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Exploring tranquillity experienced in landscapes based on social media

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ABSTRACT

People living in increasingly urbanised areas are seeking restorative environments for recreation. Consequently, the need arises to identify and map such tranquil spaces. However, collecting *in situ* data across large areas about where people experience tranquillity is usually cost-prohibitive. In this study, we use social media data from the photosharing platform Flickr to explore the experience of tranquillity in Scotland. We developed a novel methodology that combines the metadata of photographs (location and textual tags) and the content of photographs to explore where tranquillity is experienced within the landscape, and which factors influence tranquillity. Mapping locations of photographs with tags related to tranquillity reveals areas of experienced tranquillity across Scotland that are relatively easily accessible by road, for example along the West Coast, as well as near inland water bodies. Users also uploaded tranquil photographs in urban areas, but less than expected compared to the density of general Flickr uploads in these areas. Based on the content of photographs, the presence of water bodies, boats and special atmospheric conditions (e.g. sunset) were identified as significant factors influencing experienced tranquillity. Furthermore, we found no relation between potential quiet areas and the locations where people uploaded photographs with tranquil tags. This study highlights the potential of a hybrid approach to social media data analysis for exploring people's place-based experiences. By focusing on where people experience tranquillity in the landscape, our results are complementary to existing approaches modelling the potential for tranquillity and have important implications for how we conceptualise and model tranquillity as experienced by people.

1. Introduction

With increasing levels of urbanisation across Europe, people are seeking tranquil areas for recreation away from the hustle and bustle of everyday life (Beard & Ragheb, 1983; Frick, Degenhardt, & Buchecker, 2007). Restorative environments have been shown to have positive health effects by reducing stress from cognitive overload and contributing to general well being (De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Kaplan & Kaplan, 1989; Seresinhe, Preis, & Moat, 2015; Shepherd, Welch, Dirks, & McBride, 2013; Ulrich et al., 1991; Velarde, Fry, & Tveit, 2007). Such restorative environments are increasingly under pressure. In the United Kingdom, for instance, concerns over the loss of tranquil spaces prompted research into characterising tranquil areas and mapping where they still existed (Jackson et al., 2008; MacFarlane, Haggett, Fuller, Dunsford, & Carlisle, 2004; Pheasant, Horoshenkov, Watts, & Barrett, 2008). The need to protect such restorative tranquil areas has become an important policy-objective at the European level as well as in the UK. In the EU, the Environmental Noise Directive (END) highlights the importance of reducing noise pollution and protecting quiet areas, with the Quietness Suitability Index used as a model to indicate where such areas exist (EEA, 2016). In England, the protection of tranquillity was included in the National Planning Policy Framework stating that planning policies and decisions should: *'identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason'* (Ministry of Housing Communities and Local Government, 2018; §180). From a planning and policy perspective, there is thus a need for assessing and mapping tranquillity, and different approaches have been developed. In general, the focus in these approaches has been to identify criteria that allow mapping areas with a potential for tranquillity. These criteria have either been defined by experts (e.g. EEA, 2016; MacFarlane et al., 2004; Votsi, Drakou, Mazaris, Kallimanis, & Pantis, 2012) or elicited from non-expert participants in controlled experiments or public consultations and surveys (e.g.

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Hewlett, Harding, Munro, Terradillos, & Wilkinson, 2017; Jackson et al., 2008; Watts, Miah, & Pheasant, 2013; Watts & Pheasant, 2015a). Based on such input, criteria for mapping tranquillity are then operationalised in Geographic Information Systems (GIS). Such approaches allow mapping areas that have a potential for tranquillity, but identifying areas where tranquillity is actually appreciated requires *in situ* information about people's experience in the landscape. This information is costly to obtain across large geographic areas.

In this respect, social media has been shown to provide a novel source of data that allows investigating people's place-based experiences and their descriptions of landscapes across large temporal and spatial scales (Chesnokova, Taylor, Gregory, & Purves, 2019; Dunkel, 2015; Figueroa-Alfaro & Tang, 2017; Guerrero, Møller, Olafsson, & Snizek, 2016; Heikinheimo et al., 2017; Hollenstein & Purves, 2010; Purves, Edwardes, & Wood, 2011; Tieskens, Van Zanten, Schulp, & Verburg, 2018; van Zanten et al., 2016; Wartmann, Acheson, & Purves, 2018). This growing body of work makes use of the fact that people upload content in the form of photographs, associated text (e.g. *tags*) and often geolocate their photographs, providing a cost-efficient data source consisting of photographs associated with textual descriptions and a geographic location. Such data has been successfully used to map cultural ecosystem services (Figueroa-Alfaro & Tang, 2017; Guerrero et al., 2016; Tieskens et al., 2018; van Zanten et al., 2016), extract vernacular regions (Hollenstein & Purves, 2010), landscape descriptions (Purves et al., 2011; Wartmann, Acheson, & Purves, 2018) or to investigate the experience of different sounds in the landscape (Chesnokova et al., 2019; Chesnokova & Purves, 2018). This body of work highlights the potential of social media as a data source for exploring tranquillity. In this study, we use Scotland as a case study to investigate the following research questions: how can we extract where people experience tranquillity in the landscape from social media data? And what are the factors influencing this experience? The aim of this study is thus to map areas where people experienced tranquillity and model the determinants of this experience by taking stock of user-generated photographs and associated content (tags and locations). The novelty of our research lies in i) combining geotagged photographs and their textual tags from social media to analyse where people experience tranquillity and ii) assessing factors influencing experienced tranquillity. In the following, we first provide some background information on the concepts and methods to assess tranquillity, before describing our hybrid methodological approach. In the results section we present our findings on the spatial distribution of photographs containing tags related to tranquillity. We further describe the results for our model that takes as input the content of photographs and other variables to analyse factors influencing experienced tranquillity. Finally, we discuss our findings with respect to the existing literature and highlight implications for how we conceptualise and model experienced tranquillity.

