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Playing for the Planet? A Serious Game Approach to Land Use Planning with Students in Rural Iceland

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Abstract: Effective nature conservation and citizen participation are essential for sustainable development and biodiversity preservation. This paper introduces the 'Land Use Game', a prototype serious game designed to engage citizens—particularly younger demographics—in participatory land use planning. Developed within the context of the EU Horizon 2020 PHOENIX project, the game was tested with students in two rural Icelandic municipalities as part of a pilot study. The game enables participants to assign land use preferences through interactive mapping, supporting a better understanding of land use complexities while promoting active learning and dialogue. The study evaluates the game's feasibility, technological features, and practical applications, highlighting insights from gameplay observations, participant feedback, and spatial analysis. The results demonstrate the potential of serious games to collect meaningful data, support inclusive decision-making, and empower citizens to contribute to sustainable policies. By incorporating such tools, planners can enhance public understanding, promote equitable land use, and strengthen participatory democracy.

Keywords: land use; citizen participation; participatory mapping; GIS; Iceland

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1. Introduction

Effective nature conservation strategies and the active participation of citizens in democratic processes are crucial for ensuring sustainable development and preserving biodiversity [1,2]. The PHOENIX project is a European Union funded research project which seeks to give citizens meaningful participation in the European Green Deal (EGD). PHOENIX connects a multidisciplinary consortium of fifteen partners from the different macro-regions of the EU and associated countries. One of the eleven case-studies is focused on the issue of land use in the central highlands of Iceland, with the first stage of the case-study exploring the municipalities of Bláskógabyggð and Rangárþing ytra as case-study areas, where overlapping land uses as such energy production, sheep grazing, tourism, and reforestation are leading to increasing tension and conflicts.

This case-study seeks to engage citizens in the process by using so-called serious games in a public participatory approach to explore the issue and role of land use in the socio-economic transition of the EGD. In the context of this case-study, we developed a serious game to stimulate public participation in land use planning. This paper introduces the prototype of this game called the Land Use Game and explores its feasibility, technology, and practical research applications in the context of real-world land use issues. This

paper is structured as follows: First, we provide an overview of the relevant literature on public participation in planning, e-participation, and serious games. Next, we describe the prototype serious game developed in this study, along with its regional spatial context in which it was tested. We then present the results of the game's application and its potential for analysis. In the discussion, we analyse these findings in the context of research on serious games for public participatory land use, exploring their implications. Finally, we conclude the paper and suggest directions for future research.

2. Literature Review

2.1. Public Participation in Planning

Planning has increasingly become linked to democratisation and equality. The foundational work of *The Death and Life of Great American Cities* by Jacobs [3] demonstrated how the former rationalist approach to planning had catastrophic negative effects in the United States. As such, in the late 1990s and early 2000s, planning practitioners begun to reevaluate best practise. A work illustrative of this process was Forester's [4] work, *The Deliberative Practitioner*, which through detailed observations of planning practices argued in favour of public participatory planning (PPP). Demonstrating the implementation of this paradigm shift, a 2013 World Bank report highlights how PPP can 'harness the spirit of organic participation—which is driven by motivated agents, is contextually sensitive and long-term, and is constantly innovating in response to local realities' [5] (p. 284).

A popular approach within PPP is participatory geographic information systems (PPGIS) [6]. PPGIS utilise modern geographic information systems (GIS) to further engage participants in the planning process. Sieber was one of the first to lay out a framework for effective PPGIS [6]. This includes ethical considerations around anonymity and data collection. Since then, the use of PPGIS has been explored in various projects and across various disciplines. In an abstract sense, PPGIS could be viewed as turning citizens into sensors that can be utilised in the GIS environment [7].

The general development of PPGIS can be broadly categorised into three stages. (1) Desktop GIS, (2) web GIS, and (3) Geospatial Web GIS each represent a movement from 'an elite field of expert professionals to that of ordinary citizens' [8] (p. 432).

In urban planning, Rall et al. found in their research of urban green spaces in Berlin that PPGIS improved 'decision-making capacity and heightening potential acceptance of planning decisions' meaning 'PPGIS has the potential to contribute towards more sustainable urban development' [9] (p. 271). In ecology and land use, local PPGIS participants have shown to be valuable contributors of local knowledge for the planning process. Brown found that respondents were highly effective at determining areas of native vegetation with an 'error rate of about 6% in identifying native vegetation' compared to 'mapping error rates that would be expected by chance, [to be] about 22%' [10] (p. 292). Cox et al. came to similar conclusions when US respondents were asked to identify species habitat areas [11].

Barriers to PPGIS usage are no longer technological, but rather institutional [8]. Despite this, there are methodological drawbacks that need to be considered. Sample size is one such consideration. Brown and Kyttä note that 'in a large study area, it is possible that only 10 out of 300 participants actually map spatial preference' [12] (p. 131), but question how much consideration or importance should be given to the views of those individuals regarding land use in that area. Therefore, sample size and representation are key methodological considerations within the use of PPGIS processes.

Despite this, further democratisation within the planning process is still needed to combat existing inequalities. Considerable intersectional factors mean the persistence of hostile planning, specifically along the intersections of class, gender, age, and disability [13]. However, involving marginalised communities in the planning process often

proves challenging. For instance, low-income groups may lack the time and resources to participate fully, while individuals with disabilities might face inaccessible public forums or consultations [14]. Additionally, language barriers or digital illiteracy can hinder engagement [15]. To overcome these obstacles, e-participation platforms have emerged as a promising solution, allowing broader access to the planning process. By utilising digital tools, such platforms can support the inclusion of underrepresented groups, particularly by reducing physical and temporal barriers to participation [16,17]. In order to mitigate these inequalities in planning, new ways to involve the public have been developed, particularly with the support of new information and communication technologies (ICTs).

