An integrative perspective on visitor spatial behaviour in urban green spaces:
Linking movement, motivations, values and biodiversity for participatory planning and management

Silviya Korpilo

ACADEMIC DISSERTATION
To be presented for public examination with the permission of the Faculty of Biological and Environmental Sciences of the University of Helsinki in Auditorium XV, University Main Building on 28 September at 12.00 noon.

Helsinki, 2018
Supervisors

Docent/Guest Professor Susanna Lehvävirta, University of Helsinki/Swedish University of Agricultural Sciences
University Lecturer Tarmo Virtanen, University of Helsinki

Advisory Committee

Professor Jari Niemelä, University of Helsinki
Docent Timo Kuuluvainen, University of Helsinki
Research Professor Juha Heikkinen, Natural Resources Institute Finland (Luke)

Pre-examiners

Professor Cecil Konijnendijk, University of British Columbia
Professor Dagmar Haase, Humboldt-Universität zu Berlin

Opponent

Docent Åsa Ode Sang, Swedish University of Agricultural Science

Custos

Professor Jari Niemelä, University of Helsinki

Grading Committee

Associate Professor Sirkku Juhola, University of Helsinki
Professor Janne Hukkinen, University of Helsinki

Cover photo: Silviya Korpilo

ISSN 2342-5423 (print)
ISSN 2342-5431 (online)

Electronic publication at http://ethesis.helsinki.fi

Unigrafia Oy, Helsinki 2018
ABSTRACT

Understanding use by and movement of people in urban green spaces is important to planning and management in order to balance between multiple user needs and the preservation of natural resources as ecologically and socially viable. Yet, in the current literature, little attention is paid to the intraspatial (i.e. within the area) behaviour of visitors and how this relates to the socio-ecological environment. In this thesis, I extend this knowledge by examining the links between spatial behaviour, characteristics, values and motivations of visitors, visitor use impacts and biodiversity in urban green spaces.

I use a case study from Helsinki’s Central Park to answer four specific objectives. First, I aim to enhance the understanding of visitor spatial behaviour in terms of its distribution, intensity and related ecological impacts, as well as the social factors that affect it. Second, I examine the spatial relations between visitors’ movement, the values visitors assign to different landscapes and urban biodiversity, and how their integration can be used to inform spatial planning. Practically, I develop and demonstrate the use of participatory data collection methods for gathering citizen social-spatial information using smartphone GPS tracking and web-based public participation GIS. Finally, I provide recommendations for urban green space planning and management based on the findings.

I identify several general and group-specific spatial and motivational patterns of visitors by comparing running, cycling, mountain biking, walking and dog walking in Central Park. I produce multi-scale spatial knowledge on the relationship between visitor use and impacts by examining dispersion trends at the stand and landscape level. At the landscape scale, the maps direct planning and managerial attention to threatened areas with spatial overlap between high ecological value and high density of visitor use. I go beyond visual analysis and investigate such ‘hotspots’ in-situ by mapping trampling impacts on paths and the forest floor vegetation. I provide ground evidence that the smartphone GPS tracking method effectively identifies areas of intensive use and heavy wear.

In addition, my study identifies a ‘value-action’ gap in the public use of urban green spaces. The results show that visitors’ movement captures realized, everyday use that may spatially differ from the general values of people at the larger landscape scale. This highlights that both visitor spatial behaviour and perceived values provide important complementary information for urban green space planning and management.

Participatory methodologies and related ethical considerations play an important role in this thesis. I demonstrate that integrating different participation modes for collecting volunteered information can help gather data that is heterogeneous, but rich and usable for various research and planning purposes. I discuss in detail the development and the benefits and limitations of these methods in order to support future transferability to different socio-ecological contexts. Overall, my thesis promotes collaboration and knowledge exchange between citizens, decision-makers, and researchers from different disciplines.
ACKNOWLEDGEMENTS

I am reaching the end of an unforgettable journey towards gaining my doctoral degree. I learned so much in the last five years not only about science, but also about the power of knowledge to shape the world and our individual lives. I got to know incredible people, from whom I learned so much and whom I truly admire. I have always said that I am what I am because of the people I met and had the opportunity to learn from their experience, knowledge and perspectives. Thank you all for taking the time to share a piece of yourself and your world with me.

This journey was fun, exciting and full of all things new, but it was also not easy. Luckily, I have already learned that things that are worth it come with a price, so I put all my energy and effort to give my best and become better in every step I take. Fortunately, I have all these people around me who supported me and guided me when I lost my way. So I take this opportunity to put my gratitude into words, but remember that this is a weak and rather clumsy version of something of a much greater magnitude and trace.

First, I would like to express my deepest gratitude to my supervisor Susanna Lehvävirta. Susanna, you have been the best supervisor one can have. Your intelligence, passion and humane attitude towards everyone and everything have given me the best example. Thank you for being such a kind, patient, fun and inspiring supervisor, for being my friend and ‘scientific mother’ who truly cared not only about my articles and capacity as a researcher, but also about my physical and mental well-being. Thank you for guiding me and taking care of me. Thank you for always believing in me and encouraging me at every step.

I would also like to sincerely thank my second supervisor Tarmo Virtanen, who taught me so much about GIS and helped me a lot through the process. Thank you, Tarmo, for always finding time for me and sitting next to me as long as it takes until the problem is solved and I am happy.

I also greatly thank Doc. Åsa Ode Sang for taking the time to read my thesis and giving me the honour of coming to Finland as my opponent. I am looking forward to our discussion in the public defence. I would also like to express my gratitude to Prof. Cecil Konijnendijk and Prof. Dagmar Haase, who agreed to be the pre-examiners and gave very valuable comments to my thesis. Dagmar and Cecil, I admire your work and it is an honour for me that you agreed to this task.

I sincerely thank my thesis advisory committee for all their support and valuable feedback – Prof. Jari Niemelä, R. Prof. Juha Heikkinen and Doc. Timo Kuuluvainen. Thank you for continuing to work with me even when I changed my research topic after the first year. Jari, I would also like to thank you for being my custos in the public defence and most of all for being so helpful at all times. You have always responded to my worries, requests and questions immediately, even when you are drowned in million other things. This meant a lot to me, thank you. I am also very thankful to Assoc. Prof. Sirkku Juhola and Prof. Janne Hukkinen for agreeing to be part of my thesis grading committee.
Then, I wish to thank Tiina Saukkonen from City of Helsinki for all these years of collaboration. Tiina, thank you for being so encouraging, supportive and open to new ideas. Working with you was so easy and natural that it can serve as an example for any science-policy collaboration. I wish that all decision-makers could be more like you.

I also thank Prof. Marketta Kyttä from Aalto University for all the encouragement, especially at the beginning of my PhD journey when I was inexperienced and unsure. Thank you for all the valuable advice with MyDynamicForest and for being such a kind and inspiring person.

The Urban Ecology Research Group provided me with a great working environment. I would like to thank all former and current members, especially Jari Niemelä, Vesa Yli-Pelkonen, Jarmo Saarikivi, Kaisa Hauru, Johan Kotze, Stephen Venn, Kati Vierikko, Joel Jalkanen, Anna Salomaa, Karna Dahal and Yuan Wang. Johan, thank you for all the help and support you have given me even without being my supervisor. Thank you for making statistics look more ‘human’ to me and for the interesting discussions on all kinds of topics from politics to gardening. Anna, thank you for helping me during the graduation process and for the very enjoyable lunch company. Karna, thank you for being so kind, respectful and for the peer support. Jarmo, Stephen, Kati and Joel, thank you for the wonderful time in Orvieto, Italy during the GreenInfra conference. This was my first international conference and it will probably remain the best. Kati, thank you for all the support, for being so collaborative, helpful and fun person, and for introducing me to great people. Thank you Kati and Joel for the fun times together. Joel, thank you also for being my co-author and my friend. I also sincerely thank my other co-authors – Susanna, Tarmo and Tiina.

There is another research group that I wish to thank – the Green Roofs team. I always felt that I belong with you even though I was never officially part of the group. I especially thank two wonderful ladies for their peer support - Marja Mesimäki and Gosia Gabrych.

A big thank you to all the students I met as being part of the DENVI doctoral programme. I thank DENVI for all the support, for organizing interesting and useful courses, and fun events for us. Thanks particularly to the DENVI coordinator Karen Sims-Huopaniemi for being so helpful and for guiding us all. I also thank DENVI for letting me organize my first university course on citizen science. Thank you, Kaisa Korhonen, for trusting me with the organization and Vuokko Heikinheimo for helping out. I am also thankful for all the support and feedback that I received from my peers in the Environmental Science and Policy Graduate Seminar and to Pekka Kauppi and Sirkku Juhola for organizing it.

