Current Research in Environmental Sustainability 10 (2025) 100303

Contents lists available at ScienceDirect

Current Research in Environmental Sustainability

journal homepage: www.sciencedirect.com/journal/current-research-in-environmental-sustainability

An explorative analysis of gameplay data based on a serious game of climate adaptation in Aotearoa New Zealand

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ARTICLE INFO

Keywords:
Climate change adaptation
Serious game
Data analysis
New Zealand

ABSTRACT

Serious games play a crucial role in educating and engaging the public on environmental management issues, such as climate change. These games also generate valuable data that can be used in understanding players' climate change decisions. However, there is a notable gap in the literature on serious game analytics to address the significance of scrutinising the usefulness of utilising gameplay data to explore player behaviours. This paper explores this gap through descriptive and quantitative analysis of gameplay data from 'The Township Flooding Challenge' in Aotearoa New Zealand to obtain data insights and data gaps in understanding players' behaviours and decisions on climate change adaptation. The findings suggest that gameplay data can offer insights into players' decisions on climate change adaptations amid uncertainty, but also highlights data gaps such as unclear definitions and incomplete data. Leveraging gameplay data can aid in data collection, decision-making modelling, and improving serious game design.

1. Introduction

Serious games are structured and rule-based systems designed for a primary purpose rather than pure entertainment (Dörner et al., 2016). Serious games, either board- or computer-based (Hernandez-Aguilera et al., 2020), are increasingly used to engage and educate the public on environmental issues such as climate change (Lawrence and Haasnoot, 2017; Madani et al., 2017; van Schaik, 2023) and flood risk management (Forrest et al., 2022); they also generate rich datasets that illuminate players' decision-making processes, including preferences, engagement levels, and outcomes (Smith et al., 2015). Importantly, beyond their educational role, serious games serve as versatile research tools. They can act as models of complex real-world systems, facilitate hypothesis testing, offer alternatives to traditional surveys, and support behavioural economic experiments, thereby expanding their utility in environmental research (Pavlenko et al., 2024; Gordon and Yiannakoulias, 2020; Forrest et al., 2022). Moreover, when gameplay data is systematically collected and analysed (Lukosch and Cunningham, 2018), it provides valuable insights into the cognitive processes underlying both individual and collective environmental decision-making (Smith et al., 2015).

As the field of serious game studies continues to evolve, serious game analytics has emerged as a vital subfield focusing on analysing gameplay data (Correia and Simões-Marques, 2023). This area of research centres on interpreting data generated through gameplay to gain insights into performance assessment and enhancement of game design (Loh and Li, 2015; Wiemeyer et al., 2016). For example, by examining player engagement and interaction patterns, serious game analytics seeks to optimise game design and maximise its impact (Loh and Li, 2015); analytics can also reveal correlations between gameplay metrics and the development of targeted skills (e.g., students acquiring specific skills relevant to their discipline), underscoring the educational value of serious games (Wiemeyer et al., 2016). A notable advancement in this area is the integration of adaptive learning features, which enable real-time customisation of gameplay. These features adjust the difficulty levels of games and personalise content to fit individual player needs, enhancing motivation and engagement (Folkestad et al., 2015; Yang et al., 2017). Furthermore, data mining techniques, such as sequential pattern mining, offer additional tools for analysing player behaviour and improving serious game design (Kang et al., 2017).

There is considerable potential for developing frameworks and methodologies dedicated to analysing gameplay data in serious games (Schumacher et al., 2023). For example, some games focused on

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https://doi.org/10.1016/j.crsust.2025.100303
Received 17 November 2024; Received in revised form 3 March 2025; Accepted 15 August 2025
Available online 27 August 2025

agriculture and flood management are specifically designed for data collection (Pavlenko et al., 2021), hypothesis testing (Gordon and Yiannakoulias, 2020), or policy evaluation (Stefanska et al., 2011). This data can support exploration of player patterns, preferences, and the underlying mechanisms guiding their decision-making processes. However, there are ongoing challenges regarding the applicability of gameplay data to real-world contexts, as players' decisions within a game may not fully reflect their real-world behaviours (Hernandez-Aguilera et al., 2020).

Despite the growing body of research, limited exploration exists into how gameplay data drawn from serious games can inform climate change adaptation actions. Although studies have analysed the educational impact of these games, often by using pre- and post-game surveys to measure knowledge gained or communication improved (Fleming et al., 2020; Flood et al., 2018; Forrest et al., 2022; Salvini et al., 2016; van Beek et al., 2022), a critical gap remains regarding the direct analysis of in-game decision-making processes. In particular, there is scant understanding of how players' adaptive strategies evolve as they respond to simulated flood events. The gap motivates our use of an exploratory analysis. Unlike structed methodologies that begin with predefined hypotheses, the exploratory approach is especially suited to context where the underlying mechanisms are unclear. It allows us to investigate a broad array of variables and interactions within the gameplay data without restricting the analysis to anticipated patterns. In doing so, we can identify emergent trends, such as how players modify their in-game strategies over time that may be overlooked by more narrowly focused methods. Although alternative methodologies could potentially address this gap, the flexible, open-ended nature of exploratory analysis is ideal for mapping the complex dynamics of adaptive decision-making in a novel setting. By employing this method, we aim not only to reveal new insights into players' behavioural adjustments but also to lay the groundwork for future confirmatory studies that can rigorously test these emergent hypotheses, help determine the optimal extent of information to be collected, and further refine serious game design for climate change adaptation.

This study aims to conduct an exploratory examination of gameplay data gathered from a climate change serious game in Aotearoa New Zealand, 'The Township Flooding Challenge'. Our goal is to characterise player behaviours and decision-making processes within the game context, thereby illustrating the types of data that serious games can yield. While it is important to note that the game was not originally designed for behavioural analysis (i.e., we did not establish experimental benchmark or controlled evaluations), the gameplay data provides a valuable basis for investigating player decisions related to climate change adaptation. Analysing the data also helps identify data gaps in understanding players' decision-making processes. Our primary objectives are to address three key questions:

1) Data insights: What behavioural insights can be derived from the data to understand players' decision-making processes in the game? We aim to investigate the information that can be extracted from the collected data, uncovering insights into player decision patterns regarding climate change adaptation across various game scenarios. These scenarios include single-player and multi-player games, as well as different game elements, such as exposure to climate events.
2) Data gaps in climate change decision-making analysis: What additional data would enhance the understanding of climate change decision-making within serious games? We intend to identify and assess any missing elements within the dataset that are crucial for a comprehensive analysis of climate change decision-making. This aspect aims to illuminate areas where additional data may enhance the understanding of players' choices and responses, thereby improving the design of climate change serious game.
3) Next steps for gameplay data analysis: What steps should be taken to improve the data collection and analysis processes for serious games focused on climate adaptation? We aim to outline subsequent steps in the analysis of gameplay data for climate change serious games. This includes recommendations for refining methodologies, expanding datasets, and incorporating additional variables to enrich the depth and breadth of the analysis.

The study offers a novel contribution by employing an explorative methodology that combines both descriptive and quantitative analysis. Through the analysis of data extracted from a serious game dedicated to climate change adaptation, we aim to characterise the specific decision-making behaviours that players exhibit when faced with climate-related challenges and identify specific gaps in the current data – especially regarding player risk attitudes and financial investment choices. The utilisation of 950 observations ensures a substantial sample size,[1] providing robust empirical evidence, particularly noteworthy for a board-based game. Additionally, the results and findings of the study contribute to the literature on serious game design, particularly regarding the use of gameplay data. Although not designed to conduct hypothesis testing in a controlled experiment environment, the gameplay data of 'The Township Flooding Challenge' can inform game designers about the appropriateness and needs for data collection in future game designs. For instance, based on the findings of the impact of exposure to extreme climate events on adaptation actions, the designers of the 'Township' game considered introducing higher-risk elements (i.e., high-risk dice) earlier in subsequent games. In addition, the data gaps identified in the analysis will assist researchers in addressing the disconnections between quantitative and qualitative data collection, particularly concerning player risk attitudes and financial investment options.

