

## Research Paper

## Using social media to understand drivers of urban park visitation in the Twin Cities, MN

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## ABSTRACT

Green space and parks in urban environments provide a range of ecosystem services and public benefits. However, planners and park managers can lack tools and resources to gather local information on how parks are used and what makes them desirable places for recreation and a wide variety of uses. Traditional survey methods to monitor park use and user preferences can be costly, time consuming, and challenging to apply at scale. Here, we overcome this limitation by using geotagged social media data to assess patterns of visitation to urban and peri-urban green space across park systems in the metropolitan area of the Twin Cities, Minnesota, USA. We find that parks with nearby water features, more amenities, greater accessibility from the presence of trails, and that are located within neighborhoods with higher population density, are associated with higher rates of visitation. As cities grow and shifts in demographics occur, more responsive management of public green space will become increasingly important to ensure urban parks provide ecosystem services and meet users' needs. Using social media data to rapidly assess park use at a lower cost than traditional surveys has the potential to inform public green space management with targeted information on user behavior and values of urban residents.

## 1. Introduction

Opportunities for outdoor recreation are often classified as cultural ecosystem services, as they relate to the non-material health, well-being, and experiential benefits that humans derive from directly interacting with nature (Chan et al., 2012; Millennium Ecosystem Assessment, 2003). Cultural services is a broad category of physical and psychological relational benefits from nature that generally includes not only recreation but also spirituality, aesthetics, and mental health, among others (Haines-Young & Potschin, 2010). Historically, these services have been notably difficult to quantify and represent spatially (Paracchini et al., 2014) without robust, participatory mapping or engagement processes (Brown & Fagerholm, 2015; Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013). Furthermore, cultural services depend on the specific context in which they occur, surrounding infrastructure that mediates how nature is experienced, and the preferences or

perceptions of the individuals who value these services (Andersson et al., 2015). As a result, they have traditionally been the least studied service in ecosystem services assessments, which typically focus on the classes of provisioning, regulating, and supporting services that landscapes provide (Daniel et al., 2012). This is a notable gap, especially in studies of urban ecosystem services where cultural services may have a large importance in connecting urban populations with nature (Andersson, Tengö, McPhearson, & Kremer, 2015; Gómez-Baggethun & Barton, 2013; Haase et al., 2014; Luederitz et al., 2015).

In urban areas, recent examples of cultural ecosystem services assessments have demonstrated the site-specific and temporally sensitive nature of cultural values, challenges in quantifying or mapping these preferences and behaviors, and the need for additional research and methods on this topic (see, for example, Bauer, Tynon, Ries, & Rosenberger, 2014; Bertram & Rehdanz, 2015; Langemeyer, Baró, Roebeling, & Gómez-Baggethun, 2015; Thiagarajah, Wong, Richards, &

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Friess 2015; Tratalos, Haines-Young, Potschin, Fish, & Church, 2016). Our study is motivated by the growing demand for readily available, spatially-explicit information on cultural ecosystem services in cities, particularly for assessments of the drivers of recreation patterns in urban parks.

More specifically, public green space and parks in urban and peri-urban areas provide users—including urban residents and visitors—with a connection to nature not always possible elsewhere in cities and with a broad range of social, psychological, and recreational services (Bolund & Hunhammar, 1999; Chiesura, 2004; Gómez-Baggethun et al., 2013). Previous research has illustrated a range of park characteristics that affect the benefits users receive from visiting parks, though these factors may vary depending on specific context and type of green spaces analyzed (Andersson et al., 2015). For example, park size, recreational amenities like water features or trails, organized recreational activities, and accessibility have had demonstrated, positive effects on park use and suitability of nature-based recreation (Cohen et al., 2010; Dallimer et al., 2014; Kienast, Degenhardt, Weilenmann, Wäger, & Buchecker, 2012; Paracchini et al., 2014). While population density and forested land cover were associated with greater demand for green space in some contexts (Kienast et al., 2012; Paracchini et al., 2014), these factors did not always have positive effects in others (Cohen et al., 2010; Dallimer et al., 2014). Although metrics of accessibility and park amenities appear important across contexts, this literature also suggests that the full suite of factors influencing nature-based recreation in urban areas likely varies by location, type of green space, or user groups studied.

Reviewing this literature, measures of visitation to parks are also clearly important to understanding patterns of green space use in urban settings. Most studies about urban parks to-date rely, at least in part, on traditional survey measures (e.g., visitor counts at park entrances or questionnaires from random or representative samples of park users) to measure demand for recreation and elicit preferences of park users for different amenities (Cohen et al., 2010; Dallimer et al., 2014; Eagles, 2014). These methods, however, are generally limited by staff capacity (i.e., time, expertise, or number of employees to conduct rigorous surveys), costly to conduct regularly or across large or multi-jurisdictional geographic areas, and not always spatially explicit (Cessford & Muhr, 2003; Freeman, 2014). Furthermore, there is potential for implicit bias in these surveys techniques from the reference group or data collection process (*Ibid.*). With this in mind, urban park managers and researchers are both demanding and developing new methods derived from geospatial information and sensors to strengthen and expand the available toolkit for measuring and mapping park visitation (Shoval & Ahas, 2016).

Inspired by the need for readily available, low cost park use data and by these new approaches to assessing park visitation, we seek to overcome logistical challenges facing previous urban park research and management by supplementing traditional survey methods with a wealth of novel, spatially explicit data from two online social media platforms—Flickr and Twitter—used to estimate park visitation. In so doing, we estimate recreational demand in 1581 diverse public urban parks and urban and peri-urban green spaces, including, but not limited to city parks and recreation centers, regional linear parks, golf courses, and nature preserves, in the Twin Cities Metropolitan Area (TCMA) in Minnesota, USA. Hereafter, we refer to this wide range of features in the area's park systems, which make up the spatial unit of our analysis, by the simple shorthand of “parks” or “urban parks.”

Our research follows from recent studies demonstrating that social media can provide a rich source of geographic information for a broad range of applications (Goodchild, 2007; Zook & Graham, 2007), including in the ecosystem services and outdoor recreation communities. Notably, there have been broader calls to incorporate crowd-sourced and geotagged social media data and a growing number of examples using these data both in conservation science and practice (Di Minin, Tenkanen, & Toivonen, 2015; Levin, Kark, & Crandall, 2015; Levin,

Lechner, & Brown, 2017), as well as in urban planning (Dunkel, 2015; Guerrero, Möller, Olafsson, & Snizek, 2016; Tao, 2013). Other studies have shown that visitation rates to recreation sites, for example, can be reliably estimated using users' online image-sharing activity (Wood, Guerry, Silver, & Lacayo, 2013). This finding has inspired a number of recent studies of nature-based tourism that use these data across various subjects and both spatial and temporal scales (e.g., Arkema et al., 2015; Casalegno, Inger, DeSilvey, & Gaston, 2013; Keeler et al., 2015; Sessions, Wood, Rabotyagov, & Fisher, 2016; Sonter, Watson, Wood, & Ricketts, 2016; van Zanten et al., 2016). Nature-based recreation is a common focus across these examples, but researchers have tended to focus their assessments in predominantly rural wilderness areas at large scales, including at state and national levels.

However, more people now live in cities than in rural areas (United Nations & Social Affairs, 2014), making it likely that the average individual's outdoor recreation experiences occur more often in smaller-scale, more heavily managed urban parks and green spaces than in remote wilderness areas (Standish, Hobbs, & Miller, 2013). As a result, while some have started to use social media data within cities to assess, for example, transportation patterns (Toole et al., 2015; Wu, Wood, Fisher, & Lindsey, 2017) or public perceptions and values in landscape and urban planning (Dunkel, 2015), these methods are still nascent and other potential applications of these data are vast (Guerrero et al., 2016). Few studies have yet to test or use these data explicitly as indicators of recreation services or proxies for surveyed visitation to urban parks at the scale of a single metropolitan area.

Filling this gap, our study adapts and builds on existing methods that aggregate social media data within nature-based recreation sites (Wood et al., 2013) to test how well data from multiple social media platforms perform in approximating urban park visitation and how these data, combined with other geospatial information about urban parks, can be used to assess observed user preferences within the TCMA context. Specifically, we ask how social media data from two platforms compare to survey methods for estimating visitation to these parks. Then, building on previous studies of urban park characteristics and visitation, we use these data to ask what attributes within and around urban parks predict observed patterns of park use across the region. We conclude by presenting a discussion of our key findings, limitations of these results, proposed next steps for building on this approach and improving our understanding of TCMA park use, and the usefulness of social media as data to inform urban planning and park research and management more broadly.

## 2. Methods

### 2.1. Study area and park system

Our study analyzed the visitation patterns, amenities, and neighborhood characteristics of 1581 unique parks in Minnesota's TCMA (Fig. 1). Parks within the study area range in type, size, and management—from small, municipal pocket parks to large, multi-jurisdictional regional parks—representing a diverse sample of urban and peri-urban parks across a single metropolitan area. More than 50 different municipalities and agencies manage the park systems in our study.

