Gamification of forest-going: Opportunities for players, landowners and the forest industry

Samuli Laato [1,2], Sari Pynnönen [3] and Annika Kangas [4]

[1] *Gamification Group, Faculty of Information Technology and Communication Sciences, Tampere University, Finland*
[2] *Department of Computing, University of Turku, Vesilinnantie 5, Turku, Finland*
[3] *Natural Resources Institute Finland (Luke), Latokartanonkaari 9, FI-00790 Helsinki, Finland*
[4] *Natural Resources Institute Finland (Luke), Yliopistokatu 6 B, FI-80100 Joensuu, Finland*

Abstract

There is a substantial body of literature suggesting a wide range of health benefits from forest bathing, hiking and walking in nature. For this reason, it is worth looking into technologies that could direct people to these activities. In this study, we focused on location-based games (LBGs) to identify and elucidate opportunities that the games provide for forest-goers, landowners and the forest industry. We invited experts from the fields of gamification (n=5), forestry (n=8) and others (n=3) to a design workshop on this topic. Using a qualitative analysis and synthesis to organize the generated workshop material, we ended up with eight potential aspects where LBGs could benefit forest-goers, and six categories of use cases where the games could benefit landowners and the forest industry. Our findings can be understood as a general overview of the design space of LBG – forest –human interaction and serve as a basis for future work in this domain.

Keywords

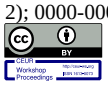
Gamification, forest, nature, forestry, location-based games, human-forest interaction

1. Introduction

For decades researchers have reported, in various empirical settings, that spending time in nature has a multitude of positive effects, both psychological [1-4] and physiological [5,6]. Even just viewing natural landscapes can have restorative effects (e.g., stress reduction) [7,8]. The positive outcomes of forest-bathing, forest-going and viewing natural landscapes and animals have been explained primarily by one of the two approaches: (1) our ancient evolutionary history and primal tendencies that have been shaped and fine-tuned to enjoy natural landscapes and nature in general [9,10] and (2) cultural aspects and other learned knowledge [11]. In the first case, it makes sense to put effort into motivating individuals, regardless of their culture and upbringing, to go to forests since we have a natural tendency to enjoy nature and receive health benefits from it [9,10,12]. Some researchers have been critical of this hypothesis [11], but also in the case that the tendency for enjoying forest landscapes is purely cultural, there are advantages of forest-going, such as obtaining exercise and healthy food through foraging [6]. Hence, we postulate that population level health benefits can be achieved by developing motivational technologies [13,14] that guide individuals to spend time in nature. In addition to benefits for the forest-goers themselves, forest visitors can be valuable for landowners and the forest industry, as forest-goers can, for example, provide data on wildlife sightings, alert owners of insect outbreaks or assess the magnitude of storm damages.

When looking for motivational approaches, gamification has received a lot of traction recently [15]. Among gamification approaches and motivational technologies, location-based games (LBGs) are particularly relevant due to their

6th International GamiFIN Conference 2022 (GamiFIN 2022), April 26-29 2022, Finland. EMAIL: samuli.laato@tuni.fi (A. 1); sari.pynnonen@luke.fi (A. 2); annika.kangas@luke.fi (A. 3)
ORCID: 0000-0003-4285-0073 (A. 1); 0000-0001-5427-8209 (A. 2); 0000-0002-8637-5668 (A. 3)



ability to influence player movement [16,17]. LBGs use a mixture of sensor data such as satellite navigation, pedometer and accelerometer data to support gameplay. Through controlling the placement of geographical in-game virtual points of interest (PoIs), LBGs can alter players' travel routes [16], highlight specific geographical areas [17], and bring players together at specific places [18]. LBGs have also been used to crowdsource data collection from specific locations [19,20], which makes them relevant for landowners and the forest industry. Hence, the games offer a lot of potential and are particularly relevant for human-forest-machine interplay.

This work seeks to fulfill two main research gaps. First, we seek to move beyond LBGs' capability to influence player movement [16,21], and understand what other potential benefits the games could offer for forest-goers beyond motivating them to go there. Second, we expand the research on crowdsourcing and gamification [20,22,23], as well as research on citizen science [24,25], by investigating what opportunities LBG players have for collecting information from forests that would benefit landowners and the forest industry. Accordingly, we formulate the following two research questions:

RQ1: What potential benefits can location-based games offer for forest-goers?

RQ2: What crowdsourcing opportunities do location-based game players offer for landowners and the forest industry?