I would like to thank all the funding organizations without which this journey could not have been possible. I sincerely thank Maj and Tor Nessling Foundation for funding my research for several years. I also thank the Finnish National Agency for Education (CIMO) for awarding me with a vital start-up personal grant. In addition, I thank the Faculty of Biological and Environmental Sciences for awarding me with a grant towards building the MyDynamicForest tool. The biggest thank you to Claus Nurro for programming the tool at such a minimal cost. I also thank DENVI for funding me with a Chancellor’s travel grant so I can attend international conferences.
Very importantly, I would like to thank my family, who live far away and I miss every day of my life – Мамо, тате, бабо, обичам ви и ви благодаря безкрайно за подкрепата! Липсвате ми всеки ден! Благодаря най-вече на теб, мамо, за всичко което си направила за мен! The biggest thank you to my kind, beautiful and supportive big sister, who has always been there for me, and to her lovely family – Peter, Alex and Zara. Kako, I admire your strength in life and your unconditional love towards everyone around you. I love you guys so much! Thanks to my in-laws here in Finland, who made me feel like part of the family since the very first time I came to visit. Kiitos Kati, Keijo, Sampsu, Sabina, Annika, Tomi ja Alina. A big thanks to all my friends from all over the world, especially to all my friends in Bulgaria, the Netherlands and here in Finland. I am so blessed and thankful to have you all in my life, you have always supported me even when we live far away. You are a very important and special part of my life and my biggest fortune.

Last but not least, I thank my husband, best friend and soulmate - Miikka. Thank you for being the kind, funny, bright, honest and down to earth person you are. Thank you for helping me, for being patient with me and for supporting me in all kinds of ways during my journey in the academic world. I admire your soul, your calmness and your wisdom, and I have always wanted to be more like you. I love you so much! Words could never express how happy and grateful I am to have you in my life.

Thank you all once again and especially thanks to all my colleagues in the field who continue to fight for our nature and a better world.

Silviya Korpilo

Helsinki, September 2018
CONTENTS

ABSTRACT .................................................................................................................................i
ACKNOWLEDGEMENTS .............................................................................................................ii
CONTENTS ....................................................................................................................................v
LIST OF ORIGINAL PUBLICATIONS .................................................................................. vi
ABBREVIATIONS ....................................................................................................................vii
LIST OF FIGURES AND TABLES ........................................................................................ vii
1. INTRODUCTION ..................................................................................................................1
2. RESEARCH FRAMEWORK ..................................................................................................3
   2.1 Visitor spatial behavior in urban green spaces ...............................................................3
   2.2 Public participation GIS in planning and management of urban green spaces ............7
3. MATERIALS AND METHODS ..........................................................................................9
   3.1 Choosing the case study ...............................................................................................9
   3.2 Data collection .............................................................................................................10
   3.3 Data analyses .............................................................................................................14
4. RESULTS AND DISCUSSION ..........................................................................................15
   4.1 Understanding general and group-specific patterns in visitor spatial behaviour .......15
   4.2 Integration of visitor movement with other social and ecological data is needed to capture key values for spatial planning ..........................................................19
   4.3 Modern participatory data collection methods can gather rich and valuable citizen information for planning and management .........................................................21
   4.4 A glimpse into the future: implementing co-produced knowledge in research and planning ...........................................23
5. REFERENCES .......................................................................................................................26
LIST OF ORIGINAL PUBLICATIONS


**Chapter IV:** Korpilo, S., Jalkanen, J. Virtanen, T. & Lehvävirta, S. 2018. Where are the hotspots and coldspots of landscape values, visitor use and biodiversity in an urban forest? *PLOS ONE* (in press)

**Authors’ contributions**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original idea</td>
<td>SK, SL</td>
<td>SK, SL</td>
<td>SK, SL</td>
<td>SK</td>
</tr>
<tr>
<td>Study design</td>
<td>SK, SL</td>
<td>SK, SL</td>
<td>SK, SL</td>
<td>SK</td>
</tr>
<tr>
<td>Data collection</td>
<td>SK, SL</td>
<td>SK</td>
<td>SK</td>
<td>SK, JJ, TS</td>
</tr>
<tr>
<td>Data analysis</td>
<td>SK, SL, TV</td>
<td>SK</td>
<td>SK, SL, TV</td>
<td>SK, SL, TV, JJ</td>
</tr>
<tr>
<td>Visualization</td>
<td>SK</td>
<td>SK</td>
<td>SK</td>
<td>SK</td>
</tr>
<tr>
<td>Manuscript preparation</td>
<td>SK, SL, TV</td>
<td>SK, SL, TV</td>
<td>SK, SL, TV, TS</td>
<td>SK, SL, TV, JJ</td>
</tr>
</tbody>
</table>

SK = Silviya Korpilo
SL = Susanna Lehvävirta
TV = Tarmo Virtanen
TS = Tiina Saukkonen
JJ = Joel Jalkanen
ABBREVIATIONS

GIS   Geographic Information System
GPS   Global Positioning System
MDF   MyDynamicForest (PPGIS tool)
PPGIS  Public Participation Geographic Information System
TPB   Theory of Planned Behaviour
UGS   Urban Green Space(s)
VGI   Volunteered Geographic Information

LIST OF FIGURES AND TABLES

Figure 1. A conceptual model of visitor spatial behaviour in urban green spaces in relation to the socio-ecological environment.

Figure 2. Study area.

Figure 3. MyDynamicForest interface (top) and steps of participation (bottom).

Figure 4. Off-trail use dispersion (x axis in metres) of different activities at the stand level.

Figure 5. Density (GPS points) and distribution trends of off-trail use for mountain biking, running and cycling at the landscape level.

Figure 6. An example of a multi-scale approach to analysing density of GPS-tracked visitor use in relation to ecological value in Helsinki’s Central Park.

Table 1. Examples of attributes that can be used to operationalise the ‘wheel’ model.

Table 2. Data used in the thesis.
1. INTRODUCTION

Contact with nature and contact with other people are essential to human beings. In cities, urban green spaces (UGS) are important places where these interactions can take place. While the type, duration and intensity of the human-environment interplay vary across different socio-ecological contexts and across individuals, an increasing body of literature has highlighted the various environmental (e.g. biodiversity, cooling, air quality and carbon sequestration), social (e.g. increased physical activity, stress reduction, opportunities for recreation) and economic benefits (e.g. higher prices of nearby real estate) of UGS in enhancing the quality of life in cities (Konijnendijk et al., 2013; Faehnle et al., 2015; Kabisch et al., 2015; Niemelä et al., 2010). Yet, preserving the quantity and quality of UGS could be challenging due to high pressure caused by population growth, multiple and often competing land use demands, densification policies, and a variety of citizens’ needs for attractive and accessible nature as an integral part of everyday life (D’Antonio et al., 2016; Kabisch et al., 2015; Koppen et al., 2014; Malmivaara et al., 2002; Van Herzele and Wiedeman, 2003). In order to balance between multiple human needs and preserve natural resources, planning and management needs to understand how people use and interact with the socio-ecological environment in public green spaces (Beeco and Brown, 2013; D’Antonio et al., 2016).

UGS research has been growing extensively in the last two decades with most of the emphasis on general recreational use, perception and preferences of citizens, and the direct and indirect benefits of their use to health and well-being (Kabisch et al., 2015). However, little attention has been paid to the actual spatial behaviour of visitors inside UGS and its interplay with the socio-ecological environment. Although this topic has been substantially examined for visitor use monitoring and management in national parks and protected areas (e.g. Beeco et al., 2014; Beeco and Brown, 2013; D’Antonio et al., 2010; Meijles et al., 2014; Norman and Pickering, 2017; Orellana et al., 2012; Stamberger et al., 2018; Walden-Schreiner et al., 2018; Wolf et al., 2015, 2012), research in urban and peri-urban parks has remained limited. In urban settings, human spatial behaviour is often studied from a interspatial mobility and accessibility perspective for analysing activity/travel patterns between different destinations (Bertolini et al., 2005; Farrington, 2007; Järv et al., 2015; Kwan and Weber, 2003; Sainio et al., 2015) or physical accessibility (i.e. distance and time) to UGS (Koppen et al., 2014; Neuvonen et al., 2007; Nielsen and Harder, 2010; Schipperijn et al., 2010; Van Herzele and Wiedeman, 2003). A number of studies have investigated intraspatial visitor behaviour (i.e. within a green space area) focusing on user interactions, crowding and conflicts on multiple use trails (Arnberger and Brandenburg, 2007; Rossi et al., 2012; Santos et al., 2016) or use patterns and preferences towards amenities and trail characteristics (Chow et al., 2016; Gobster, 2005; Keith et al., 2018). This thesis aims to enhance this knowledge by presenting a wider, integrative perspective that links movement, characteristics, perceived values and motivations of visitors, visitor use impacts and biodiversity. Such knowledge is needed in order to efficiently monitor and manage visitor use and impacts in public parks (Beeco et al., 2013; Cole and Daniel, 2003; Coppes and Braunisch, 2013; Orellana et al., 2012), while providing high-quality recreational experiences for a variety of users. Further, spatially explicit data on visitor use can serve as a link between...
current supply (e.g. available bio-physical infrastructure, opportunities for activities) and user demand (Hegetschweiler et al., 2017).

In this thesis, I define *visitor use* as including all kinds of active and passive use such as sports and physical activities, nature observation, social interaction or simply the act of reaching a destination. *Spatial behaviour* can be defined as movement in space that is affected by decision-making processes (Golledge and Gärling, 2002). *Urban green spaces* are broadly understood here as green spaces inside cities that are predominantly dominated by trees and other vegetation elements (though may include water elements, buildings and hard-surfaced areas) and are generally reserved for public use (Fors et al., 2015; Dunnett et al., 2002).