For spatial information on these parks, we compiled available vector data with the locations of these features within our study area from the regional metropolitan planning agency Metropolitan Council (Met Council), Hennepin County, Three Rivers Park District, Ramsey County, Minneapolis Park and Recreation Board, and City of Saint Paul Parks and Recreation Department. From these datasets, we then selected those parks located within a three-mile radius of Hennepin and Ramsey counties, allowing us to include parks whose boundaries overlapped with or extended just beyond county lines (see Table S1, in supplementary material, for summary statistics of these parks). Hennepin and Ramsey Counties, which cover approximately 2000 square kilometers (800 square miles), were chosen because they contain the Twin Cities of

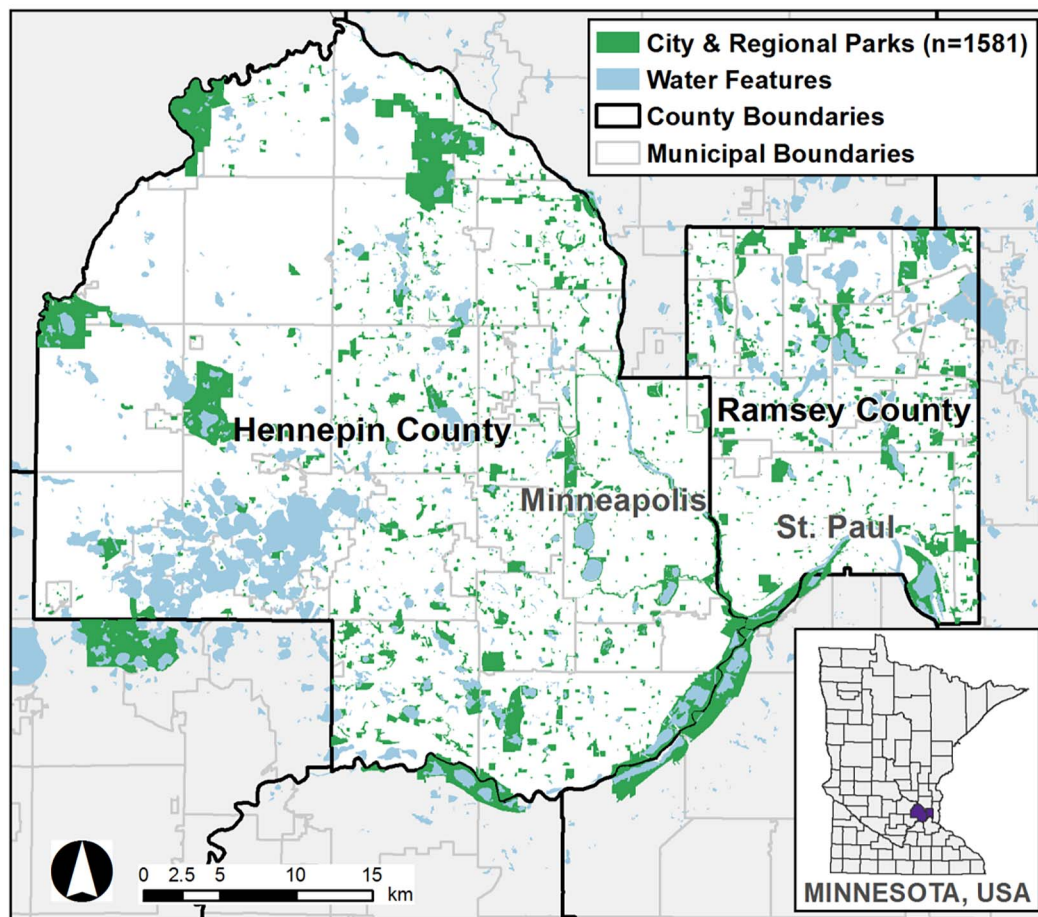


Fig. 1. Distribution of urban park and green space polygons in the Twin Cities Metropolitan Area, MN, USA. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Minneapolis and Saint Paul and, as a result, have the highest population density within the seven-county TCMA, with a combined population of over 1.7 million residents as of 2014 (U.S Census, 2015). Within these urban and peri-urban counties, there are many well-known natural features in our study area including the Mississippi River, which runs through both the cities of Minneapolis and Saint Paul, Minnehaha Falls, and hundreds of lakes, including the Minneapolis Chain-of-Lakes, Como Lake, Lake Minnetonka, and Lake Phalen, for example, many of which are adjacent to or near public parks. In recent years, the cities of both Minneapolis and Saint Paul have been nationally recognized for the quality of their park systems (Trust for Public Land, 2016).

## 2.2. Park visitation

To understand park use across the TCMA, we first collected existing local survey data on park visitation. Survey-derived estimates of park visitation were only readily available from two agencies (Met Council and the City of Saint Paul's Parks and Recreation Department) for 132 individual parks and recreation features: representing 8% of the total number of parks included in our study. This relatively small amount of available survey data across park agencies in the TCMA is not uncommon—many urban park systems do not have resources to maintain comprehensive, systematic data on park use or make existing data readily available (Walls, 2009).

More specifically, we obtained eight years of estimated visits corresponding to park boundaries from Met Council's Twin Cities Metropolitan Regional Park and Trail System (visitation from the calendar years 2005–2013 for 44 aggregated park systems corresponding to 100 individual parks in our original dataset from Met Council,

2015a). Met Council collects and aggregates visitor surveys for its regional system annually from local agency partners to evaluate park use and support its funding allocation process (Met Council, 2015b). The agency acknowledges that more frequent, disaggregated, or detailed visitation surveys would be cost-prohibitive (Met Council, 2014). The City of Saint Paul's Parks and Recreation Department provided annual visitation counts for 32 of its city-owned and managed park and recreation centers (visitation from the calendar years 2006–2014 from City of Saint Paul, 2015). From these two data sources, we calculated annual average visits to the subset of available, aggregated surveyed parks ( $n = 76$ , see Table S2 for summary statistics of the corresponding survey visitation variable).

We then compared these survey data to visitation estimates based on voluntarily provided, geotagged social media data from the websites Flickr and Twitter, also aggregated by park feature. A similar method was first applied by Wood et al. (2013) to compare the relationship between proxy visitation rates derived from Flickr photograph densities and visitation rates based on traditional surveys in nature-based recreation contexts including national parks and tourist attractions worldwide, but few studies applying this approach specifically to urban parks have yet been completed.

Flickr is a popular online photo-sharing platform where users can upload their digital photographs, making them publicly available. The Flickr database of public images is accessible via the Flickr Application Programming Interface (API) (Flickr, 2015), which has been a novel social media data source for mapping and research since 2009 (Crandall, Backstrom, Huttenlocher, & Kleinberg, 2009). As a whole, this global database includes over 250 million publicly available, geotagged photographs over ten years (from the calendar years



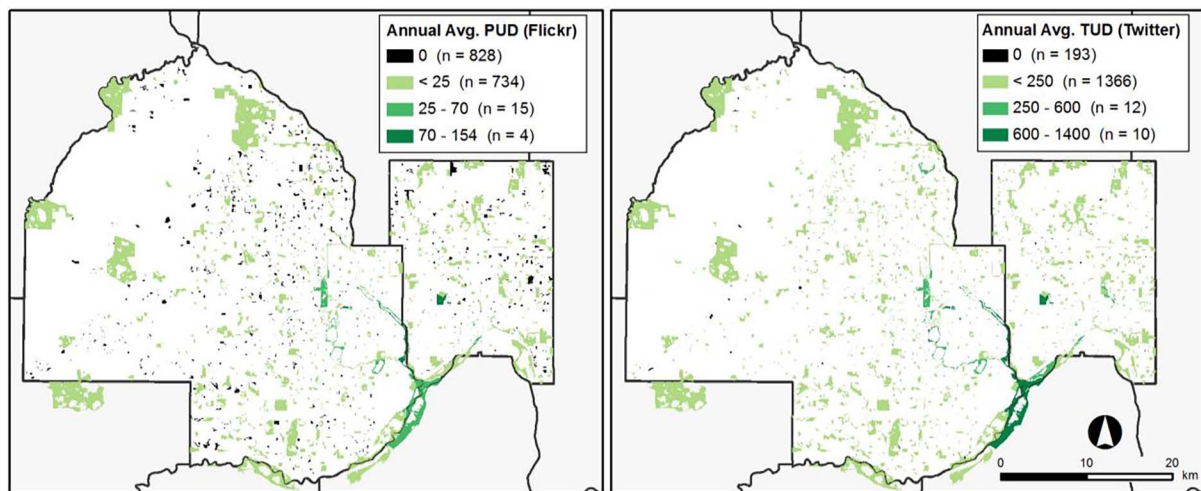


Fig. 2. Maps of annual average geotagged social media visitation data: Flickr photo-user-days (PUD, left) and Twitter tweet-user-days (TUD, right) for urban park and green space polygons in the Twin Cities, Minnesota, USA.

