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Farmer Options and Risks in Complex Ecological-Social systems: The FORCES game designed for agroforestry management of upper watersheds

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HIGHLIGHTS

- An adaptive game design on resource use in upper watersheds can connect local ecological knowledge to general principles.
- By balancing generic and specific aspects of design, game reusability can increase returns on research investment.
- The generic water balance representation in the FORCES game supports transferability to different landscapes.
- Game dynamics that mimic realistic local conditions, evoke engagement, and trigger close-to-real-life choices.
- When choosing trees, individual farmers seek synergy between the tree's economic and ecological performance.

GRAPHICAL ABSTRACT

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ABSTRACT

CONTEXT: Serious games have gained popularity as an innovative participatory approach to explore the complexity of social-ecological systems, managing the trade-offs between economic and ecological targets. Serious games can be abstract and generic, or more complex and specific. They can be used to raise awareness, increase shared understanding of options and risks, and/or commitment to common goals.
OBJECTIVE: We here aim to clarify design principles applied in the FORCES game (Farmer Options and its Risk in Complex Ecological-Social systems) as single-player game to be easily adaptable to diverse (upper) watershed contexts. Three steps involved are game design (balance generic and site-specific information), game use in (and possibly adaptation to) specified context(s) and evaluation of contextualized impacts.
METHODS: The FORCES game design was based on three contrasting watershed case studies in East Java, Indonesia, rather than on single, specific case study. Game development consisted of preparation (defining the

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context, generic core issues and game objectives), development process (ideating, setting the actors, resources, elements, and mechanisms), and assessment (prototyping, exploration of solution space, game trial and player feedback). Fifty-five smallholders played the FORCES in three landscapes to test the game's performance and impact on participants' insights. Therefore, we recorded every game session and performed pre- and post-game interviews for each participant.

RESULTS AND CONCLUSIONS: The developed FORCES game focuses on decisions of individual farmers involving plot-level plant (annual crops, trees) choices with financial cost-benefits consequences and links to ecological impacts on the litter layer, water balance, and erosion. The FORCES game was successfully applied in three distinct landscapes, demonstrating its adaptability. The game's generic water balance supported the transferability to different contexts, while fine-tuning of plot management options to reflect local variation was simple due to the solid underlying game mechanics. According to players, the game reflects local dynamics in the landscapes and provides a realistic experience, triggering participants to make decisions close to their real-life choices and learn from the consequences. While the game has limited representation of social interactions due to its single-player design, FORCES allowed relational values to be recognized in players' responses.

SIGNIFICANCE: Balancing the combination of generic setting with easily adaptable site-specific elements in the game design plays an essential role to increase game adaptability and reusability to different locations. FORCES adds to the growing array of games that can be used to support farmers' participation in higher-level decision-making processes to secure environmental services in productive landscapes.

1. Introduction

Managing landscapes for resilient livelihoods and environmental integrity in the context of forest-water-people interactions requires coordination, collective action, and internalized externalities (Thaxton et al., 2017; Meinzen-Dick et al., 2018; Villamor et al., 2022). Coordination builds on human sociality that in various cultural contexts combines four basic psychological models distinguished by Fiske (1992): communal sharing, authority ranking, reciprocity and market pricing. As human decision-making responds to both rational and emotional clues (Kahneman, 2011), both instrumental (goal-oriented) and relational (two-way interactions that establish and reflect affinity) values appeal to different aspects of rationality in interhuman and human-nature interactions (van Noordwijk et al., 2023a). Water flows, overland or sub-surface, connect farmer choices in the upper watershed with downstream consequences. Coordination of individual farmer decisions can be achieved through various 'levels of internalization', that range from punishments, fines, compensation, commoditized ecosystem services, co-investment in stewardship to peer pressure and taking responsibility for footprints (van Noordwijk et al., 2023b). Broadening the range of options and clarifying environmental consequences can be the art of a comprehensive approach to internalizing externalities (van Noordwijk, 2019). Such changes require cognitive aspects and emotional shifts (Mankad, 2016; Rose et al., 2018) in increasing awareness and stewardship that have been hard to achieve in existing projects, extension systems and social media campaigns.

Serious games become a promising approach to shift cognitive and emotional aspects of complex socio-ecological systems (Hofstede et al., 2010; Tschakert and Dietrich, 2010; Dernat et al., 2022b). In the social construction of reality and the world of engineering, material aspects of human activities interact with beyond-human nature, and the game interacts with how it is used. Both in the design-in-the-large (of a process in which games play a role) and in the design-in-the-small of the game as such, the organized complexity of a systematic arrangement of elements determines their becoming part of a whole (Klabbers, 2003). Serious games have gained popularity as an innovative participatory approach to learn about (Falk et al., 2023), discuss (Janssen et al., 2023), and explore the complexity of global socio-environmental problems (Speelman et al., 2019). Serious games are used for various purposes: education, research, and intervention (Rodela et al., 2019), including arising public awareness of issues such as water (Rebolledo-Méndez et al., 2009), sustainability (Lameras et al., 2013), and social related issues (Damani et al., 2015), and exploring options in the socio-environmental-political domain (Harteveld et al., 2007; Orduña Alegría et al., 2020). A game-based approach provides a contextualized experience to facilitate learning through practice, failure, reflection, and repetition (Whitton, 2012). It can engage participants, supporting experiential learning (Csikszentmihalyi, 1990; Michael and Chen, 2006), possibly leading to learning gains (Craig et al., 2004), problem-solving, improved communication and group activities (Degirmenci, 2017). Thus, a game-based approach can trigger creative emotional tension, encouraging the participants to explore system behavior through external pressure scenarios, and enabling the discovery of new possibilities for action (Damani et al., 2015; van Noordwijk et al., 2020). The benefit of experiential learning could address social difficulties by smoothening information transfer when a traditional teaching approach does not properly work for adults. Therefore, the interest of researchers and practitioners in games has grown significantly.