2. Background

2.1. Benefits of forest-going

The literature on the benefits of spending time in forests has been traditionally divided into research on forest-bathing [5,6] (which can be defined as spending time in forests with the aim to immerse with the environment) and habitual short walks in forests [3]. The literature review of Payne and Delphinus [6] discovered 31 papers observing benefits of forest-bathing. They identified multiple physiological benefits, including increased immune and cardiovascular function and stabilization of the neuroendocrine function. Much of this body of research has been conducted in Japan, Asia and the northern hemisphere, and thus, the findings may not be relevant in, for example, Australia [6]. Forest-bathing has also been found to increase rumination, compassion and scaffold a connection with nature [5] as well as increase learning and concentration, especially in young children [1,2,4].

One of the often-discussed benefits of forest-going is reduced stress [3,7,8,26] which is also connected to self-reported increases in positive mood [5,26]. Taken together, we conclude that the evidence of the benefits of forest-bathing and habitual walking in forests seem overwhelming, but in addition, there is evidence that simply viewing forest scenery may have similar, albeit perhaps not equally strong effects [27,28]. Having access to parks and recreational grounds in urban environments can boost self-reported health as well as physical activity during leisure time [29]. In summary, there appears to be both research and practical justification in looking at how motivational technologies could be used to bring individuals into forests.

2.2. Gamification to address the challenges in the forest industry

We focus on a country that has a major forest industry, Finland. In Finland, 86% of the entire geographical area is forest land, which includes productive forests as well as open mountain areas and open bogs. 67% of the total area is being used at least to some extent for commercial timber production, and the rest is conserved by law, owner's decision or land use plan [30]. Around 60% of the forest area is owned by individuals with an average area of 30 ha per owner [31]. This means that in the Finnish population, there are roughly 600 000 individuals owning forest land.

Due to the large number of forest owners and the financial importance of the forest sector for Finland [32], there is a tradition of forest owners receiving advisory services from the forest administration and from market-oriented timber procurement and forest management service providers. Various forest service organizations employ foresters and forestry engineers to advise forest owners about the use of forests, produce information by compiling holding-level forest management plans and assist the forest owners in conducting timber sales. Technological development and the drive for more cost-effectiveness has increased the number of digital services also in forest management.

One challenge that forest owners face is the difficulty of knowing exactly what is in the land they own. To resolve this issue, the Finnish forest authority regularly collects and produces information from forests via sensors and remote

sensing methods[2] (e.g., camera shots taken by drones). However, the challenge here is that sensors provide information only from a limited forest area every year, and there are limits in what kind of information can be obtained from limited sensor data. Thus, currently collected information concerns mainly timber quantity. This means limited knowledge regarding flora and fauna, timber quality, possible storm damages, quality of water reserves in the area, hikers and travelers visiting the forest and so forth.

One way to further develop data collection from forests is gamification [20,22,23]. Past work has shown that individuals can contribute high quality data through gamified services that help benefit the larger population [22]. Even in Finland there currently do exist some services that make use of crowdsourcing, and these services are popularly used by hunters. However, it is clear there is a lot of unharnessed potential. For this reason, and addressing **RQ2**, we investigate how crowdsourcing, and gamification could be used in conjunction with location-based technologies to collect data from forests for landowners and the forest industry, and what this data could be.

3. Materials and methods

3.1. Data collection

The current research lies at the intersection of gamification and forest sciences, and therefore, it is crucial to obtain viewpoints from both disciplines. To this end, we designed a workshop for academic stakeholders for answering the two **RQs** presented in this work and joint discussions about how to reach these goals.

We recruited informants from primarily the fields of gamification and forestry by utilizing our extended networks. In addition to the organizing authors, altogether 16 participants joined the workshop, of whom 8 worked primarily in forest sciences, 5 in gamification and 3 in other related disciplines. The participants are detailed below in Table 1. Participants joined the workshop for 3 hours on September 23rd, 2021. The workshop was held online at Zoom due to limitations in travel caused by the COVID-19 pandemic. All participants stayed at the workshop until the end and agreed to the recording of the sessions as well as to the use of their anonymized answers in research.

Table 1
Informants of this study

ID	Primary field	Position
1	Gamification	Senior researcher
2	Gamification	Postdoc
3	Gamification	PhD student
4	Gamification	PhD student
5	Gamification	PhD student
6	Forestry	PhD student
7	Forestry	Postdoc
8	Forestry	Professor
9	Forestry	Project researcher
10	Forestry	Research fellow
11	Forestry	Research fellow
12	Forestry	Professor
13	Forestry	Senior researcher
14	Landscapes	Senior researcher
15	Business	Senior researcher
16	Psychology	Senior researcher

The workshop itself was organized as follows. In the beginning, the first author introduced the workshop topic by presenting the design space, design issues and a summary of past work on the topic (45min). This was followed by a group session (15min) in small teams about the design issue of how LBGs could benefit landowners and the forest industry. We went through the results together (15min) and had a small break (15min). Next, in the same small groups we discussed the potential of LBGs for forest-goers (15min) and again went through the results together afterwards (15min). We closed the workshop by collectively designing solutions to the identified issues (30min) and having general discussion on the feasibility of these solutions (30min). The second author took notes during the entire duration of the workshop and assisted in ensuring that the parallel group sessions operated smoothly. Immediately following the workshop, both organizing authors wrote down thoughts regarding the ideas presented at the workshop, and information related to them. These notes together with the workshop recording and transcription were used as data sources in the analysis.