2. The township flooding challenge game

2.1. Context of the game

'The Township Flooding Challenge' is a multi-player board game designed to help players explore complex adaptation choices for communities in flood-risk areas under a changing climate.[2] The game is set among a small fictional community comprised of a riverside township, dairy farm, and marae,[3] all at risk of fluvial flooding. The game can accommodate up to five players, each representing a specific role within the community: townspeople (homeowners, $n = 3$), a dairy farmer ($n = 1$), or a representative from the marae (n = 1). Single-player gameplay is also possible. Gameplay is structured over up to 10 rounds, with each game round representing a decade. During each round, players decide on flood adaptation measures they wish to implement, from various options, including raising or moving buildings, selling properties, building a community stopbank, or doing nothing. After these decisions, a 12-sided dice is rolled to determine whether a flood event occurs and its degree of severity. There are three outcomes: No event (5 out of 12 chance), high flood event (4 out of 12), or severe flood event (3 out of 12).

At the discretion of the facilitator, the initial dice is swapped partway through the game for a higher-risk dice with a greater probability of a severe flood occurring (1 in 3 chance). This is done to reflect the

[1] To address potential dependencies from grouping within game sessions, we applied robust clustering of errors at the game level. This adjustment ensures that our statistical inferences account for any within-game correlation, while still allowing us to analyse all 950 individual observations.

[2] A web-based game has been developed based on the board game. More details about the game can be found at: https://niwa-temp.web.app/.

[3] Marae are the meeting grounds and hub of Māori communities, the Indigenous Peoples of Aotearoa New Zealand. The observed preference for one action over another may stem from participants interpreting the game mechanics as opportunities for flexible adaptation under uncertainty, rather than aiming to replicate real-life behaviours directly. This approach aligns with decision-making strategies under uncertainty, where individuals assess multiple options and potential outcomes without complete information.

increasing frequency and severity of flooding in a changing climate. The players are not informed about the dice change when they begin, although they are not prevented from examining both dice to determine the probability of a flood event occurring.

All player starting places are in a flood risk zone, as shown in Fig. 1. Players are given in-game incomes which they can choose to spend on a range of flood adaptation options:

- Raise house (townsperson's house, farmer's house, or the wharenui[4])
- Move house onto an area of the existing property that is not at risk of flooding (here 'house' refers to all buildings, including the farmer's dairy shed and the wharekai[5] and urupā[6])
- Sell house and move to a property outside of the flood risk zone ('safe house')
- Sell house and move to another at-risk property
- Build a stopbank (requires consensus among all players)
- Do nothing

A breakdown of the costs and efficacy of each adaptation option, as well as incomes and flood damage repair costs, is provided in Appendix Table 1. With the exception, of stopbanks players can implement adaptation actions independently, if they can afford to do so. However, there is a limited supply of available safe land, and once a safe home has been purchased it is removed from the market. Game-end thresholds include reaching 10 rounds (representing a timeframe of 100 years), player bankruptcy (can no longer afford to continue), all players achieving 'safety' (outside of a flood risk zone),[7] or when players choose to discontinue playing.

Gameplay allows participants to explore the tensions that can arise between people's desire to remain in place, their financial constraints, and their need to make decisions about flood risk among uncertainty. Facilitated gameplay also allows for discussions to arise with (and among) players about other real-world influences and constraints on adaptation decision-making (e.g., insurance cover, ethical considerations regarding the sale of at-risk properties etc.).

2.2. How the data was gathered

Data for this study were collected over four days at Mystery Creek Agricultural Fieldays (30th November-3rd December 2022), the Southern Hemisphere's largest annual agricultural show, held in Hamilton, Aotearoa New Zealand. A physical game stand was set up at the National Institute of Water and Atmospheric Research's (NIWA) presenter stall, and event attendees were invited to take part in a short, facilitator-led game for approximately 10–15 min per game (gameplay photos taken at the Fieldays are included in the Appendix). Gameplay data was manually recorded by the game facilitator or assistant on a physical record sheet. We collected the following data: player occupation; whether it was their first time playing or a repeat play-through; whether players counted the dice sides to determine the probability of each event occurring; the event type rolled each round; and the adaptation options players chose to adopt. The analysis here focuses on this collected physical gameplay data, though an online version of the game is now available.

[4] Meeting house situated on marae grounds.

[5] Dining hall and cooking area situated on marae grounds.

[6] Burial grounds, cemetery. It is located on the marae property.

[7] Achieving 'Safety" (or 'safe round') refers to a state where players were no longer living in properties (or on sections of their property) that were at risk of flooding, due to previously undertaken adaptation options.

3. Methods and data

3.1. The exploratory research strategy

This study employs a data-driven approach to investigate whether gameplay data can offer insights into adaptation behaviours within the specific context of flood-risk decision-making. Our analysis is entirely driven by the data, ensuring that any emergent patterns and relationships observed are grounded in empirical evidence rather than post-hoc justification. Given the emerging nature of research on game-based methods for climate adaptation (Flood et al., 2018; Schenk and Susskind, 2014), we adopted an exploratory approach to data analysis (Swedberg, 2020; Neset et al., 2020). This approach is particularly suitable for studying decision-making in uncertain environments, as it allows us to observe emergent patterns without imposing rigid theoretical assumptions. The choice of an exploratory methodology is informed by the lack of extensive literature on structured decision-making in game-based climate adaptation settings.

As stated in the study of Swedberg (2020): "Exploratory research is used to investigate phenomena when the problem is not clearly defined, and its primary aim is to uncover patterns, generate hypotheses, and build new theoretical insights rather than to test pre-existing theories." (Swedberg, 2020, p. 102). Furthermore, given that gameplay is a novel data source with unique challenges, such as variability in player experience, risk perception, and interaction effects between game elements, an exploratory approach enables use to discern possible trends and behaviours that more structured methods might overlook at this stage. Neset et al. (2020) explain: "In an exploratory study, researchers employ flexible, open-ended methods to systematically examine data, allowing for the discovery of unexpected relationships and variables that structured, hypothesis-driven approaches might overlook." (Neset et al., 2020, p. 68).

Here, we employ descriptive statistics and multinomial regression analysis to investigate adaptation choices in the game, adding granularity to our understanding of decision-making in flood-risk scenarios. In the context of our data-driven approach to analysing decision-making within gameplay data, employing both descriptive statistics and regression analysis is particularly suitable for uncovering potential patterns and phenomena.

3.1.1. Descriptive statistics analysis

Descriptive statistics provide a foundational understanding of the data by summarising key features (Jones and Goldring, 2022), allowing us to identify trends and distributions within players' adaptation behaviours. This initial analysis offers insights into how players make decisions under varying conditions, serving as a basis for more complex analyses. For instance, by examining the frequency and patterns of chosen adaptation options, we can identify shifts in player preferences as they progress through the game. This analysis can reveal temporal trends, such as a gradual increase in investments in flood defences or a shift toward more conservative approaches after experiencing flood events in earlier rounds. Descriptive statistics also allow us to compare decision-making across different player roles, such as township, dairy farm, or marae representatives, which could highlight role-specific tendencies and risk tolerances within adaptation choices.