While many game design frameworks are available, existing frameworks are not commonly (re)used to develop simulation games in the context of natural resource management. These frameworks define distinct phases of game development and guide the basic conceptualization of various game design concerns (Mochizuki et al., 2021). Existing frameworks such as Companion modelling – ComMod (Barreteau et al., 2014) and the Triadic Game Design approach: Reality, Meaning, Play (Harteveld, 2011) can be utilized for developing a serious game and identify the relationship between designers and players (linking design and the users of simulation games). The Triadic Game Design approach, for example, constitutes elements of fun and learning in a game, including the balance and trade-off between reality, meaning, and play. The DPSIR framework (Drivers, pressures, systems, impacts, and responses) (OEDC, 2003) was originally not developed for game development, but can also be used to identify the major interdisciplinary issues for game conceptualization in a complex system. These frameworks can be combined to produce effective boundary work, and to gain a deeper understanding of the social-ecological system for model conceptualization (van Noordwijk et al., 2020; Villamor et al., 2023), and to develop a meaningful, and fun game. However, game design focus on the game reusability has not yet been widely explored.

Game design involves simplification and abstraction, by simplifying rules as much as possible ('but no further') (Burns et al., 1990), and excluding irrelevant details (Gentry, 1990; Villamor et al., 2023). This type of game prioritizes engagement and conceptual congruence instead of precision of facts since the facts alone do not change minds (Toomey, 2023). Most games are a simplification of reality. However, a game that oversimplifies reality and lacks complexity with little dynamics to explore is boring for participants (Rasim Langi and Munir Rosmansyah, 2016). Designing a game is challenging, particularly to incorporate (1) an adequate level of complexity without reducing the learning effectiveness (Cannon et al., 2009) and (2) sufficiently representing realistic dynamic to evoke engagement and maintain the interest of the participants. Only a few studies have taken the generic setting into account in the game design (Dernat et al., 2023). On the other hand, games face similar challenges in the validation step as other types of models (Kooij et al., 2015), although the question is not whether they are 'right', but whether they 'help', in achieving the initial objective of the game. However, the effectiveness of game design should be explored (Caserman et al., 2020). A game design is considered successful when it can satisfy the expectations concerning knowledge gain of participants, and when, as for models in general, a game is credible, salient (relevant and enhancing understanding), and legitimate (a fair representation of the views, values, and concerns) (Lusiana et al., 2011; van Voorn et al., 2016). Other elements that determine the success of a game are player engagement, including the provision of a fun and enjoyable experience, and the suitability of the interaction for the target group (Caserman et al., 2020).

In complex social-ecological systems, such as livelihoods in watersheds, the game design in the context of a triple-bottom-line sustainable production system needs to represent a search for synergy between maintaining agricultural productivity, sociality, and ecological functions across natural resources management issue cycles (Rodela and Speelman, 2023). At the first stage, raising awareness about the issues as part of agenda setting may need to be clarified before targeting further steps such as shared understanding, commitment to goals, implementation and monitoring (van Noordwijk, 2019). The logical connections need to be visualized and clarified between farmer choices which mostly refer to the individual decision at their plot/field level, economic benefits and ecological consequences (such as water balance), and social feedback systems where goals like good quality water for all are not yet achieved, and conflicts arise. In this paper, we present FORCES as a plot-level single-player game, its development and its evaluation mainly focused on the game's playability exploration. The game itself aims to create a setting in which one can gain a deeper understanding of the rationale behind farmer choices in their social context (Githinji et al., 2023) in the game making, as it may vary across gender and age groups (Mulyoutami et al., 2015). Restrictions that prevailed during the 'lockdown' response to the COVID-19 pandemic did not allow for group sessions and individual games were the only option feasible. The focus on individual decision-making processes, however, may still allow for response to pointers of social context and environmental externalities to be explored. The resulting individual game may complement the recent multi-player game literatures on watershed issues, for example, a role playing game about watershed management in Ethiopia (Assefa et al., 2021), a collaborative game for ground water resource use in Tunisia (Ferchichi et al., 2020), and an integrated water resource management game in Ghana (Daré et al., 2018). While those games were generally developed based on a single, specific case study, in this paper, we proposed the game design which was developed based on the several case studies and focused on the individual decision making of farmers.