2005–2014), a small subset of which were taken within the TCMA. For each park polygon in our study area including those without existing survey data, we spatially queried this global set of pictures. From the set of photographs taken within each defined park boundary, we counted unique combinations of Flickr user and date information and called the sum of these unique user days within a given park “photo-user-days” (abbreviated PUD, Wood et al., 2013). The PUD variable (Fig. 2) used in our analysis is the annual average photo-user-days per park.

Twitter is a widely popular social media platform that allows users to make succinct, public geotagged posts or “tweets” that may include text, link, photo, or video content. The Twitter streaming API (Twitter, 2015) distributes one percent of all public tweets, chosen randomly. Over 13 million geotagged tweets within the TCMA were available from the Twitter streaming API over three years (from the calendar years 2012–2014). To calculate a comparable Twitter-derived user-day metric for each park polygon feature to the PUD measure described above, we calculated each park’s annual average count of tweet-user-days (abbreviated TUD) from available data (Fig. 2).

Both Flickr and Twitter data are unique tools and provide coverage for estimating use across TCMA parks. However, there are some differences in availability of social media data for estimating park use across both platforms, allowing for further comparison and discussion. We found slightly less than half of the parks in our study area (48%;  $n = 753$ ) had at least one geotagged Flickr photograph posted between 2005 and 2014, whereas the majority of parks (88%,  $n = 1388$ ) had at least one geotagged tweet posted between 2012 and 2014. To explore spatial differences in these data, we compared which parks had no data from social media, data only from Flickr, data only from Twitter, and data from both websites. We found coverage of parks with data from both platforms generally distributed evenly across the study area (Fig. S1). In addition, we found that, for those parks with data from both platforms, the majority of values for TUD were larger than those of PUD across parks (Fig. S2), further indicating that, in general and on average, a greater number of unique social media users who post from TCMA parks used Twitter during the period of analysis.

### 2.3. Comparison of survey and social media visitation

To evaluate the use of social media data as a proxy for urban park visitation, we compared our annual average measures of PUD and TUD to corresponding survey-based estimates of visitation provided by agencies across the available time frames described earlier. We manually matched sites included in the full TCMA park database using name and location to the validation dataset of 76 aggregate regional systems

and local recreation centers with available, annual average agency survey estimates from Met Council and City of Saint Paul, respectively. Summary statistics of PUD, TUD, and survey visitation for these validation sites are available in Table S2, and maps of these variables are available in Fig. S4. We then plotted annual average visits per park from agency estimates (measured in units of 1000 s of visits, as commonly used in available park agency estimates), PUD, and TUD data against one another and estimated the fit using simple nonlinear regressions (log-log form) of untransformed data. This allowed us to compare how well the annual average survey and social media visitation estimates for available park features corresponded with or could be proxies for one another. We also completed a simple, preliminary comparison of the sampling bias we might expect when relying on social media users, as opposed to other types of survey methods, using demographic information of social media users derived for marketing purposes (Ignite Social Media, 2012) and comparing that information to existing survey data on park user demographics in the TCMA (Met Council, 2009).

### 2.4. Park attributes

Once we completed the process of developing and exploring park visitation indicators, we compiled and summarized information on attributes within and around each park in the TCMA from a range of publicly available data sources. We could then couple these data with information on visitation rates to understand which characteristics were important to recreation in the parks across our study area.

We assembled various geospatial data layers to construct explanatory variables corresponding to each park by using GIS software and spatial operations. We identified specific variables from four general categories that include attributes within and around urban parks: 1) landscape factors, which includes natural amenities and land cover (e.g., park area, nearby water features, percentage of tree canopy cover), 2) built infrastructure, such as recreational facilities and highly-managed amenities (e.g., sports fields and courts), 3) proxies for accessibility (e.g., regional trails, bus stops, and nearby large roads), and 4) neighborhood characteristics (i.e., demographic information, such as population density, race and ethnicity, and household income). While we have noted that factors predicting visitation are context dependent (Andersson et al., 2015), the selected categories and compiled variables that we tested were supported by a previous survey of factors influencing urban park visitation in the TCMA (Met Council, 2009) and further supported by studies of urban parks in other contexts, as well (Cohen et al., 2010; Dallimer et al., 2014; Kienast et al., 2012).

Some of these data such as water features, regional trails, and bus

stops were available from local sources (e.g., Met Council). When local sources were not readily available for the study area, however, we extracted geospatial data from the online mapping community and open source database OpenStreetMap.org, which researchers have shown to be a reliable, useful tool for crowdsourced geospatial data in major urban areas that generally have greater numbers of active contributors (Haklay, Basiouka, Antoniou, & Ather, 2010). We derived park facility and amenity layers in this way because not all TCMA park agencies maintain a database of these features. Neighborhood variables of demographics were primarily derived from 2008 to 2012 American Community Survey block group information (U.S. Census, 2012).

As a final step in the data processing and variable construction process, we recoded some predictors to presence-or-absence dummy variables (e.g., presence of a nearby water feature within a 0.1-mile or 0.161-km buffer around the park) and aggregated some count variables (e.g., aggregated hard court and sports fields into a “total sports facilities” variable or created a “Total Amenities” variable that was a count of all built infrastructure, such as field houses or sports facilities, within a park). Ultimately, following this process, our database of park attributes included 24 unique explanatory variables (Tables S1, S3, and S4 outline variables, summary statistics, detailed descriptions, and data sources for these data).

## 2.5. Analysis and regression modeling

Once we compiled a diverse set of attributes for each urban park in the TCMA, we selected a subset of relevant predictor variables and developed multiple regression models, combining these data with the dependent variables of PUD, TUD, and survey visitation. We did this to understand the influence that certain attributes within and around urban parks have on observed visits. In this modeling process, we were most interested in evaluating which variables were important to the observed variation in positive visitation across the study area (i.e., frequency of visits to parks across the system). We also developed models to test whether the same or different factors were important to the likelihood that parks were visited (i.e., visited vs. not visited). Furthermore, by using the same predictors across these multiple regression models, we could also compare in general terms how consistent results were using direct observations (survey) and social media (PUD and TUD) proxy measures of park visitation. These various regression approaches helped us to investigate what factors and patterns are generally important for both the magnitude and likelihood of park visitation across the TCMA.

As part of the model building process, we narrowed down the full set of possible predictors to a final subset of relevant factors based on exploratory and correlation analyses. We stipulated that models would have at least one variable from each of the four general park attribute categories of landscape factors, built infrastructure, accessibility, and neighborhood characteristics. Informed by and based on support from previous research, these general categories and specific variables within each have been shown to be important indicators of park use in the TCMA and other contexts (Cohen et al., 2010; Dallimer et al., 2014; Kienast et al., 2012; Met Council, 2009). Then, to narrow down predictors within these categories, we either eliminated or aggregated within-group variables that were highly correlated with one another (see correlation tables for predictor variables in Fig. S5a–e; Pearson's coefficients higher than 0.5 were considered highly correlated). For example, during this process, we selected the aggregate count variable “Total Amenities”, which represented an aggregation of the total number of sports and non-sport facilities within a park, which were then eliminated as individual variables from subsequent models. Overall, this correlation-based elimination process reduced the likelihood of multicollinearity in the full models.

In addition to minimizing multicollinearity, we sought explanatory variables that would be relatively consistent predictors of visitation across models using PUD, TUD, and survey measures. To begin to

understand how consistent the remaining predictor variables would be, we tested and compared sets of predictors in a series of backward stepwise and recursive, partitioning decision-tree modeling analyses using approaches available in the JMP Pro statistical software's Partition Platform that selects algorithms and statistical tests appropriate to each variable's data type. We repeated the same models for each dependent variable before settling on the final set of predictors (additional explanation of variable selection in Panel S1).

Ultimately, based on these variable selection and preliminary modeling processes, we selected seven variables to include in our final multiple regression models: park area, presence of a nearby water feature, percentage tree canopy cover, total number of amenities (including sports and non-sports facilities) offered within a park, length of regional trail segments, number of nearby large roads, and population density. We used these variables as predictors of visitation in our full models across measures of visitation, assessing the direction and strength of the effect corresponding to each variable.