2.2. E-Participation

'E-participation involves the extension and transformation of participation in societal democratic and consultative processes, mediated by information and communication technologies' [18] (p. 406). In a practical sense, e-participation can be seen as a way for citizens to provide input and exert influence over government policy and actions [19]. Tambouris outlines a framework for e-participation ascending in levels from the least to the most meaningful participation as 'e-informing, e-consulting, e-involving, e-collaborating and e-empowerment' [20] (p. 7).

The benefits of e-participation to the processes of democratisation have been shown, e.g., by Fedotova who demonstrated the success of the national 'O Meu Movimento' platform in Portugal, which from January to February of 2012 generated over 1007 policy ideas from the public [21]. However, the project was dominated by male respondents (82%), suggesting a lack of active outreach and engagement. Therefore, ensuring representative sampling is of importance to ensure that participation is fair and representative. Whilst national level e-participation was effective, local municipal level e-participation was mainly focused on 'e-informing' where government used ICT resources to push information out to constituents, rather than to engage in a constructive dialogue [21] (p. 157).

E-participation has been discussed in academic literature, though Wirtz et al. describe the field as suffering from 'a diffuse, heterogeneous state of knowledge' [19] (p. 9). The authors suggest that a framework focusing more on accountability, transparency, technology, and stakeholder engagement must be employed when utilising e-participation. They identify six key objectives for e-participation: '(1) increase overall participation, (2) enhance information provision, (3) improve quality of public policies, (4) strengthen public trust, (5) improve and share responsibility for policymaking, and (6) raise public awareness and understanding for policy issues' [19] (p. 4).

2.3. Gamification and Serious Games

Gamification refers to the use of game-like experiences to 'motivate' and 'foster' participation [22]. A game, whilst having a fluid definition in the literature, broadly conforms to ten elements [23]. The most important of these are rules, functions, players, goals, and objectives. Games can be both digital and non-digital. Whilst the precise definition of gamification varies, there exists a commonality in the literature, with definitions commonly including the idea of using game mechanics and game thinking to engage users in problem solving on topics not usually included in traditional games [24], such as land use planning.

However, the concept of what constitutes a game remains highly debated in academic circles. Juul [25] presents games as 'half-real', involving a combination of real rules and fictional outcomes, where players navigate between the two. Salen and Zimmerman [26] offer a more system-based definition, seeing games as systems where players engage in artificial conflicts defined by rules that result in quantifiable outcomes. These diverse

interpretations highlight the complexity of defining games and underline the importance of considering a range of perspectives in gamification discourse.

Research into gamification for education has shown that both non-digital and digital gamification boosts student outcomes, with non-digital games having slightly higher user satisfaction [27]. Effective gamification is interdisciplinary, utilising diverse research skills such as psychology to develop a user-centred experience which adds value to participation [28].

Thiel [29] presents two forms of gamification: (1) rewards-based gamification and (2) social-based gamification. In rewards-based gamification, respondents are motivated to complete the game through tangible rewards and incentives or through digital (or other) rewards and incentives. In social-based gamification, respondents are incentivised to engage with the game through a sense of community and social standing. An example of this can be seen in the GreenMapper project, which collected 15,000 responses from participants in The Netherlands, Germany, Denmark, Switzerland, Italy, Brazil, and South-Korea. These respondents were asked to choose a location of natural value, initially within a local, regional, national, and global scale [30]. Participants could then engage in a discussion with one another, as well as taking on roles as discussion moderators for their local communities. Both rewards-based and social-based gamification have been shown to increase participation rates when compared to control groups with the same tasks without elements of gamification [29,31].

Whilst gamification did 'add to some users' motivation' to engage in a topic they were already interested in, it did 'not succeed in engaging new groups' [31] (p. 158). Therefore, gamification may increase the quality of engagement, but is less likely to be able to attract new groups to the discussion. As such, gamification techniques should be used alongside other forms of community outreach.

Smaller sample size studies are not necessarily a problem and may be justifiable as remaining relevant. Thiel's study on rewards vs. social gamification [29] had only fifteen respondents. This is far below the standard accepted in academic journals [32]. These findings are therefore not described as statistically significant results but rather as 'tendencies'. As such, whilst sample sizes for general PPGIS applications are of considerable importance to reliability, gamification appears to be more dynamic when approaching respondent numbers.

One form of gamification is known as serious games. As noted in the literature, defining a serious game is difficult given the plethora of serious game applications ranging from military, government, educational, corporate, and healthcare [33]. Laamarti et al. define a serious game as 'an application with three components: experience, entertainment, and multimedia' [34] (p. 4) which contains game elements alongside a key learning point.

2.4. Land Use and Serious Games

Engaging citizens in decision-making processes related to land use planning and environmental policies is essential for fostering a more inclusive and participatory democracy. However, many individuals feel disconnected from such processes due to complex technicalities and a lack of accessible platforms for meaningful participation [35]. In addition, overly complex legal frameworks and administrative inefficiencies contribute to this sense of disconnection, highlighting the need for streamlined processes that balance public objectives with private property rights and ensure equitable and productive land use [36,37]. Interactive online games present a unique opportunity to bridge this gap by providing an engaging and accessible means for citizens to interact with or propose land use scenarios that can feed into the development of green policies [38].