We aimed to design a game to understand how individual farmers make decisions on plant and farming systems selection, including raising awareness about the trade-off issues. It contributed to provide a game design on the first phase of issue cycles. In this paper, we describe (1) the development process of FORCES game, (2) reusability of the game (transferability), and (3) evaluation of the performance regarding its design. We did not evaluate the impact of the game session on participants' real- life choices. In the current game, we firstly aimed to design a game that balances generic and specific elements so that it can be easily adapted for any broadly similar upper watershed context, filling in the middle ground of stylized generic and locally fine-tuned specific game-designs that has not been explored yet. We intended to represent real-world situations that can evoke engagement, stimulate experiential learning, and provide a 'fun' experience in which participants can learn from the direct consequences of their individual decisions through external pressure scenarios. We evaluate the game performance by questioning the following criteria: (1) Can a balanced design of generic and specific elements and adjustable settings be found that supports game transferability to different locations (salience, legitimacy)? (2) Does the FORCES game as developed provide a realistic experience to the participants based on their evaluation (credibility)? A follow-up study (in separate paper) will analyze site-specific game results and explore what insights the participants gained by playing the game. Combination of these studies can evaluate to what degree the resulting FORCES game can be readily adjusted and applied in different landscapes.

2. Material and methods

2.1. Case study

As part of a pantropical set of landscapes where the forest-water-people nexus is explored (van Noordwijk et al., 2020), the current effort focused on mountain slopes and valleys in East Java (Indonesia) where human population densities of 300–1000 persons km^{-2}, are found with annual rainfall of 2000 m y^{-1} on young volcanic soils, a range of agriculture-based rural livelihoods and strongly modified forest cover. Three contrasting landscape settings were identified here. Two upstream sub-watersheds of the Brantas river and the adjacent Rejoso watershed have experienced progressive deforestation on the higher slopes (Nurrizqi, 2012; Andriyanto and Sudarto, 2015; Amaruzaman et al., 2018). High soil erosion in Kali Konto pollutes the Selorejo reservoir (Andriyanto and Sudarto, 2015; Ambong and Sayekti, 2018), impacting crop production (Jackson et al., 2005). Additionally, unsustainable farming practices in Rejoso affect infiltration and groundwater flows, with reported impacts on the discharge of the Umbulan spring (Toulier, 2019), and water availability in artesian wells (Khasanah et al., 2021). Brantas Hulu is facing similar water issues as Kali Konto with higher severity, thus less water discharge (Nurrizqi, 2012; Witjaksono et al., 2018), affecting the number of springs remaining in the landscapes (Sulistyaningsih et al., 2017). Since the 20th century, various soil conservation programs, mainly aimed at agricultural land, have been implemented, including a joint multidisciplinary Kali Konto project implemented by the governments of Indonesia and the Netherlands in 1987 to 1990 (Rijsdijk, 2005); and the Management Action Plan of Brantas Watershed (Sulistyaningsih et al., 2017). However, the problems persist and the effectiveness of these programs has been challenged (Rijsdijk, 2005). It indicates that alternative approaches are necessary to address these issues, as previous top-down programs have only provided partial solutions. In this context, innovative participatory methods, such as games, could be valuable in promoting a bottom-up approach and making meaningful contributions to problem-solving.

2.2. The process of the game design

The game development was an iterative process consisting of three different phases, i.e., preparation, development, and assessment. Phase I started with defining the context of the social-ecological system (IA), identifying the generic core issues and objective of the game (IB). Phase II was game development, it involved: ideating, setting the elements, and mechanics (IIA), integrating empirical data (IIB), and specifying the structure (IIC). Phase III involved prototyping and exploration of possible solutions (IIIA), and game trial and monitoring (IIIB, Fig. 1). During this process, we combined two existing frameworks and approach, namely the DPSIR framework and the ARDI method (Actors, Resources, Dynamic, Interactions) to guide the foundational conceptualization of issues and steps in the game development, respectively.

2.2.1. Preparation stage (phase I)

In phase I, we firstly defined the context of the social-ecological system of the study cases (IA), adapting the DPSIR framework to understand the complexity of the systems and its related socio-hydrological issues (OEDC, 2003; Tscherning et al., 2012; van Noordwijk et al., 2020). We chose this framework as it is widely used as a general framework for analyzing the environmental problem (Kelble et al.,