3.2. Analysis

The goal of the data analysis was to identify and demystify all unique ideas presented at the

[2] Finnish Forest Centre, 2021. Open forest and nature information. Visited on Dec 1st 2021. https://www.metsakeskus.fi/en/open-forest-and-nature-information

workshop regarding the potential benefits that LBGs offer for (1) forest-goers; and (2) landowners and the forest industry. As is typical with inductive qualitative research, this process was iterative, and we adjusted our analysis to ensure all data points were considered and meaningfully connected [33,34]. The analysis process can be described as following three principal steps.

First, we familiarized ourselves with the data sources. We re-listened the recording of the workshop a couple of times and read the notes taken during and immediately after the workshop. At this stage, we fetched unique ideas and concepts of LBGs potential for forest-goers and landowners, guided by our a priori formulated research questions. Second, we conducted open coding [34] to fetch all the unique suggestions from the data. This was done by going through the session transcript and marking all mentions of these suggestions. At this stage, we stayed close to the data and avoided injecting our own interpretations to the process. Third and finally, we conducted axial coding to connect similar concepts together [33,34]. This was done by placing identified higher order keywords on each of the first order concepts, and then formulating higher level categories in which individual suggestions belonged to. At this stage we organized the presented ideas in a way that would offer a clear conceptual framework for understanding the data. Regarding **RQ1**, which concerned the potential benefits for forest-goers, we sought to distinguish between (1) mechanisms, (2) benefits, and (3) outcomes. Regarding **RQ2**, which was about the potential of forest-goers to crowdsource information, we distinguished between (1) motivators, (2) what data to collect, (3) and potential uses of the data. We conducted axial coding to connect similar concepts together [33,34]. This was done by placing identified higher order keywords on each of the first order concepts, and then formulating higher level categories in which individual suggestions belonged to. At this stage we organized the presented ideas in a way that would offer a clear conceptual framework for understanding the data. Regarding **RQ1**, which concerned the potential benefits for forest-goers, we sought to distinguish between (1) mechanisms, (2) benefits, and (3) outcomes. Regarding **RQ2**, which was about the potential of forest-goers to crowdsource information, we distinguished between (1) motivators, (2) what data to collect, (3) and potential uses of the data.

4. Findings

4.1. Potential of LBGs for forest-goers

We investigated the potential of LBGs to offer forest goers meaningful, positive or otherwise beneficial experiences. As a result of the workshop and included parallel expert discussions, eight potential positive outcomes were identified and connected to specific LBG mechanics. These are displayed in Figure 1 in the Appendix. The mechanisms and potential benefits are derived directly from the data, but their interconnections and the aggregate outcomes are part of the authors' interpretation of the data. Next, we go through these eight potential outcomes in detail.

4.1.1. Learning

The experts thought that it would be prudent for LBGs to teach players about how to behave in forests or natural environments. For example, in Finland, irrespective of forest ownership, there are everyman's rights that grant people the legal right to walk in forests as well as gather berries and mushrooms from there. LBGs could inform players about such rights. Furthermore, the games could teach about how to navigate in nature by providing a terrain map or teach about flora, fungi and animals that dwell in the forest.

Besides informative content, the experts theorized that LBGs could help players get acquainted with nature through connecting game mechanics to the real-world environment the players are in. One presented idea related to building a sensor network on top of which LBGs could be created that make detailed use of the environment. For example, aspects such as humidity, rain, slipperiness, terrain, birds and ant hills could be incorporated into the game.

According to the experts, these goals could be achieved through on-spot teaching, machine learning techniques for identifying sounds in the forest and machine vision or other techniques for identifying flora and fauna that the player encounters, providing them with information about. These approaches could be gamified and integrated as part of the LBG playing in such a way that players would learn about their environment while playing.

4.1.2. Obtaining food

The forests in Finland, Canada and elsewhere provide a lot of free healthy food, which serves as nutrition for e.g., bears, reindeer, multiple bird species, insects, bugs and humans. This nutrition includes, for example, lingonberries, blueberries, wild mushrooms and wild herbs. According to some estimates, over 90% of berries in Finnish forests are unpicked every year, even though roughly 3000 foreign foragers are invited to Finland annually to assist in the foraging[3]. Hence, despite the various life forms enjoying the nutrition as well, there is room for humans to increase the collection of this free food without harming the ecosystem.