With our variable set finalized, for the subsets of parks with positive visitation data (PUD  $n = 753$ , TUD  $n = 1388$ , and survey visitation  $n = 76$ ), where at least one photograph, tweet, or surveyed visit was observed, we ran negative binomial generalized regressions, appropriate for count data with overdispersed, highly skewed distributions (Cameron & Trivedi, 1998). We selected the negative binomial form based on mean-variance ratios of the count data and significance tests of the Pearson dispersion coefficients, confirming overdispersion of the dependent variables of interest. We then used multiple logistic regression to explain dummy PUD and TUD dependent variables for the full set of parks with complete attribute data ( $n = 1581$ ), to improve our understanding of the factors influencing the likelihood that parks are visited or not, based upon the social media-derived proxies for visitation.

Results from the negative binomial regression and multiple logistic models across dependent variables of PUD, TUD, and survey visitation, further enabled us to compare consistency and incongruity across these measures. Through this comparison, we then evaluated how factors predicted a park's magnitude of observed visitation and the likelihood that users of different social media platforms would visit these parks. Results from the various modeling exercises provided us with insights into drivers of park use, information which could be relevant to park managers for prioritizing improvements or investments to parks across the study area.

## 3. Results

### 3.1. How do different visitation indicators compare?

In our analysis comparing measures of park visitation based on traditional survey approaches and social media, we found significant, positive relationships across visitation rates measured by agency survey estimates, Flickr, and Twitter use in selected parks ( $R^2 = 0.67$  and  $R^2 = 0.64$ , for regressions comparing surveyed visits to PUD and TUD, respectively) (Fig. 3). Additionally, we verified that PUD and TUD were significantly correlated with one another ( $R^2 = 0.90$ ). Notably, since we know not all urban park visitors share photos online or tweet, these results also illustrate that it would likely take a minimum number of visitors to a given park per year in the TCMA, before we would see social media being a representative indicator of visitation. This is shown by the positive regression line intercepts on the comparisons between empirical visitation and both PUD and TUD measures (Fig. 3A and B, respectively). In general, these findings support the use of social media data as a proxy for park visitation and our application of these data to evaluate factors influencing park visitation in an urban area. These results build on existing evidence that has validated the use of data from social media platforms as tools to evaluate cultural ecosystem services across other scales and contexts (for examples, see Wood et al., 2013; Keeler et al., 2015; Sessions et al., 2016; van Zanten et al., 2016).

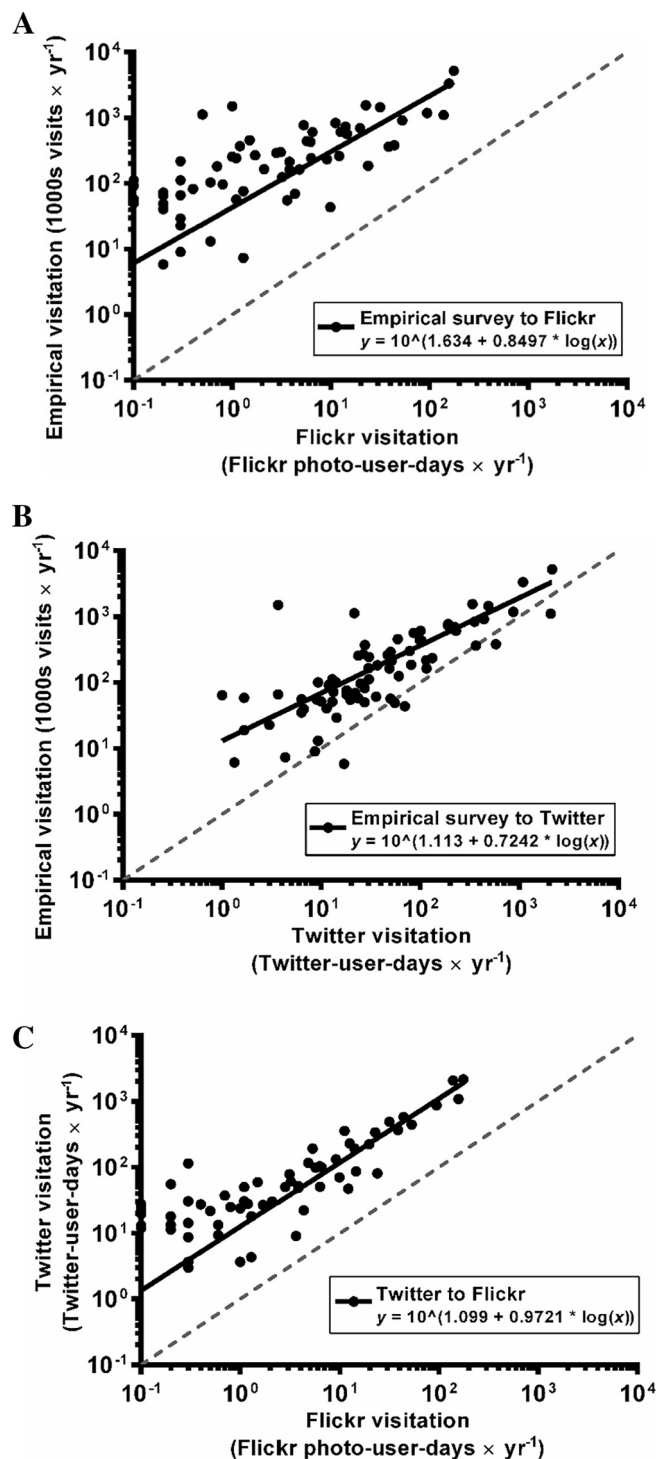


Fig. 3. Social media validation plots of annual average visitation to parks in the Twin Cities, Minnesota, USA, measured by 1,000 s of visits per year (common unit of analysis in available park agency visitation estimates) from empirical survey counts, Flickr photo-user-days per year, and Twitter tweet-user-days per year. Observations are features for which we had survey data ( $n = 76$ ). Regression lines are nonlinear fits plotted on log-log axes. Corresponding  $R^2$  values for each regression are 0.67 (A. survey-PUD), 0.64 (B. survey-TUD), and 0.90 (C. TUD-PUD). The dotted line in each panel represents a 1:1 relationship between the compared measures of visitation.

Acknowledging the bias inherent in social media platforms and the corresponding potential for bias in our particular application and study context, we also compared characteristics of average users from both Twitter and Flickr (Ignite Social Media, 2012) to reported demographics of park users in the Twin Cities available from a

comprehensive survey of the TCMA regional parks system (Met Council, 2009). From this comparison, we found that, in general, users of both the Flickr and Twitter social media platforms are somewhat younger and more likely to be female than the sample of park users that agencies surveyed. Specifically, in terms of age, Flickr users were approximately 40.2 years old on average and Twitter users were 37.1 years, while park users in the TCMA were 40.8 years old on average, according to agency surveys. In terms of gender, users of Flickr were reported to be 55% female and Twitter users were 62% female; compared to average park users in the TCMA who were only 48% female. That said, in the absence of more disaggregated demographic data on recreational users of urban parks and the subset of those using Flickr and Twitter in the same area, it remains a challenge to understand precisely how representative our study's samples of social media users are relative to the area's urban park users. At this time, we were unable to disaggregate or infer user data from the aggregate data we extracted from the social media platforms. However, others have started to develop approaches to gather information from social media users public profiles (see e.g., Sessions et al., 2016) to begin to improve our understanding of who are represented by these data and how we may begin to correct for bias when applying these methods across urban areas with diverse sets of park users in the future.

### 3.2. Which factors predict urban park visitation?

Indicators of the presence of nearby water features, number of total amenities within a park, length of trails, and population density of nearby neighborhoods had positive and significant effects on visitation rate across all three models of visits to parks containing at least one geotagged photograph, tweet, or surveyed visit (Fig. 4, Table S4). This result illustrated factors that are strongly and consistently associated with higher park use in our study area.

The remaining predictor variables of park size, land cover, and nearby large roads, had inconsistent results—in either sign or significance—across models of park visitation. For example, while park size and number of nearby large roads were positive and significant predictors in models of park visits according to PUD and TUD, these variables were not significant in the model of surveyed visits. Land cover measured by the percentage of tree canopy within a park was significantly and positively related with park visitation measured by PUD, was significantly but negatively associated with TUD visitation, and was a non-significant predictor of surveyed visitation. While we had originally posited that more 'natural' land cover would have a positive influence on park visitation, these inconsistent model results reveal the relationship between land cover and urban park visitation may be more complex than originally hypothesized. This result may also suggest that the percentage of tree canopy across an entire park is not be the best-suited indicator of the importance of natural land cover at this scale or for the purpose of comparing across park systems with a wide variety of park and green space types.

We also evaluated factors that influenced the likelihood that a park was visited or not as measured by social media data (i.e., the probability that a park would have a Flickr photograph or tweet posted within its boundaries or not, represented by PUD\_dummy and TUD\_dummy variables). The characteristics that affected the likelihood of visitation varied from those that explained the magnitude of visits (Table S5). Measures of the presence of water features, land cover, and total amenities had significant effects on both social media dummy variables, while the number of large roads and neighborhood population density were important for the PUD dummy variable, but not for the TUD dummy variable. These results suggest that different predictors influence visitation for those parks that have recorded social media use (and how many visits those parks have) than by those with no recorded social media use during our study period.