Based on a case study from Helsinki’s Central Park, the thesis aims to:

- Enhance the understanding of visitor spatial behaviour in UGS in terms of its distribution, intensity, related ecological impacts, and the social factors that affect it (Chapters I, II and III)
- Examine the spatial relation between visitors’ movement, the values visitors assign to different landscapes and urban biodiversity, and how an integrative perspective on these can be used to inform spatial panning (Chapter IV)
- Develop innovative participatory data collection methods for gathering citizen socio-spatial information (using smartphone GPS tracking and web-based public participation GIS) (Chapter I, II, III, IV)
- Provide recommendations for UGS planning and management (Chapters III, IV)

The study involves collaboration with local authorities, citizens and researchers from different disciplines in order to provide context-based and up-to-date assessment of visitor spatial behaviour in Helsinki’s Central Park, and inform the new management plan of the area. The case study is the foundation for all four chapters of the thesis.

**Chapter I** illustrates the use of the smartphone GPS tracking method for examining spatial patterns and density of visitor use. We investigate movement on formal trails and informal paths of mountain bikers and runners, identify hotspots of intensive off-trail mountain biking, and map path and vegetation wear *in-situ* in order to validate the accuracy and usefulness of the smartphone GPS-tracked data.

**Chapter II** focuses on the development and use of a web-based PPGIS tool called ‘MyDynamicForest’ that combines smartphone GPS tracking, digital drawing of routes and a questionnaire for gathering data on the socio-spatial dimensions of visitor use. We examine visitors’ demographic characteristics and the accuracy and societal representativeness of the spatial route data, while comparing the smartphone GPS tracking and digital route drawing methods.

**Chapter III** presents empirical results using the data collected via MyDynamicForest. We analyse spatial use patterns of different activity groups (runners, cyclists, mountain bikers, walkers and dog walkers) and the social factors (demographics, frequency of use and
motivations) that affect route choice. We further examine the spatial distribution and motivations for off-trail behaviour, and compare the spatial dispersion of running, cycling and mountain biking off-trail use at the stand and landscape level. Based on the findings, we provide recommendations for managing visitor spatial behaviour in off-trail areas.

Chapter IV discusses the guidance that different types of spatially-explicit social and ecological data, and their integration, can provide for spatial planning. We examine the relations and spatial concurrence between two social variables i.e. visitor movement and perceived landscape values, and two ecological variables i.e. forest habitat quality and urban biodiversity. Using hot/coldspot mapping, we visualise areas with overlaps and discrepancies between the social and ecological values, and provide recommendations for landscape planning based on the results.

2. RESEARCH FRAMEWORK

This thesis is interdisciplinary and linked to different fields of science including urban ecology, recreational ecology, environmental psychology, human geography, geographical information science, and urban planning and management. In the next sections, I discuss two central approaches to the thesis: visitor spatial behaviour in UGS and public participation in UGS planning and management.

2.1 Visitor spatial behaviour in urban green spaces

Human spatial behaviour has been studied in various research fields such as transportation and mobility, tourism, and protected area management, and despite some theoretical differences, it is generally investigated as comprising of a realized spatial dimension - physical movement and a socio-psychological dimension – spatial decision-making. Physical movement refers to the explicit act of moving through space, while spatial decision-making refers to the implicit behaviour of making a conscious choice among alternatives that is based on prior experience and knowledge of the individual, and the socio-cultural environment (Golledge and Gärling, 2002).

In the context of outdoor recreation in natural areas, probably the most widely adopted perspective to study human spatial behaviour comes from the Theory of Planned Behaviour (TPB) (Ajzen, 1991). TPB conceptualises and examines behaviour as an outcome of individual choice (a cognitive perspective) that is affected by attitudes towards the behaviour (positive and negative evaluations of the behaviour and its outcomes), subjective norms (driven by social values) and perceived behaviour control (the capacity to change one’s behaviour) (Kidd et al., 2015; Marzano and Dandy, 2012). For example, TPB has been applied to investigate various aspects of human behaviour in natural environments such as recreational disturbance on wildlife (Aipanjiguly et al., 2003; Martin and McCurdy, 2009) and predicting participation in leisure activities (Ajzen and Driver, 1991; Galea and Bray, 2006; Rossi and Armstrong, 1999). However, TPB theory has been widely criticized for concentrating excessively on rational reasoning while disregarding unconscious influences and the strength of habits (Gardner et al., 2011; Sheeran et al., 2013; Sniehotta et al., 2014). In addition, a major criticism to TPB comes from its limited predictive ability i.e. individuals
may have an intention towards a behaviour but may fail to act, as well as its rather static nature that discounts change in conditions (Shove, 2010; Sniehotta et al., 2014). Thus, researchers have started to develop extended forms of the theory such as Wang et al. (2015a, 2015b, 2013) who added past use and perceived accessibility in terms of physical and non-physical factors (e.g. cultural background and leisure time available) to the TPB model in order to analyse urban park use.

Despite being a widely used theoretical approach, TPB seems insufficient to explain the complexity of visitor spatial behaviour in UGS. This behaviour is often habitual meaning that people perform routine activities as part of everyday life, not necessary led by conscious decision-making. It is also a multi-purpose behaviour that comprises of both a goal-oriented/optimal behaviour such reaching a destination (e.g. commuting or using recreational facilities) and a leisure-oriented behaviour, in which the ability to explore and enjoy the environment is a key component of spatial decision-making. These two aspects can be integrated within a single visit or route and can be subject to implicit motivations and impulsive actions triggered by environmental stimuli. For example, commuting home from work through a green space may include additional activities and destinations changing the spatial manifestation of that route (Golledge and Gärling, 2002).

In this view, social practice theory (Hargreaves, 2011; Reckwitz, 2002; Shove, 2010) could present a more appropriate approach for understanding visitor behaviour in urban green spaces. Social practice theory extends the boundaries of behaviour analysis to include a broader socio-ecological perspective. It considers behaviour and its practices as a result of people’s everyday interactions with their environment, available technology, and other people, emphasizing that these interactions are dynamic and evolving as they are done repeatedly (Marzano and Dandy, 2012; Shove et al., 2007).

To facilitate comparative interpretation, I present an example of how these behaviour theories may be utilized to understand spatial behaviour of mountain bikers in an urban forest. TPB theory suggests that a mountain biker will use off-trail rocky areas because of the perceived positive outcomes in terms of physical exercise, excitement, and the opportunity to enjoy the environment (Goeft and Alder, 2001; Newsome and Davies, 2009). TPB will also consider perceived behaviour control meaning that a mountain biker will ride on multiple-use trails that are shared by e.g. walkers and dog walkers, due to the lack of specifically designated mountain biking trails. Yet, influenced by social/subjective norms and past experiences, mountain bikers may avoid using horse-riding trails due to e.g. potential social conflict or danger of accidents.

Examining spatial behaviour of mountain bikers from a social practice perspective will focus on the activity and socio-ecological context. It will incorporate a wider range of influential factors such as the biophysical aspects of the forest (e.g. type and spatial distribution of paths, path surface, natural barriers such as fallen logs) and the available technology and equipment e.g. bike types that will enable different riding styles associated with different impact potential (Newsome and Davies, 2009). The shared meaning and information around mountain biking and the feelings of joy, health and well-being it provides, the aesthetic
perceptions and perceived values that mountain bikers assign to different areas will all need to be understood in order to analyse when, where and why mountain bikers regularly recreate.

Drawing on the holistic perspective of social practice theory, socio-ecological systems theory (Collins et al., 2011; Grimm et al., 2000; Liu et al., 2007; McGinnis and Ostrom, 2014; Ostrom, 2009), environmental psychology (Kaplan and Kaplan, 1989; Knopf, 1983) and behaviour research (Giles-Corti et al., 2005; Golledge and Gärling, 2002; Golledge and Stimson, 1997; Sallis et al., 2006), I propose an integrated conceptual model to illustrate the relationship between visitor spatial behaviour and the socio-ecological environment in UGS (Figure 1). The conceptual model is inspired by the dynamic nature of movement and is therefore represented as a wheel, which has sever key characterises.

**Figure 1.** A conceptual model of visitor spatial behaviour in urban green spaces in relation to the socio-ecological environment. Based on Giles-Corti et al. (2005), Knopf (1983) and Sallis et al. (2006).

**First, spatial behaviour is embedded in a specific socio-ecological context.** Spatial behaviour is influenced by specific personal characteristics (internal circle) and the specific social-ecological setting (outer circle) within which the behaviour is performed. The ecological system in UGS consists of both natural and human-made features. The social and ecological systems and all components within are integrated in a “hybrid” entity through metabolic and circular relationships (Gandy, 2005; Swyngedouw, 2006). There are no linear
cause-effect relationships and all components can simultaneously interact and affect each other (Knopf, 1983; Liu et al., 2007).

The wheel is driven in time and space by three major drivers (outer dashed circle): socio-cultural change (e.g. changes in demography, economy, institutions, social norms, recreational trends, information and technology), policy & practice (e.g. recreation and public use policies and funding, planning processes and management practices, public participation in decision-making) and ecosystem dynamics (e.g. long-term successional changes, ecosystem level disturbances, climate change). These drivers and the different elements of the model are shaped by socio-ecological processes at various regional, national and global scales. For example, changes in the built infrastructure or population dynamics surrounding the urban green space can have direct impact on the spatial behaviour of visitors. However, in the thesis, I focus on the intraspatial perspectives.