There are several reasons why so much of the nutrition ends up wasted from the human perspective. First, finding mushrooms, blueberries etc. in their optimal season is not always a straightforward task. Second, it takes time and effort (and typically a car) to travel to distant forests. Some of the most remote areas also require hiking. A lot of people either lack the time or are willing to spare the effort. Third, not all forest-goers are able to identify which mushrooms, berries and herbs are edible, or may not know where to look.

The experts brought up machine vision methods, but also several other means through which LBGs could be designed or enhanced to help players identify nutritious food around them. For example, players could be given a set of questions about how a mushroom they found looks like, and through answering the questions the system could identify the mushroom and provide information about it. The concept of on-spot teaching was judged to be superior in terms of teaching, as it combined the experience in the forest and the discovery of something new with learning about what it is.

In addition to on-spot teaching and learning, the participants discussed how players could be directed to find berries and mushrooms. Here crowdsourcing and other means to pinpoint berry and mushroom locations could be investigated. These functionalities could also include a multiplayer component, as players could see which areas have already been checked by other players, meaning they could go look elsewhere. Furthermore, players could voluntarily choose to reveal optimal harvesting locations to other players. The experts also discussed how LBGs could utilize special in-game events to direct players to forests in specific times and seasons when interesting things happen, so they could be around when, for example, berries are ripe for picking.

4.1.3. A sense of belonging in nature

The concept of belonging was discussed at the levels of social belongingness and a sense of being united with nature. The experts discussed LBGs' potential to influence players' social life in two ways. First, the games provide ways to find companionship from other players. Second, the games can help players find time alone. Being united with other forest-goers can have social benefits but being alone in a forest can have meditative and restorative advantages. Some people may visit nature specifically to avoid busy and noisy urban life. The experts pinpointed that some forest-goers may specifically seek to avoid encounters with other people. Hence, both individual and multiplayer functionalities should be implemented to provide players the opportunity to enjoy nature as they want.

With regards to being united with nature, the experts associated the processes of spending time in forests, learning about the forest and having meaningful experiences in the forest with the development of a sense of belonging in nature. Furthermore, one of the introduced ideas suggested that LBGs could also connect homebound people to forests by, for example, creating games that are played from home, but which are based on real forests. Such games could be (1) purely map-based through using real world maps as the background; (2) built on top of a digital twin of a real forest; or (3) make use of 3D cameras mounted on top of a physical player where player 1 would physically go to the forest wearing a headset and player 2 would be home seeing what player 1 sees and participating in the experience.

4.1.4. Benefits to society

Players may obtain gratifications for participating in "the common good" such as

[3] More than 1000e income. This is how it's done with berries, https://www.is.fi/taloussanomat/oma-raha/art-2000001802063.html, visited 4th of December, 2021

climate change activism, collecting trash from forests, citizen science or informing other players about locations of nutritious food in a forest. While some of these aspects such as collecting trash from forests can be difficult to gamify, academic studies suggest that crowdsourcing information can be an effective strategy for collecting detailed and high-quality information [20, 22]. This was also the position taken by the experts in the workshop, as various ideas for crowdsourcing information were presented. Next, we discuss these ideas.

4.2. Potential of LBGs for crowdsourcing information about forests

Crowdsourcing was identified by the experts as the single biggest way LBG players could be useful to landowners and forest industry, but also to land use planning more widely. The ideas presented by the experts could be divided into ways to motivate crowdsourcing, what data to collect and use cases where the data could be used. These ideas arose directly from the data and the authors were responsible only for identifying and organizing them. They are summarized in Figure 2 in the Appendix.The experts brought forward five motivators for participating in crowdsourcing of forest data: (1) citizen science; (2) carbon conservation revenue programs as a source of external motivation; (3) learning and acquiring new skills; (4) having an emotional connection to nature and wanting to protect it; and (5) gamification elements.

These categories of motivation are broad, as for example, learning and acquiring new skills can encompass things such as the identification of plant species and bracket fungi, knowledge about forest wildlife and being able to navigate in forest landscapes. Regarding the emotional connection to nature, we note that while being in forests can boost this connection, it can also serve as a reason to go to forests in the first place.