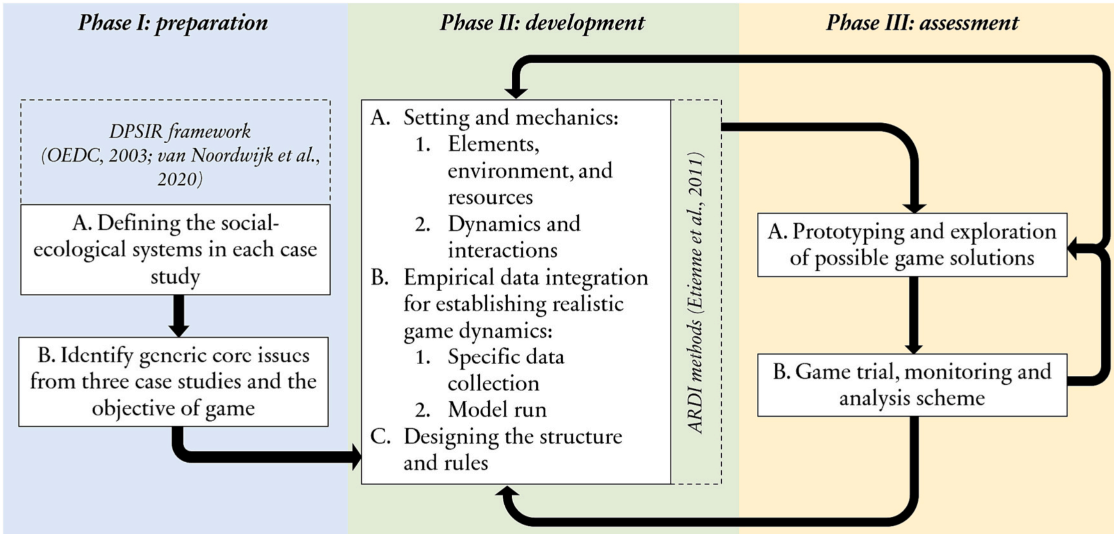


Fig. 1. Phases in for developing the FORCES (Farmer, Options, Risks in Complex Ecological-Social system) game.

2013). We used three contrasting case studies within the volcanic mountains of East Java, Indonesia: the Kali Konto sub-watershed ($7^0$45′57″- $7^0$56′53" S and $112^0$19′18″- $112^0$29′57″ E), Rejoso watershed (07° 32′ 34″ -07° 57′ 20″ S and 112° 33′ 55″-113° 05′ 37″ E), and Brantas Hulu sub-watershed (7° 44′- 8° 26′ S and 122° 17′- 122° 57′ E). These case studies followed the Rapid Hydrological Appraisal-RHA (Leimona et al., 2015) guidelines for combining spatial analysis and exploration of local, science-based and public/policy ecological knowledge systems. We collected and utilized the information from various published and unpublished references from previous studies on watershed-related issues in each study location (including the result of RHA), and the broader comparison with the pantropical set to check on relevance beyond the focal landscapes (van Noordwijk et al., 2020). Based on this information, the drivers, pressures, system-state, impacts, and responses for each of our study locations were identified to obtain broader and comprehensive understanding on the common important issues. In each case study, the current land-use system-state was set as the starting point, and the pressures that the landscape actors respond to were determined, including their underlying drivers and the social and ecological impacts of the system state. The identification result of driver, pressures, interaction, systems, and responses in three case studies in phase IA, was utilized for the next phase.

In phase IB, we identified the generic core issues shared among the three case studies by pinpointing the differences and overlapping aspects. Thus, we determined the generic core elements that serve as a bridge across the specific issues.

2.2.2. *Development process (phase II)*

In phase II, we developed the game by specifying the setting and mechanics including the elements (IIA), integrating empirical data (IIB), and structuring the game (IIC). The topic used in the specification of the game setting and mechanics (IIA) was based on the generic core issues identified in phase I. In this step, we adopted the ARDI method (Etienne et al., 2011) to specify phase IIA, where key elements of the systems, their interactions, and the dynamics are reflected. The key resources, dynamics, and interaction of the mental model were constructed based on the steps in ARDI methods. The actor action was determined based on the information generated from the local literature which came from the long-term previous research in the study area, complemented and verified by several farmers through in-depth interviews, as we aimed to include ecological processes as the consequences of actor decision. In this specific context, farmers were the primary actors involved, with 'top-down' actions of a changing market or policy context represented in successive changes between rounds of the game.

We used empirical data (IIB) from the landscapes including the model runs in the game development to ensure realistic dynamics during the gameplay. We translated the socio-eco-hydrological system theory into the game through the set of rules derived from available empirical data from previous research (Saputra et al., 2020; Sari et al., 2020; Sari et al., 2022) as data source for model simulation. We utilized a local parametrization of the WaNuLCAS model (van Noordwijk and Lusiana, 1998) to generate the environmental impact estimation, to be used as a basis to build the rules for open-field, partial tree cover (agroforestry) and closed-canopy forests. We performed around two or three model runs for different plant combinations that are commonly found in the three landscapes. We performed a cost-benefit analysis of various types of farming systems based on in-depth interviews with twenty farmers. The inquiries were referred to the number of person-days of work and responses to low (or high) market prices. We used this result to build the game rules associated with the economic characteristics like production costs, labor requirement, and economic benefit, including the income associated with climatic variation.

We considered bringing several external pressure scenarios to the game to test (1) the persistency of choice; (2) provide surprise elements to maintain participants' interest. The external pressure scenarios were decided based on the common pressures that appear derived from the result in phase I, representing natural, social, and economic pressures. Due to the additional complexity associated with external pressure scenarios that would be brought into the game, cognitive load was considered in determining the sequence of complexity in game structure (IIC). We avoided providing too much information at the same time as it may not allow participants to process the information effectively. We also included mood swings (player emotions) to make sure that the game results in a fun experience. The sequence in which different steps and elements (including complexity) are introduced was carefully considered to maintain manageable loads for players. It may result in a longer duration of game session. However, we considered developing a game with sufficient duration, avoiding too long time spent. Careful consideration of the time spent during game session is essential to maintain the optimum condition where the participants are interested still (Thomas and Young, 2010).