## Explaining Urban Park Visitation in the Twin Cities, MN, USA

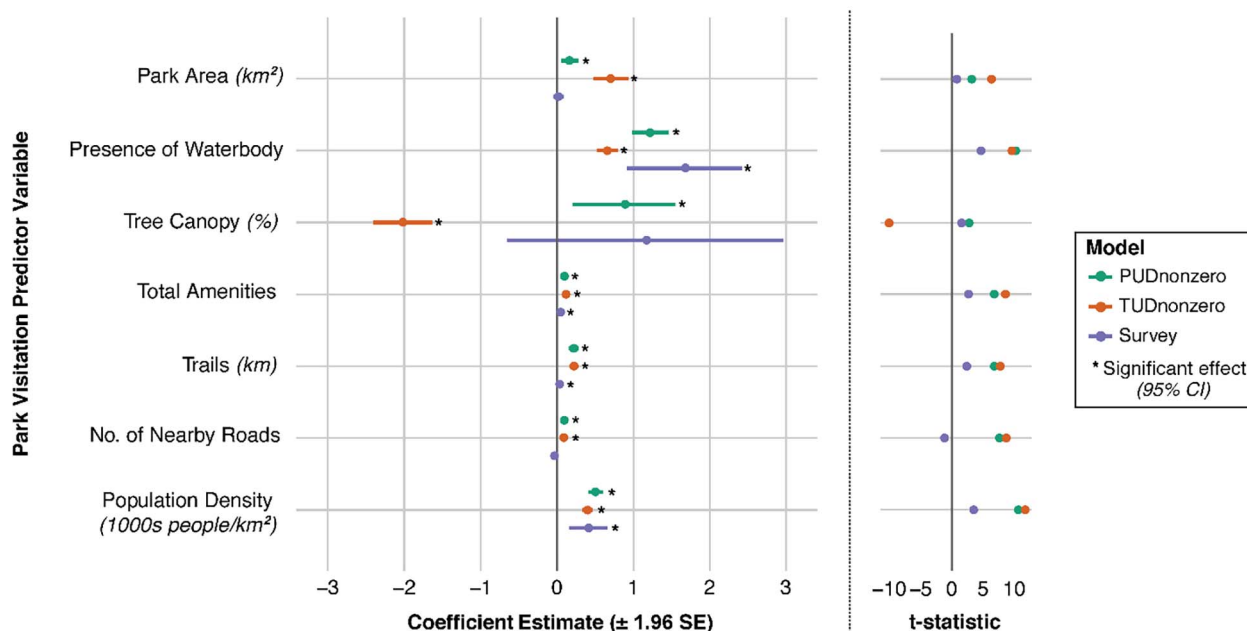


Fig. 4. Explaining urban park visitation in the Twin Cities, Minnesota, USA, with multiple generalized negative binomial regression results visualized using dot-whisker plot (on left) of coefficient estimates and t-statistics (unitless measure calculated as coefficient/SE, on right) to illustrate direction and magnitude. Asterisks indicate significant effects of variables on visitation measures at 95% confidence interval. Models were fit using negative binomial distributions (supported by overdispersion test) and maximum likelihood estimation.

## 4. Discussion

Through the use of social media and on-site surveys as data sources, we confirm the importance of different landscape, built infrastructure, accessibility, and neighborhood attributes in influencing recreational use of urban parks and green spaces, which has implications for how managers invest in or manage these spaces. Parks with nearby waterbodies, a greater number of amenities, and accessible trails, and those located in more densely populated areas have significantly more visits. These results are consistent with factors that have been shown to influence recreation in the Twin Cities and elsewhere (Cohen et al., 2010; Kaczynski et al., 2014; Kienast et al., 2012; Met Council, 2009). For example, surveys of TCMA park system users illustrated that the majority of users relied on cars and trails to access parks and that primary activities of park users included biking, walking, swimming in nearby water features, and other uses of available amenities (Met Council, 2009). Previous studies have also shown that the number of facilities and activities offered by parks were significantly correlated with visitation to diverse park systems in metropolitan areas in Southern California (Cohen et al., 2010) and in Kansas City, Missouri, USA (Kaczynski et al., 2014), for example. Others have shown that the presence of waterbodies correlates with higher use in neighborhood parks located in cities and towns in Switzerland, for example (Kienast et al., 2012). Our findings, which support these previous studies, lend additional evidence to the importance of both natural and built infrastructure to recreational users of urban parks.

In this study, we examined how well estimates from two social media platforms—Flickr and Twitter—can approximate results of more traditional surveys of visitation. We then used these location-based social media data as proxies for urban park visitation, combined with information about parks themselves, to assess determinants of park use in a specific case study of parks in the TCMA. More specifically, we validated annual average user-days derived from Flickr photographs and tweets from Twitter by comparing them to available survey estimates of visitation (Fig. 3). Relative to surveyed visitation data, social media data sources offered a greater magnitude of observations across the study area, which generally reduced the size of the standard error

bounds associated with regression model results (Fig. 4). As illustrated, geotagged social media data can provide urban park agencies and researchers with information and trends on recreation patterns across park systems that may not be otherwise accessible. This case study and analysis illustrated that the annual estimates from both social media websites are flexible and reasonable proxies for agency-estimated park visitation derived from more traditional survey methods.

Despite these clear benefits for using social media data to evaluate drivers of park use, there are a range of limitations that these data present, as well. Our results that park size, tree canopy as an indicator for natural land cover, and the number of nearby large roads are not always consistently significant across models of park visitation suggest some of these limitations (Fig. 4). Further analysis is needed to understand the nuanced relationship between these variables and social media use in our study area—or even differences in the social media platforms and users themselves. In our study, the change in direction that the percentage tree canopy cover variable had across models (i.e., positive for PUD and negative for TUD, while significant for both models) could suggest that those users who take and upload a photograph to Flickr may be drawn more to forested urban parks, whereas less canopy cover may be an important factor for park users who post to Twitter. Previous research in other contexts suggested that parks with more natural vegetation are not always visited more than others, although these same studies noted that individuals with preferences for nature may travel farther for more vegetated parks than those without these preferences (Lin, Fuller, Bush, Gaston, & Shanahan, 2014; Shanahan, Lin, Gaston, Bush, & Fuller, 2015). Further cross-platform comparison of social media user behavior could help test which explanation is best supported in this context. In addition, future analyses of the typology of different park areas or types of parks across the region (i.e., splitting parks into those with or without nature-based features of interest such as lakes versus rivers, parks with a certain threshold of forest cover and with not, or by use type such as linear versus neighborhood parks; see also: Ibes, 2015) could help us better understand the nuances across parks within the TCMA system and the types of users attracted by specific factors.

We demonstrated a number of benefits of using social media data

and their application in urban park planning contexts, supporting previous work that has validated their use in nature-based recreation (Keeler et al., 2015; Wood et al., 2013). However, as we presented in our results from comparing typical social media users to those visiting urban parks in the TCMA, it becomes clear there remains the potential for sampling bias and other limitations when using these data that also need attention (Di Minin et al., 2015; Li, Goodchild, & Xu, 2013). While we explored the importance of neighborhood factors such as population density on park use in our final models and featured other demographic variables such as race and ethnicity or income from the U.S. Census in our initial, exploratory analyses, we acknowledge limits in our ability to understand and fully characterize existing bias, when we focus solely on data posted to social media platforms that are used by only a subset of the population. An analysis of Internet users by the Pew Research Center reported that only about 20 percent of adults used Twitter in 2013 and 2014 (Duggan, Ellison, Lampe, Lenhart, & Madden, 2015), and social media sites like Flickr and Twitter generally have more active user bases in denser urban areas than elsewhere (Hecht & Stephens, 2014). These social media sites tend to be biased towards younger, wealthier and more technologically-savvy people (Ignite Social Media, 2012). Further evidence suggests users of the website Flickr were not necessarily representative of all nature-based recreationalists across the states of Iowa and Minnesota (Keeler et al., 2015). As we presented in a comparison between social media users and existing survey data on users across the TCMA park system, we confirmed that in general, users of both Flickr and Twitter are more likely to be younger and female than the sample of park users that local park agencies identified. Ultimately, these findings show the need for both continued analysis and a discussion of bias when using these methods and results for park management and for the utility of using multiple measures of visitation for comparison and indicators of uncertainty.

We also compared parks with and without social media use during the study period to understand if the availability of social media data were influencing our results. We found a number of parks where no photographs or tweets were shared publicly online (Fig. S3). Based on this initial observation, we determined which predictors influenced whether or not a park was visited using social media data (Table S5). We found both commonalities and differences in the significant predictors across these measures when compared to the models of variation in positive visits in our study area (Table S4). This result illustrates that there may be potential limitations to using social media data to explain or extrapolate visitation behavior and user preferences for urban parks with low visitation rates where no public, geotagged social media data are currently available.