From the LBG design perspective, the most relevant motivators are (3) learning and acquiring new skills; and (5) gamification. The rest will either come automatically, externally or implicitly in such a manner that it is difficult to incorporate them into LBG artifact design. The panel of experts produced some preliminary ideas for both (3) and (5). With regards to learning, the experts discussed e.g., on-spot teaching and augmented reality for enhancing the forest experience. Regarding gamification, the experts felt it was important that the game mechanics would be meaningfully connected to nature. Multiplayer functionalities were seen as particularly important, and they were also in focus when looking at the enjoyment of the forest-goers. This also aligns with previous studies on the use of gamification to motivate crowdsourcing [20].

4.2.1. Data collection

The experts highlighted the following aspects that LBG players could collect data from: (1) detection of dead wood; (2) obtaining knowledge which areas are popular among forest dwellers; (3) photos of beautiful scenery within the forest; (4) photos of storm damage, insect outbreaks or other calamities; and (5) pinpointing the location of animals, rare plant species, desired vegetation or undesired vegetation.

Regarding photos of beautiful scenery, this could also be used in research through investigating which elements contribute to the LBG players' preferences of a beautiful location (e.g., stones, streams and other water elements, paths, rocks, cliffs, vegetation, scenic landscape, trees, wildlife…). Regarding photos of storm damage and insect outbreaks, they are useful when combined with the players' location, as this can help pinpoint the locations, enabling a targeted investigation by professionals or other stakeholders. The pinpointing of animals and vegetation could be used to find berries and mushrooms, to remove invasive vegetation, or to understand the territories of wild animals. Altogether this information can be useful for both landowners, conservationists and foresters, where perhaps foresters are more concerned with timber quality, conservationists with animal locations and invasive vegetation and landowners with all the data points.

4.2.2. Use cases

Connected to the collected data and arising from having it at disposal, several use cases arose. The data could be used to support forestry decision making, or decision making, cities, municipalities, landowners, public organizations or other stakeholders. The decision-making processes can draw from all the data sources mentioned in the previous section, as well as other data sources. For example, photographic data of

beautiful scenery could be used to design hiking trails that take people to these beautiful places, promoting hiking, tourism and enjoyment in nature. Landowners can use the data to learn about their forests.

The data on insect outbreaks and storm damages can be particularly useful for forest officials when mitigating damages or deciding what action to take in the case of a calamity. For example, if a forest fire breaks out it may be useful to know what all wildlife could be in that area, how the fire is expected to spread (by knowing the type and quality of the vegetation) and so forth. Overall, this data can be useful in supporting the planning of forest management and voluntary conservation programs.

5. Discussion

5.1. Key findings

We summarize our findings regarding the two research questions of this study as follows: Regarding **RQ1 "***What potential benefits can location-based games offer for forest-goers?"*, we identified eight unique benefits ranging from learning how to behave in forests and establishing a connection with nature to assistance in finding companionship or time alone. The benefits could be connected to four aggregate themes, which were: (1) learning; (2) obtaining nutrition; (3) a sense of belonging; and (4) benefitting society. The participants also detailed out design ideas and mechanisms for reaching these goals, which lay the groundwork for design-oriented studies in LBGs for supporting beneficial human-forest interaction (See Figure 1).

Regarding **RQ2** *"What crowdsourcing opportunities do location-based game players offer for landowners and the forest industry?",* our findings were sorted into three categories: (1) motivators; (2) what data to collect; and (3) how the data can be used. The motivation part was largely a collection of gamification and design strategies for making participation more fun. This information can be used as ideas in design – oriented work. Among what data to collect we obtained a diverse set of ideas ranging from detection of decayed wood to pinpointing locations of unwanted or desired vegetation (See Figure 2). The use cases were also manifold, and according to the informants crowdsourcing forest information can be beneficial for forestry decision making, tourism, landowners to learn about their land, the creation of digital twins and simulation games.

5.2. Theoretical and practical implications

Our findings revealed some new potential benefits which have not yet been mentioned in the extant literature on LBGs (see, e.g. [35]). These included the potential of LBGs to direct players to learn about nature, find nutrition, assist in the formation of an emotional connection with nature, find time alone and support walking in more uneven terrain than what is likely to be found in urban spaces. These findings are important, as most contemporary LBGs are designed primarily for urban spaces [16,36] and the potential of the games for scaffolding meaningful interactions with nature is still largely unharnessed.

With regards to the discovered opportunities for crowdsourcing data from forests for landowners and the forest industry, we contribute to the research on crowdsourcing and gamification [19,20] by identifying and elucidating what data could be collected that would be valuable for stakeholders in the field of forestry. Our findings can also be relevant for the research in forest management using field data [37], as we present ideas on what data to collect and propose preliminary design ideas on how crowdsourcing could be implemented to get the data. Finally, work on engagement with citizen science [24,25] could benefit from these findings, as our findings included mechanisms and motivators involved in player participation in crowdsourcing data from forests.