By leveraging the power of technology and gamification, online platforms can simulate real-world land use scenarios, allowing users to make decisions and witness the consequences of their choices [39,40]. Such interactive games create a dynamic and immersive experience that encourages active learning and empowers participants to understand the complexities of land use and its implications for nature conservation. Furthermore, incorporating a playful element into policy engagement promotes increased citizen interest, motivates information sharing, and enhances critical thinking skills [41,42].

Research on the motivation and personal perceptions of citizens engaged in such a process can provide valuable insights into their experiences and attitudes and behavioural outcomes that can be useful for planning and policy making that is more oriented at citizens' views and aligned with the demands of local communities [43].

The quality of our democracies can be improved by incorporating a playful approach to land use engagement through interactive online games such as a game exploring people's land use preferences. Such a land use game can be incorporated as a tool at several stages during the democratic process as an additional democratic innovation, such as in citizen consultation, education and awareness, collaborative planning, policy evaluation, data collection and analysis, or stakeholder engagement. By enhancing public understanding of land use issues, facilitating informed decision-making, and empowering citizens to propose green policies, these games have the potential to strengthen nature conservation efforts while fostering a more inclusive and participatory democratic society.

Since the first use of serious games in land use planning linked to climate change issues in 2011 [44], there has been a considerable upwards trend in studies related to serious games and climate change planning. Sgueo identifies three accelerators of serious game usage for land use planning projects [45]. Firstly, there is an enhanced level of communication and scrutiny between citizens and government through the use of digital technology. This has changed the way that citizens, interest groups, and stakeholders interact with governments. Secondly, fiscal austerity following the 2008 global financial crisis led to government actors viewing serious games as a cost-efficient method of citizen participation, requiring less costly human-based consultative processes. And thirdly, increasing regulatory requirements create issues around regulatory compliance. Governments view public participation such as through the use of serious games as an important step in a planned project which can be utilised to validate a social license to operate.

As such, the width and breadth of land use serious games has expanded beyond traditional industry and academic uses. The mass market land use game SimCity is one of the manufacturer Electronic Arts' (Redwood City, CA, USA) best-selling video games [46]. These mass market games have been so popular and effective, that some have been modified for professional use. For example, Cities Skylines has even been modified to train future real estate and land use planners [47]. These modified games 'can teach anything from economics, urban planning, and even environmental studies' [48] (p. 3).

Much like regular gamification, land planning-based serious games rely on three drivers of citizen participation, the (1) utilitarian, (2) hedonic, and (3) socially motivated [49]. The utilitarian views their participation as aiding in the policy process to potentially facilitate a more desirable outcome. The hedonic respondent participates due to enjoying the process, e.g., they may find a particular game aspect enjoyable. Finally, the socially motivated respondent engages with the serious game due to sociological drivers, e.g., conforming to group behaviour, feeling part of community, or emulating a target behaviour which has social value in the respondents' society. It is important for land use serious games to ensure the user-experience tailors to all three of these respondents' motivations to maximise response rates.

One major benefit of land use serious games is that they lower the practical and social barriers to participation within the planning process. This increases participation in the planning process and thus makes the processes more representative of diverse stakeholders. Significant drawbacks in the representation of traditional consultation practices include [50] the amplification of social conflict and power dynamics, inequality of power from stakeholders, overrepresentation of traditional interest groups, lack of motivation and expertise on the topic amongst the general public, barriers to the inclusion of minorities and disadvantaged social groups, and, finally, suspicion and cronyism and lack of trust in the governmental process.

To address this, the gamification of the planning process is a 'way to foster civil society engagement, confront the decline of trust in the public sphere, revive democratic legitimacy, and possibly overcome the disruptive populist political offers that are flourishing across Western democracies' [45] (p. 7). Similarly, in their land use planning game for ecosystem services in two test sites in France, Brunet et al. note that gamification broke down social barriers and traditional power structures 'create a friendly atmosphere through which ecosystem services knowledge could be used and communicated more easily' [51] (p. 32). Similar findings were replicated by Michalscheck et al. who demonstrated that land use games reduced traditional power dynamics and lead to more equitable land use in Northern Ghana [52]. Therefore, serious games can have considerable benefits by increasing the representativeness of the planning process. This has been shown to be effective across various contexts, cultures, and countries.

Moreover, serious land use games facilitate access to insider knowledge which can be invaluable to planners. Local stakeholders often have sources of information unavailable to the planner, for example, generational knowledge on the local area. This form of information is 'actionable knowledge' [51] (p. 27), knowledge a policy maker can actively use to improve the outcomes of the project. This form of knowledge has been shown to increase the effectiveness of planning. For example, in a stakeholder land use game in rural Brazil, stakeholders' responses to the game were able to provide dynamic and immediate feedback on policy proposals [53]. This feedback could then be actioned at an expedited pace when compared to traditional feedback loops such as impact assessments.

Finally, land use serious games boost engagement between planners and stakeholders. In their study of 64 published research papers on serious games, Galeote et al. found 'the vast majority of the results reported indicate that games can impact multiple engagement dimensions at the same time, as well as provide engaging and enjoyable ludic experiences' [44] (p. 21). In addition to this, serious games assist planners in communicating complex planning issues in ways which empower learning and engage respondents [50]. More recently, the use of virtual reality (VR) serious games in the designing of a suburb of Istanbul, Turkey, found the game dynamic allowed citizens to engage with the design process and provide feedback on the project's direction [48].

Limitations of serious games in a research context include poor game design, functionality, and a lack of rewards as constraining factors in serious game effectiveness for land use planning [50]. These limitations can be overcome by employing a proper game design framework [54]. On the respondent side, serious land use games can be limited in their value through confusion and lack of gaming experience by the participants [50]. This can be mitigated through proper game instructions, intelligent user-interfaces, and in-person demonstrations. However, it remains a concern that some respondents may find engaging with serious games a challenge. This is especially true for those who may have a disability or for elderly people, especially if games require a high level of digital literacy. Therefore, gameplay features should be tested for accessibility.