2. Background

The importance of providing restorative environments and tranquil areas for an increasingly urbanised population has been widely recognised (EEA, 2016; MacFarlane et al., 2004; Ministry of Housing Communities and Local Government, 2018). But what makes an environment restorative or tranquil? Attention Restoration Theory (ART) developed by Kaplan and Kaplan (1989) postulates that natural environments offer restoration from the directed, effortful attention in urban environments by relieving our fatigued attention. The theory is based on four concepts: *extent* as the scope and richness of an environment, *compatibility* as the match between an individual's expectations and the environment, *being-away* as the feeling of being removed from everyday life, and *soft fascination*, a combination of pleasure (aesthetic enjoyment) and involuntary, effortless attention (Kaplan, 1995; Kaplan & Kaplan, 1989). This involuntary attention is captured by pleasing levels of sensory input through stimuli such as clouds passing by, the rustle of leaves or a burbling stream (Berman, Jonides, & Kaplan, 2008). Informed by ART, Herzog and Bosley (1992) and Herzog and Barnes (1999) empirically investigated the concepts of *soft fascination*, which they described as tranquillity, or as 'how much you think this setting is a quiet, peaceful place, a good place to get away from everyday life' and *preference* defined as 'how much you like this place for whatever reason'. Through ratings of colour slides showing environmental scenes, both studies found that although tranquillity and preference were positively related, they were separate constructs. For instance, scenes showing large water bodies were rated higher for tranquillity than preference (Herzog & Bosley, 1992). Furthermore, tranquillity was found to be rated higher for natural than urban scenes, and the amount of foliage in an image correlated positively with tranquillity in natural environments (Herzog & Chernick, 2000). Building on the work by Herzog and colleagues (1992; 1999; 2000), research in applied acoustics investigated the combination of visual and acoustic stimuli in the construction of tranquil spaces (Pheasant, Horoshenkov, Watts, & Barrett, 2008; Watts, Pheasant, & Horoshenkov, 2011, Watts, Miah, & Pheasant, 2013; Watts & Pheasant, 2013, 2015a, Watts & Pheasant, 2015). In an experiment, Pheasant et al. (2008) had participants rate 100 photographs of landscapes across England in terms of perceived tranquillity. The images were also analysed by estimating the percentage of natural features (greenery), people and man-made structures. In a subsequent experiment, participants were exposed to visual and audio-recordings from a subset of locations in an audio-visual lab (Pheasant et al., 2008). A negative linear relationship was established between tranquillity ratings and measured noise indices, and a positive relationship between tranquillity and percentage of natural features (Pheasant et al., 2008). These relations were expressed in the adapted Tranquillity Rating Prediction Tool or TRAPT (Pheasant, Watts, & Horoshenkov, 2009, 2010), where in addition to natural features, man-made features such as historic buildings and landmarks that were deemed to contribute to tranquillity were included in the assessment of the visual scene. The TRAPT tool was subsequently tested and refined in different experimental settings. Its utility was shown for urban green spaces (Watts et al., 2011, 2013), where predicted ratings were compared with actual *in situ* ratings by visitors. Visitor ratings of tranquillity in urban green areas were higher than predicted with data from experiments, probably because the visitors were conditioned by their immediate experience of busy urban environments, in which green areas offer a respite despite absolute noise levels that are higher than in rural, remote areas (Watts et al., 2013). In another study, auditory and visual footage taken in rural environments of England and Scotland were evaluated by participants in a controlled laboratory setting, showing that the addition of man-made sounds decreased tranquillity ratings (Watts & Pheasant, 2015a). Results of these studies indicated that both visual and auditory factors impact people's sense of tranquillity. Similar findings were reported from a study that administered an online survey to residents and visitors of the Serre natural park in Italy, where respondents indicated that visual, olfactory and auditory factors influenced their experience of tranquillity (Modica, Zoccali, & Di Fazio, 2013).

Another approach to investigate tranquillity was adapted by the Campaign to Protect Rural England (CPRE), which has been drawing attention to the loss of tranquillity in England for decades (CPRE, 2005; Jackson et al., 2008; MacFarlane et al., 2004). CPRE uses the definition of 'tranquil areas' as: *'places which are sufficiently far away from the visual or noise intrusion of development or traffic to be considered unspoilt by urban influences'* (CPRE and the Countryside Commission, 1995). Mapping the impact of audio-visual disturbances such as roads and settlements in a GIS resulted in the identification of areas showing where tranquillity could still be said to exist in England. In a commissioned critique of this approach, a number of limitations were identified, including that the sources of disturbance and the thresholds for the distance criteria were solely based on expert assessments (Levett, 2000). A subsequent study in the Northumberland National Park and West Durham Coalfield in England sought to address these limitations by defining the criteria and thresholds based on public consultations (Jackson et al., 2008).

Similarly, a study in the Dorset Area of Outstanding Beauty used participatory appraisals including focus groups, household and on-site surveys to identify criteria from different stakeholders to map tranquillity in a GIS (Hewlett et al., 2017). Such approaches seek to answer the question 'what is tranquil?' by identifying operationalisable criteria that allow mapping areas where these criteria are fulfilled, in other words, where there is a supply of tranquillity. Landscape managers and planners, however, also need information about where this supply meets the demand, that is, where people 'consume' tranquillity. This approach thus seeks to answer the question 'where do people experience tranquillity?'. In order to investigate such experiences across large spatial scales, recent approaches rely on user-generated place descriptions to explore people's experiences, e.g. of sounds in outdoor landscapes (Chesnokova et al., 2019; Chesnokova & Purves, 2018). In their study in the English Lake District, Chesnokova et al. (2019) show that descriptions of silence or quietness associated to user-generated landscape images from the Geograph Britain and Ireland project (Geograph Project Limited, 2019) do not necessarily match the locations identified as tranquil on the CPRE tranquillity map. We take this observed discrepancy as a starting point for our analysis of experienced tranquillity in Scotland.

3. Materials and methods

3.1. Study area

Scotland exhibits a large diversity of landscape types (Scottish Natural Heritage, 2002). In the south and east of Scotland the interaction of the physical landscape and human activity created a land use pattern of rolling hills and fertile straths with farming and more densely populated estuaries along the eastern coastline (Scottish Natural Heritage, 2002). There is a pronounced contrast between these areas and the landscape character of the north and west that is dominated by mountains, vast expanses of moorland and a highly indented coastline with numerous islands. This sparsely populated area is often referred to as the Highlands and Islands.