**Second, it is a dynamic social practice.** Spatial behaviour is understood as part of everyday social practices. The ‘doings’ or practices of spatial behaviour (e.g. movement, activity choice, route choice, materials used such as outdoor equipment) are influenced by the dynamic interactions between the different elements of the wheel, all of which constantly reproduce as they are done regularly (Marzano and Dandy, 2012; Reckwitz, 2002; Shove and Pantzar, 2005). This means that any current state of the spatial behaviour is also shaped by past learning based on prior actions, knowledge, events and experiences (Arnberger and Brandenburg, 2007; Golledge and Gärling, 2002; Shove and Pantzar, 2005; Wang et al., 2015b).

**Third, it requires an interdisciplinary perspective.** The researcher’s perspective, which is influenced by scientific discipline, work experience and implicit knowledge, defines how the wheel is examined. Current knowledge and understanding of visitor spatial behaviour in UGS can evolve by adopting an integrated and interdisciplinary approach involving researchers from both natural and social sciences.

Table 1 below presents examples of different attributes that can be used to operationalise the ‘wheel’ model in general, as well as their use in this thesis. The list is compiled based on environmental psychology (Knopf, 1983; Kaplan and Kaplan, 1989) and behaviour geography literature (Golledge and Gärling, 2002; Golledge and Stimson, 1997), several review and conceptual studies on outdoor recreation and physical activity in urban green spaces (Andkjær and Arvidsen, 2015; Bedimo-Rung et al., 2005; He et al., 2016; Hegetschweiler et al., 2017; Starnes et al., 2011), as well as studies examining specific factors that are included in the table. This is not an exhaustive list and the different cells should not be seen as restrictive since some attributes can be placed in several or in between different elements. Instead, I aim to provide relevant aspects that can serve as guidance for future analysis. I hope that the presented framework can ultimately inspire scientific discussion around visitor spatial behaviour in UGS where natural scientists, social scientists, geographers and practitioners will equally engage.
Table 1. Examples of attributes that can be used to operationalise the ‘wheel’ model. Attributes in bold have been examined in this thesis.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Examples of attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-cultural environment</td>
<td>user group size and composition (Gobster, 2005); <strong>participation in activity, sports and leisure groups</strong> <em>(Chapter I, III, Cord et al., 2015)</em>; social interactions and conflicts (Amberger, 2012; Amberger and Haider, 2005; Santos et al., 2016; Wolf et al., 2017)</td>
</tr>
<tr>
<td>Home &amp; work environment</td>
<td>family status; living/work/school conditions; neighbourhood conditions (Galpern et al., 2018); accessibility to UGS (Keith et al., 2018; Koppen et al., 2014; Schipperijn et al., 2010; Van Herzele and Wiedeman, 2003); <strong>population density in the surrounding areas</strong> <em>(Chapter IV; Lindsey and Nguyen, 2004)</em></td>
</tr>
<tr>
<td>Personality system</td>
<td><strong>demographics</strong> <em>(e.g. age, gender, ethnicity, education, occupation, income)</em> <em>(Chapter III, Gobster, 2005)</em>; <strong>activity choice and frequency of use</strong> <em>(Chapter I, II, III; Keith et al., 2018)</em>; health and personal mobility (Hirsch et al., 2014); <strong>motivations</strong> <em>(Chapter III)</em>; personal traits and preferences e.g. personal space requirements (Amberger and Haider, 2005), <strong>use of technology such as sports tracking applications</strong> <em>(Chapter I, II, III)</em>; available time (hours per visit, times of the day, weekdays, seasons) <em>(Gobster, 2005)</em></td>
</tr>
<tr>
<td>Cognitive system</td>
<td>aesthetic and naturalness preferences, restorative experiences (Gobster and Westphal, 2004; Keith et al., 2018); past use, knowledge and experiences (Amberger and Brandenburg, 2007); perceived constraints (e.g. safety, perceived accessibility and distance, cleanliness) (Gobster and Westphal, 2004; Keith et al., 2018); <strong>perceived social/landscape values</strong> <em>(Chapter IV; Kothencz et al., 2017)</em></td>
</tr>
<tr>
<td>Ecosystem type, structure &amp; functioning</td>
<td><strong>size; shape; spatial distribution of land cover types</strong> <em>(e.g. forests, fields, water elements)</em> <em>(Chapter IV)</em> and their connectedness (Lindsey et al., 2008); <strong>biodiversity indicators</strong> <em>(e.g. functional structure and diversity of communities, degree of communities specialization)</em> <em>(Chapter IV)</em></td>
</tr>
<tr>
<td>Landscape quality &amp; attractiveness</td>
<td>structural diversity between and within land cover types e.g. plant and animal species richness, number of elements per area; degree of naturalness (Shafer et al., 2000); <strong>level of wear</strong> <em>(Chapter I)</em>; public safety (Luymes and Tamminga, 1995); presence of waste (Shafer et al., 2000); noise levels</td>
</tr>
<tr>
<td>Trail &amp; facility infrastructure</td>
<td>entrances; <strong>density, distribution and condition of trails</strong> <em>(Chapter I, II, III, IV, D’Antonio et al., 2016; Gobster, 1995; Reynolds et al., 2007)</em>; trail signage and information boards; environmental barriers along the trails (e.g. fallen logs) (Lehvavirta, 1999); distribution and condition of recreational facilities e.g. benches, rubbish bins, playgrounds, dog parks, picnic and outdoor fitness equipment, sport centres, cultural buildings (Chow et al., 2016; Kaczynski et al., 2014; Lindberg and Schipperijn, 2015)</td>
</tr>
</tbody>
</table>

2.2 Public participation GIS in planning and management of urban green spaces

Modern spatial technologies can provide decision-making with immediate and efficient ways to understand human spatial behaviour. This thesis combines PPGIS and Volunteered Geographic Information (VGI) approaches, together with mobile phone GPS technology to gather data on the spatial and social dimensions of visitor use for planning and management purposes.
The PPGIS concept was introduced two decades ago at the meeting of the National Center for Geographic Information and Analysis in the USA (Sieber, 2006). PPGIS can be defined as a “field within geographic information science that focuses on ways the public uses various forms of geospatial technologies to participate in public processes, such as mapping and decision making” (Tulloch, 2008). Since the 1990s, various definitions have developed as PPGIS has been used by different researchers and practitioners in a wide variety of disciplines, contexts and applications (Brown and Kyttä, 2014; Sieber, 2006). The list is extensive including urban-specific applications e.g. investigating perceived environmental quality and urban development preferences (Kyttä et al., 2013; Schmidt-Thomé et al., 2013), mapping perceived social values of urban forest and parks (Brown, 2008; Tyrväinen et al., 2007), as well as applications in the fields of conservation and environmental planning (Alessa et al., 2008; Bagstad et al., 2016; Beeco and Brown, 2013; Brown et al., 2014; Brown and Reed, 2009; de Vries and Goossen, 2002; Sherrouse et al., 2011; Wolf et al., 2015).

Despite the contextual and methodological diversity in PPGIS studies, a shared understanding in the literature is that PPGIS is not merely a piece of technology, but a process of engaging the public at different levels ranging from data collection to implementation and evaluation of outcomes. PPGIS is often described as an approach initiated by governmental agencies to enhance public involvement in generating spatial data that can be used to inform land use planning and management (Brown and Kyttä, 2014). As such it differs from participatory GIS that is largely used in developing countries and rural contexts as a tool to empower local communities and marginalised groups, often being part of grassroots and community-based initiatives (Brown et al., 2015). The PPGIS concept is therefore more relevant to this thesis as the focus is on co-production of spatial information in order to inform the new management plan of Helsinki’s Central Park (2018-2032). The research is part of a larger public participation process lead by City of Helsinki that includes various ways of public engagement in developing the new management plan (e.g. interactive websites and public meetings, workshops with relevant stakeholders and organizations). Data collection and discussion by local citizens is promoted at the early stages of planning before the new management plan is drafted by city officials.

Another relevant approach to this thesis is VGI which relates to citizen-initiated use and production of geographic information driven by individual and community interests (Feick and Roche, 2013; Goodchild, 2007). The sheer volume of crowd-sourced spatial data has been growing with the increasing integration of technology in our everyday lives. In this case study, VGI has been adopted through the lens of smartphone GPS self-tracking i.e. citizens using sports tracking applications to voluntarily generate spatial information for different personal reasons such as monitoring health and fitness performance, and sharing routes and everyday experiences. Few studies have demonstrated the potential of smartphones in gathering detailed, useful and timely information on the spatial patterns of recreational behaviour (e.g. Doherty et al., 2014; Santos et al., 2016), however, the opportunities for UGS research remain largely unexplored. Here, I contribute to this growing body of literature by presenting a web-based PPGIS tool that combines smartphone GPS tracking, digital route drawing and a questionnaire. The tool is described in detail in Section 3.2.
3. MATERIALS AND METHODS

3.1 Choosing the case study

Helsinki’s Central Park was chosen as a case study together with City of Helsinki as part of a collaboration project. There were two major reasons for selecting the site. First, there was a need to gather spatially-explicit information on visitor use to inform the new management plan of the area. In addition, Central Park is vital to Helsinki’s urban life, but it experiences heavy pressure from intensive public use. The park is the biggest single green area in Helsinki (Figure 2) covering more than 1000 ha of land, which consists of 700 ha of woodlands as well as other terrains and habitats like agricultural fields, rocks, rivers, golf courses, sports areas etc. Central Park includes four nature protection areas and it is an excellent representative of the rich and varied nature and wildlife in the Finnish southern coastal region, being home to many species of mammals, forest birds and other taxa (City of Helsinki Urban Facts, 2005). The park is intensively used for a wide range of recreational activities as well as for commuting. It is the most popular park in Finland receiving around 2-2.5 million visits a year (Ilvesniemi and Saukonen, 2015), which is close to the total annual number of visitations to all Finnish National Parks combined (3.1 million visits) (Metsähallitus, 2017).