2.2.3. *Assessment stage (phase III)*

2.2.3.1. Prototype. In phase III, a game prototype was built. The possible solutions regarding its challenge (IIIA) were explored, followed by testing the game in trial sessions for its applicability, including monitoring and analysis schemes of the performance of the game (IIIB). In this study, the game performance was evaluated in terms of its design as presented through the research questions.

Creating a meaningful game that triggers participants engagement in the game can make people conscious of the importance of issues and their lack of knowledge or skills and create a strong sense of individual commitment (Hofstede et al., 2010). Based on this, the visualization of the game environment was carefully considered as realistic representation and became one of the important points in the development process. We carefully selected the miniatures of plants and tokens which have identical representation as in real-life during prototyping stage (IIIA). For example, the dimension of ratio between trees and crops miniature should be meaningfully determined. We chose the identical color as in real-life for the board details and tokens. For example: blue tokens with water drop shape represented the water; and brown cube tokens represented soil tokens.

2.2.3.2. Solution space. In this phase, we also explored the 'solution space' that can emerge during games if any of the possible choices is used (e.g., in a random sequence). Envelopes of this solution space indicate the best and worst outcomes for strategies to solve the game challenge. The solution space served as a check on whether the parameters at the level of individual choices would lead to 'reasonable' overall results. We tried all possible options that could be chosen by participants and calculated the points generated in each round and cumulative points by the end of the session from those choices in excel sheets. For the 'random walk' calculations consequences of the degree of persistence of choices between rounds were specifically explored (five levels of persistence: 0, 15, 30, 50, 80, and 100% of likelihood of change from the previous round; 250 random walk game sessions per parameter setting; the calculation of game points (economic and ecological tokens) was automatized in an excel sheet). This solution-space information benefits as an important point of reference to discuss during the debriefing to clarify the strategy after gameplay.

2.2.3.3. Test sessions. For the trial sessions, we conducted eight individual game sessions (IIIB). We firstly played the game with four undergraduate students to assess the playability of the game. Then, we performed four additional trial sessions with farmers who were not the main participants in this study: one farmer in each location, and an additional one in Kali Konto, to check the context and system recognition of the game, including whether other elements or dynamics need to be added or excluded. In the game development process, trial game sessions played an essential role to make sure all the game settings and rules worked as expected.

2.2.3.4. Monitoring scheme. We developed an in-depth monitoring and analysis scheme to evaluate the performance of game design in response to the questions defined in the introduction section. The scheme consisted of (1) a pre-game interview, (2) a quantitative and qualitative analysis of communication/responses during the game through audio recordings, (3) a debriefing session, and (4) a post-game interview. The pre-game interview included a structured questionnaire to identify the current situation/background of the participants, such as the socio-economic background and the actual farming system type, including tree species composition on their land. This information was utilized to determine the common species and farming system type in the research area. We recorded the whole communication during the game session, debriefing, and post-game interview. Thus, we counted the most frequent keywords mentioned during those sessions quantitatively. We use this information to evaluate the game's performance and impact on participants' knowledge gain (see section 2.3 for more detail). The game session was debriefed after the player completed the game session, providing essential steps of the learning process to foster reflection. The debriefing provided a space to "stop and reflect," offering players a much-needed opportunity to understand their own actions and mental models within the larger context of social and environmental challenges (Boud et al., 2013; Mochizuki et al., 2021). At this stage, players could share their thoughts and emotions, reflecting on the whole experience (Crookall, 2010). During the debriefing session, we (1) clarified the existence of a trade-off between the socio-economic and ecological aspects of the system; (2) discussed the experience during the game about the key reasons that determined farmers' decision-making, including their response to the external pressures; and (3) evaluated how the game experience can be linked to their real-life experiences. Both the gameplay experience and debriefing reflections allowed participants to see their real-world problems in a new light. The post-game interview was conducted after a debriefing session on the same day as game session or on the subsequent day. The post-game interview was conducted to obtain feedback of the participants on game performance, i.e., an assessment of the game and a self-assessment of learning. The feedback form included (1) an open question about the benefit of the game on the participants' knowledge and realistic experiences during the game session, and (2) closed questions to evaluate the game design in terms of the time spent, playability, easiness, and complexity with scores between 0 and 10 (low to high), including the scores for its realistic representation (between 0 and 5 for unrealistic to very realistic).

2.3. *The evaluation of game performance*

To evaluate the performance of the game, we played the game with (smallholder) farmers as the target group who own and/or manage private agricultural land (crops or tree-based systems). We aimed to include participants who can fully manage their field and choose the plants and land-use type as they like. We selected prospective participants for the sessions using a random sample of registered household heads in the community, varying in age and gender. In total 55 game sessions were performed between July 2021 to February 2022 in Kali Konto, Rejoso, and Brantas Hulu, to test the applicability and adaptability of the game to different locations. The difference locations in this study represented the variety of farmers in terms of their agricultural orientation and socio-economic background (Appendix 1).