The Scottish landscapes are valued not only for providing sustenance and natural resources, but also for their scenic qualities and opportunities for recreation. These qualities are protected in designated National Scenic Areas and two National Parks, the Cairngorms NP, and the Loch Lomond and The Trossachs NP (see Fig. 1). The latter specifically includes the enhancement and protection of tranquillity in its strategic planning document (LLTNP, 2017). While for England and Wales, comprehensive tranquillity mappings have been conducted, for Scotland, a tranquillity map at national scale is so far lacking (Landscape Institute, 2017). The present study thus aims to explore the potential of social media data to study the experience of tranquillity in Scottish landscapes.

3.2. Methodology

We use geolocated landscape photographs from the social media platform Flickr to assess the appreciation of tranquillity in Scotland. Flickr (http://www.flickr.com) is a photosharing platform where registered users upload photographs that they optionally tag with descriptive keywords (Fig. 2) and/or coordinates (geotags).

Our methodology consisted of two main approaches, one was a spatial analysis of the distribution of Flickr photographs and the second was an analysis of the content of photographs (Fig. 3).

We applied automated image processing and keyword filtering to select a data set containing geolocated landscape photographs with tranquillity tags. For the spatial analysis, we mapped the distribution of this set of photographs with tranquil tags in comparison to the distribution of all Flickr photographs. This approach allows identifying areas where we found unexpectedly high/low densities of tranquil photographs. For the content analysis, we manually annotated image content

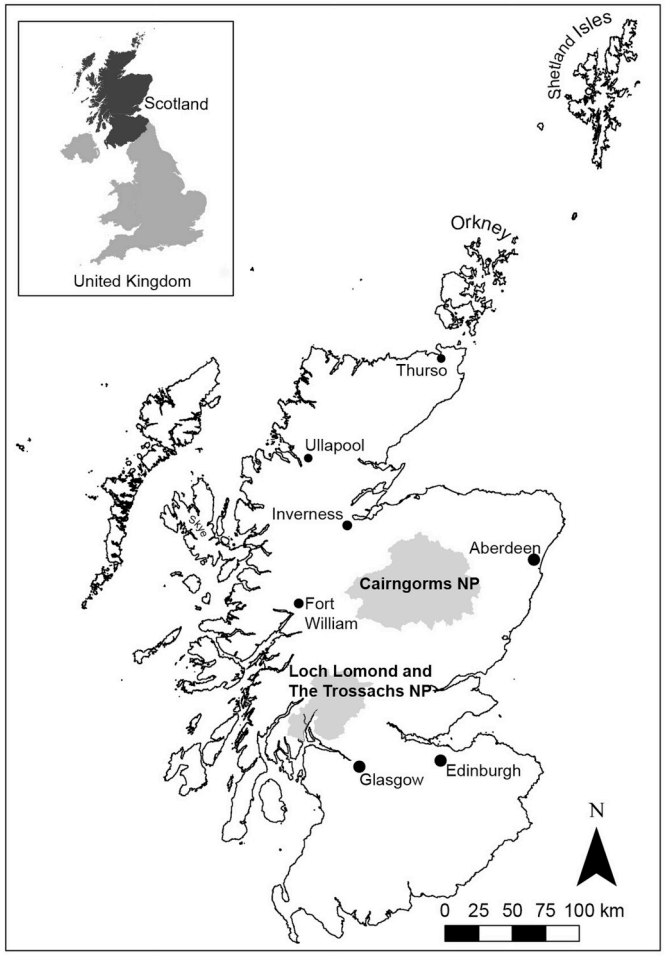

Fig. 1. The study area of Scotland. Copyright Scottish Government, contains Ordnance Survey data ©Crown copyright and database right (2019); Open Government Licence http://www.nationalarchives.gov.uk/doc/open-government-licence/.

of tranquil landscape photographs and compared these annotations to a control set of landscape photographs without tranquil tags. Finally, we used our image annotations and other variables that characterise the landscape where the photographs were taken in a logistic regression to analyse factors influencing experienced tranquillity. In the following, the methodology is explained in more detail.

3.2.1. Data collection and semantic filtering based on tags associated with tranquillity

We used an automated download script for the Flickr API that we accessed through the flickrapi package in Python (https://pypi.org/project/flickrapi/) to download all geotagged Flickr photographs in Scotland and adjacent waters that were publicly available since the inception of Flickr until the download date (24th of April 2018). In the Python script, we defined our study area of Scotland in decimal degrees, and set the initial size of the bounding boxes for download as 0.01 decimal degree. We then programmed our script to iterate through all the bounding boxes of Scotland and for each bounding box, to send automated queries to Flickr to download all photos in each bounding box. Per query, Flickr provides a maximum of 16 pages with 250 photographs each. For queries where there were more than 16 pages of photos returned, we split the bounding box in 4 equally sized bounding boxes and performed 4 new queries using these bounding boxes. This process was repeated iteratively until there were less than 16 pages of photos in each bounding box or we reached a minimum bounding box

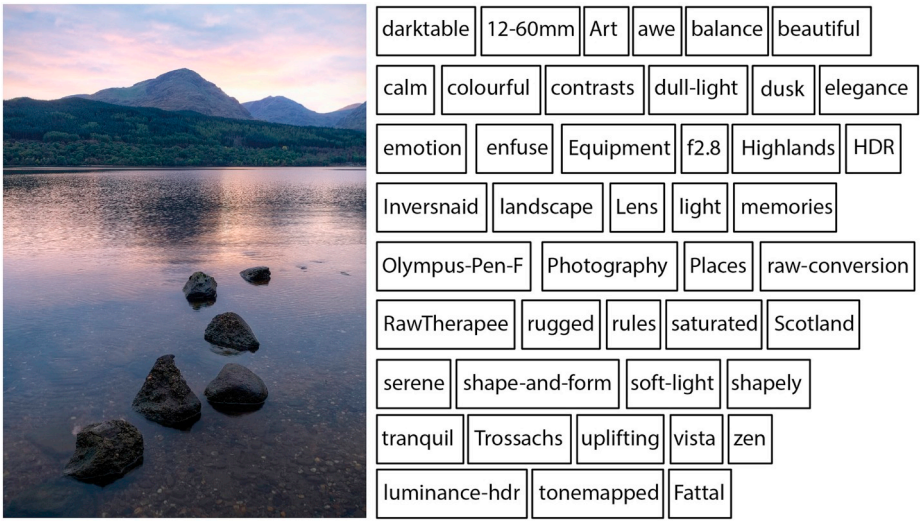

Fig. 2. Example of a Flickr photograph 'Inversnaid sunset' with a selection of associated user-generated tags uploaded to the Flickr platform by user ShinyPhoto-Scotland under Creative Commons License (CC BY-NC-ND 2.0).