Figure 2. Study area. Adapted from Chapter IV.
3.2 Data collection

For this doctoral research I have applied a mixed methods approach (Johnson and Onwuegbuzie, 2004) to integrate a wide range of data and data collection methods (Table 2). This includes quantitative and qualitative, and spatially-explicit and non-spatial data, which were gathered via conventional (questionnaires, paper maps, fieldwork observation) and novel data collection methods (smartphone GPS tracking, web-based PPGIS).

Table 2. Data used in the thesis.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Source</th>
<th>Type</th>
<th>Spatial resolution</th>
<th>Used in chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visitor use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smartphone GPS-tracked</td>
<td>Sports tracking applications, MyDynamicForest PPGIS web-based tool</td>
<td>GPS point data (spatial)</td>
<td>variable, one-min interval at accuracy of GPS</td>
<td>I,II,III,IV</td>
</tr>
<tr>
<td>Iroutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawn routes</td>
<td>MyDynamicForest PPGIS web-based tool</td>
<td>line data (spatial)</td>
<td>variable</td>
<td>II,III,IV</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>MyDynamicForest PPGIS web-based tool</td>
<td>quantitative and qualitative data (non-spatial)</td>
<td>-</td>
<td>II,III,IV</td>
</tr>
<tr>
<td>Visitor use impacts</td>
<td>Fieldwork mapping</td>
<td>observational data (spatial)</td>
<td>5 m x 5 m</td>
<td>I</td>
</tr>
<tr>
<td>Landscape values</td>
<td>paper PPGIS (City of Helsinki)</td>
<td>polygon data (spatial)</td>
<td>variable, polygon size 0.6-83 ha</td>
<td>IV</td>
</tr>
<tr>
<td>Forest habitat quality</td>
<td>forest inventory data (City of Helsinki)</td>
<td>inventory data at stand level (spatial)</td>
<td>variable, stand size 0-11 ha</td>
<td>IV</td>
</tr>
<tr>
<td>Urban biodiversity</td>
<td>expert elicitation via online questionnaire (Jalkanen and Vierikko, 2018)</td>
<td>expert scoring assigned to raster based biotope classification (spatial)</td>
<td>20 m x 20 m</td>
<td>IV</td>
</tr>
<tr>
<td>Formal trail network</td>
<td>National Land Survey of Finland</td>
<td>line data (spatial)</td>
<td>1:10 000</td>
<td>I,II,III,IV</td>
</tr>
<tr>
<td>Population density</td>
<td>Statistics Finland</td>
<td>grid data (spatial)</td>
<td>1 km x 1 km</td>
<td>IV</td>
</tr>
</tbody>
</table>

Collecting data on visitor use and impacts

A practical aim of this thesis was to develop a participatory data collection method that is cost-effective, user-friendly and adaptable. Limited municipal budgets, tight schedules for planning and management, and short-term delivery pressures of public agencies (Kabisch et al., 2015; Mulgan and Albury, 2003; Randrup and Persson, 2009) call for development and use of inexpensive and efficient data collection tools. User-friendliness is related to usable interfaces and to providing multiple means of participation, which are important for reducing
the burden on participants and increasing the study sample. Adaptability refers to smart, easily-transferrable technologies that can be applied in different research contexts and at various spatial and temporal scales. In order to fulfil these criteria, instead of invention (e.g. developing a new smartphone application), I focused on configuration of existing research elements and use of available VGI data. As Shove and Pantzar (2005) argue “innovations in practice are not simply determined by the generation of new products, images or skills. What really matters is the way in which constituent elements fit together.”

As a first step, we tested the capacity of smartphone GPS tracking to collect useful and accurate information for urban forest planning and management. In summer 2014, we collected and analysed GPS route data, which was tracked by volunteers using any sports tracking application (e.g. Sports Tracker, Strava, Endomondo) on their personal smartphones. The volunteers were recruited both on-site and online. Different areas of the park were covered in different days and busiest times of the week following a purposive maximum variation sampling design: the interviewer was positioned on pre-planned strategic places on and outside the formal trails and at intersections with a high amount of visitors, choosing passers-by who appeared to represent different age, gender and activity type. In addition, online purposive sampling was used through the Sports Tracker application, which is widely used by Finnish sport enthusiasts (Suvanto and Oksanen, 2013). The website allows for navigation to any geographical area and a view with publically shared tracks in Central Park. Once relevant tracks were identified, users were contacted individually and invited to participate in the study. Overall, 173 people were approached in the pilot study (66 on-site and 107 online), of which 27 took part (12 on-site and 15 online), indicating an overall response rate of 15.6% (18.2% and 14% respectively). Additionally, 18 participants were acquired through ‘word-of-mouth’ and a mountain bike organisation (Mountain Bike Club Finland Ry), leading to a total of 45 local citizens who participated in the pilot phase. Although this sample was sufficient to explore runners’ and mountain bikers’ use of formal and informal trails (Chapter I), the data collection method was time-consuming and had a low response rate.

As a next step, we improved the methodology based on the knowledge and experience gained from the pilot phase, and developed the ‘MyDynamicForest’ (MDF) PPGIS tool (Figure 3). The data collected via MDF played a key role in the analysis in Chapters II, III, and IV. Similar to the pilot phase, MDF gathered smartphone GPS-tracked routes, however, in order to avoid bias towards sports tracking users only and increase the representativeness of the study sample, we introduced an option of drawing a route on the MDF website. After submitting a route, participants answered a questionnaire related to their social-cultural background, activity choice, frequency of use, and the type of trails they used. If they had used trails outside the formal network, respondents were asked to state the motivations behind their off-trail route choice. The questionnaire included a list of 14 different pre-defined motivations and an option to suggest others using a free-from text. The presented motivations were adapted from a typology for off-trail behaviour in national parks (Wimpey and Marion, 2011). The list included reasons related to attraction (e.g. to view/study interesting animals and plants), exploration (e.g. to explore unknown and interesting areas),
avoidance (e.g. to avoid other people/dogs), shortcut (to take a shortcut), routine (to take a usual route) and practical reasons (e.g. because of getting lost). A detailed description of the questionnaire is included in Chapter III.

Figure 3. MyDynamicForest interface (top) and steps of participation (bottom). Based on Chapters II and III.
The data collection period was from June until December 2015. The study was advertised via traditional (local newspapers and radio) and social media. Altogether 233 participants took part based on self-selection, providing 366 tracks (139 GPS and 227 drawn tracks) and 340 questionnaire responses (see Chapters II and III). Overall, 54% of participants were male and 46% female, and 64% were in the 25-44 age group. Participants were mostly highly educated holding a Master's degree or higher (44%) and regular park users - 46% visit the park 2-5 times a week and 70% visit at least once a week. The GPS data contributors were mainly middle-aged men - 72% male and 46% in the 35-44 age group. The drawn dataset showed a more equal gender and age distribution: 47% male and 53% female, 35% in the 25-34 age group, 26%:35-44 and 21%:45 - 54 age group. The GPS tracks consisted primarily of vigorous physical activities (running, cycling and mountain biking), while the drawn routes included also walking and dog walking (Chapter II).

As a user-centred approach, MDF focused on privacy protection of study participants due to ethical considerations of using smartphone GPS tracking data (i.e. possible tracing of people to their home or work location (Sainio et al., 2015)). The tool was designed according to national research ethics guidelines and the principles of informed consent. As a final step, all respondents signed a Letter of Consent that provided clear terms and conditions of voluntary participation. The ethical issues have been discussed in all four chapters of this thesis.

Other social and ecological spatial data

In Chapters I, II, III and IV, different types of openly available spatial data were used including topography data from the National Land Survey of Finland and data on population density provided by Statistics Finland. In Chapter IV, we used data on citizen perceived landscape values that were gathered by City of Helsinki in 2007-2009 as part of a large visitor use study that utilized on-site and postal methods (Chapter IV). A total of 599 respondents took part in the survey and similar to the MDF survey, they were mainly local residents and frequent park users, however the predominant age group was > 50 years-old (53.4%). The survey included paper PPGIS methodology i.e. study participants were given a paper map of Central Park with pre-defined and numbered polygons, and a list of seven positive landscape values: ‘scenic view’, ‘valuable nature site’, ‘feeling of forest’, ‘feeling of space and freedom’, ‘history and culture’, ‘peace and quiet’, and ‘opportunities for activities’. Respondents were asked to assign areas for each value by writing down the number(s) of the polygons next to the value they found applicable (Chapter IV).

In Chapter IV, we also used detailed forest inventory data that was provided by City of Helsinki. We used the data to calculate a forest habitat quality index (using a sigmoidal function of average tree diameter (m/ha) multiplied by wood volume (m³/ha)) (Lehtomäki et al., 2015) as a proxy for biodiversity value for different areas in Central Park. In addition, we incorporated expert elicitation data which was collected in a study examining urban biodiversity in the Helsinki Metropolitan Area (Jalkanen and Vierikko, 2018). Overall 24 local experts from the Finnish Museum of Natural History, University of Helsinki, Finnish Environment Institute, and local environmental NGOs participated in the study. The experts evaluated independently via an online questionnaire how well various urban biotopes support
different taxonomic groups by scoring several community attributes. The compilation of
attributes, which included 'species richness', 'specialist species', 'biomass', 'abundance',
evenness', 'uniqueness' and 'representativeness', was guided by ecosystem functioning and
conservation principles (Balvanera et al., 2005; Harrison et al., 2014; Kremen, 2005; Luck et
al., 2003). A detailed description of all datasets and methods is included in Chapter IV.