While we acknowledge a range of limitations in using social media data, it is also important to note that more traditional methods of site-specific surveys currently used by most agencies and researchers to characterize patterns of park visitation are not without their own biases. Field observations, derived by staff using hand counters or recording forms, can be subjective, used in unsystematic and opportunistic ways, and are generally constrained to a specific study site—limiting the accuracy of surveys and where and how they can be applied (Cessford & Muhar, 2003; Freeman, 2014). Indeed, the survey visitation data provided by Met Council (2015a) and the City of Saint Paul (2015) analyzed in this paper are not random samples of parks from the Twin Cities and only include the metropolitan area's regional park system and select parks with recreation centers in the City of Saint Paul, where visitor counts are routinely collected and publicly available. As such, with content and data from social media presenting a unique source of information about cultural ecosystem services and observations of people's revealed preferences (Gliozzo, Pettorelli, & Haklay, 2016; Guerrero et al., 2016), it can be helpful to compare and combine multiple approaches, as we have illustrated in this analysis, to see a broader picture of recreation demand and patterns across urban park systems. We argue that this discussion highlights the need for continued and critical analysis of the strengths and weaknesses of both social

media data and other methods used in park planning and monitoring efforts to track visitation. Additional research into these topics will ensure the methods and tools available to managers continue to improve and are accurately and transparently used in future applications.

## 5. Conclusions

As urban areas continue to grow and demographics shift, it is likely that park usage and patterns of visitation to public green spaces in cities will also change. Park managers will need flexible tools to understand visitors and use patterns and to be responsive to these changes. Drawing on a comprehensive database of compiled characteristics of over 1500 urban parks and new methods and information on park visitation using social media data, we demonstrate that the landscape, built infrastructure, accessibility, and neighborhood attributes of a given park are likely to influence the number of visits it receives. We rely on a specific case study from the Twin Cities in Minnesota, which is this region's first large-scale, multi-jurisdictional statistical analysis of recreational demand across the area's urban park systems that combines available survey and proxy social media measures of visitation from both Flickr and Twitter. During the course of our analysis, the Minneapolis Park and Recreation Board, one of the local park agencies within our study area, launched a 20-Year Neighborhood Park Plan that will include prioritizing investments of close to \$300 million over the next two decades to improve the city's neighborhood parks (Minneapolis Park, 2016). Decisions about what types of amenities or areas to prioritize investments, such as those faced by the Minneapolis Park and Recreation Board, can be strengthened by improving our understanding of where and why users are visiting parks, which our analysis does for urban park systems throughout the TCMA.

While this approach has implications for local planning in the TCMA, our methods and the use of social media data as a planning tool have the flexibility and potential to be applied to other contexts and at other scales of analysis by urban park managers and researchers. Furthermore, results from our analysis could be readily compared to those from other geographies that apply similar methods, such as recent work by collaborators exploring visitation across the park system of New York City, NY (Hamstead et al., 2018), to understand similarities and differences of patterns that emerge from these data across cities. Applications of this approach elsewhere can allow urban planners and park managers to rapidly assess visitation, utilizing new tools to understand the demand for recreation services and public green space in their cities.

Further analysis and future applications using social media data and methods either in the TCMA or across other urban park contexts could address limitations outlined in this study and other gaps that researchers have identified in both park management practice and cultural ecosystem services research in cities (Larson, Jennings, & Cloutier, 2016; Andersson et al., 2015). Planners could use these data predictively to assess marginal changes in visitation as a result of changes in park characteristics, amenities offered, or neighborhood demographics in alternative future scenarios and use these results to inform city- or regional-scale recreation studies, tourism assessments, and other types of spatial urban planning. Future research or applications could also adjust our methods and approach by disaggregating data from social media to finer temporal scales than the annual averages used within the scope of our analysis, lending insights into how park visitation may vary seasonally or day-to-day. As urban areas grow and demographics shift, the ability for park management to understand and respond rapidly to changes in visitation provided by such analyses may become even more important.

Additionally, one could analyze the raw social media content—such as elements within a Flickr photograph or the keywords in a tweet—to evaluate the social benefits an urban green space provides, to understand the behavior and preferences of park users (Richards & Friess, 2015). This additional information from social media data could also



connect park use with management of these spaces (Ernstson, Barthel, Andersson, & Borgström, 2010; Guerrero et al., 2016). Or, these data and approaches have the potential to be used to assess the intersection between the distribution of visits or amenities and the equitable access to benefits in park systems, a growing area of both research and policy in nature-based recreation and urban sustainability (see, e.g., The White House, 2017; Boone, Buckley, Grove, & Sister, 2009; Rigolon, 2016; Wicks & Crompton, 1989). For example, looking at documented equity problems associated with park investments and gentrification (see e.g., Wolch, Byrne, & Newell, 2014), one could explore ways of assessing changes in social media content and user data (Li et al., 2013) over time, coupled with other fine-scale socio-economic or cultural factors, to assess how new park investments impact who has access or who uses urban parks and, as a result, what impacts those park investments have on surrounding neighborhoods.

Ultimately, this study and the range of next steps we have outlined illustrate how novel sources of data from social media platforms can inform future urban planning practice and research to improve our understanding of patterns of recreation and cultural ecosystem services in urban parks and public green spaces.

## Software

Esri ArcGIS 10.2 (Maps and Spatial Analysis), JMP Pro 11 (Statistics), Graphpad Prism 6 (Validation Regression Visualization), R Project (Plots of Multiple Regression Results and Correlation Matrices), Adobe Illustrator CC 2017 (Plots of Multiple Regression Results).

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.landurbplan.2018.02.006>.