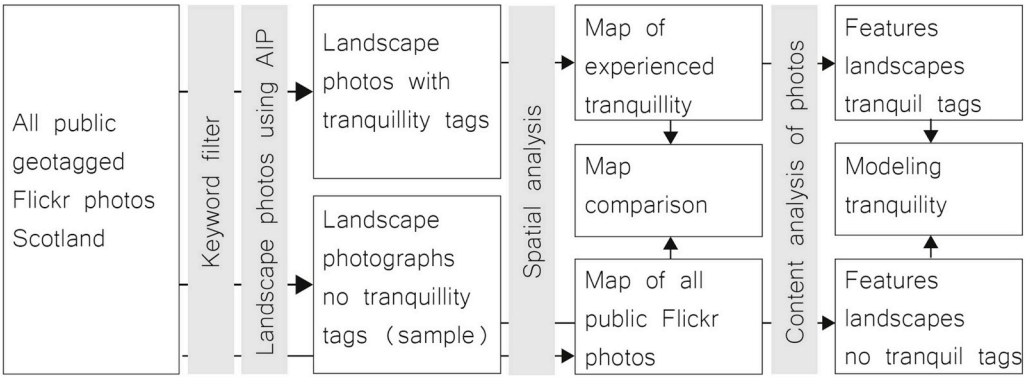

Fig. 3. Research design for modelling tranquillity based on user-generated content.

size of 75m × 75m. To control for bulk-uploads and very active users we only included one photograph per user per square kilometer in our dataset (Casalegno, Inger, DeSilvey, & Gaston, 2013).

We then filtered all photographs based on the tags associated with them, selecting only photographs that matched at least one term in our list of keywords. We base our keywords on terms that were stated in previous research as being used synonymously with tranquillity, such as *calm, peaceful*, and *quiet* (Chesnokova et al., 2019; Herzog & Barnes, 1999; Hewlett et al., 2017). Additionally, we extended this list through results from empirical research with 100 visitors to the Loch Lomond and the Trossachs National park that were asked in face-to-face interviews what they associated with tranquillity (Wartmann and Mackaness, in review). This empirical research identified 11 terms that are semantically closely associated with tranquillity: *atmosphere, calmness, peace, peaceful, pleasant, serene, tranquillity, tranquil, silence, silent, quiet*. Using this set of keywords to filter Flickr photographs, 12,279 photographs were retained for Scotland with at least one tag related to tranquillity.

3.2.2. Automated image processing of user-generated flickr photographs

As we were interested in the experience of tranquillity in landscapes, we used automated image processing (AIP) to filter out all non-landscape photographs (e.g. indoor spaces, cars, portraits of people or animals). First, we created a training dataset for which we manually classified 3,000 photographs into two classes: landscape or non-landscape. Then we used Google Cloud Vision API to attach up to ten keywords to each tranquillity photograph. Google Cloud Vision API is a tool that based on pre-trained machine-learning models can match a photograph to a large existing database of tagged photographs based on pixel values. Subsequently, we used a Naïve Bayes Classifier to categorise each photograph as either belonging to the category *landscape* or *non-landscape* based on the words generated by Google Cloud Vision and the categorisation of the training dataset (Richards & Tunçer, 2017). We validated the Naïve Bayes Classifier with a test set of 500 photographs, showing a Cohen's Kappa of 0.93 for the comparison of manual and automated classification. This filtering resulted in a total of 2,805 georeferenced landscape photographs with tags related to tranquillity.

From the remaining subset of downloaded geotagged Flickr photographs that did not contain tranquil tags, we drew a random sample (n = 8,000). We again used the Google Cloud Vision API to select landscapes photographs. Processing a subsample of 8,000 photographs enabled us to reach a roughly balanced sample compared with the 'tranquil landscape photographs'. This step yielded 2,602 georeferenced landscape photographs that did not contain tags any from our list of terms related to tranquillity.

Dividing our photographs into two sets (landscape photographs with/ without tranquil tags) is based on the assumption that if people tagged a photograph with keywords related to tranquillity, they associated an experience of tranquillity with the landscape depicted. For this exploratory study we further assume that the presence of tags associated with tranquillity indicates that tranquillity was more noteworthy than in locations where no such tags were used. The absence of a tranquil tag,

however, does not indicate the absence of tranquillity.

3.2.3. Mapping experienced tranquillity with user-generated landscape photographs

We calculated a density surface for landscape photographs with tranquil tags (n = 3210) and a dataset of general Flickr photographs in Scotland (n = 2,271,168) at a resolution of 500m using a 5 km kernel smoothing radius. We normalised the surfaces to allow for a calculation of Chi values (c.f. Hollenstein & Purves, 2010) as an indication of how unexpected the observed distribution of landscape images with tranquil tags is compared to the overall distribution of photographs in Flickr. We calculated 20 quantiles of the Chi values, and retained the lowest (1 & 2) and highest (19 & 20). We converted these raster cells to polygons, and counted the number of photograph locations found in the polygons, retaining the 62 polygons which have at least 5 points in the tranquillity layer. Selecting polygons that contain photographs with tranquil tags ensures that we display only locations for which there were observations of tranquil landscape photographs, which we then compare with the overall distribution. We first show where these areas are found across Scotland, before zooming in to a smaller area as an example.