3.1.2. Regression analysis

Building on these initial observations from descriptive statistics, regression analysis enables us to examine relationships between variables, such as player roles and their adaptation choices. This method helps in modelling decision-making behaviours, providing a deeper understanding of the gameplay data regarding the factors influencing players' adaptation strategies (the modelling details are presented in section 3.3). Specifically, we adopt a multinomial regression model to explore the impact of factors like player roles, round-specific experiences, and game outcomes (e.g., occurrence or severity of flooding

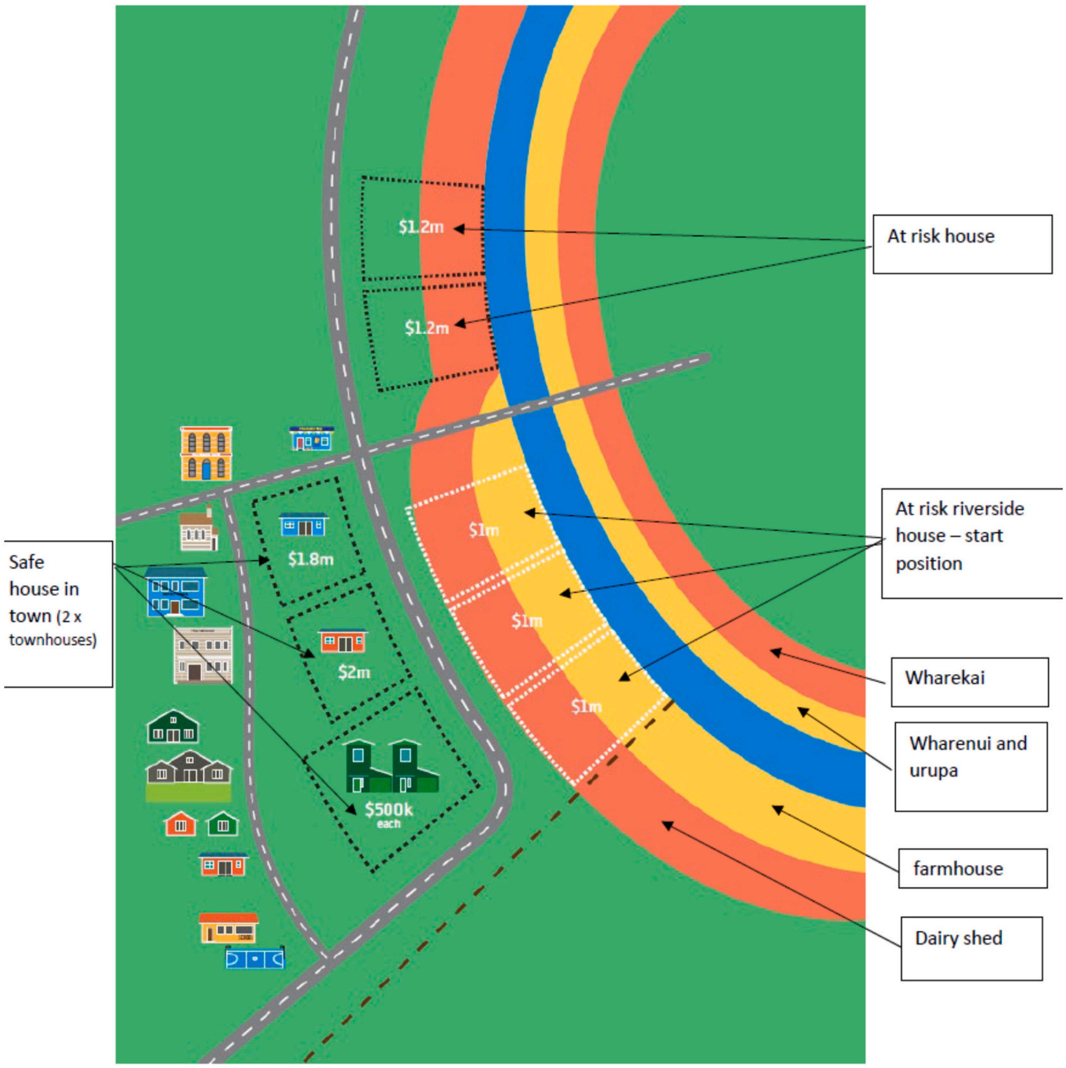


Fig. 1. Township Flooding Challenge physical game board. Note: Arrows show the start positions of all buildings. The blue strip represents the river running through the town. Red indicates the area affected by a severe flood, and yellow indicates the area affected by a high flood. Dotted lines indicate property boundaries. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

events) on subsequent decisions. Including variables that capture environmental conditions and player feedback from previous rounds also provides insights into adaptive learning processes. Furthermore, the analysis can uncover interaction effects, such as whether players facing frequent flooding are more likely to adopt specific defensive strategies, or if prior experiences shape more proactive adaptation choices as the game progresses.

Integrating descriptive statistics and regression analysis provides a comprehensive, data-driven examination of adaptation behaviours within the game's flood-risk environment. This approach allows for the identification of patterns and factors influencing decision-making, offering preliminary insights that can inform future, more structured research on adaptation strategies in climate-vulnerable communities. While these findings may not be directly generalisable to all real-world adaptation contexts, they serve as an initial step toward understanding the complexities of adaptation choices, guiding the development of more formalised game-based research designs with broader applicability.

3.2. Data and variables

The study's analysis was conducted using a sample dataset comprising 950 observations from a total of 84 games. Variables were constructed based on information related to adaptation actions, roles, game characteristics, and flood events. Table 1 provides a comprehensive overview, presenting variable descriptions along with descriptive statistics for each variable.

3.3. Multinomial regression analysis

We assume that players make the decision of adopting (or not adopting) adaptation actions based on utility maximisation: if the player i decides to adopt adaptation j, we assume that U_{ij} representing the utility associated with the adaptation j is the maximum among the J utilities, with Y_i denoting the choice made; also, it is assumed player i faces J adaptation actions ($J = 0, 1, 2, 3, 4, 5, 6$), with zero set as the base 'do nothing' and 1–6 representing other adaptation actions. Hence, the econometric model is driven by the probability of choosing j as $Prob(U_{ij} > U_{ik})$ for all other $k \neq j$. A multinomial regression model was employed to explore the relationships between the factors X_i (details about the factors are shown in Table 1) and players' choices of adaptation actions Y_i (i.e., outcomes shown in Table 1):

$$Prob(Y_i = j|X_i) = \frac{\exp(X_i\beta)}{\sum_{j-1}^{J}\exp(X_i\beta)}. \quad (1)$$

Table 1
Variable description and descriptive statistics.

Variable	Description	Mean[a]
Outcomes		
Adaptation actions	Categorical variable including seven actions:	
	Buy safe house (including townhouse and standalone house)	0.87
	Do nothing	47.63
	Move house	14.54
	Raise house	15.17
	Move house Raise house	1.79
	Sell house	11.59
	Stopbank	0.53
Factors		
Climate events	Categorical variable representing the type of climate event that happened at the end of the last round of the game, including:	
	High flood event	31.59
	No event	41.29
	No Roll (players did not roll the dice)	1.85
	Severe flood event	25.27
Game type	Dummy variable, =1 if multi-player game, =0 single-player game.	89.05
Player type	Dummy variable, =1 if repeated player, =0 new player.	10.53
Count dice	Dummy variable, =1 if the player counted dice, =0 otherwise.	19.89
Property type	Categorical variable including three property types:	
	Farm	22.36
	Marae	1.58
	Town	75.78
Occupation	Categorical variable including five occupations:	
	Youth/child	30.63
	Farmer	8.11
	General public	35.68
	Government	3.79
	Industry	21.79
Rounds	Continuous variable representing rounds of game played	3.56 (2.19)
Safe	Continuous variable representing the round where players became safe.	4.46 (1.85)

[a] Note: for categorical and dummy variables the mean values represent the percentage of the sub-category in that variable. For example, 55.58 for "do nothing" represents 55.58 % of players who did not adopt any adaptation actions; for the continuous variables, the standard deviation is included in the paratheses.

Here, β represents the unknown parameters associated with the factors X_i to be estimated through Eq. 2, with a constant α_i and an error term ε_i:

$$\log\left[\frac{Prob(Y_i = k)}{Prob(Y_i = 0)}\right] = \alpha_i + X_i\beta + \varepsilon_i, k = 1, 2, 3, 4, 5, 6, \quad (2)$$

which provides six sets of regression results, given we have seven choices, with the baseline set to be 'do nothing'.

4. Results and discussion

4.1. Trend of the adaptation actions over time

As shown in Table 1, among all adaptation actions, excluding the option of 'do nothing', it is noteworthy that 'raise house' constitutes the highest proportion at 15.17 %, closely followed by the alternative strategy of 'move house' at 14.54 % and 'sell house' at 11.79 %. These statistics indicate that players predominantly opt for these three proactive measures as part of their adaptive strategies that reduce immediate vulnerability to flood events. In contrast, actions such as 'buy a safe house' (0.87 %) and 'build a stopbank' (0.53 %) were less popular, likely reflecting the financial constraints inherent in these more substantial adaptations. These trends may reflect real-world challenges where affordability often limits the adoption of robust protective measures against climate-related risks.