3.3 Data analyses

The research presented in this thesis integrates spatial analysis using ArcGIS (v.10.2.1),
statistical analysis using R (v.3.2.2) and SPSS (v.21.0) software, and content analysis. Visitor
spatial behaviour in Central Park was investigated as comprising of intraspatial physical
movement and intraspatial route choice (i.e. as the motivations for choosing a route). Physical
movement was analysed using the collected self-recorded routes (via smartphone GPS
tracking) and self-reported routes (via digital route drawing). In Chapter I, we investigated
the accuracy of the GPS-tracked route data using proximity analysis by calculating average
deviation of GPS tracks from the formal trail network. In Chapter II, we compared the
accuracy (using proximity analysis) and level of detail of the GPS-tracked and drawn routes.
Buffer analysis of the formal trail network was used in Chapters I and III to distinguish
between on-trail (i.e. use of formal/maintained trail infrastructure) and off-trail movement
(i.e. use of informal/spontaneous path systems). We used a data-driven and heuristic
approach to select the size of the buffer. In Chapter I, we used a 10 m buffer size based on the
mean accuracy of the collected self-reported on-trail GPS data (from participants who stated
to follow only formal trails). The 10 m buffer size was found sufficient using visual
inspection and it was also in line with the typical 5-10 m GPS location accuracy of
smartphones as indicated by previous studies (Hess et al., 2012; Menard et al., 2011;
Zandbergen, 2009). However, when the data sample grew to include more tracks and various
types of activities, we expanded the buffer size to 15 m to incorporate the maximum width
(up to 5m) of the formal trails in Central Park (Chapter III).

The interplay between spatial behaviour and the socio-ecological environment was analysed
in several ways. In Chapter I, we used kernel density analysis and hot/coldspot mapping to
locate areas of intensive mountain biking off-trail use. Then, we conducted fieldwork
mapping and observation in order to validate the results of the hotspot analysis and test the
hypothesis that areas with high density of GPS-tracked off-trail movement (i.e. hotspots)
display higher level of vegetation wear than areas with no off-trail movement (i.e. coldspots).
We sampled the spatial distribution, width and level of wear of each path and vegetation
segments in three of most prominent mountain biking off-trail hotspots and their respective
nearby coldspots. The in-situ mapping served as a 'real life verification' of the effectiveness
of the smartphone GPS tracking methodology to accurately locate areas of heavy wear. A
detailed description of the fieldwork methods can be found in Chapter I.

Chapters II and III studied in more detail the social-spatial dimension of visitor use. In
Chapter II, we analysed visitors’ characteristics in relation to the data source (GPS-tracked
vs. drawn routes) in order to discuss internal validity in terms of representativeness associated
with each data collection method. We also compared the overall representativeness of the
study sample to similar PPGIS studies in the same context (Ilvesniemi and Saukkonen, 2015; Kytta et al., 2013) as a way to evaluate external validity. In Chapter III, we analysed and compared the overall spatial patterns of different activity groups using kernel density analysis. We employed a multi-scale approach to examine dispersion patterns of the GPS-tracked off-trail use at the stand level - with proximity analysis, and at the landscape level - with directional distribution analysis. In addition, we used generalized linear mixed model statistical analysis and double-blind content analysis to investigate the effect of demographics (i.e. age and gender), frequency of use, and activity type on off-trail behaviour, and the main motivations that drive it. Off-trail use motivations were analysed according to activity type to gain insights on user-group differences since perceptions and preferences towards the environment of one activity group are likely to differ for those of another group (Andkjær and Arvidsen, 2015).

In Chapter IV, we calculated social value based on visitor use density and the combined/multiple perceived landscape values, as well as ecological value based on the forest habitat quality index and urban biodiversity expert scoring for different areas in Central Park. We analysed the correlations (using Spearman correlation coefficients) between the different datasets and measured the degree of spatial overlap by calculating Jaccard coefficients (De Vreese et al., 2016; Karimi et al., 2015; van Jaarsveld et al., 1998). We carried out socio-ecological hot/coldspot mapping, which is a commonly used method in conservation planning and natural resource management (e.g. Alessa et al., 2008; Bagstad et al., 2016; Bryan et al., 2011; Karimi et al., 2015; Lyon et al., 2011; Whitehead et al., 2014), to visualize areas of spatial overlap and discrepancies between the ecological and social values. Compared to previous studies, we added visitor movement to inform planning and management on potential threats to specific areas with high ecological value due to intensive use. We also conducted density analysis of formal trails and calculated population density in the surrounding areas to further investigate the relationship between landscape values and visitor use.

4. RESULTS AND DISCUSSION

This chapter presents the key contextual and methodological results of my thesis. Based on the main findings, I also propose practical recommendations for UGS planning and management (Chapters III and IV).

4.1 Understanding general and group-specific patterns in visitor spatial behaviour

Based on the results from all chapters (I – IV) in this thesis, I could identify several common patterns in visitor spatial behaviour in Helsinki’s Central Park. First, we found that visitors are frequent users who generally followed existing trail infrastructure, regardless if it is formally maintained (Chapter III, IV) or informally/spontaneously created (Chapter I and III). This corroborates findings from studies of outdoor recreation in national parks and protected areas in Europe and the US (Coppes and Braunisch, 2013; Hockett et al., 2010; Walden-Schreiner et al., 2018). In fact, according to the questionnaire responses, only 7% of self-reported use was located in forest areas without any paths, suggesting that existing trails are
strong pull factors (Brooks and Titre, 2003; Coppes and Braunisch, 2013; Hocket et al., 2010; Wimpey and Marion, 2011) and play a key role in spatial decision-making.

Chapter III indicated that the demand side of off-trail use is shaped by multiple motivations and the type of activity visitors engage in, rather than personal characteristics such as age, gender and frequency of use. Visitors left the formal trails for various reasons including a mixture of utilitarian motives (following a routine route, taking a shortcut and commuting) as found in other urban studies (Gobster, 2005; Shafer et al., 2000), as well as nature-oriented motives (e.g. exploring the environment, scenic view, viewing flora and fauna) typical for outdoor recreation in rural natural sites (Hockett et al. 2010; Park et al., 2008; Wimpey and Marion, 2011). The number of motivations was also positively associated with probability of leaving the formal trails (Chapter III).

Intensive use of informal paths may signal a mismatch between available supply and current demand by different user groups. Existing trail infrastructure may not respond to preferences of some users whose activities are dependent on specific environments e.g. off-trail dependent activities such as mountain biking, orienteering, trail running etc. For example, in Central Park, there is no designated trail infrastructure for mountain biking and this has led to bikers riding on multiple-use informal trails (Chapter I, II and III). Many studies have investigated conflicts among different user groups on multiple-use trails (e.g. Arnberger, 2012; Arnberger and Haider, 2005; Moore, 1994; Santos et al., 2016), however encountering other visitors may not always generate conflict as found in Chapter III of this thesis and also by e.g. Rossi et al. (2012) and Pickering and Rossi (2016) in several peri-urban parks in Queensland, Australia. Nevertheless, it is important to monitor emerging and changing informal use as increased use levels of different activities at the same spatial and temporal scales could potentially induce crowding and conflicts (Arnberger, 2012; Santos et al., 2016; Wolf et al., 2017), as well as vegetation wear and erosion (Ballantyne and Pickering, 2015a; Hamberg et al., 2008; Lehvävirta et al., 2014; Leung and Marion, 2000; Pickering et al., 2010).

The results from Chapters I and III also led to the identification of several group-specific patterns in spatial behaviour: 1) routine use predominantly on or close to formal trails (runners and cyclists); 2) spatially concentrated off-trail use confined to a few informal paths (mountain bikers); and 3) dispersed off-trail use (walkers and dog walkers). The first group is mainly characterized by routinized optimal behaviour e.g. regular use of maintained trails for exercise and fitness, or using the shortest path to commute (Gobster, 2005; Wolf and Wohlfart, 2014). Recognizing such practices is important as habitual users may be more sensitive to changes that could potentially disrupt their use (e.g. due to trail modification, increase use and crowding) (Arnberger and Haider, 2005; Gobster, 2005; Wolf and Wohlfart, 2014). However, the results of Chapter III showed that runners and cyclists may sometimes diversify their route choices. Once leaving the formal trails, they were driven by a variety of motivations e.g. to explore the environment, reach a scenic view, view flora and fauna or use a shortcut, making their spatial behaviour and associated impacts less predictable. While runners and cyclists did not disperse far from the maintained trails (Figure 4), their off-trail
use was widespread across the landscape meaning that the spatial extent was relatively high despite the low amount of off-trail use (Figure 5).