3.2.4. Detailed content analysis of landscape photographs

To further investigate what makes people tag a landscape photograph as tranquil, we compared landscape photographs with and without tranquillity tags using detailed manual content analysis. For the annotation we used a set of categories based on a literature review and additional categories derived from our data set. We first compiled a set of categories for image annotation based on studies about landscape preferences and restorative environments. Attention Restoration Theory (Kaplan & Kaplan, 1989) states that open spaces induce restoration, which we operationalised through the category *open views* (horizon visible in the photograph). The presence of greenery was demonstrated to be linked to restoration and to the experience of tranquillity (Pheasant, Watts, & Horoshenkov, 2009; Ulrich et al., 1991; Watts et al., 2011), which we operationalised as a category *presence of greenery* (more than 30% of the photograph covered in greenery or dominant as foreground). Furthermore, the presence of water bodies, particularly with still surfaces, was linked to higher ratings of tranquillity (Herzog & Barnes, 1999), which we expressed through the category *presence of water bodies*. The presence of people was shown to be negatively linked to tranquillity ratings (Watts et al., 2011). We therefore included a category *presence of people*. In order to assess other potential categories, whose presence or absence may influence the experience of tranquillity, we examined a random selection of 1000 landscape photographs from our two Flickr datasets balanced between landscape photographs with and without tranquillity tags. We used a process of 'open coding' (Crang & Cook, 2007), a qualitative research method commonly applied in the humanities, to identify recurring themes that we then operationalised as additional categories for our manual image annotation. These were *dominant sky* (more than 30% of the image), *special atmospheric conditions* (sunset, sunrise, snow, mist), *topography* (presence of hills, mountains or islands), *presence of boat, ship or ferry*, *presence of wild or domestic animals* and *presence of man-made constructions* (e.g. houses, streets, bridges or other infrastructure clearly visible). These annotation categories were not mutually exclusive, and a photograph could be annotated with multiple categories. To ensure consistency and reproducibility of our annotation, we devised written annotation guidelines with definitions of when we consider a certain category to be present. For a random set of 100 photographs, two annotators classified the photographs independently using the annotation guidelines, reaching a substantial inter-annotator agreement of Cohen's Kappa = 0.79 (Cohen, 1960), indicating that the annotation is reproducible with different annotators. To further improve reproducibility and consistency in the annotation, cases of disagreements were discussed and the guidelines revised accordingly. Finally, we drew a balanced random set of 3000 photographs (1500 landscape photographs with tranquil tags and 1500 landscape photographs without tranquil tags). Using a process called structured coding (Crang & Cook, 2007) one annotator manually annotated image content during a total of 26 h, equaling on average 31 s per photograph. We then statistically compared the counts of the different categories (e.g. greenery, presence of people) between landscape photographs with and without tranquil tags using non-parametric Mann-Whitney-U tests with a Bonferroni-adjusted significance level of $\alpha^{adjusted} = 0.0001$ (Dunn, 1961).

3.2.5. Logit model

We fit a multivariate logistic regression to explore which variables influence experienced tranquillity. For this analysis, we pool the landscape photographs with tranquil tags (n = 1500) and landscape photographs without tranquil tags (n = 1500), which represent the binary dependent variable. The explanatory variables are taken from a) the categories derived through manual content annotation of photographs and b) a set of location variables extracted from spatial datasets at the location where the photograph was taken. The categories of photograph content are categorical variables, where values indicate the absence (0) or presence (1) of a category. The variables that describe the location where the photograph was taken are continuous. The location variables are i) travel time to the nearest city with at least 100,000 inhabitants where a one unit increase means a 15 min increase in travel time (as a proxy for accessibility), ii) quietness suitability index (EEA, 2016) and iii) 1 km^2 grid cell population density derived from LandScan (ORNL, 2019). We monitored multicollinearity in our predictors by calculating the variance inflation factors (VIF) and found little to no multicollinearity, with values for all VIFs below 2.

4. Results

4.1. Distribution of tranquil photographs in Scotland

Comparing the density distribution of photographs with tranquil tags (observed distribution) to a set of over 2.2 Million photographs without such tags (expected distribution) we observe some noteworthy differences. For illustrative purposes we only display the two top and bottom quantiles, highlighting where the contrasts are most pronounced. In the Central Belt between Glasgow and Edinburgh clusters of tranquil photograph locations shows that people take landscape photographs and tag them with keywords related to tranquillity also in cities. This indicates that tranquillity is also experienced in urban settings, and not limited to the countryside. However, compared to the underlying distribution of all photographs, there are relatively few with tranquil tags in the most densely populated areas of Scotland, resulting in values for the expectation surface lower than expected. These coldspots are illustrated in blue in Fig. 4. In addition to the Central Belt, such relative coldspots also include areas around larger settlements including Fort William, Dundee, Aberdeen, and Inverness. However, in some cases, we find more photographs with tranquillity tags than expected around settlement areas, for example in the town of Oban on the Scottish west coast. Oban has a higher than expected density of photographs with tranquil tags (indicated in red in Fig. 4). This hotspots extends across the sea along the ferry crossing to Mull. We observe other hotspots of photographs with tranquillity tags along the West coast that are ferry crossings, including Brodick (Isle of Arran), Rothesay (Isle of Bute) and Largs as the ferry crossing to the island of Millport (Fig. 5). Other hotspots of tranquillity that can be found inland are mostly related to water bodies, including for example clusters around Loch Alainn, Loch Leven and around Rannoch Moor. The Loch Lomond and The Trossachs National Park also stands out for a concentration of tranquillity clusters (Fig. 4). If we zoom in to the data (not graphically represented here), we observe that these clusters are located around freshwater lochs, such as Loch Chon, Loch Achray or Loch Ard. In contrast to the Loch Lomond and the Trossachs National Park, the Cairngorms National Park shows relatively few photographs with tranquil tags, with two small clusters around Loch