Another limitation is the relative cost and complexity of creating a land use serious game. As such, there has been a growth in the open-source software and more cost-efficient alternatives. For example, the gdevelop.io platform allows users to create and publish their first game for free, before a nominal fee is charged for subsequent games and services. More recently, the PlayWithUnicam project has been aiming at creating a free open-source platform for serious games [55]. Therefore, whilst cost is a consideration to the efficacy of serious games, cost-efficient alternatives are increasingly available.

Finally, some land use topics may be too controversial or contentious to include in serious games. Brunet et al. found that the use of ecosystems services as a game dynamic made respondents uncomfortable, as respondents felt this topic was 'to serious an issue for game play' [51] (p. 32). Whilst serious games can enhance participatory land use practices, they should be employed with sensitivity. Moreover, reproducibility may be a major limiting factor for serious games. The same study showed that it can often be the case that respondents misunderstand land use serious games and play in ways researchers had not expected. Therefore, the reproducibility of results acquired through serious land use games is problematic.

3. Materials and Methods

3.1. The Icelandic Pilot Study

The Iceland case-study of the PHOENIX project makes use of public participatory land use serious games to stimulate discussion around land use in relation to the green transition. For this study, we employed a pilot study method [56] to introduce our serious game and use of a small sample size to examine the gameplay of the serious game and analyse the resulting data. Our initial pilot was designed to engage predominantly with young people in the rural municipalities of Bláskógabyggð and Rangárþing ytra (Figure 1). Both municipalities are located in rural areas, with large portions of the central highlands within their boundaries. These regions face growing tensions among community members and between the communities and national and regional authorities due to overlapping land use interests, particularly regarding traditional sheep grazing, tourism, and environmental restoration initiatives.

Figure 1. Map overview of the study areas in Iceland (highlighted in red).

3.2. Overview of the Game

The Land Use Game is built on the 'Your Priorities' platform created by the Citizens Foundation [57]. This platform is widely utilised in participatory processes at the local level in Iceland. The Land Use Game takes advantage of this core idea of citizens submitting ideas for online deliberation, but incorporates a game element inspired by other educational land use games, like Zone! [58] and the Land Use Simulation Game by the US National Park Service [59]. The Land Use Game enables players to participate in real-world deliberative processes with the aim to create a more immersive experience, allowing participants to engage with their actual surroundings in a playful way, while simultaneously contributing to planning and policy discussions.

The Land Use Game offers a visual display of land use proposals through 2D and 3D maps, helping participants grasp the spatial distribution of various land use options. This feature enables the game to visualize community preferences and priorities, highlighting areas of consensus and conflict. Additionally, the game produces various output data, such as survey responses and discussion records, which can provide deeper insights, guide future land use planning, and support scenario modelling.

The game consists of several phases. First, players can choose to either log in or participate anonymously, allowing flexibility in how they engage. In the core game phase, players navigate a 2D/3D map of a study area. They are presented with up to six land use categories (Conservation, Restoration, Sheep Grazing, Tourism, or Energy), which are most commonly practiced in the central highlands of Iceland. Participants can assign their preferred land uses by 'painting' sections of the map, with each square representing approximately 2.5 square kilometres of land area (Figure 2). Visual aids such as 3D icons, colour-coded land use areas, and options for satellite or traditional map views help players visualize their choices. Players can also leave comments on specific areas for additional context or modify their selections before submission. Once land use proposals are submitted, the game enters a deliberation phase. Players can see a collective map of all responses, including popular choices and areas of conflicting land uses. They can explore user comments and participate in debates by upvoting, downvoting, and adding their own opinions. The interactive map remains available during this phase for continued exploration.

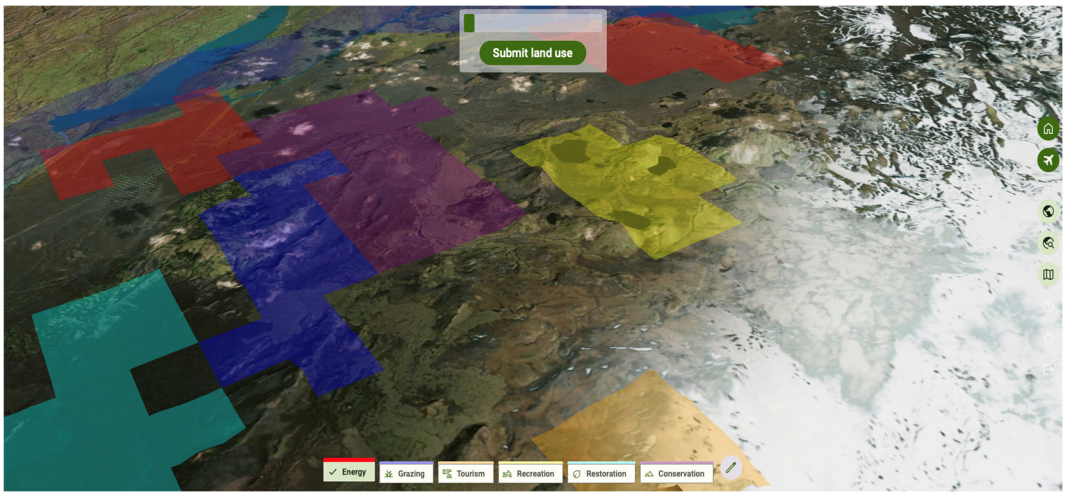

Figure 2. 3D land use mapping example from the Land Use Game.