The adaptation trends over game rounds, illustrated in Fig. 2a, suggest a decline in new adaptation actions as rounds progress. Specifically, only 37.8 % of players chose not to adopt at round 1 whilst the non-adoption rate started to hike from round 7, higher than 70 % on average in the last few rounds. This pattern aligns with a plausible real-world scenario in which individuals, once having undertaken protective actions, refrain from further investment unless prompted by significant risk increases. A 'safe round' achieved by most players by round 6 may have reinforced this sense of security. Raising a house was the most common first choice, then tailed off, then moving the house became popular, then tailed off. There is no clear increasing or decreasing pattern of selling houses, only that the adoption rate was low in the middle rounds (round 5-round 7), when most players became safe, and more players sold houses in the end, possibly to get the return of their investments in previous rounds. Lastly, more players were able to buy safe houses in the later rounds of the game.

The frequency of climate events (based on rolling the dice) was mapped in Fig. 2b to explore the relationships between adaptation actions and climate events over time. It was expected that if severe or high flood events occurred at the end of the previous round of the game, players may be more willing to adopt, and adopt more, adaptation actions in the following round. However, it was not until round 6 that the negative relationships occurred: for example, in round 7, the frequency of having either a high or severe flood event at the end of the previous round was low, and the rate of doing nothing was high; in round 8, given the highest chances of a severe flood in the previous round, the frequency of doing nothing dropped. This finding indicates that players may be more cautious about extreme weather events at a later round of the game, where the previous experience of dealing with flood risks makes it important to collect and interpret information, in this case, the frequency of extreme weather events. This adaptive behaviour underscores the role of past experience and the perception of risk in motivating future adaptation actions, aligning with findings in climate adaptation literature (Berrang-Ford et al., 2011; Gould et al., 2024).

4.2. Group-specific adaptation patterns

We further investigate the adaptation actions across different groups, including property types, game types, user types, and occupations.

As shown in Fig. 3, clear distinctions are presented in adaptation actions adopted by those playing as farmers, marae representatives,[8] and townspeople. Marae representatives, reflecting cultural values and real-world limitations on Māori land sales, predominantly selected strategies that involved moving rather than raising buildings or selling. This pattern contrasts with townspeople, who were more likely to buy safe houses, an option aligning with urban settings where relocation within safe zones is less feasible. Players acting as farmers were more likely to move houses to a safe zone but less likely to raise houses or sell their farms ('sell house'). This is partly because townspeople have no safe zone on their starting property, unlike the farm and marae, and hence they must undertake the combination of moving and raising houses to become safe. These variations suggest that adaptation strategies need to account for context-specific cultural, economic, and environmental considerations, particularly in diverse communities.

Overall, repeat players (10.53 %) were prone to adopt fewer adaptation actions regarding both the number of actions and the extent to which the actions were adopted (except for 'sell house' and 'move house raise house'), as shown in Fig. 4. For example, investment in safe houses and building stopbanks were not on the list of repeat players; compared

[8] Marae are communally owned by iwi (tribes), hapū (sub-tribes) or whānau (family). Marae are set on Māori reservation land, of which the ability to sell is extremely limited under New Zealand law (The Community Law; Whaanga (2013)).

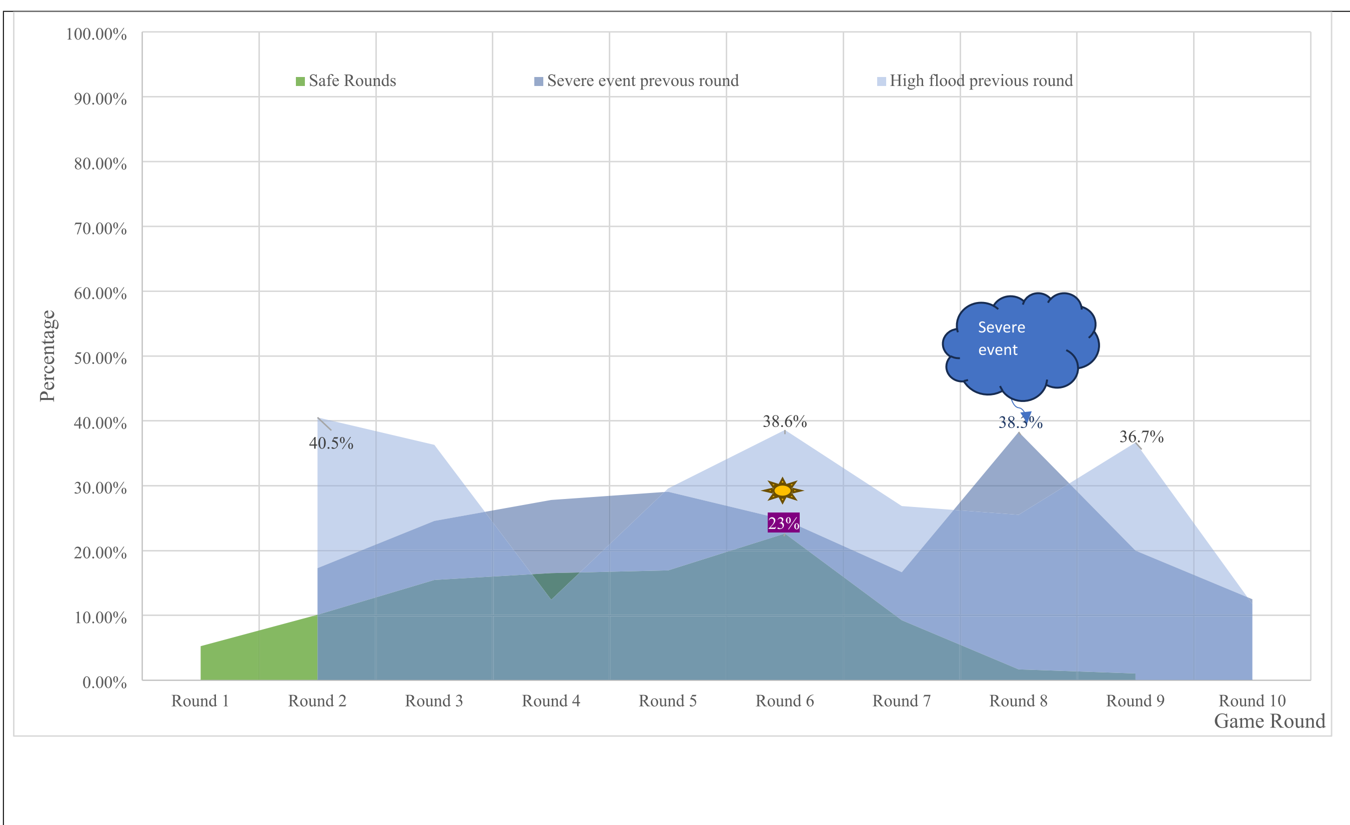


Fig. 2. Adaptation actions and climate events across game round. a. Adaptation actions adopted at each round of the game. b. The frequency of climate events and the percentage of players became safe. Note: the icon sun represents the highest frequency of achieving "safe" and the cloud icon represents the highest frequency of severe flood events.

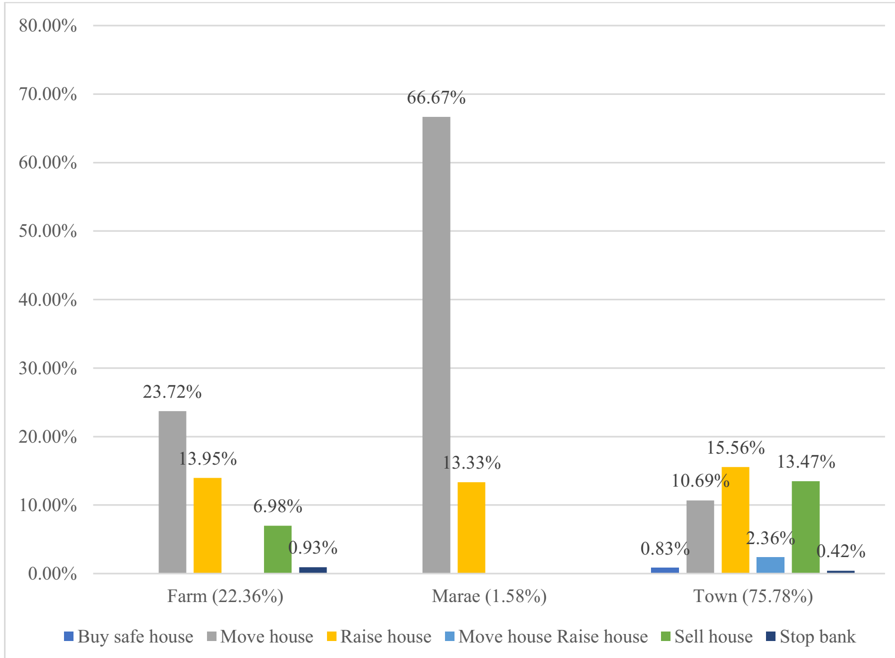


Fig. 3. Adaptation actions adopted across different property types.