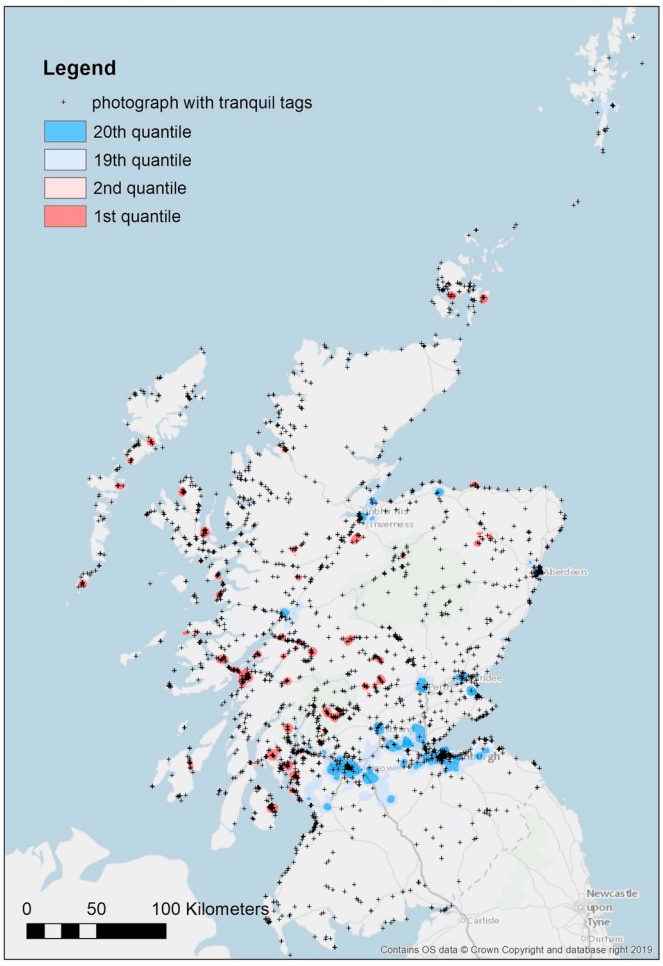

Fig. 4. Density distribution for photographs with tranquil tags compared to underlying distribution of all photographs on Flickr across Scotland. Red areas (1st and 2nd quantile) indicate higher densities of tranquil photographs than expected (hotspots) and blue areas (19th and 20th quantile) indicate areas with lower density than expected (coldspots). Contains OS data. Crown Copyright and database right 2019. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Morlich and Loch Garten.

In general, we observe a strong relation between presence of water, either along the coast or inland, and the uploading of photographs with tranquillity tags. Furthermore, ferry ports and crossings are often at the centre of observed tranquilly hotspots at the coast, particularly along the ferry crossings to the islands of the West Coast.

In the following, we explore in more detail the characteristics of landscape photographs with tranquil tags and compare them to the landscape photographs without such tags.

4.2. Differences in content of landscape photographs with and without tags related to tranquillity

We found significant differences in the content of landscape photographs with and without tranquil tags (Table 1). Water bodies were prevalent in both sets of photographs, but significantly more in photographs with tranquil tags than in photographs without such tags. Another significant difference between the two sets is that photographs with tranquil tags significantly more often depicted special atmospheric conditions such as sunrise or sunset than photographs without tranquil tags (Table 1).

Furthermore, vessels such as sailing boats or ferries are significantly more prevalent in photographs with tranquil tags than in photographs without those tags. Tranquil photographs also significantly more often depict open views extending to the horizon than photographs without tranquil tags. People are not often depicted in photographs, which has to do predominantly with our automated photograph processing approach to select landscape photographs, which filtered out portraits and groups of people. However, we still identify people in landscape photographs (e.g. in the background), and they are depicted significantly less in photographs with tranquil tags. Interestingly, greenery (including forest, trees, shrubs etc.) is significantly more often dominant in landscape photographs without tranquil tags. It is important to note that we identify the presence of man-made structures both in photographs with and without tranquil tags. However, they are slightly more prevalent in photographs without tranquil tags, but not significantly. These man-made structures often take the form of roads, houses, ports, marinas, bridges or benches. Given that we identify such structures in more than a third of all photographs that people describe with tranquil tags indicates that the complete absence of all visible man-made structures does not seem to be a prerequisite for people experiencing tranquillity. We do not find differences between the two sets of landscape photographs relating to topography (the presence of landforms such as mountains, hills or islands). Moreover, the presence of wild or domestic animals does not differ significantly between the two sets of photographs.

From our detailed content analysis we conclude that landscape photographs are tagged with keywords related to tranquillity more often when certain landscape elements such as water bodies are visible, views are open and specific ephemeral atmospheric conditions are present. In the following, we include these criteria and other variables into a spatial regression model.

4.3. Predicting experienced tranquillity

We included all variables from the manual photograph annotation and added three locational variables (travel time to nearest city, population density and the measure of the quietness suitability index (EEA, 2016)). Table 2 shows the model output of the logistic regression. The table shows the coefficient, odds ratio and standard error for each explanatory variable. The model is a fair fit with an AUC of 0.74. As for the categories determined through manual annotation of photograph content, the presence of water bodies, atmospheric conditions and ships/ferries are strong positive predictors of photographs with tranquil tags, with odds ratios higher than 2. The presence of people is a significant negative predictor of tranquillity photographs with an odds ratio of 0.5. The location variables travel time to nearest city and population density also have statistically significant coefficients, indicating a lower likelihood of a photograph tagged as tranquil when travel time to the nearest city increases. There is a higher likelihood of tranquil photographs in areas with a higher population density. The quietness suitability index value as a combined measure of noise level and naturalness was not a significant predictor in our analysis.

5. Discussion

This study goes beyond earlier work on user-generated content for exploring landscape qualities and values by applying a hybrid approach. This approach combines automated image processing to identify landscape photographs from social media, and keyword filtering of tags associated with tranquillity that were selected based on existing literature and empirical research. Furthermore, we manually analysed the content of photographs as an important step in more fully utilising the potential of user-generated content. We used this image content as input for a logistic regression model with further explanatory variables such as population density and modelled levels of quietness in order to find variables predicting experienced tranquillity.