Mountain bikers on the other hand, dispersed the furthest from the formal trails (Figure 4), but portrayed very purposive and spatially confined behaviour, indicating strong spatial and social preference towards existing informal routes. Our fieldwork mapping showed that intensive mountain biking off-trail use can cause path widening and heavy wear on the forest floor vegetation (Chapter I), which is in line with the results of others (Newsome and Davies, 2009; Pickering et al., 2010). However, the use and extent of impacts were spatially concentrated both at the stand level, being confined to the trail itself (Chapter I; Goeft and Alder, 2001), and at the landscape level (Chapter III, Figure 5). This has important implications since the severe but localised impacts of concentrated off-trail use may be less damaging than degradation caused by spatially dispersed activities that lead to widespread path creation with cumulative impacts on trails and trails’ edges (Ballantyne et al., 2014; Ballantyne and Pickering, 2015b; Hamberg et al., 2008).

In Central Park, a dispersed use pattern and a high rate of self-reported off-trail use were observed for walkers and dog-walkers. Although these two activities are among the most popular in the park (Ilvesniemi and Saukkonen, 2015), insufficient GPS-tracked route data limited the possibilities for detailed analysis of their spatial behaviour. Gathering further GPS data from these user groups can help gain accurate and detailed spatial information on trail use and impacts for adaptive planning and management purposes. Results from Chapter II revealed that in our study sample, most walkers and dog walkers did not use sports tracking applications, but instead preferred the route drawing option. This requires further investigation and possibly finding new, fun and creative methods of engagement e.g. by gamification or using targeted advertising campaigns with integrated images of smartphone GPS tracking (see e.g. Shove and Pantzar (2005) on the importance of images for establishing Nordic walking as a social practice).
Figure 4. Off-trail use dispersion (x axis in metres) of different activities at the stand level. Dispersion is calculated based on the mean distance of off-trail GPS points to the edge of the 15 m buffered formal trails. Based on Chapter III.

Figure 5. Density (GPS points) and distribution trends of off-trail use for mountain biking, running and cycling at the landscape level. Adapted from Chapter III.

Conclusions and recommendations: Planning and management needs to understand the spatial and social aspects of visitor behaviour in order to balance human use and impacts, and
protection of natural resources (Beeco et al., 2013; Cole and Daniel, 2003; Orellana et al., 2012). The results from this study suggest that visitor spatial behaviour in urban green spaces is complex and influenced by the type of activity, as well as multiple utilitarian and nature-oriented motivations. While from a practical perspective it may be neither feasible nor useful to integrate the whole range of visitor motivations and demands, which may be often conflicting in multiple-use recreational areas (Arnberger, 2006; Moore, 1994; Santos et al., 2016), recognising spatial and motivational patterns of visitor behaviour could be of great benefit to planners and managers. Understanding common social-spatial structures among activity groups can help facilitate decision-making that is context- and user group-specific. Several recommendations for managing visitor spatial behaviour based on public engagement, co-planning and co-design are proposed in Chapter III. These are related to: 1) developing methods for encouraging use of a limited number of existing well-established informal paths in order to minimise cumulative spatial impacts in areas with high ecological value; 2) continuously using participatory techniques to reconcile resource conservation and the diversity of visitor needs, preferences and motivations; and 3) investigating the effect of new strategies on visitor spatial behaviour and refining practices based on those findings.

4.2 Integration of visitor movement with other social and ecological data is needed to capture key values for spatial planning

Chapter IV of the thesis compared and integrated the participatory route data (combined GPS-tracked and drawn routes) with other social data (i.e. multiple perceived landscape values of citizens) and ecological data (i.e. forest habitat quality index and urban biodiversity expert scoring). The spatial and statistical analysis indicated three main findings. First, we found only low mean spatial concurrence between the social and ecological datasets, which indicates their high complementary value to multi-criteria decision-making. Similar results have been found in other studies employing socio-ecological hotspot analysis for conservation and land use planning, however they were performed at much larger regional scales (Bryan et al., 2011; De Vreese et al., 2016; Karimi et al., 2015; Whitehead et al., 2014).

Second, the comparison between visitor use and landscape values indicated visually opposite spatial distribution patterns, a negative correlation, and very low overlap between their hot/coldspots. Although explanations for this spatial discrepancy may lie in the local context related to intra-site trail density and population density in the surrounding areas (see Chapter IV), these findings may be pointing to a more general trend. Landscape values and actual movement represent distinctive aspects of human relationships with the environment and the realized, everyday use may conceptually and spatially differ from general values at the larger landscape scale. Although a growing number of studies incorporates social values (including recreational values) into hot/coldspot analysis (e.g. Alessa et al., 2008; Bagstad et al., 2016; De Vreese et al., 2016; Karimi et al., 2017; Schröter and Remme, 2016; Whitehead et al., 2014), our results indicate the necessity of including visitor movement as a powerful complementary variable for informing planning and management. By excluding actual movement, there is a risk that spatial planning does not reflect everyday social practices and the habitual aspect of spatial behaviour.
The existence of a ‘value-action’ gap i.e. that environmental values may not necessarily be reflected in actual behaviour, is well-documented in environmental policy literature and research on environmental attitudes and behaviours (Barr, 2006; Blake, 1999; Kollmuss and Agyeman, 2002; Shove, 2010). This thesis highlights the need for further research on the ‘value-action’ gap of visitor use in UGS, which can be acquired from comparing case studies across various socio-ecological contexts. This will include investigating cultural differences and various spatial and temporal barriers such as trail infrastructure, seasonality, changing environmental conditions, and perceived barriers. For example, similar to other Nordic countries, the Finnish population has strong relationships with and values forests highly since forests have been an integral part of the landscape even in urban areas (Tyrväinen, 2001; Tyrväinen et al., 2007). This may give one explanation to why visitors value highly woodland areas in Central Park even without necessarily appropriating them. However, in other cultures and bio-physical contexts, or in cities with very culturally diverse populations, the relations and level of spatial (dis)agreement between perceived values and realized use may differ.

Further, in Chapter IV, we also found that the two methods for measuring ecological value in Central Park had a moderate degree of overlap. Thus, integrating forest inventory data and expert elicitation can provide a more comprehensive assessment of biodiversity in UGS consisting of diverse landscapes. Researchers and practitioners can take advantage of the detailed spatial information contained within each dataset, such as ecological characteristics and quality of particular stands or biotopes within a hotspot area, as a foundation for more fine-scale spatial analysis. Similarly, spatial outputs of the hot/coldspot analysis can be used to direct attention to areas of concern, where further social and ecological data can be obtained and analysed as part of iterative and adaptive processes. For example, this thesis produced multi-scale spatial knowledge on the relationship between visitor spatial behaviour and the bio-physical environment. In Chapter IV, the hotspot mapping provided a ‘snapshot’ of threatened areas at the landscape scale i.e. areas of overlap between high ecological value and high density of visitor use. These areas can be investigated with a finer resolution using smartphone GPS tracking and fieldwork mapping as demonstrated in Chapter I and visualised in Figure 6.

**Conclusions and recommendations:** Chapter IV showed that visitor movement, the values citizens assign to different landscapes, and biodiversity, provide important complementary information for UGS planning and management. These data hold distinctive value and each one can largely influence the spatial mapping, consequently leading to different guidance for decision-making. Integration of multiple social and ecological data can be beneficial to landscape planning in several ways. The hot/coldspot analysis can inform planners on overall social and environmental quality of the landscape and point out areas of spatial synergies and discrepancies between the different values. In addition, tapping into multiple sources of knowledge and stakeholder perspectives can make landscape planning generally more inclusive and socially-acceptable (Alessa et al., 2008; De Vreese et al., 2016; Donovan et al., 2009; Whitehead et al., 2014). In Chapter IV, we provide examples of science-based
guidelines for managing the multiple and conflicting elements, which can be developed and implemented with different levels of citizen engagement depending on the specific context.

Figure 6. An example of a multi-scale approach to analysing density of GPS-tracked visitor use in relation to ecological value in Helsinki’s Central Park. The ecological value consists of the summed and equally weighted forest habitat quality and urban biodiversity values analysed in Chapter IV. The sampled hotspot and sampled coldspot refer to the fieldwork mapping presented in Chapter I.

4.3 Modern participatory data collection methods can gather rich and valuable citizen information for planning and management

The smartphone GPS tracking method used in this thesis offers several methodological and practical benefits. First, it can help capture the dynamic dimension of spatial behaviour. Even with little data, the mountain biking off-trail GPS tracks accurately identified areas where heavy use and impacts occur. Such data can be used to analyse and monitor trends and changes in visitor use and ecological impacts (Hadwen et al., 2007), pointing out where management needs to be adapted before ecological conditions are too difficult to restore (Wolf et al., 2012). In addition, smartphone GPS tracking presents a valuable alternative to field surveys which can obtain accurate spatial data on informal paths but are generally time-consuming, expensive and invalid over time (Norman and Pickering, 2017; Walden-Schreiner and Leung, 2013). GPS tracked routes could be used as an accurate spatial foundation for
planning, managing and monitoring of trail infrastructure to meet changing visitor needs (Beeco et al., 2014; Higuera de Frutos and Castro, 2014; Hood et al., 2011; Santos et al., 2016). In the case of Central Park, the collected GPS tracks will be used to inform the new planning of trails e.g. to design mountain biking routes.

Further, participants in this study used their own mobile devices and did not need to carry a GPS logger or download a specific software application, which decreases the need for observation by researchers or self-reported routes of participants that may be biased or less accurate (Arnberger and Haider, 2005; Hallo et al., 2012; Wolf et al., 2012). It also reduces investment costs (Norman and Pickering, 2017), the potential loss of research equipment and the need for training for participation (Wolf et al., 2015). Study participants were asked to share routes they have already collected, which has an intrinsic value of using available VGI data for new and undiscovered purposes, while potentially improving the co-production of geographical knowledge (Feick and Roche, 2013).