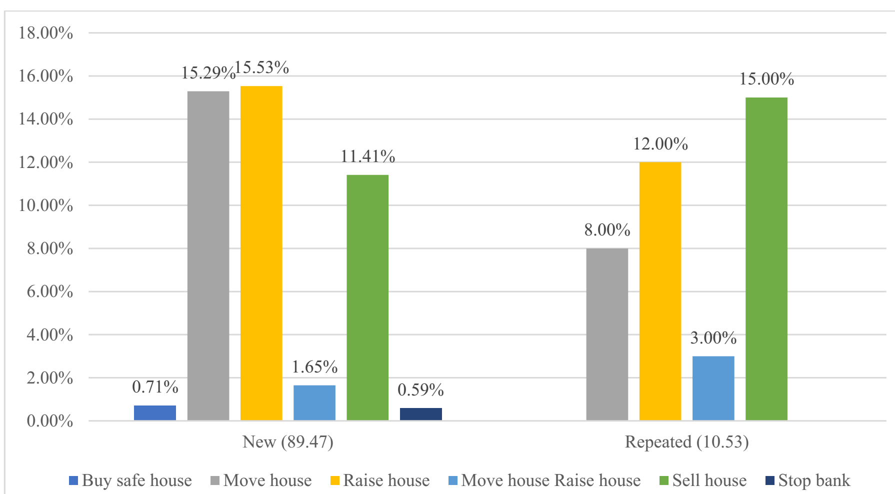


Fig. 4. Adaptation actions adopted by new and repeat players.

to new players, repeat players were less inclined to opt for moving houses back on their property or raising houses. It is interesting to explore what drives the changes for repeat players, likely because of their strategic use of initial adaptation measures and knowledge of risk progression or they just wanted to play a riskier version of the game the second time around – to see what would happen.

In a single-player game, players exhibited a greater inclination toward engaging in 'move house', 'move house raise house', and building a stopbank, as shown in Fig. 5. Notably, a substantial 19.19 % of players in single-player games chose to move houses, surpassing the corresponding figure of 14 % in multi-player games. The trend continued with the construction of stopbanks, where 3.03 % of players in single-player games opted for this strategy compared to a 2.88 % in multi-player games. On the contrary, raising houses and buying safe houses proved to be more popular in multi-player games than their single-player counterparts. The findings suggest that players in single-player games demonstrated a certain degree of flexibility, for example for building stopbanks which required negotiation with other players, while the decision-making processes regarding adaptation strategies were possibly constrained and consequently distinct within the context of multi-player group decisions. It is also possible that multi-player games exerted pressure on the players to secure 'safe land' due to competition for a restricted number of these properties.

Players were categorised into five main occupation groups based on the information they provided (see Fig. 6). Across all occupation groups, 'raise house', 'move house', and 'sell house" emerged as the most popular options. Interestingly, the adoption of moving houses was exceptionally high among those employed in government departments, and they were less inclined to sell houses. The consideration of building stopbanks was unique to youth/child players, those from the farming industry, and the general public. For policymakers, understanding such occupation-specific trends can help in designing tailored risk mitigation policies that align with different economic and social contexts.

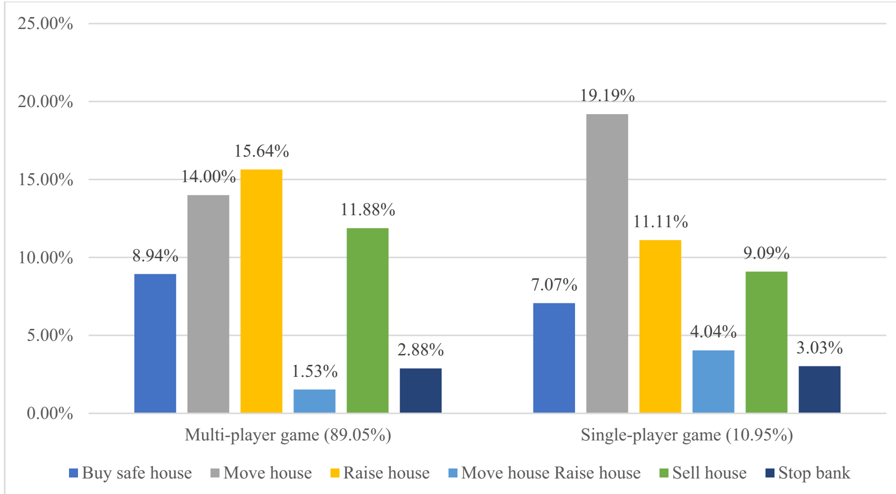


Fig. 5. Adaptation actions adopted by multi-player and single-player players.

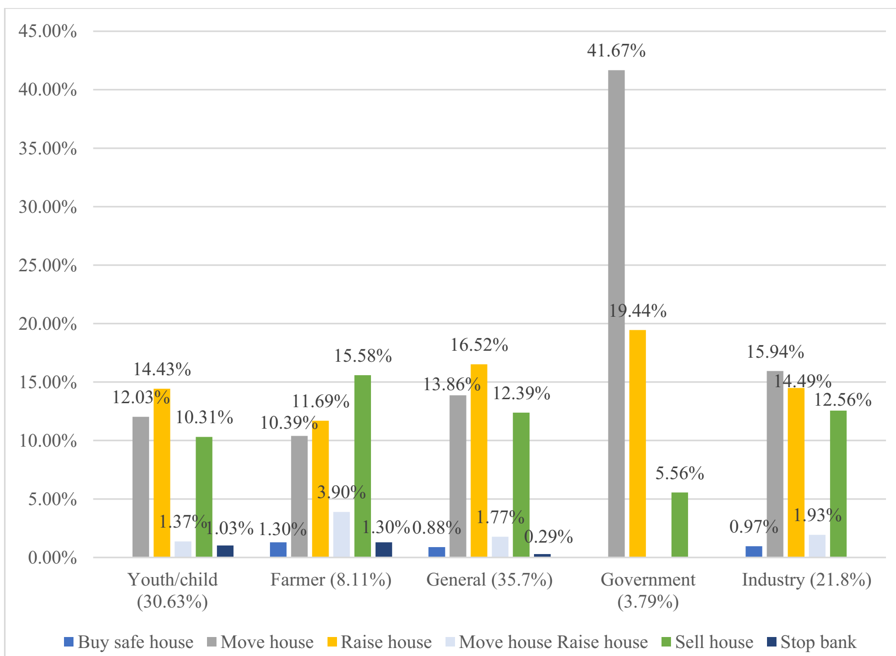


Fig. 6. Adaptation actions adopted across different occupations.

4.3. Regression results and key determinants of adaptation choices

Before presenting the regression results, we conducted additional tests to examine whether players' adaptation decisions exhibited dependency over time. First, we performed an autocorrelation analysis (i.e., Durbin-Watson statistic), to detect potential serial correlation in decision patterns. The results showed no significant autocorrelation (DW = 2.12), suggesting that past choices had a limited influence on subsequent decisions. Second, we estimated lagged variable models, incorporating prior adaptation choices as explanatory variables, to assess whether past actions systematically shaped current decisions. The likelihood ratio tests ($\chi^2 = 3.72, P = 0.04$) indicated that including these lagged terms did not substantially improve model fit.