To address the question on the transferability and adaptability of FORCES (1), we evaluated whether the generic (i.e. water balance, land-use system option) and specific elements (the variation of plants and income with its climate variation) of the game and its settings could work properly in each landscape, as indicated by the participants' responses through their comments (acceptance or suggestion to modify) in the trial and during the initial stage of the session in each landscape. To address the question about the game design evaluation (2), the qualitative and quantitative data from pre- and post-game interview was utilized. Pre-game data interview on actual tree composition and land-use types was used to quantitatively compare the real-life choices vs the choices during game session by counting the number and evaluating the variety of species. It indirectly indicates whether the decision making during the game session is close to real-life choice. We assessed the qualitative answer from post-game interview to evaluate whether participants acknowledge the realistic dynamic during the session. In this context, we collected all qualitative participants statements and performed simple thematic analysis following the steps: 1) Familiarization, where all data were thoroughly checked, 2) Coding the qualitative data: highlighting text, phrases, or sentences which come up with short code to describe the content, and 3) Categorizing (determining/reviewing) the theme. In the context of realistic dynamic aspects, the answers were categorized into two themes: related to game dynamics and the external pressure scenarios. Furthermore, the frequency of each category/theme mentioned by the participants were calculated. Additionally, the scored data was analyzed to evaluate the level of realistic representation expressed by participants derived from closed question on feed-back form in post-game interview. We calculated the average percentage number of participants based on each category (0 and 5 for unrealistic to very realistic). Similarly, we used the scored data from post-game interview to evaluate the performance of the game based on participants perspective.

We followed similar steps as described above to evaluate the game's impact on the knowledge gain. In this context, the qualitative answers from post-game interview were categorized into five group/themes. For cross checking, the voice recording was utilized by transcribing each game session. Simple thematic analysis was performed to evaluate whether the important keywords (codes) that associated to certain theme were mentioned during the game session, representing a realistic experience, new insights, and awareness of environmental impact. The analysis was followed by calculating the frequency of each theme that was mentioned by participants. The important keyword in this context refers to any verbs/nouns or short sentences, including their synonym that referred to short code that indicates awareness (example of (key) words: "realize", "I previously do not know", "aware"); knowledge gain (example of (key)words: "it protects soil", "risk", "trade-off", "economic and ecological functions", etc.). Where these keywords and themes match with the answer from post-game interview, it could strengthen the discourse.

All smallholder participants signed a consent form for being part of the study on a voluntary basis and agreed to be recorded anonymously. To assess the difference in participants' response within landscapes and participants categories (gender and age), we performed a two-way ANOVA. The 'solution space' results were used as reference of potential game outcomes. All statistical analyses were performed in R 4.2.0 (R-Core-Team, 2022).

3. Results

3.1. The emergent FORCES game

3.1.1. Identification of social-ecological context and generic core issues (phase I)

We identified the overlapping and specific issues in three case studies in our analysis. Despite the topographical position, hydroclimatic conditions and tropical monsoon climate type are being identical, the water-related issues were locally specific (Appendix 1, Table 1). The common issue that we identified in the DPSIR table (Table 1), seemed to relate to farmer land management choices that are not suitable for the local conditions. These mismanagement choices disrupt the water cycle, triggering water-related problems at plot and landscape level. Apart from the specific water issues in each landscape, the water balance emerged as the main driver of the specific local context such as erosion and soil infiltration in Kali Konto, decrease of springs in Brantas Hulu and ground water recharge in Rejoso watershed. Infiltration and run-off, involving soil erosion and sedimentation, which affect water quality, have been identified as major watershed issues in Kali Konto, Rejoso, and Brantas Hulu. We highlighted the interaction between farmer decision-making on land management (farming system), water balance, and economic consequences (trade-off) as a generic core issue for the game design. As the game design involves decision-making, we considered instrumental (economic: income, production cost, labor; and ecological factors: water, litter, soil) and relational (socio-culture and belief) values to be integrated in game development as socio-cultural background and economic situation of communities in the case studies relatively varied (Appendix 1). Given the importance of trade-off as a generic core issue in this context, we decided to set the game's objective on finding a strategy to tackle the trade-off issue. We bring the challenge on searching the synergy between maintaining economic and environmental services at plot level to support the achievement sustainable agricultural landscapes. As the study was conducted during the Covid-19 pandemic, we decided to develop a single player game as the social interaction allowed in the villages was limited.

The generic game elements, which are mostly under the domain of instrumental value, consisted of (1) management choice; (2) economic benefit; (3) the water balance: precipitation (P: rainfall) = evapotranspiration (E: evaporation of intercepted water and at the soil surface, and transpiration by plants) + streamflow (Q: overland, groundwater discharge) + change in storage terms (DeltaS); (4) external pressure scenarios. The rational aspect behind people's choices, which tends to consider the consequences (cost and benefit), is expected to determine how farmers select the management type. The research teams included various external pressure scenarios, representing natural, market uncertainty and the relational value (socio-cultural influence) such as: A. prolonged drought, B. individual (social) water-conflict with neighbor (competing water right), C. price fluctuation, and D. social group involvement to test whether participants choices may include considerations beyond material benefit (as represented in the game). It may well be that qualitative aspects of the work involved, beyond the accounting for person days of work, as known to the players, influences choices within the game, as work in a shaded mixed agroforestry system differs from that in open-field crop systems. Sometimes this was commented on in game reflection sessions. We selected the four external pressure scenarios (A-D) in the game from phase I that were generic and relevant for all those landscapes. Since we aimed to develop a single player game, we developed an attractive board game with enough challenge to trigger participants engagement.