For further analysis of the game's output by game administrators, the system offers a backend that allows for data export, including geocoded land use selections, heatmaps, survey responses, and debate records. This data links each user's input across game

components, offering comprehensive insights into public preferences and supporting informed decision-making in real-world planning processes.

3.3. Testing the Game

The prototype of the Land Use Game was tested with students in the 8th and 9th grades at two primary schools within the case-study area. The participating schools were Reykholtskóli in Bláskógarbyggð and Lugalandsskóli in Rangárþing Ytra. These sessions were held in cooperation with the schools and the teachers at each school. We used an observation technique [59] to gather information on the students' gameplay experiences in the classroom, considering the relatively small sample size, the young age of the participants, and the ability to conduct the data collection in a controlled environment.

All the students present in these two grades participated in playing the game. The participants were introduced to the concepts of land use, public participation, and direct democracy through a brief presentation. In addition, they were introduced to the concept of serious games and were shown the Land Use Game and how to use it before they played the game themselves. The participants played the game on individual devices. In the case of Bláskógarbyggð, they used tablets and in the case of Rangarþig Ytra, they used desktop computers.

In the game, the respondents were able to interactively highlight, in a 2D or 3D 'flight simulator' style environment, as many of these squares in the municipalities as they would like and assign these squares to a categorical land use. Following this, the respondents were asked a range of questions related to environmental views and demographics. The land use game was available in both Icelandic and English, with responses recorded in both languages.

Because of the low sample size, more advanced statistical analyses such as factor-analysis were dismissed as not practical for this stage of the project. However, by combining the respondents from Bláskógabyggð and Rangárþing ytra, the number of unique respondents increased to a level where some basic statistics could be applied with the results having a low level of statistical significance.

Throughout the project, ethical issues were considered, including the anonymisation of data. The respondents' data were anonymised unless the respondents opted to identify themselves. Moreover, all data were stored on secure devices and networks to prevent data breaches.

3.4. Analysing the Game's Output

For coding and statistical analysis of the data derived from the land use game, the open-source statistical software R (version 4.4.0) was utilised. For further analysis and visualisation, the use of the GIS technology was deployed in form of the open-source QGIS (version 3.20). The data derived from the land use game consisted of three datasets containing the geographic area (square polygons) for respondents' land use choices for each of the three municipalities. Accompanying this data were two separate datasets containing the attitudes and demographic data for Bláskógabyggð and Rangárþing ytra. The datasets for Bláskógabyggð and Rangárþing ytra were joined in QGIS for spatial analysis, incorporating both geographic land use and statistical variables. Land use data were converted from text to numerical variables to allow for statistical analysis. Larger differences in numerical coding were used for contrasting land uses (e.g., conservation vs. energy) to better identify land use contestation using standard deviation. Basic spatial geospatial statistical operations [60] then identified the most popular land use types in each area with survey responses.

The standard deviation was then employed to generate a heat map showing areas of contestability. The standard deviation measures the average variance of observation from the mean of a variable, and therefore measures the spread or distribution of the data in that variable [61]. In this case, the conscious decision was taken to code conflicting land uses as further apart numerically to allow for the level of disagreement to be determined.

Higher standard deviations indicate greater contestability between land use options, whereas lower values reflect more agreement. This combination of the majority preference and standard deviation allows for a clear representation of both land use choices and the level of conflict or agreement among respondents.

After determining the standard deviation for each area with survey responses, the data were joined again to determine the standard deviation for each polygon as a proxy for contestability and level of disagreement between the survey responses. These values were then mapped for a spatial representation of the findings.

In the last step, contestability hot spots with clusters of high standard deviation values were isolated and further analysed for the respondent's land use choices. This helped to determine what land uses were contested in hot spot areas. For each contested cluster, the share of land use responses was determined through a descriptive spatial analysis.

4. Results

4.1. Pilot Results

A total of 25 students participated in the Land Use Game prototype (13 students from Reykholtskóli in Bláskógarbyggð and 12 students from Lugalandsskóli in Rangárþing Ytra), with all students completing the game. The participants' ages ranged from 13 to 15 years old and the gender balance was evenly divided between male and female participants.

The students were adept at following the process of initiating the game, though several asked questions about the survey section that precedes the game. This was due to language barriers, such as dyslexia or other language related limitations. Participants spent between twenty minutes and an hour playing the game and remained engaged with the platform throughout. However, students in both Bláskógarbyggð and Rangárþing Ytra encountered some difficulties with the game's functionality. The main challenges they faced were related to technical playing modes such as the zoom in and out function, which required using two fingers simultaneously and sliding up and down on a trackpad, and the process of switching between choosing a land use type and adding a comment on a land use choice.

The two student groups collectively allocated land use preferences to over 21,000 land area parcels, each covering 2.5 km², across a total accessible terrestrial area of 40,000 km². While all available land use categories were utilised by the students, certain categories were significantly more allocated than others in both groups.

Additionally, the players tagged a total of 78 distinct comments regarding land use issues to specific areas. These comments ranged from a few catchwords like "protect the beautiful" to more detailed statements such as "I think the land should continue to be used as it is now, and not for tourism, because it only damages the roads and the land due to the rubbish tourists leave behind and their lack of access to toilets. The pastures should only be used for sheep".

Despite the relatively large number of comments made by the students and the instructions given at the start of the game sessions, only two students responded to other players' comments during the deliberation phase of the game.