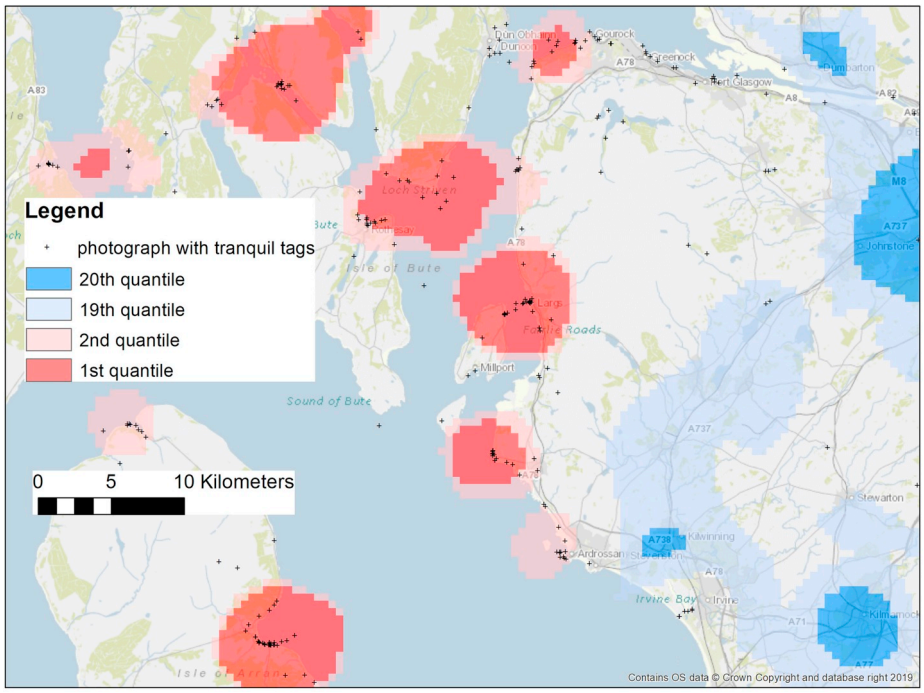

Fig. 5. Close-up of density distribution for photographs with tranquil tags compared to underlying distribution of all photographs on Flickr for the Firth of Clyde. Contains OS data. Crown Copyright and database right 2019.

Table 1
Comparison of categories present in photographs with tranquil tags (N = 1500) and photographs without tranquil tags (N = 1500) (asterisks indicate statistical significance).

	% of photographs with tranquil tags	% of photographs without tranquil tags	Z-values	p-values
presence of water bodies	81.9	53.5	−16.591	<0.001***
open views	69.3	57.9	−6.450	<0.001***
dominant sky	59.1	49.6	−5.204	<0.001***
topography: presence of hills, mountains or islands	50.9	46.5	−2.447	0.014
presence of anthropogenic elements	39.5	47.6	−4.455	<0.001***
presence of greenery	37.9	59.0	−11.579	<0.001***
special atmospheric conditions	32.9	15.1	−11.369	<0.001***
presence of boat, ship or ferry;	24.7	6.5	−13.746	<0.001***
presence of people	4.7	10.1	−5.660	<0.001***
presence of wild or domestic animals	3.1	4.1	−1.476	0.140

Table 2
Logit model including features annotated from photograph content and features extracted from spatial datasets at the location where the photograph was taken (features sorted by Odds ratio).

		Coefficient	Odds ratio	Std. Error
	Intercept	−0.95***		
features annotated from landscape photographs	presence of boat, ship or ferry	1.22***	3.37	0.13
	presence of water bodies	1.06***	2.87	0.10
	special atmospheric conditions	0.95***	2.58	0.10
	open views	0.07	1.07	0.11
	presence of wild or domestic animals	0.07	1.07	0.22
	dominant sky	0.06	1.07	0.09
	topography: presence of hills, mountains or islands	−0.08	0.92	0.10
	presence of man-made structures	−0.14	0.86	0.08
	presence of greenery	−0.20*	0.82	0.09
	presence of people	−0.68***	0.51	0.16
features from locations of photographs	population density	0.0001*	1.0001	0.00
	travel time to nearest city	−0.001*	0.99	0.00
	quietness suitability index	−0.00003	0.99	0.00
N = 2999	AUC = 0.74			

5.1. Mapping tranquil areas based on user-generated content

Our results show that the distribution of photographs with tranquil tags as opposed to the distribution of photographs without such tags (the underlying distribution) provides information about locations where we find unexpectedly high densities of tranquil tags, which we take as an indicator that these locations are perceived as tranquil. The mere density of photographs with tranquil tags does not allow for identifying such tranquil areas, as image counts are strongly biased by the overall distribution of uploaded photos and thus, a comparison with the underlying distribution is indicated for making inferences about the observed distribution (Hollenstein & Purves, 2010). Correcting for the underlying distribution, we found clusters of unexpectedly high densities of landscape photographs tagged with tranquillity keywords in protected natural areas, such as the Loch Lomond and The Trossachs National Park, and along the Scottish coastline, particularly around ferry ports and crossings. Even though such areas are accessible by road and may not be

characterised through a complete lack of infrastructure and absence of anthropogenic noise, they seem to instil tranquillity, reflected in people taking pictures and tagging them with keywords related to tranquillity. Similar findings were made in a recent study on extracting descriptions of sounds from large user-generated text corpora in the English Lake District, where often areas were described as tranquil despite busy roads nearby (Chesnokova et al., 2019). Contrary to the idea that remoteness and quietness are prerequisites for experiencing tranquillity, which has been implemented in mapping approaches where tranquillity can be said to exist (CPRE and the Countryside Commission, 1995; MacFarlane et al., 2004), we found hotspots of photographs with tranquillity tags in accessible areas visited by many people. This indicates that accessibility is an important factor in where tranquillity can actually be experienced. Users also uploaded landscape photographs with tranquil tags in urban areas such as Glasgow and Edinburgh, which is in line with previous research that indicates urban green areas are important tranquil areas for the resident population (Watts et al., 2011). Such areas constitute a stark contrast with the overwhelming busyness of urban areas and thus are conducive to an experience of tranquillity, accessed by many urban dwellers seeking recreation. However, compared to the underlying distribution of photographs, we found the density of photographs with tranquil tags to be lower than expected in highly urbanised areas such as Glasgow, Edinburgh or Inverness. In contrast, we found that for areas that are theoretically very tranquil (fulfilling criteria such as lack of road noise, lack of visible infrastructure), but that are inaccessible due to lack of transport, few or no users upload photographs, indicative of the fact that only few are enjoying the tranquillity of these places. Our results thus provide a spatially explicit indication of where people experience (consume) tranquillity. This is an important distinction from existing tranquillity maps that show where tranquillity could be said to exist (Hewlett et al., 2017; MacFarlane et al., 2004).