Table 2 presents the regression results indicating the factors (shown in columns) influencing players' adoption of climate adaptation actions. As the McFadden's Pseudo R^2 (0.17) and the Likelihood Ratio (LR) test ($-1212.5, p = 0.00$) indicate, the model demonstrates an acceptable fit, capturing meaningful variation in players' adaptation decisions. While McFadden's R^2 values tend to be lower than traditional R^2 measures in linear regression, a value of 0.17 suggests that the model explains a reasonable proportion of the variance in adaptation choices. The significant LR test ($p < 0.01$) confirms that the inclusion of predictor variables significantly improves the model's explanatory power compared to a null model with no predictors. The six sets of regression results (shown in rows) represent six adaptation actions, with 'do nothing' as the baseline set. Therefore, the interpretation of the coefficients in Table 2 is based on comparisons between each adaptation action and the baseline. Here, we focus only on the coefficients of the factors that are statistically significant, as indicated by the associated *p*-values in parentheses. Significance levels are denoted as *, **, and *** for 10 %, 5 %, and 1 % levels, respectively. Key findings from the regression results are summarised below:

Climate event: severe flood events in the previous round increased the likelihood of players buying safe houses and moving houses but

Table 2
Factors affecting the adoption of climate adaptation actions.

					Factors
Dependent Variable	Intercept	Severe	High flood	No roll	Multi-player
Buy safe house	−2.04(0) ***	0.93 (0.04)**	0.07 (0.86)	−0.19 (0.54)	0.05 (0.37)
Move house	−1.02 (0.05)**	1.14 (0.01)***	−0.64 (0.13)	0.18 (0.47)	−0.09 (0.09)*
Raise house	−0.14 (0.81)	−0.29 (0.72)	−0.35 (0.34)	−0.27 (0.28)	−0.88 (0)
Move house Raise house	−12.32 (0.73)	0.3(0.79)	0.5(0.5)	−0.42 (0.5)	−0.18 (0.15)
Sell house	−1.22 (0.05)**	0.57 (0.27)	0.63 (0.07)*	0.01 (0.96)	0.2(0) ***
Stopbank	−2.05(0.2)	−5.08 (0.02)***	−5.73 (0.9)	−2.18 (0.07)	−0.04 (0.86)
					Factors
Dependent Variable	Repeated	Count dice	Marae	Town	Farmer
Buy safe house	0.11(0.81)	0.58 (0.08)*	−10.34 (0)***	1.67 (0.02)**	−0.14 (0.05)**
Move house	−0.1(0.77)	−0.74 (0)	−0.45 (0.67)	1.85 (0.03)**	0.06 (0.81)
Raise house	0.56(0.16)	0.15 (0.26)	0.38 (0.74)	0.7 (0.89)	0.12 (0.07)*
Move house Raise house	−0.74 (0.57)	8.61 (0.81)	−0.05 (0.97)	1.13 (0.73)	−0.25 (0.72)
o=Se8ll house	0.1(0.25)	0.95(0) ***	−10.62 (0)***	−9.3(0) ***	0.34 (0.23)
Stopbank	−2.98 (0.01)***	−0.05 (0.97)	−3.99 (0.95)	−1.42 (0.77)	−1.38 (0.32)
					Factors
Dependent Variable	Public	Government	Industry	Rounds	Safe
Buy safe house	0.39 (0.41)	0.11(0.7)	−0.46 (0.68)	−0.14 (0.65)	0.11 (0.95)
Move house	−0.24 (0.38)	0.28(0.03)	0.99 (0.05)**	0.1 (0.95)	0.61 (0.03)**
Raise house	0.22 (0.28)	0.3(0.26)	0.83 (0.17)	0.24 (0.38)	0.14 (0.06)*
Move house Raise house	0.45 (0.53)	0.33(0.64)	−6.75 (0.59)	−0.16 (0.07)	−0.25 (0.72)
Sell house	0.76 (0.07)*	0.19(0.82)	0.24 (0.76)	−0.34 (0.3)	−0.34 (0.23)
Stopbank	−1.51 (0.23)	−1.47(0.24)	−8.23 (0.9)	−9.98(0) ***	−4.1 (0.9)
AIC	2211.41				
McFadden pseudo R^2	0.17				
Likelihood Ratio Test	−1212.5 ($p = 0.00$)				

Note: Base group is 'do nothing' for the model; Base group for property is 'farm'; Base group for Game type is 'Single-role player'; Base group for User type is 'New User'; Base group for Flood event is 'No event'. *P* values in parentheses, and shaded cells are coefficients that are statistical significance.

decreased the likelihood of building stopbanks which do not protect against damages from severe flood events. A high flood event in the previous round increased the likelihood of selling houses. Players who did not roll the dice in the previous round were less likely to build stopbanks.

Game characteristics: ***Game type***: multi-player game players were less likely to move houses but to sell houses; repeat players were less likely to build stopbanks. ***Player type***: repeat players tended not to build stopbanks. ***Safe round***: players who became safe in later rounds were more likely to have moved houses and raised houses. ***Game round***: As the game progressed to later rounds, players were less likely to adopt actions of moving and raising houses, and selling houses.

Property type (dairy farm as the base): players acting as marae representatives were more likely to move their existing buildings ('move house') but less likely to buy safe houses, and unable to sell their property; townspeople were more likely to buy safe houses and move houses, but less likely to sell houses.

Player characteristics: ***Count dice:*** counting dice increased the likelihood of buying safe houses and selling houses, however only a few players counted the dice to quantify the risk. ***Occupations***: compared to youth/children, farmers were less likely to buy safe houses but more likely to raise houses; the general public were more likely to sell houses; governmental officials were more likely to move houses; industry people were more likely to move houses.

These findings highlight that adaptation decisions are influenced by a combination of perceived risk, resources, and prior experience, underscoring the complexity of fostering adaptive behaviours in flood-risk contexts.

5. Discussion

We come back to the three questions raised in earlier sections: 1) what data insights can be drawn from the collected data? 2) what are the data gaps in climate change decision-making analysis? 3) what are the next steps for gameplay data analysis in the realm of climate change adaptation? We conclude the following from the findings in section 4.

5.1. Data insights: insights reflecting climate change decision-making literature

Our findings within the serious game, 'The Township Flooding Challenge', reveal patterns in adaptation choices that resonate with studies in real-world climate adaptation. The gameplay data analysis offers meaningful insights into climate adaptation decision-making under uncertainty, highlighting how knowledge and experiences with climate change - such as experiencing extreme weather events - can impact players' adaptation choices. In short, losses within the game often trigger adaptive actions, aligning with real-world studies indicating that extreme events are significant stimuli for climate adaptation (Berrang-Ford et al., 2011; Carlson and McCormick, 2015; Gould et al., 2024). Information types, like details on event scale and influence, as well as traditional and local knowledge, may also motivate adaptive responses (Carlson and McCormick, 2015; Kvamsås et al., 2021; Mekonnen et al., 2021). However, as van Valkengoed and Steg (2019) note, knowledge and experience alone may not strongly drive adaptation adoption, and thus information must be relevant and effectively framed. The framing of climate change as a singular environmental problem may hinder the integration of adaptation measures in local plans, suggesting that decision-makers' perceptions of climate change (e.g., its impact on local areas) play a crucial role in adaptation adoption (Carlson and McCormick, 2015; Picketts et al., 2014; van Schaik, 2023).

Our findings reinforce the need to provide clear, context-specific information that encourages effective adaptation decisions and emphasises the diversity in adaptation strategies across roles in the game. The results demonstrate that players' choices were influenced by their perceived risk, resources, and prior experience. For instance, severe flood events in previous rounds increased the likelihood of players buying safe houses and moving, while reducing their likelihood of building stopbanks, as stopbanks do not provide adequate protection against severe flooding. Similarly, differences in adaptation strategies were evident across property types—marae representatives were more likely to relocate existing buildings but less likely to buy safe houses or sell property, whereas townspeople were more inclined to move and purchase safe houses. These differences mirror real-world adaptation research, which emphasises that tailored approaches are often necessary due to the distinct resources, perceptions, and motivations of diverse groups within a community (Adger et al., 2005; Berkes and Ross, 2013).