4.2. Analysis Results

In order to demonstrate the direct applications of the game's output, this study processed and analysed the players' land use preferences data to provide insight into the

popularity of certain land uses and the degree of contentiousness of specific parts in the case-study areas.

Land Use by Majority (Figure 3)

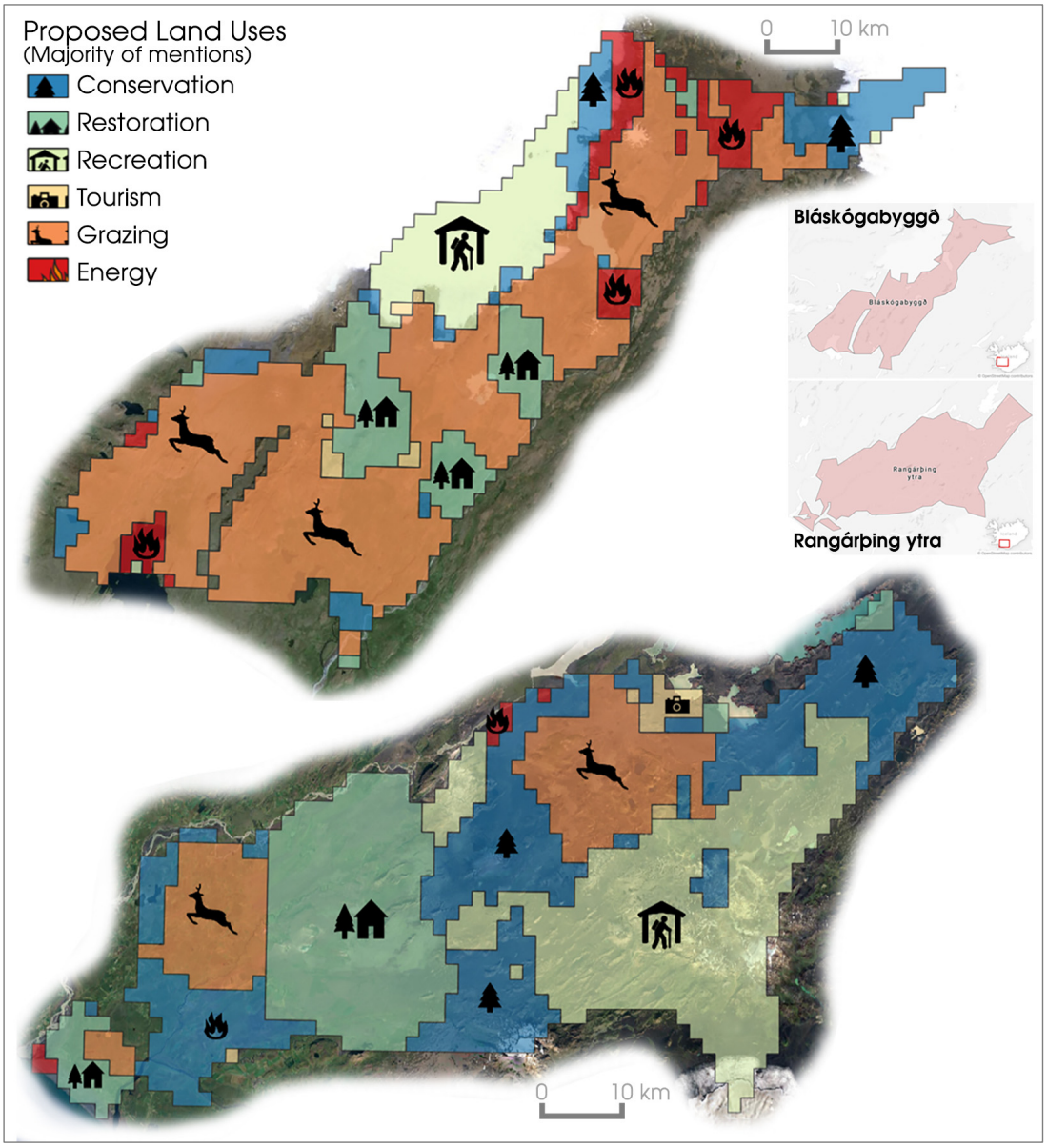

Figure 3. Land uses proposed by the majority of participants in each study area.

In Bláskógabyggð, responses for land use preferences were relatively mixed with the largest area belonging to land for grazing. The next most popular land use choice was recreation, which focused on the area on and surrounding the Langjökull glacier in the northeast of the municipality. On the edges of this area is a small band of conservation-designated areas suggested by the majority of the responses. Energy as a preferred land use was sporadically spread around the northeast and southwest of Bláskógabyggð. Proposed restoration was confided to parts of central Bláskógabyggð. Tourism as a proposed land use was minimal with a small area in the southwest of the glacier and in the south of the municipality.

Proposed land uses dominant in Rangárþing ytra were far more contained in single large areas spread across the municipality. Conservation and restoration were the largest proposed land uses that are evenly spread across the municipality. Restoration was a

prominently proposed land use southwest. Proposed grazing areas were confined to three areas in the north and the west. A proposed tourism area was confined to the northeast. Energy was far less present as a suggested land use, with two small areas in the north and towards the coast in the west.