5.3. Limitations and future work

In all research involving experts, the sampling of the experts opens some limitations, since likely there will always be some viewpoints that are excluded. For this reason, the ideas generated by the experts are not an exhaustive list of all possibilities. To address this limitation, future work could involve stakeholders with even more diverse backgrounds. In addition, we collected data from a single session. While the workshop contained parallel sessions and produced rich data, additional iterations involving the experts could yield further ideas and help rank the ideas based on significance and applicability. To address this limitation, we propose that this line of

research is continued by adopting iterative qualitative methods such as the Delphi-method [38].

With regards to the presented design suggestions and goals of LBGs for the forest industry, we encourage future studies to look further into the discovered goals and benefits. Our findings offer a groundwork for design science research that seeks to come up with prototype designs and LBG artifacts that aim to fulfill one or several of the design goals identified in this study. Finally, while our focus was on the benefits of LBGs, recent research has urged scholars to also acknowledge and study the negative outcomes of gamification [39]. Hence, future work should involve the careful study and appraisal of LBGs potential negative influence.

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7. References

[1] Kaplan, R., & Kaplan, S. The experience of nature: A psychological perspective. NewYork: Cambridge University Press (1989).

[2] Sivarajah S, Smith SM, Thomas SC. Tree cover and species composition effects on academic performance of primary school students. PLoS ONE 13(2): (2018).

[3] Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. The influence of urban green environments on stress relief measures: A field experiment. *Journal of environmental psychology*, *38*, 1-9. (2014).

[4] Wells N. M. At home with nature, Effects of "Greenness" on Children's Cognitive Functioning. Environment and behavior, 32(6), 775-795. (2000).

[5] McEwan, K., Giles, D., Clarke, F. J., Kotera, Y., Evans, G., Terebenina, O., ... & Weil, D. A Pragmatic Controlled Trial of Forest Bathing Compared with Compassionate Mind Training in the UK: Impacts on Self-Reported Wellbeing and Heart Rate Variability. *Sustainability*, *13*(3), 1380. (2021).

[6] Payne, M. D., & Delphinus, E. A Review of the Current Evidence for the Health Benefits Derived from Forest Bathing. *International Journal of Health, Wellness & Society*, *9*(1). (2019).

[7] Hartig, T., & Staats, H. Linking preference for environments with their restorative quality. *From landscape research to landscape planning: Aspects of integration, education and application*, *12*, 279-292. (2005).

[8] Purcell, T., Peron, E., & Berto, R. Why do preferences differ between scene types?. *Environment and behavior*, *33*(1), 93-106. (2001).

[9] Ulrich, R. S. Aesthetic and affective response to natural environment. In *Behavior and the natural environment* (pp. 85-125). Springer, Boston, MA. (1983).

[10] Ulrich, R. S. Human responses to vegetation and landscapes. *Landscape and urban planning*, *13*, 29-44. (1986).

[11] Joye, Y., & Van den Berg, A. Is love for green in our genes? A critical analysis of evolutionary assumptions in restorative environments research. *Urban Forestry & Urban Greening*, *10*(4), 261-268. (2011).

[12] Orians, G. & Heerwagen , J. Evolved responses to landscapes in the adapted mind: Evolutionary psychology and the generation of culture . New York: Oxford University Press. (1992)

[13] Koivisto, J., & Hamari, J. The rise of motivational information systems: A review of gamification research. *International Journal of Information Management*, *45*, 191-210. (2019).

[14] Oinas-Kukkonen, H. Behavior change support systems: A research model and agenda. In *International Conference on persuasive technology* (pp. 4-14). Springer, Berlin, Heidelberg. (2010).

[15] Hamari, J. Gamification. G. Ritzer, C. Rojek (Eds.), The Blackwell Encyclopedia of Sociology, New York John Wiley & Sons (2019).

[16] Colley, A., Thebault-Spieker, J., Lin, A. Y., Degraen, D., Fischman, B., Häkkilä, J., ... & Schöning, J. The geography of Pokémon GO: beneficial and problematic effects on places and movement. In *Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 1179-1192). (2017).