## References

- Andersson, E., McPhearson, T., Kremer, P., Gómez-Baggethun, E., Haase, D., Tuvendal, M., et al. (2015). Scale and context dependence of ecosystem service providing units. *Ecosystems Services*, 12, 157–164. <http://dx.doi.org/10.1016/j.ecoser.2014.08.001>.
- Andersson, E., Tengö, M., McPhearson, T., & Kremer, P. (2015). Cultural ecosystem services as a gateway for improving urban sustainability. *Ecosystems Services*, 12, 165–168. <http://dx.doi.org/10.1016/j.ecoser.2014.08.002>.
- Arkema, K. K., Verutes, G. M., Wood, S. A., Clarke-Samuels, C., Rosado, S., Canto, M., et al. (2015). Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. *Proceedings of the National Academy of Sciences of the United States of America*, 112(24), 7390–7395. <http://dx.doi.org/10.1073/pnas.1406483112>.
- Bauer, J. W. R., Tynon, J. F., Ries, P., & Rosenberger, R. S. (2014). Urban parks and attitudes about ecosystem services: does park use matter? *Journal of Park and Recreation Administration*, 32(4), 19–24 Available: [http://www.forestry.oregonstate.edu/sites/forestry.oregonstate.edu/files/PDFs/Tynon2014\\_JPRA.pdf](http://www.forestry.oregonstate.edu/sites/forestry.oregonstate.edu/files/PDFs/Tynon2014_JPRA.pdf). Viewed 20 Feb. 2017.
- Bertram, C., & Rehdanz, K. (2015). Preferences for cultural urban ecosystem services: Comparing attitudes, perception, and use. *Ecosystems Services*, 12, 187–199. <http://dx.doi.org/10.1016/j.ecoser.2014.12.011>.
- Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecol. Econ.* 29(2), 293–301. [http://dx.doi.org/10.1016/S0921-8009\(99\)00013-0](http://dx.doi.org/10.1016/S0921-8009(99)00013-0).
- Boone, C. G., Buckley, G. L., Grove, J. M., & Sister, C. (2009). Parks and people: An environmental justice inquiry in Baltimore, Maryland. *The Annals of the American Association of Geographers*, 99(4), 767–787. <http://dx.doi.org/10.1080/00045600903102949>.
- Brown, G., & Fagerholm, N. (2015). Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. *Ecosystems Services*, 13, 119–133. <http://dx.doi.org/10.1016/j.ecoser.2014.10.007>.
- Cameron, A. C., & Trivedi, P. K. (1998). *Regression analysis of count data*. New York: Cambridge Press.
- Casalegno, S., Inger, R., DeSilvey, C., & Gaston, K. J. (2013). Spatial covariance between aesthetic value & other ecosystem services. *Plos One*. <http://dx.doi.org/10.1371/journal.pone.0068437>.
- Cessford, G., & Muhar, A. (2003). Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation*, 11(4), 240–250. <http://dx.doi.org/10.1078/1617-1381-00055>.
- Chan, K. M. A., Guerry, A. D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., et al. (2012). Where are cultural and social in ecosystem services? A framework for constructive engagement. *BioScience*, 62(8), 744–756. <http://dx.doi.org/10.1525/bio.2012.62.8.7>.
- Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, 68(1), 129–138. <http://dx.doi.org/10.1016/j.landurbplan.2003.08.003>.
- City of Saint Paul. (2015). City of Saint Paul Parks and Recreation Department Recreation Center Visitor Survey Estimates, 2006–2014. Personal correspondence: 23 April 2015.
- Cohen, D. A., Marsh, T., Williamson, S., Derose, K. P., Martinez, H., & Setodji, C. (2010). Parks and physical activity: why are some parks used more than others? *Preventive Medicine*, 50. <http://dx.doi.org/10.1016/j.ypmed.2009.08.020> Supplement (0), S9–S12.
- Crandall, D. J., Backstrom, L., Huttenlocher, D., & Kleinberg, J. (2009). Mapping the world's photos. *Proc. of 18th Int. Conf. on World Wide Web*(pp. 761–770). <http://dx.doi.org/10.1145/1526709.1526812>.
- Dallimer, M., Davies, Z. G., Irvine, K. N., Maltby, L., Warren, P. H., Gaston, K. J., et al. (2014). What personal and environmental factors determine frequency of urban greenspace use? *International Journal of Environmental Research and Public Health*, 11(8), 7977–7992. <http://dx.doi.org/10.3390/ijerph110807977>.
- Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M. A., et al. (2012). Cultural ecosystem services: potential contributions to the ecosystems services science and policy agenda. *Proceedings of the National Academy of Sciences of the United States of America*, 109(23), 8812–8819. <http://dx.doi.org/10.1073/pnas.1114773109>.
- Di Minin, E., Tenkanen, H., & Toivonen, T. (2015). Prospects and challenges for social media data in conservation science. *Frontiers in Environmental Science*, 3, 63. <http://dx.doi.org/10.3389/fenvs.2015.00063>.
- Duggan, M., Ellison, N. B., Lampe, C., Lenhart, A., & Madden, M. (2015). Social Media Update, 2014. Pew Research Center. Available: <http://www.pewinternet.org/2015/01/09/social-media-update-2014>. Viewed: 14 Aug. 2015.
- Dunkel, A. (2015). Visualizing the perceived environment using crowdsourced photo geodata. *Landscape and Urban Planning*, 142, 173–186. <http://dx.doi.org/10.1016/j.landurbplan.2015.02.022>.
- Eagles, P. F. J. (2014). Research priorities in park tourism. *Journal of Sustainable Mining*, 22(4), 528–549. <http://dx.doi.org/10.1080/09669582.2013.785554>.
- Ernstson, H., Barthel, S., Andersson, E., & Borgström, S. T. (2010). Scale-crossing brokers and network governance of urban ecosystem services: The case of Stockholm. *Ecological Society*, 15(4), 28 Available: <http://www.ecologyandsociety.org/vol15/iss4/art28/>.
- Flickr. (2015). Flickr API. Available: <https://www.flickr.com/services/api>. Viewed: 1 June 2015.
- Freeman, A. M., III (2014). *The measurement of environmental and resource values: Theory and methods* (3rd ed.). Washington, DC: RFF Press.
- Gliozzo, G., Pettorelli, N., & Haklay, M. (2016). Using crowdsourced imagery to detect cultural ecosystem services: A case study in South Wales, UK. *Ecological Society*, 21(3), 6. <http://dx.doi.org/10.5751/ES-08436-210306>.
- Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecology Economics*, 86, 235–245. <http://dx.doi.org/10.1016/j.ecolecon.2012.08.019>.
- Gómez-Baggethun, E., Gren, Å., Barton, D. N., Langemeyer, J., McPhearson, T., O'Farrell, P., Andersson, E., Hamstead, Z., & Kremer, P. (2013). Urban Ecosystem Services. In T. Elmqvist, (Ed.). *Cities and biodiversity outlook: Urbanization, biodiversity and ecosystem services: Challenges and opportunities*(pp. 175–251). Netherlands: Springer. [http://dx.doi.org/10.1007/978-94-007-7088-1\\_11](http://dx.doi.org/10.1007/978-94-007-7088-1_11).
- Goodchild, M. F. (2007). Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69(4), 211–221. <http://dx.doi.org/10.1007/s10708-007-9111-y>.
- Guerrero, P., Möller, M. S., Olafsson, A. S., & Snizek, B. (2016). Revealing cultural ecosystem services through instagram images: The potential of social media volunteered geographic information for urban green infrastructure planning and governance. *Urban Planning*, 1(2), 1–17. <http://dx.doi.org/10.17645/up.v1i2.609>.
- Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., et al. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, 43(4), 413–433. <http://dx.doi.org/10.1007/>