Table 1
The analysis of the drivers, pressures, system state, impacts and responses in three different case studies in East Java, Indonesia.

Properties	Kali Konto sub-watershed	Rejoso watershed	Brantas Hulu sub-watershed
Pressures	• Land use conversion into intensive agricultural farming with minimum tree cover on hillslopes increases soil surface exposure • Increase of livestock	Land use conversion into non-tree-based system in the recharge area (upstream and midstream)	• Land use conversion • Forest fire
Driver	Livelihood, population growth, market, and demand	Livelihood	Livelihood, population growth
System-state	• Less litter input increases soil exposure to erosion • Increasing run-off and decreasing water infiltration to the soil • Cattle excretions directly flow to the ditch/river	Increasing runoff and reducing infiltration (upstream and midstream)	• Increasing run off • Less water infiltration
Impact (issues)	• Increasing runoff (low water infiltration) which increases risk of flooding during rainy season • Decrease of water quality due to high sedimentation and pollutants	• Decreasing groundwater supply in the Umbulan spring • Flood (during rainy season)	• Less springs • Water user competition • Frequent flood in the rainy season • Infrastructure damage caused by flood
Response	Land use/cover management	Land use/cover management	Reforestation

3.1.2. Specifying the design for FORCES game (phase II)

3.1.2.1. Game setting and mechanics (IIA). Based on ARDI scheme, the interaction between actor and resources was established by integrating farmer decisions, plant production system processes and the general concept of hydrological systems (Fig. 2). We included a simplified water balance at plot level in the game, where input from precipitation is

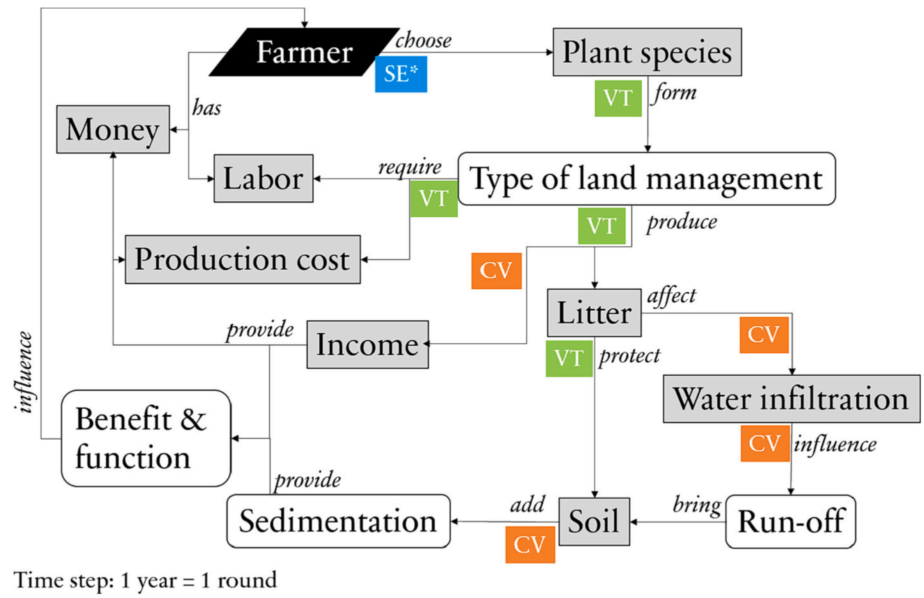


Fig. 2. The ARDI analysis for the general context of the study area. The actor involved is indicated in the black label, resources in grey squares, interactions by black arrows, and dynamics were represented by capital letters (VT = vegetation transition, CV = climate variation, SE* = scenarios of external pressure that emerge in every 4 rounds).

related to two main pathways out of the system: evapotranspiration and streamflow. In this game, we distinguished whether water infiltrates into the soil as groundwater or flows as surface water out of the system (run-off), causing soil erosion. The role of plants in a certain type of farming system was highlighted by emphasizing the benefit of the presence of trees in the system, because leaf litter protects the soil surface from erosion. To avoid overcomplication, we determined farming system (instead of plant species) as a basis that influences ecological and economic processes of the system. The farming system options were categorized into six types which based on several type of combination of tree and crops, including monoculture system (see Appendix 3, table A3.1). The selection of farming system option was determined based on the common combination found in study area (derived from pre-game interview, see section 2.2). We divided the resources into economy (points/money), labor, and natural resources (plants, litter, water, and soil). Accessible natural resources were the key elements to show the ecological consequences of individual decisions. A wet or dry climate was introduced as a random yearly internal dynamic in the game, appearing in every round, influencing economic and ecological benefits earned, representing the uncertainty of climatic fluctuations (Table 2). Four external pressures were included in the game, representing natural-socio-economic pressures (Table 3).

3.1.2.2. Integration of empirical data (IIB). We build the economic and ecological consequences table (impact of decision making in Table A3.2) based on the result of model run that was performed in various

Table 2
Game structure and dynamics during 15 rounds of the FORCES game (Climate variation: wet year = >6 months of rain in a year; dry year = >6 months without rain in a year).