Contentious Land Use (Figure 4)

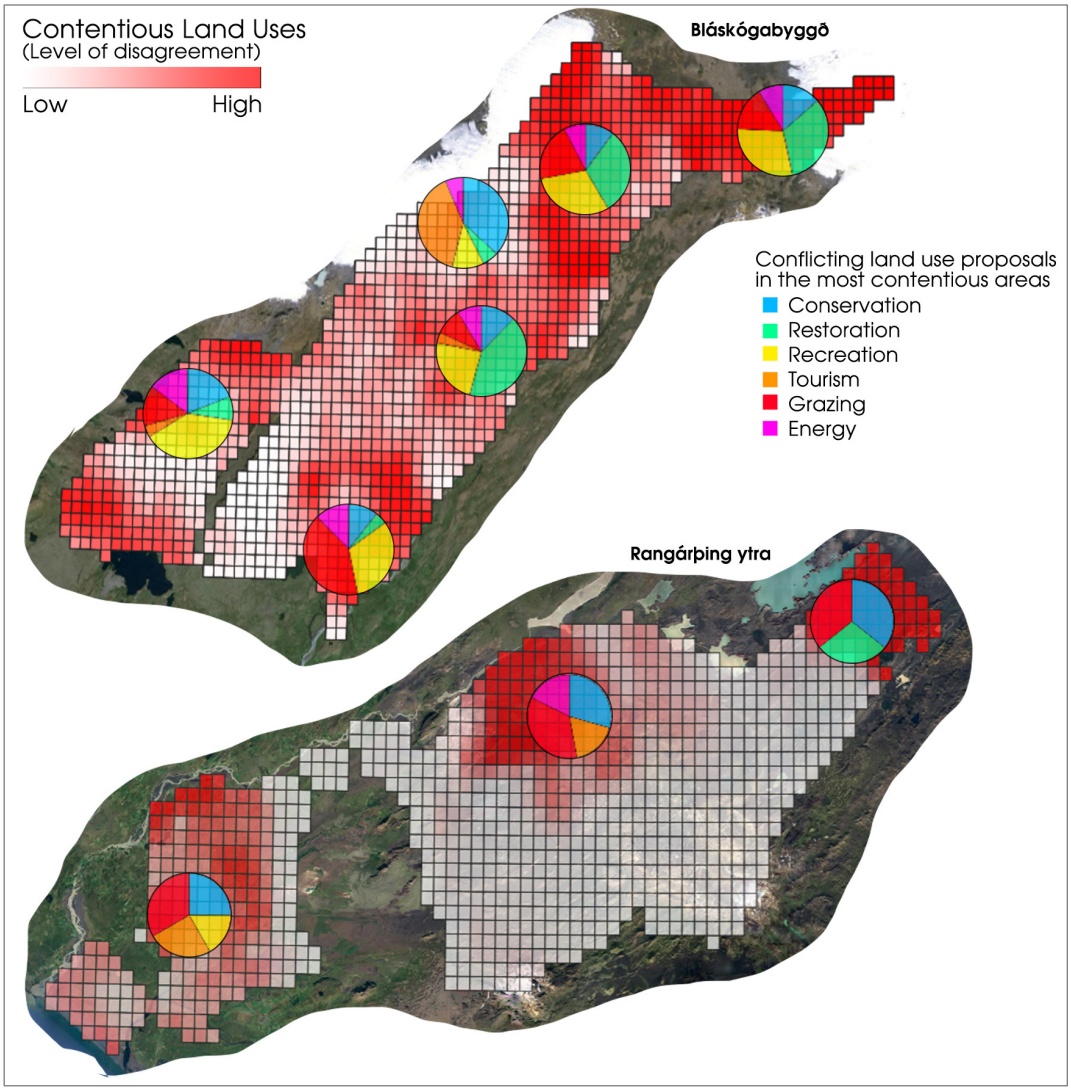

Figure 4. Contentious land uses identified for each study area.

In Bláskógabyggð, areas with highly contested proposed land use centred on areas at the glacier and in two areas in the southwest. For the two areas in the southwest, the proposed use of the land for grazing was contested mainly by the proposed land uses of restoration and conservation. The three areas surrounding the glacier show tensions mainly between the proposed energy and grazing land uses, although restoration and conservation were also present in some mentions. An area on the glacier demonstrates a tension between respondents who see the glacier as a place for recreation in conflict with those who see it as a place for conservation. This was the case for a small area on the glacier. The full extent of the Langjökull glacier also exceeds the municipal boundaries. This suggests that there is an exogenous factor which the respondents are considering. This could be the presence of cultural, traditional, or historic value at this site which makes it a popular place for recreation. It could also have unique wildlife or nature which explains the views on conserving the area.

In the glacier region of Bláskógabyggð, proposed land use is categorised into several types with varying shares of individual square polygons that respondents chose to select. Conservation areas consist of 129 polygons, while energy-related land use includes 48 polygons. Grazing areas are represented by 56 polygons, and recreational areas have the highest count with 166 polygons. There are no polygons designated for restoration purposes.

In the northeast of Rangárþing ytra, the land use game showed a tension between the proposed use of the area bordering the Þórisvatn lake for energy purposes as opposed to restoration and conservation. In the centre of the municipality, there are some synergies between the proposed land uses of conservation, restoration, and recreation. Towards the southeast, the conflict is between proposed restoration, conservation, and grazing.

In the contested coastal area of Rangárþing ytra, proposed land use is distributed among various categories with different numbers of polygons. Conservation areas have 206 polygons, energy-related land use includes 20 polygons, and grazing areas are represented by 289 polygons. Recreational areas consist of 59 polygons, restoration areas have 103 polygons, and tourism-related land use includes 44 polygons.

Statistical analysis of the Land Use Game's output found a slight but significant difference in land use preferences for conservation based on the respondents' gender. However, due to the small sample size, the results should be interpreted with caution, as serious games are prone to such low sample sizes [29], as was the case in this pilot study.