- s13280-014-0504-0.
- Haines-Young, R. H., & Potschin, M. B. (2010). Proposal for a common international classification of ecosystem goods and services (CICES) for integrated environmental and economic accounting (V1). Report to the European Environment Agency. Department of Economic and Social Affairs Statistics Division, United Nations, Nottingham, UK. Available: <http://www.nottingham.ac.uk/cem/pdf/UNCEEA-5-7-Bk1.pdf>. Viewed 15 July 2015.
- Haklay, M., Basiouka, S., Antoniou, V., & Ather, A. (2010). How many volunteers does it take to map an area well? The validity of Linus' law to volunteered geographic information. *Cartographer Journal*, 47(4), 315–322. <http://dx.doi.org/10.1179/000870410X12911304958827>.
- Hamstead, Z. A., Fisher, D., Ilieva, R. T., Wood, S. A., McPhearson, T., & Kremer, P. (2018). Geolocated social media as a rapid indicator of park visitation and equitable park access. *Computers, Environment and Urban Systems*. <http://dx.doi.org/10.1016/j.compenvurbysys.2018.01.007> In Press, Corrected Proof.
- Hecht, B., & Stephens, M. (2014). A Tale of Cities: Urban Biases in Volunteered Geographic Information. Eighth Int. AAAI Conf. Weblogs Soc. Media. Available: <http://www.aaai.org/ocs/index.php/ICWSM/ICWSM14/paper/view/8114/8120>.
- Ibes, D. C. (2015). A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. *Landscape and Urban Planning*, 137, 122–137. <http://dx.doi.org/10.1016/j.landurbplan.2014.12.014>.
- Ignite Social Media. (2012). Social Network Analysis Report for 2012: Demographic, Geographic and Search Data Revealed. Available: <http://www.ignitesocialmedia.com/social-media-stats/2012-social-network-analysis-report> Viewed 14 Aug. 2015.
- Kaczynski, A. T., Besenyi, G. M., Wilhelm Stanis, S. A., Koohsari, M. J., Oestman, K. B., Bergstrom, R., Potwarka, L. R., & Reis, R. S. (2014). Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. *International Journal of Behavioral Nutrition and Physical Activity*, 11(1), <http://dx.doi.org/10.1186/s12966-014-0146-4>.
- Keeler, B. L., Wood, S. A., Polasky, S., Kling, C., Filstrup, C. T., & Downing, J. A. (2015). Recreational demand for clean water: Evidence from geotagged photographs by visitors to lakes. *Frontiers in Ecology and the Environment*, 13(2), 76–81. <http://dx.doi.org/10.1890/140124>.
- Kienast, F., Degenhardt, B., Weilenmann, B., Wäger, Y., & Buchecker, M. (2012). GIS-assisted mapping of landscape suitability for nearby recreation. *Landscape and Urban Planning*, 105(4), 385–399. <http://dx.doi.org/10.1016/j.landurbplan.2012.01.015>.
- Langemeyer, J., Baró, F., Roebeling, P., & Gómez-Baggethun, E. (2015). Contrasting values of cultural ecosystem services in urban areas: The case of Park Montjuïc in Barcelona. *Ecosystems Services*, 12, 178–186. <http://dx.doi.org/10.1016/j.ecoser.2014.11.016>.
- Larson, L. R., Jennings, V., & Cloutier, S. A. (2016). Public parks and wellbeing in urban areas of the United States. *Plos One*. <http://dx.doi.org/10.1371/journal.pone.0153211>.
- Levin, N., Kark, S., & Crandall, D. (2015). Where have all the people gone? Enhancing global conservation using night lights and social media. *Ecological Applications*, 8, 2153–2167. <http://dx.doi.org/10.1890/15-0113.1>.
- Levin, N., Lechner, A. M., & Brown, G. (2017). An evaluation of crowdsourced information for assessing the visitation and perceived importance of protected areas. *Applied Geography*, 79, 115–126. <http://dx.doi.org/10.1016/j.apgeog.2016.12.009>.
- Li, L., Goodchild, M. F., & Xu, B. (2013). Spatial, temporal, and socioeconomic patterns in the use of Twitter and Flickr. *Cartography and Geographic Information Science*, 40(2), <http://dx.doi.org/10.1080/15230406.2013.777139>.
- Lin, B. B., Fuller, R. A., Bush, R., Gaston, K. J., & Shanahan, D. F. (2014). Opportunity or orientation? Who uses urban parks and why. *Plos One*, 9(1), e87422. <http://dx.doi.org/10.1371/journal.pone.0087422>.
- Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., et al. (2015). A review of urban ecosystem services: Six key challenges for future research. *Ecosystems Services*, 14, 98–112. <http://dx.doi.org/10.1016/j.ecoser.2015.05.001>.
- Metropolitan Council (Met Council). (2009). Metropolitan Council Regional Parks and Trails Survey, 2008. Publication Number 78-09-10. Available: <http://www.metrocouncil.org/METC/files/4c/4cfb5a4e-c7c0-4b48-94c3-1d3704e4d718.pdf>. Viewed 12 Aug. 2015.
- Metropolitan Council (Met Council). (2014). Annual Use Estimate of the Metropolitan Regional Parks System for 2013. Available: <http://www.metrocouncil.org/METC/files/c7/c7d33d34-b6de-4bd2-bac7-05d6e2feb822.pdf>. Viewed 27 July 2015.
- Metropolitan Council (Met Council). (2015a). Annual Use Estimate of the Metropolitan Regional Parks System for 2005–2013. Personal correspondence: 18 May 2015.
- Metropolitan Council (Met Council). (2015b). 2040 Regional Parks Policy Plan. Available: <http://www.metrocouncil.org/METC/files/40/40d78518-295b-474e-a26c-e85f62b9e706.pdf>. Viewed 27 July 2015.
- Millennium Ecosystem Assessment (2003). *Ecosystems and human well-being: A framework for assessment*. Washington, DC, USA: Island Press245.
- Minneapolis Park & Recreation Board. (2016). Resolution 2016-195. Board Code of Ordinances: 20-Year Neighborhood Park Plan. Available: <https://minneapolis-parksmn.igm2.com/Citizens/DetailLegiFile.aspx?ID=3101&highlightTerms=Resolution%202016-195>. Viewed 30 October 2017.
- Paracchini, M. L., Zulian, G., Kooperoien, L., Schägner, J. P., Termansen, M., Zandersen, M., et al. (2014). Mapping cultural ecosystem services: a framework to assess the potential for outdoor recreation across the EU. *Ecological Indicators*, 45, 371–385. <http://dx.doi.org/10.1016/j.ecolind.2014.04.018>.
- Plieninger, T., Dijk, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy*, 33, 118–129. <http://dx.doi.org/10.1016/j.landusepol.2012.12.013>.
- Richards, D. R., & Friess, D. A. (2015). A rapid indicator of cultural ecosystem service usage at a fine spatial scale: Content analysis of social media photographs. *Ecological Indicators*, 53, 187–195. <http://dx.doi.org/10.1016/j.ecolind.2015.01.034>.
- Rigolon, A. (2016). A complex landscape of inequality in access to urban parks: A literature review. *Landscape and Urban Planning*, 153, 160–169. <http://dx.doi.org/10.1016/j.landurbplan.2016.05.017>.
- Sessions, C., Wood, S. A., Rabotyagov, S., & Fisher, D. M. (2016). Measuring recreational visitation at U.S. National Parks with crowdsourced photographs. *Journal of Environmental Management*, 183, 703–711. <http://dx.doi.org/10.1016/j.jenvman.2016.09.018>.
- Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology*, 30(1), 153–165. <http://dx.doi.org/10.1007/s10980-014-0113-0>.
- Shoval, N., & Ahas, R. (2016). The use of tracking technologies in tourism research: The first decade. *Tourism Geography*, 18(5), 587–606. <http://dx.doi.org/10.1080/14616688.2016.1214977>.
- Sonter, L. J., Watson, K. B., Wood, S. A., & Ricketts, T. H. (2016). Spatial and temporal dynamics and value of nature-based recreation, estimated via social media. *Plos One*, 11(9), e0162372. <http://dx.doi.org/10.1371/journal.pone.0162372>.
- Standish, R. J., Hobbs, R. J., & Miller, J. R. (2013). Improving city life: Options for ecological restoration in urban landscapes and how these might influence interactions between people and nature. *Landscape Ecology*, 28(6), 1213–1221. <http://dx.doi.org/10.1007/s10980-012-9752-1>.
- Tao, W. (2013). Interdisciplinary urban GIS for smart cities: advancements and opportunities. *Geo-Spatial Information Science*, 16(1), 25–34. <http://dx.doi.org/10.1080/10095020.2013.774108>.
- The White House of President Barack Obama (The White House). (2017). Presidential Memorandum – Promoting Diversity and Inclusion in Our National Parks, National Forests, and Other Public Lands and Waters. Office of the Press Secretary. 12 January 2017. Available: <https://obamawhitehouse.archives.gov/the-press-office/2017/01/12/presidential-memorandum-promoting-diversity-and-inclusion-our-national>. Viewed 16 January 2017.
- Thiagarajah, J., Wong, S. K. M., Richards, D. R., & Friess, D. A. (2015). Historical and contemporary cultural ecosystem service values in the rapidly urbanizing city state of Singapore. *Ambio*, 1–12. <http://dx.doi.org/10.1007/s13280-015-0647-7>.
- Toole, J. L., Colak, S., Sturt, B., Alexander, L. P., Evsukoff, A., & González, M. C. (2015). The path most traveled: Travel demand estimation using big data resources. *Transportation Research Part C, Emerging Technologies*, 58B, 162–177. <http://dx.doi.org/10.1016/j.trc.2015.04.022>.
- Tratalos, J. A., Haines-Young, R., Potschin, M., Fish, R., & Church, A. (2016). Cultural ecosystem services in the UK: Lessons on designing indicators to inform management and policy. *Ecological Indicators*, 26(1), 63–73. <http://dx.doi.org/10.1016/j.ecolind.2015.03.040>.
- Trust for Public Land. (2016). The Trust for Public Land's 2013-2016 ParkScore® Indices. Available: <http://parkscore.tpl.org>. Viewed 15 December 2016.
- Twitter. (2015). Twitter Platform Documentation. Available: <https://dev.twitter.com/overview/documentation>. Viewed: 1 June 2015.
- U.S. Census Bureau. (2012). 2008-2012 American Community Survey 5-year estimates block group data for the State of Minnesota. TIGER/Line® with Selected Demographic and Economic Data: 2008 – 2012 Detailed Tables by Block Group for Minnesota. TIGER Prod. Available: <http://www.census.gov/geo/maps-data/data/tiger.html>. Viewed 15 March 2015.
- U.S. Census Bureau. (2015). Population Census, April 1, 2010, Hennepin and Ramsey counties. Available: <http://www.census.gov/quickfacts>. Viewed 15 July 2015.
- United Nations, Department of Economic and Social Affairs, Population Division. (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). Available: <https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf>. Viewed 15 December 2016.
- van Zanten, B. T., Van Berkel, D. B., Meentemeyer, R. K., Smith, J. W., Tieskens, K. F., & Verburg, P. H. (2016). Continental-scale quantification of landscape values using social media data. *Proceedings of the National Academy of Sciences of the United States of America*, 113(46), 12974–12979. <http://dx.doi.org/10.1073/pnas.1614158113>.
- Walls, M. (2009). Parks and Recreation in the United States: Local Park Systems. Resources for the Future. Available: <http://www.rff.org/research/publications/parks-and-recreation-united-states-local-park-systems>. Viewed: 6 March 2016.
- Wicks, B. E., & Crompton, J. L. (1989). Allocating services for parks and recreation: A model for implementing equity concepts in Austin, Texas. *Journal of Urban Affairs*, 11(2), 169–188 Available: [http://agrilifeedn.tamu.edu/cromptonrpts/files/2011/06/64\\_5.pdf](http://agrilifeedn.tamu.edu/cromptonrpts/files/2011/06/64_5.pdf).
- Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning*, 125, 234–244. <http://dx.doi.org/10.1016/j.landurbplan.2014.01.017>.
- Wood, S. A., Guerry, A. D., Silver, J. M., & Lacayo, M. (2013). Using social media to quantify nature-based tourism and recreation. *Scientific Reports*, 3, 2976. <http://dx.doi.org/10.1038/srep02976>.
- Wu, X., Wood, S. A., Fisher, D., & Lindsey, G. (2017). Photos, tweets, and trails: Are social media proxies for urban trail use? *Journal of Transport and Land Use*, 10(1), <http://dx.doi.org/10.5198/jtlu.2017.1130>.
- Zook, M. A., & Graham, M. (2007). Mapping DigiPlace: geocoded Internet data and the representation of place. *Environment and planning B, Planning & design*, 34(3), 466–482. <http://dx.doi.org/10.1068/b3311>.