For example, farmers in real-world settings may prioritise adaptation measures that protect their livelihoods, such as investing in flood-resistant infrastructure, because these decisions directly impact their income and resource security (Howden et al., 2007). Our findings align with this, as farmers in the game were more likely to raise their houses but less likely to buy safer properties, reflecting their preference for on-site resilience strategies. Meanwhile, townspeople may focus more on infrastructure improvements or community-based solutions that safeguard local assets and public spaces (Moser and Ekstrom, 2010), a pattern reflected in the game by their higher likelihood of relocating.

Moreover, providing context-specific information is crucial for adaptation success, as shown in studies by Carlson and McCormick (2015), which found that clarity and relevance of information significantly influence adaptation uptake. However, simply supplying information may not be sufficient. Adaptation support must also involve clear guidance on how different groups can utilise this information in ways that suit their unique conditions. For example, townspeople in flood-prone areas might benefit from resources focusing on collective measures, such as community-managed levees or cooperative disaster preparedness programs. In contrast, farmers may require detailed information on individual resilience strategies, like farming risk management practices suited to their particular geographical and climatic conditions. Our results support this notion, as adaptation actions in the game varied significantly based on players' roles, experiences, and decision-making constraints, reinforcing the importance of targeted adaptation strategies.

Furthermore, the diverse preferences on adaptation practices among players with different occupations highlight the importance of considering occupational roles in designing climate change adaptation strategies within serious games. Studies on climate adaptation show that individuals' adaptive responses often correlate with their roles in society, as these roles shape both knowledge and priorities (Kvamsås et al., 2021; Mekonnen et al., 2021). Players may integrate their occupations into the roles and decision-making processes within the serious game, aiming to connect everyday experiences and practices with the conceptual framework of the game-setting (Dang et al., 2019). Nevertheless, there is a potential for conflict between the game contents and reality, impeding players' ability to make sense of the experience (Asplund et al., 2018). Therefore, future games, especially those focused on climate change adaptation for a broad audience rather than a specific group, should carefully account for the impact of players' occupations on their preferences and aspirations (Dang et al., 2019). Also, the design of climate change-focused serious games should consider components to encourage participants' in-depth discussions and interactions during the game to help data gathering and analysis of the 'sense-making' process (Wibeck and Neset, 2020).

5.2. Data gaps: missing data dimensions in climate adaptation strategy analysis

Our examination of gameplay data in understanding decision-making for climate change adaptation reveals several notable data gaps that warrant further investigation. While we observed that knowledge of probability and experience of extreme weather events may influence players' adaptation decisions, distinguishing the impact of certainty from risk attitudes remains challenging. The current design of the game did not capture players' explicit risk preferences (e.g., risk-averse or risk-seeking tendencies), which are often essential in real-world climate decisions as they influence the willingness to adopt adaptive measures (Abbass et al., 2022). Although players' counting of dice rolls to estimate flood probabilities provides insight into how some base actions on known probabilities, most players relied on intuition. This finding aligns with research suggesting that individuals often prefer heuristics or intuitive judgments over complex calculations, particularly under uncertain conditions (Kahneman, 2011). Communicating the risks of natural hazards more explicitly may therefore impact decisions, emphasising the need for game designs that incorporate clear representations of risk to facilitate informed adaptation choices.

Significant differences in adaptation strategies also emerged between single-player and multi-player game dynamics. In multi-player scenarios, decisions hinge not only on individual risk assessments but on group dynamics, reflecting the complexities of real-world adaptation contexts where coordination with others is often required (Adger et al., 2005). For instance, multi-player games require consensus on constructing stopbanks, introducing a layer of negotiation that is absent in single-player settings. This mirrors real-world findings where community-based adaptation often involves collective decision-making and consensus-building (Barrett, 2013; Lopez et al., 2013). Additionally, competition for safe land introduces a "fear of missing out" (FOMO) effect, which influences individual choices in competitive adaptation scenarios. Documenting these interactive dynamics systematically could further enhance our understanding of how social interactions shape adaptation strategies, an aspect increasingly recognized as critical in community resilience studies (Berkes and Ross, 2013).

Further data gaps centre around the exploration of players' financial capacities, actions affordable to players, and the nuances of investment activities, such as the types of households at different game stages. In the Township Flooding Challenge serious game, players' investments in townhouses (unless specified otherwise for rental purposes) were considered adaptation actions due to their location in the safe zone. However, the intentions behind these investments were not consistently captured, leaving it unclear whether decisions were motivated by adaptation, financial gain, or a combination of both. In real-world settings, studies have shown that financial motivations frequently drive adaptive actions, especially in household-level adaptation (Eakin et al., 2014; Lemos et al., 2013). Additionally, although selling houses constituted a substantial portion of adaptation actions, the specific types of houses sold were not recorded, due to the limited time and staff available at the Fieldays. However, this information can be relatively easily handled in a computer-based game. As a result, it remains unclear whether players intended to invest, adapt, or both through their decisions to buy and sell houses.

Lastly, qualitative insights are an underexplored dimension in gameplay data analysis. Incorporating both qualitative and quantitative data could reveal deeper connections — or contrasts — in players' decision-making processes, especially regarding their perceptions of climate risks and adaptation strategies (Harrison et al., 2013). For example, in real-world adaptation, qualitative feedback often highlights barriers or unanticipated challenges in ways quantitative data cannot capture alone (Paton, 2017). Enhancing the design of serious games with mechanisms to capture qualitative insights, such as reflective debriefs or post-game interviews could bridge this gap, enriching our understanding of adaptation decision-making within the nuanced context of climate change.

5.3. Next steps

Building upon our exploration of gameplay data analysis within the context of climate change serious games, our next steps involve a deliberate consideration of methodological refinements, dataset expansions, and the incorporation of additional variables to augment the richness of our analyses. By carefully analysing and validating the Township Flooding Challenge serious game, we open avenues for theory-building and empirical testing, allowing us to glean insights into a diverse array of human actions and behaviours related to climate change (Asplund et al., 2018; Moreno-Ger et al., 2012). In the context of water management, Aubert et al. (2018) proposed that the results of water-related serious games could be used to serve the purpose of multi-criteria decision analysis, including problem structuring, stakeholder analysis, defining objectives, and exploring alternatives. Serious games, when designed appropriately, could be used as both an educational/

engagement tool and data collection tool to gather information to be used in decision-making analysis, such as agent-based modelling (Banos et al., 2020; Taillandier and Adam, 2018) and economic analysis (Ahmed et al., 2023; Manshoven and Gillabel, 2021). Note that forethought is needed on what data needs to be collected prior to gameplay, which is specific to each game and its purposes. Also, researchers may confront different challenges in data collection in board-based and computer-based games: while the latter provides relatively easy and accurate means of data collection, the channels/tools for players to communicate in the game need to be properly designed and monitored.

In parallel, we consider the role of gameplay data analysis in reflecting real-world decision-making processes (Flood et al., 2018) and exploring potential disadvantages or ineffectiveness in game designs. As highlighted by Hernandez-Aguilera et al. (2020), although some hypotheses may underlie the games, explicit experimental purposes may not always be apparent; generalisability of results is not always appropriate given the often context-specific nature of project goals. When appropriately collected, the analysis of the quantitative and qualitative information may help explore the connection between gameplay data analysis and post-game data analysis, such as players' reflections or feedback, to gain a more comprehensive understanding of player experiences and decision-making dynamics.

Finally, we deliberate on the question of investment versus adaptation actions, exploring how gameplay data analysis can inform decision-making in these critical domains. This finding also indicates the direction for data collection in future serious games regarding different purposes. For example, more detailed information about the financial statuses is needed to understand financial constraints and the relationship to players' adaptation actions.

While our study centres on an Aotearoa New Zealand-based game, the insights shown above may have broader applicability. Serious games could serve as valuable tools for understanding climate adaptation behaviours globally, particularly in regions where climate risks are immediate and pressing. For instance, similar game-based analyses in flood-prone communities in areas such as Southeast Asia could reveal adaptations influenced by cultural norms and economic constraints unique to that region. Such comparative studies would enrich our understanding of how local factors shape adaptive behaviour, informing the design of context-specific serious games that can address distinct regional vulnerabilities and priorities.