[17] Juhász, L., & Hochmair, H. H. Where to catch 'em all?–a geographic analysis of

Pokémon Go locations. *Geo-spatial information science*, *20*(3), 241-251. (2017).
[18] Laato, S., Inaba, N., & Hamari, J. Convergence between the real and the augmented: Experiences and perceptions in location-based games. *Telematics and Informatics*, 101716. (2021).
[19] Celino, I., Cerizza, D., Contessa, S., Corubolo, M., DellAglio, D., Della Valle, E., & Fumeo, S.. Urbanopoly--A social and location-based game with a purpose to crowdsource your urban data. In *2012 International Conference on Privacy, Security, Risk and Trust and 2012 International Confernece on Social Computing* (pp. 910-913). IEEE. (2012)
[20] Morschheuser, B., Hamari, J., & Maedche, A. Cooperation or competition–When do people contribute more? A field experiment on gamification of crowdsourcing. International Journal of Human-Computer Studies, 127, 7-24. (2019).
[21] de Souza e Silva, A., Glover-Rijkse, R., Njathi, A., & de Cunto Bueno, D. Playful mobilities in the Global South: A study of Pokémon Go play in Rio de Janeiro and Nairobi. *New Media & Society*, 14614448211016400. (2021).
[22] Morschheuser, B., Hamari, J., Koivisto, J., & Maedche, A. Gamified crowdsourcing: Conceptualization, literature review, and future agenda. International Journal of Human-Computer Studies, 106, 26-43. (2017).
[23] Yang, C., Ye, H. J., & Feng, YUsing gamification elements for competitive crowdsourcing: exploring the underlying mechanism. *Behaviour & Information Technology*, *40*(9), 837-854. . (2021).
[24] Crocker, E., Condon, B., Almsaeed, A., Jarret, B., Nelson, C. D., Abbott, A. G., ... & Staton, M. TreeSnap: A citizen science app connecting tree enthusiasts and forest scientists. *Plants, People, Planet*, *2*(1), 47-52. (2020).
[25] Poisson, A. C., McCullough, I. M., Cheruvelil, K. S., Elliott, K. C., Latimore, J. A., & Soranno, P. A. Quantifying the contribution of citizen science to broad-scale ecological databases. *Frontiers in Ecology and the Environment*, *18*(1), 19-26. (2020).
[26] Reese, G., Stahlberg, J., & Menzel, C. Digital shinrin-yoku: Do nature experiences in virtual reality reduce stress and increase well-being as strongly as similar experiences in a physical forest? (preprint) accessed 13th of October 2021, available at: https://psyarxiv.com/bsmdq/
[27] Takayama, N., Korpela, K., Lee, J., Morikawa, T., Tsunetsugu, Y., Park, B. J., ... & Kagawa, T. Emotional, restorative and vitalizing effects of forest and urban environments at four sites in Japan. *International journal of environmental research and public health*, *11*(7), 7207-7230. (2014).
[28] Tsunetsugu, Y., Lee, J., Park, B. J., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landscape and Urban Planning*, *113*, 90-93. (2013).
[29] Pietilä, M., Neuvonen, M., Borodulin, K., Korpela, K., Sievänen, T., & Tyrväinen, L. Relationships between exposure to urban green spaces, physical activity and self-rated health. *Journal of outdoor recreation and tourism*, *10*, 44-54. (2015).
[30] Natural Resources Institute Finland E-yearbook of food and natural resource statistics 59/2017. Finnish forests 2009-2013 and their development 1921-2013 (2017).
[31] Leppänen, J., Torvelainen, J., Tilasto: Metsämaan omistus 2013. Statistics 23.1.2015 (No.5/2015), Luonnonvara- ja biotalouden tutkimus, Natural Resources Institute Finland (2015)
[32] Rantala T., Primmer E. Value positions based on forest policy stakeholders' rhetoric in Finland. Environmental Science and Policy 6:205–216. (2003). doi: 10.1016/S1462-9011(03)00040-6
[33] Saldaña, J. The coding manual for qualitative researchers. Thousand Oaks, CA: Sage. (2013).
[34] Strauss, A., & Corbin, J. *Basics of qualitative research techniques* (pp. 1-312). Thousand oaks, CA: Sage publications. (1998).
[35] Laato, S., Pietarinen, T., Rauti, S., & Sutinen, E. Potential benefits of playing location-based games: an analysis of game mechanics. In *International Conference on Computer Supported Education* (pp. 557-581). Springer, Cham. (2019).
[36] Papangelis, K., Chamberlain, A., Lykourentzou, I., Khan, V. J., Saker, M., Liang, H. N., ... & Cao, T. Performing the digital self: Understanding location-based social networking, territory, space, and

identity in the city. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *27*(1), 1-26. (2020).

[37] Hyyppä, E., Yu, X., Kaartinen, H., Hakala, T., Kukko, A., Vastaranta, M., & Hyyppä, J. Comparison of backpack, handheld, under-canopy UAV, and above-canopy UAV laser scanning for field reference data collection in boreal forests. *Remote Sensing*, *12*(20), 3327. (2020).

[38] Linstone, H. A., & Turoff, M. (Eds.). *The delphi method* (pp. 3-12). Reading, MA: Addison-Wesley. (1975).