5. Discussion

Taking a more general view of the project presented in this pilot study, despite the small sample size, this project has presented a framework for the establishment for a serious game dealing with land use preferences that demonstrates significant potential in terms of participants' comprehension, engagement, and its usefulness for providing valuable data for land use planning. The results of this pilot reveal that most participants adapted well to the Land Use Game, in successfully initiating and completing the game. While some students faced challenges with the pre-game survey, particularly due to language barriers, they were still able to understand the core mechanics of the game. This suggests that, overall, the game is accessible to young participants, though it may benefit from further refinement in terms of clarity and ease of use, especially in areas that require language comprehension. Furthermore, the level of student engagement was consistently high. All 25 students completed the game, remaining engaged with the platform for periods ranging from 20 min to an hour. Despite encountering some technical challenges, the students demonstrated commitment to the task. Their active participation in tagging 78 distinct comments shows that the game facilitated meaningful interaction with the content, allowing students to express their opinions and preferences on land use.

This pilot also provided some suggestions for the analysis and presentation of the resulting data and their relevance in a planning context. Considerable time was spent in filtering, transforming, and analysing data to facilitate the most effective demonstration of land uses for decision makers. Because of the small sample size, the geographical land use analysis is best described as 'tendencies' and cannot be constructed as statistically significant results. However, with a wider rollout of such a serious game in the wider population, or even nationwide, larger numbers of responses have the potential for statistically significant statements and valuable propositions for decision makers.

There was some initial success in aggregating survey features to explore statistically significant results. Whilst these results are on the lower end of normal confidence intervals, they provide some initial interesting insights, both in their spatial distribution as well as possible correlations between respondents' views and land use preferences. These methods

could be replicated on larger datasets to explore how demographic factors influence land use choices.

The land use serious game is experimental and is highly effective at demonstrating the value of these techniques in community outreach and engagement. However, the implementation of this land use game requires some modifications. To be relevant, statistical variables need to follow standards of validity, reproducibility, and representativeness [61].

Validity is the requirement for a variable to accurately measure the operationalised concept. In this case, the concept was the respondents' preferences for land use. However, the dynamics of the game do not facilitate the respondents making an informed land use decision considering the opportunity cost. The testing results indicate that many players appeared confused by the game, and instead highlight large areas for a single land use (in some cases almost the entire map). This issue could be exacerbated by a lack of clarity in the different land uses and their trade-offs. For example, conservation and recreation can easily be considered as non-dichotomous. As such, the respondents' selection of recreation may be based on their perceived understanding of recreation as a land use rather than a planner's definition. The pre-selection of land uses offered in the game also adds further bias and limits the choices that the respondents have. These factors question some of the validity of the land use measure.

Similarly, reproducibility is important for an effective measure as it ensures that respondents' answers can be depended on and do not change over time. It is highly unlikely that a respondent here would be able to reproduce the areas they assigned a land use for. This links back to the aforementioned issue with the land use types not being clearly defined. Representativeness is the need for a measure to conform to a normal stochastic distribution both internally and regarding respondents' representativeness of the population being samples. As mentioned, the low sample size currently makes the representativeness a major shortcoming.

Finally, there is somewhat a lack of engaging game dynamics in the current iteration of the serious game. The test results show that only two respondents actually interacted with other players' land use preferences by responding to comments during the deliberation phase of the game. Whilst there are some social-based rewards through engaging with others comments, these elements only present themselves towards the end of the game and in another user interface, such elements need to be presented to the respondent earlier to stimulate further deliberation, and the overall usability of the game needs to be simplified to appeal to a broader audience.

To increase the game's feasibility with a broader audience, the existing game could be improved by including more gamified features and focusing on respondent motivation. The viewpoint of reward-based vs. social gamification should be combined. Players could be given a limited number of land use options linked to objectives such as environmental protection or energy production, de facto limiting their option in each category so that more conscious decisions need to be made as to what a respondent's most important proposed land use is across an area. Players could be ranked on how well they distribute land to achieve certain objectives. This ranking is a rewards-based gamification. The ability to read and engage with other comments on land use should be placed at the forefront of the game. This would increase engagement through social gamification. A clear definition of each land use category should be provided, and a rating on how contrasting land uses would impact the other land use based on existing research could be integrated.

6. Conclusions

This study demonstrates the feasibility, technological features, and practical research applications of the Land Use Game as a tool for participatory land use planning. Through its

pilot implementation with students in two rural Icelandic municipalities, the game proved accessible and engaging, with all participants successfully completing the gameplay and providing land use preferences alongside qualitative feedback. The observations indicate that the game effectively stimulates an engagement with the complexities of land use issues, despite some minor technical challenges, and highlights its suitability for involving younger participants in participatory processes.

The spatial data generated through the Land Use Game offer valuable insights into land use preferences and areas of contestation, demonstrating the game's potential to support evidence-based decision-making in planning contexts. By integrating interactive mapping and participatory elements, the game facilitates discussion around land use issues and empowers participants to contribute to sustainable solutions. While the pilot revealed areas for improvement—particularly in refining technical functionality and fostering deliberative interaction during gameplay—the findings suggests that there is a value of serious games as tools for bridging gaps between planners and stakeholders.

As global challenges such as climate change and biodiversity loss demand more inclusive and innovative approaches to land use planning, serious games provide a promising framework to democratise access to decision-making processes. They reduce barriers to participation, integrate local knowledge, and promote equitable outcomes. Continued refinement of the Land Use Game, alongside robust data management and representative sampling practices, will be key to further unlocking its potential. The results of this study highlight the importance of these tools in transforming participatory land use planning into a more accessible, engaging, and effective process for diverse communities.

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