However, using smartphone GPS tracking and VGI data also presents important challenges for research and practice. Data quality and spatial accuracy are commonly discussed issues in VGI and PPGIS literature (Brovelli et al., 2016; Brown et al., 2015; Feick and Roche, 2013; Flanagin and Metzger, 2008). In line with these studies, Chapter II showed that the user-generated GPS-tracked and drawn data exhibited heterogeneity and variation in data quality within and between the datasets, as well as within individual records. However, the mixed-methods approach adopted in this thesis allowed for cross-validation of the data and results. For example, the drawing of routes is unlikely to be sufficient as a stand-alone method as it is less accurate and detailed, and it is highly recall-dependent. Nevertheless, the density maps demonstrated that the method can be used to complement and strengthen the GPS mapping (Chapter III). In addition, the questionnaire provided information on self-reported behaviour that was used as a reference for estimating location accuracy of the VGI data (Chapters I, II and III).

The multi-method nature of the MyDynamicForest PPGIS tool had another important advantage. In Chapter II, we found that providing multiple modes of participation can help increase response rates and reduce bias associated with each data collection method (Brown et al., 2015). Despite that the GPS routes were generated by a number of sports tracking applications, the data was biased towards middle-aged males and vigorous movement (mountain biking, cycling and running), indicating similar gender and activity-dependent trends noted for sports tracking applications in general (Hirsch et al., 2014; Oksanen et al., 2015). The drawn data on the other hand, captured some of the most popular outdoor activities in Central Park such as walking and dog walking, and portrayed more equal gender and age distribution, thus increasing the socio-demographic representativeness of the sample (Chapter II). In addition, the utilization of a web-based PPGIS tool helped to reach younger generations that were under-represented in previous visitor use surveys conducted by City of Helsinki (see Ilvesniemi and Saukkonen, 2015). However, this should be considered with caution since under or over-representation of particular groups in PPGIS may not be systematic (Brown and Kyttä, 2014).
Conclusions and recommendations: The choice of data generation methods remains a subjective judgement between available inputs and useful outputs in relation to the focal practical and scientific targets, however, the trade-offs should be well understood. In this thesis, I showed that the integration of smartphone GPS tracking, PPGIS and questionnaires can help gather data that is heterogeneous, but rich and usable. While such data may be of less quantity (compared to e.g. big data sources), it may nevertheless provide more depth to the spatial behaviour analysis. In addition, PPGIS could be highly relevant when the aim is to encourage collaboration between citizens and land use planners (Brown and Kyttä, 2014) or facilitate knowledge exchange between managers and different user groups. Nevertheless, it is crucial to understand who has been involved in the process and develop methods to engage those that have been underrepresented.

4.4 A glimpse into the future: implementing co-produced knowledge in research and planning

To make this study and the presented approach more comprehensive, there are two major directions for future research including a temporal and a cross-comparison component. First, it is important to capture and integrate time and spatial change into more sophisticated spatial-temporal analysis of visitor spatial behaviour in urban green spaces similar to e.g. Walden-Schreiner et al. (2018) study in Hawaii Volcanoes National Park, USA, or Kim et al. (2018) study in Seoraksan National Park, South Korea. In the case of Central Park, this would involve extending the study sample to investigate use patterns in different seasons in order to examine variations in spatial behaviour and monitor associated impacts over time. For example, cross-country skiing is a very popular activity in the northern part of Central Park (Ilvesniemi and Saukkonen, 2015), which includes several protected areas and old-growth forests being home to a variety of wildlife such as many species of birds (e.g. hazel grouse, black woodpecker, crested tit), elk, badgers, foxes, bats and flying squirrels. Winter recreational activities (especially off-trail) can cause disturbance such as increased flushing distances, which is particularly problematic for wildlife when food is limited and additional energy expenditures are hard to compensate (Coppes and Braunisch, 2013). Although in Central Park there are a designated ski trails and cleared hiking trails, accurate spatially-explicit information on winter visitor use is still lacking. In addition, as discussed in Chapter IV, due to the rapidly changing climate and more frequent lack of snow cover during winter (Finnish Meteorological Institute, 2018), some of the existing formal trail infrastructure (e.g. duckboards) may become slippery and unfit for use, potentially leading to widening of paths or creation of informal networks.

In regard to expanding the sampling period, a great benefit of web-based data collection platforms like the MyDynamicForest is that they can be used over time, provided that citizen involvement is sustained. Chapter II suggested that the choice of advertising techniques may play a crucial role in recruiting participants. Therefore, the continuous or repeated use of the PPGIS tool would require a number of advertising campaigns as part of an iterative process, in which different user groups or time periods are targeted based on the response rate, representativeness of the sample and obtained results (Chapter II).
Another important aspect relates to the transferability of the applied methods and scientific findings. An essential advancement of this study would include a cross-city, -landscape, and –user group approach that will help to assess how the obtained knowledge can support UGS planning in different socio-ecological contexts. This is of international relevance as comparative interdisciplinary studies are needed in UGS research (Kabisch et al., 2015; Niemelä, 2014). Such comparative analysis can provide more insights on socio-cultural differences in spatial behaviour in UGS (e.g. demographics, preferences, values and motivations behind movement) and variations in spatial behaviour in different types of urban landscapes (e.g. woodlands, fields, highly maintained parks).

The presented PPGIS tool could be adapted to different case studies according to the local geographical context, research questions and availability of data. In Chapters I and II, I focused on the methodological perspectives of using smartphone GPS tracking and the PPGIS tool in order to provide detailed and thorough explanations of these methods, and consequently contribute to more reproducible work. While the study was based on Helsinki’s Central Park, I anticipate that this PPGIS approach can be highly relevant for various applications in inclusive and user-centred planning for sustainable cities (e.g. planning of commuter routes), provided that the study area is of sufficient spatial scale. The effect of scale requires further research, but I speculate that the method is not well suited for studying individual small-size pocket parks or green spaces due to inability to incorporate movement patterns and trajectories of different user groups. Instead, it could be used to analyse a network of pocket parks at the neighbourhood level in terms of connectivity and promotion of physical activity (see Cohen et al., 2014; Galpern et al., 2018). Stamberger et al. (2018) argued that battery life could be a possible barrier to applying the smartphone GPS tracking method in parks and protected areas, however this limitation could be surpassed in the near future with innovations in smartphone technologies and growing use of portable mobile phone chargers. Yet, it may be challenging to apply self-tracking GPS methodologies in areas where visitor use is restricted or prohibited as bias towards socially acceptable behaviour is likely to occur (Chapter III).

Finally, it is also important to remember that public participation is more than collecting data or using innovative technologies (Brown and Kyttä, 2014). One way to enhance the social benefits of using the MDF tool is to make communication more interactive through education and information feedbacks as demonstrated by various citizen science projects worldwide (Dickinson et al., 2012; Palacin-Silva et al., 2016). The MDF website includes description of how the generated data is used in planning and research, and real-time visualization of the collected route tracks. However, important findings from the questionnaire (e.g. on demographics, activities and motivations of participants), educational materials and recognition messages could be used to further promote learning, sense of community, and personal or social reward. Future research could also investigate how this participatory knowledge will be implemented in local planning and management, and how it directly benefits the physical quality of the environment (Fors et al., 2015) e.g. by conducting before and after analysis of the spatial distribution and intensity of use and impacts. Developing transferrable and replicable methods would require good understanding of the mechanisms of
success and failure in each context, as well as building on feedback processes from all stakeholders involved.

Overall, with this thesis I promote the general idea of participatory user-centred planning for liveable cities. Modern spatial technologies provide new and exciting opportunities for collecting and analysing data on the interplay between humans and the environment, however it should be considered by who and for whom such data is produced, and how it is used to benefit nature and society. Co-production of knowledge and responsible collaboration between citizens, planners and managers, and researchers from multiple disciplines should become a norm for planning the landscapes of tomorrow.
5. REFERENCES


Ballantyne, M., Pickering, C.M., 2015b. Differences in the impacts of formal and informal recreational trails on urban forest loss and tree structure. J. Environ. Manage. 159, 94–105. doi:10.1016/j.jenvman.2015.05.007

Balvanera, P., Kremen, C., Martínez-ramos, M., 2005. Applying Community Structure


27


Fors, H., Molin, J.F., Murphy, M.A., Konijnendijk van den Bosch, C., 2015. User participation in urban green spaces - For the people or the parks? Urban For. Urban Green. 14, 722–734. doi:10.1016/j.ufug.2015.05.007


Kim, J., Thapa, B., Jang, S., Yang, E., 2018. Seasonal Spatial Activity Patterns of Visitors with a Mobile Exercise Application at Seoraksan National Park, South Korea. Sustainability 10, 2263. doi:10.3390/su10072263


Lehtomäki, J., Tuominen, S., Toivonen, T., Leinonen, A., 2015. What data to use for forest


Rossi, S., Pickering, C.M., Byrne, J., 2012. Differences among hikers, runners and mountain bikers in a peri-urban park. The 6th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas, Stockholm, Sweden


Schipperijn, J., Ekholm, O., Stigsdotter, U.K., Toftager, M., Bentsen, P., Kamper-Jørgensen, F., Randrup, T.B., 2010. Factors influencing the use of green space: Results from a