In the following, we discuss in more detail the potential factors contributing to the experience of tranquillity.

5.2. Factors influencing the experience of tranquillity

Through detailed manual content analysis we identified several key characteristics that distinguish landscape photographs with keywords related to tranquillity from landscape photographs without such tags. Some of these characteristics were related to the landscape, such as the presence of water bodies, which fits well with previous experiment-based preference studies that found a link between water bodies and perceived tranquillity (Herzog & Barnes, 1999; Herzog & Bosley, 1992). Another characteristic associated with photographs tagged as tranquil were fewer visible man-made structures. The dominance of greenery in a photograph was observed more in photographs without tranquillity tags. This is somewhat surprising, because the amount of greenery in urban parks was found to be correlated with perceived tranquillity in previous studies (Watts et al., 2013, 2011), but Scottish landscapes, particularly in the Highlands and along the coast are often characterised by the absence of a tree cover. This finding may thus be particular to our case study in Scotland. We found ferries and boats to be present more often in photographs with tranquil tags than in other landscape photographs. The presence of sailing vessels is strongly related to water bodies, which by themselves are predictors of tranquillity. We would argue that boats and ferries provide people with picturesque photo opportunities to document their experience, leading to the observed high densities of photographs around ferry ports. In addition, ephemeral, specific conditions of the atmosphere were also more prevalent in photographs with tranquil tags. This indicates that other factors that are not related to a location or landscape characteristics also influence people's experience of tranquillity. Therefore, when modelling tranquillity based on densities of photographs, we would ideally need to correct for such occurrences.

Apart from the variables identified through manual image annotation, we used population density, distance to nearest city and the quietness index as input for a logistic regression. The analysis demonstrated that population density and distance to nearest city were negative predictors of the occurrence of a photograph tagged as tranquil, indicating that tranquillity is experienced near cities and in populated areas. This is in contrast to early tranquillity maps highlighting the most remote areas as the most tranquil ones (CPRE, 2005; MacFarlane et al., 2004), but is in line with recent research indicating people find tranquillity also near busy and noisy roads (Chesnokova et al., 2019). Furthermore, the quietness suitability index was not a significant predictor of tranquillity, suggesting quietness and tranquillity are two different concepts, and that the experience of tranquillity may be modulated by other factors than noise (Van Renterghem, 2019). In addition to the identification of quiet areas, we argue that our approach provides a complimentary perspective on landscapes where people experience tranquillity. Combining these approaches has the potential to highlight important deviations between the supply and consumption of tranquillity in landscapes.

5.3. Limitations and further work

Our choice of Flickr as the social media platform for this study was based on the fact that Flickr contains both images and textual content in the form of tags. Furthermore, at the time of writing, this content was freely available through an API that allowed geographic queries without limiting the search area or time frame for the query. Comparisons among platforms have showed relatively similar patterns across platforms (Tenkanen et al., 2017; van Zanten et al., 2016), however, this would need to be tested for the case of tranquillity mapping with social media data from other platforms. Well-known challenges of social media data are related to the bias due to specific user groups of social media platforms that are not representative for society as a whole (Li, Goodchild, & Xu, 2013). However, recent empirical work highlighted that results derived from social media data match relatively well with high-precision official data of visitor counts (Tenkanen et al., 2017), but more work would be needed to directly compare estimates of tranquillity from social media with field-based interviews (Wartmann and Mackaness, in review).

We used our set of empirically-grounded keywords to filter content and assigned equal importance to every keyword. A photograph was selected if one or more keywords were present. As our set of keywords was based on empirical research with respondents in Scotland, we are confident that as a first step, this produced valuable results. For more detailed studies, we propose to investigate different combinations of keywords. We are aware that by selecting photographs based on keywords to represent the experience of tranquillity we assume that only landscapes tagged as tranquil are perceived as tranquil. We thus ignore landscapes that would be perceived as tranquil, but where photographs were not tagged using such keywords. The use of machine learning algorithms has potential to overcome this limitation, as algorithms can be trained on an existing data set of landscape photographs that users tagged as tranquil. These algorithms can the identify photographs similar to the training data set, but which have not been labelled with tranquil keywords. Such an analysis could be complemented by active crowdsourcing projects, where users have to rate the perceived tranquillity based on a photograph. For the landscape quality of scenicness, such ratings have already been successfully combined from a crowdsourcing-platform (http://scenicornot.datasciencelab.co.uk/) with textual descriptions of photographs (Chesnokova, Nowak, & Purves, 2017). Through such experiments, we could also test for the influence of different socio-demographic factors (age, gender, education and others) on the perception of tranquillity in photographs. The advantage of Flickr photographs is that we assume the same person who took the photograph was also describing it through tags. The tags are thus more than a description of the photograph itself, as they encapsulate the place-based experiences of the photographers. Compared to photograph-ratings in surveys, Flickr is thus a unique dataset that allows

us to gain insights into where users were and what they photographed, but it typically does not result in complete spatial coverage. Large parts of Scotland are therefore not covered, which could be mediated through more active crowd-sourcing approaches.

6. Conclusions

Analysis of geolocated social media photographs combining tag filtering and photograph content indicates that in Scotland, areas experienced as tranquil are not located in the most remote areas, but in accessible areas, often near water bodies. We also found landscape photographs tagged as tranquil in urban centres such as Edinburgh and Glasgow. We found unexpectedly high densities of tranquillity photographs along the West coast, often concentrated around ferry ports and crossings, and near inland water bodies. We did not find locations perceived as tranquil to be related to low population densities and low noise levels. Areas that are not impacted by noise are usually remote, poorly accessible and not conducive to many visitors experiencing tranquillity. Our results thus challenge existing conceptualisations of tranquillity as an objective quality of the landscape that can be modelled in a GIS. We argue that the notion of tranquillity as experienced is an important one for policy-making and planning, so that areas where people actually experience tranquillity can be taken into account. We show that these areas of experienced tranquillity may be different from areas previously identified as tranquil, where tranquillity can be said to theoretically exist. While there are limitations associated with the use of social media content, our results show that we can identify clusters of experienced tranquillity through social media data across large areas, which can complement existing mapping approaches.

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