[39] Schöbel, S., Schmidt-Kraepelin, M., Janson, A., & Sunyaev, A. (2021). Adaptive and Personalized Gamification Designs: Call for Action and Future Research. *AIS Transactions on Human-Computer Interaction*, *13*(4), 479-4.

8. Appendix

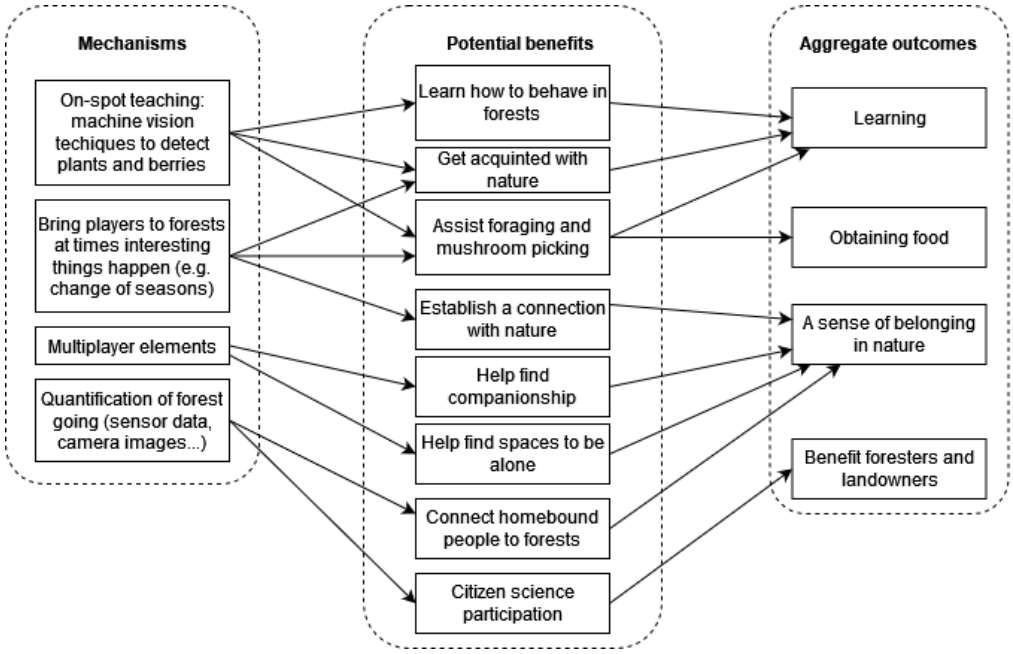

Figure 1: Mechanics, potential benefits and aggregate outcomes that LBGs can have for forest-goers.

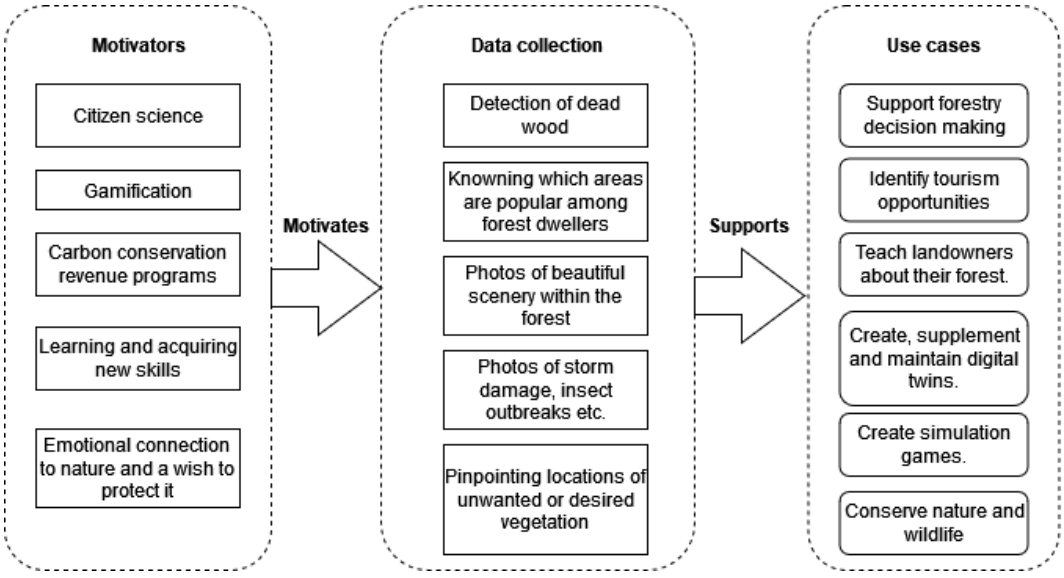

Figure 2: Motivators, what data to collect and use cases with regards to crowdsourcing data from forests using LBGs.