6. Conclusion

The important value of serious game-playing lies in its ability to serve as a safe, engaging, and interactive platform for the exploration of various climate futures. Analysing gameplay data from climate change serious games not only aids in identifying opportunities but also informs strategic adaptation planning, contributing to the development of resilience strategies. In our study, we conducted an exploratory analysis using data from a township flooding game in Aotearoa New Zealand to investigate the potential of utilising gameplay data to explore players' decision-making regarding climate adaptation. The findings suggest that gameplay data can offer insights into players' decisions on climate change adaptations amid uncertainty. However, our analysis also revealed several notable data gaps, such as ambiguous definitions (e.g., investment vs. adaptation) and incomplete data (e.g., player interactions). These insights and gaps underscore the potential of leveraging gameplay data to support decision-making modelling and enhance the design of serious games.

While our exploratory approach, utilising descriptive statistics and regression analysis, has yielded valuable insights into adaptation behaviours within game-based flood-risk decision-making, it is crucial to acknowledge inherent limitations. One significant concern is the potential for overfitting, where models may capture noise rather than underlying patterns, leading to misleading conclusions. Additionally, the absence of predefined hypotheses in exploratory studies can result in data dredging, increasing the risk of identifying spurious relationships. These limitations underscore the necessity for cautious interpretation of exploratory findings and highlight the importance of validating results through confirmatory studies with larger datasets. Moreover, our study is constrained by its focus on a single board-based game in Aotearoa New Zealand that was not originally designed for behavioural analysis. This limitation may affect the generalisability of our findings to other game formats or contexts. To address this, future research will expand our exploration of gameplay data analysis by including a wider range of climate change serious games, encompassing both board and computer-based formats. This expansion will provide a more comprehensive understanding of how gameplay data can inform decision-making processes and improve the effectiveness of serious games in addressing climate change challenges. Additionally, the methods and insights from our current study may guide similar explorations globally, particularly in areas with differing climate-related risks and socioeconomic conditions. Future studies might adapt and test this game and analysis approach to capture region-specific adaptations, providing deeper insights into the role of cultural, economic, and environmental factors in shaping effective climate change responses. Lastly, another limitation concerns the data collection setting. Data were gathered at an agricultural event stand, where participants casually dropped in, often amid distractions. This environment contrasts with controlled serious game settings, where players typically engage in a quiet, focused manner. Future studies may consider incorporating these environmental factors to better assess their potential impacts on engagement and outcomes.

Funding acknowledgment statement

The study is supported by the Ministry of Business, Innovation & Employment (MBIE) Endeavour projects "Transforming coastal lowland systems threatened by sea-level rise into prosperous communities" (Grant No. C01X2107) and "Mā te haumaru ō nga puna wai ō Rākaihautū ka ora mo ake tonu: Increasing flood resilience across Aotearoa" (Grant No. C01X2014).

Ethics approval statement

Ethics approval was obtained from the Human Ethics Office of the National Institute of Water and Atmospheric Research, New Zealand.

CRediT authorship contribution statement

Wei Yang: Methodology, Conceptualization, Data curation, Writing and Revising. **Sarah Harrison:** Conceptualization, Writing and Revising. **Paula Blackett:** Conceptualization. **Andrew Allison:** Conceptualization and Revising.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

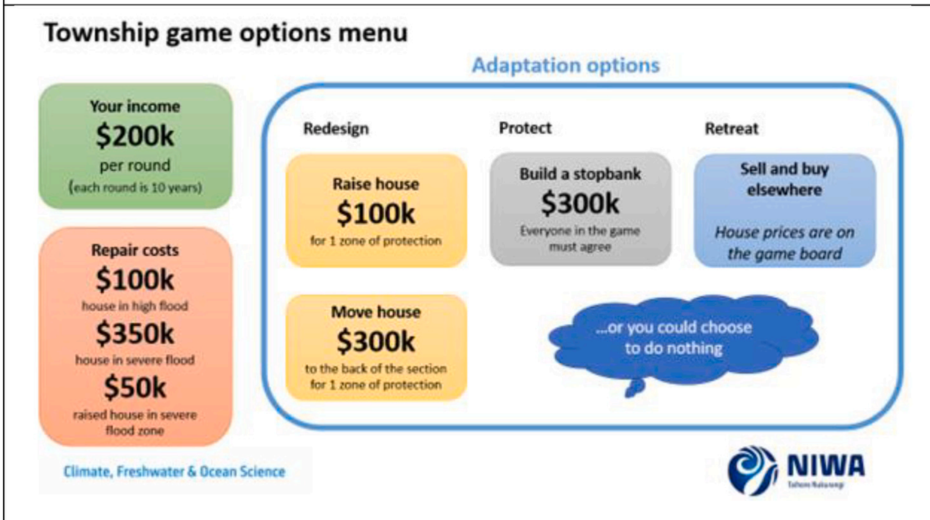
Appendix A

Appendix Fig. 1. Gameplay photo taken at the Fieldays.

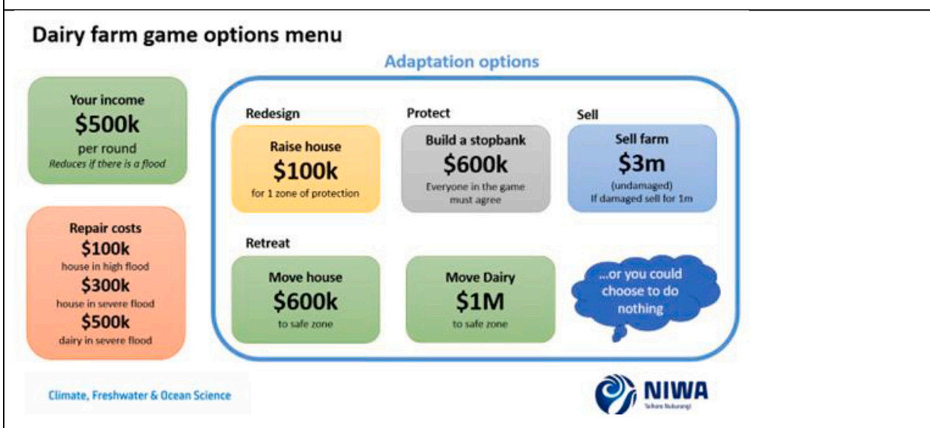
Appendix Fig. 2. Gameplay photo taken at the Fieldays.

Appendix Table 1
Game summary cards.

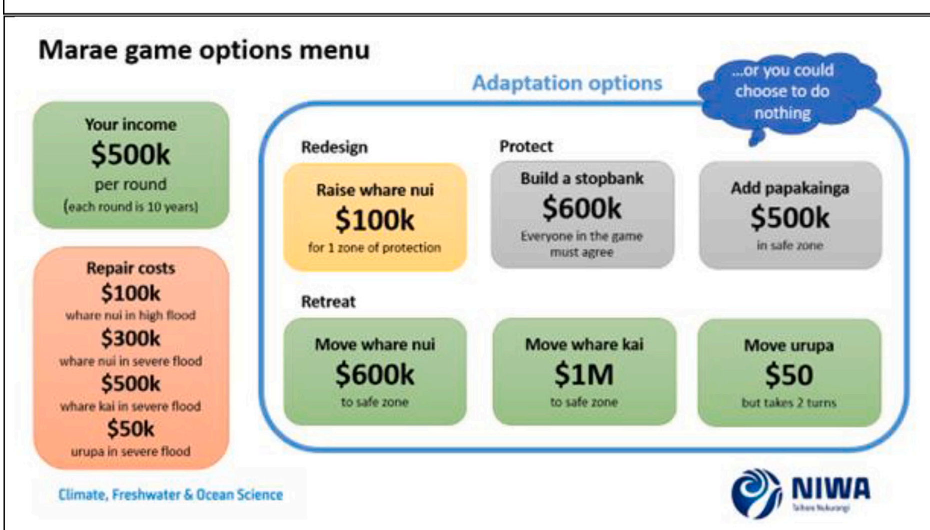
Township



Dairy farm



Marae



Data availability

Data cannot be made available due to data confidentiality.

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