et al., 2015) or activity tracking has potential to reveal unexpected relationships.

5. Conclusions

Spatial assessment of CES and more specifically LA requires the consideration of multiple variables, expressing subjective perceptions and values. The novelty of this study consists in the development of a methodological approach for assessing LA-capacity and LA-flow at the regional scale, linking an expert-based evaluation of landscape features and social media photo data. Using social media data provides a new understanding of CES flow based on real observations of preferences expressed by a large number of landscape users. The use of social media data for CES assessments is still in its infancy, and several potential limitations, such as social representativeness, need to be addressed in future research. However, our case study of the Province of Barcelona shows a large potential to use social media data alongside classical expert based-approaches to assess CES across larger scales. Our study showed social media data can unravel novel insights on people’s preferences, namely that built infrastructure is not always negatively affecting LA. Thus, the analysis of social media data makes CES assessment more operational and broadens the empirical base to integrate CES into land-use policies.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.landusepol.2018.05.049.

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