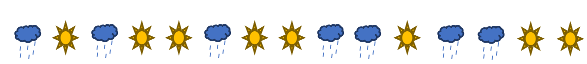
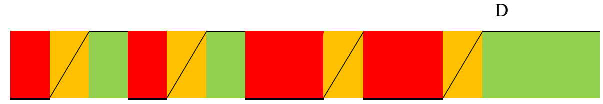
Game elements	Round														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Game structures:															
1. Receive resources	v														
2. Choose plants		v	v	v	v	v	v	v	v	v	v	v	v	v	v
3. Pay production cost	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
4. Receive consequences	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Internal dynamics:															
Climate variation															
External pressures:															
Natural pressure				A											
Social conflict							B								
Market pressure										C					
Social/group agreement													D		
Estimated mood level of the participants															

Table 3
External pressure scenarios which represent typical socio-economic aspect during the game session.

Variable	Scenario A	Scenario B	Scenario C	Scenario D
Pressure	Prolonged drought	Neighbor conflict on water blockage	Price drop	Farmer group agreement
Definition in game	A prolonged drought, affecting yield and environmental conditions	Neighboring farmers block the ditch and use the water to irrigate their own plots	Market price of dominant commodity significantly decreases	Offer to change to a certain farming system as was agreed in farmer group
Income consequences	Crop failure or yield reduction	Pay more irrigation cost to bring back water in the plot	Prices reduced 50–75%, depending on type of management and plant diversity	Increase of income
Environmental risk	Two water tokens will be subtracted from the field, or a higher irrigation cost needs to be paid	Crop failure or yield reduction or no effect when paying additional irrigation cost	No effect	Based on the management type

combinations of farming system types. To maintain the balance between generic and specific setting, we produce one average value for each farming system type, we averaged the total income based on different combinations of plant species within the same farming system category. For instance, we averaged total income (IDR per ha) from maize, potato, and cabbage to obtain the average total income for the annual crop system. The model and interview analysis results were scaled, simplified, and used as a basis to run the game (Appendix 3, table A3.1). Data were calculated and estimated with a timestep of one calendar year, which represents one round in the game.

3.1.2.3. Game structure and rule (IIC). The game has approximately fifteen rounds (50–60 min), containing multiple steps per round. Initially, the player would receive resources, select plants, and pay associated cost including receive consequences (Fig. 2, Table 2). To ensure that players pay sufficient attention to engage and learn the basic rules and mechanics of the game, we purposely made the game to be played in fifteen rounds where game environment was less challenging at the beginning. Fifteen rounds were needed for one game session to balance the achievement of the learning objective and to provide sufficient experience from the dynamics provided during the game simulation. As players learn the rules and logic, the game progressively challenges them by introducing external pressure scenarios, observing the consistency of participants on their decision-making on tree and land-use choices (Table 3). In round 4, 7, 10, and 13, the external pressures of A, B, C, and D, respectively, was added. By playing the game, we challenged participants to find synergies between obtaining sufficient income, and maintaining the basic condition of plots as it will minimize the overall damage to the environment. The participants solve the game when the minimum of 70 units of money (for fulfilling daily necessities) and <10 tokens of total erosion are obtained at the end of the game. We included an additional fine in every 5 rounds when the participants accumulate soil sedimentation in the river to emphasize ecological consequences of polluting the river (Appendix 3). We predicted the mood level of the participants in each round (mood line in Table 2) considering the complexity (external pressure scenarios) that emerges during the game.

3.1.3. The game prototype: FORCES game

The FORCES game is a 3D board game representing a piece of (hilly) land or a ‘plot’ and consists of 24 connected hexagons where the water flows from the upper plot to the river. The game elements consist of a set of various plant miniatures (trees and crops), tokens (water, litter, and soil), cards (labor and climate), and dummy money (Appendix 3). The hexagons in the board can be filled by one or a combination of plant species. At the beginning, the participants receive an initial budget, labor (cards), and the basic plot condition which contains one water and two soil tokens (Appendix 3). The implementation of diverse plant species options offers the player abundant possibilities to optimize the production on their plot. The combination of plants formed a certain type of farming system. Thus, it affected the production costs (for fertilizer, pesticides, and irrigation), labor needed and their income which is influenced by the climate cards (Appendix 3, Table A3.1). Ecologically, the chosen farming system (together with the climate that emerges in each round) influences whether litter is produced in the plot to protect the soil surface and increase water infiltration or whether soil material is lost, contributing to sedimentation in the river (Appendix 3, Table A3.2). Litter does not only protect the soil but can also be used to reduce production costs for the next round. Litter is considered as a source of organic matter that can reduce fertilizer use. All economic elements (cost and income) in the game involve dummy money while ecological consequences use tokens.

Before the game starts, the participants are informed about the goal of the game, the game set-up and rules: (1) they can select and combine any plant species, forming one of the six available farming options; (2) each of the farming system options has a different production cost and labor requirement; and (3) the income generated in each round is determined by climate variation (Appendix 3, Table A3.1). The round in this context is independent as player always receive their income and ecological tokens in each round. At the end of each round, the participants can calculate their economic and ecological benefits and consider these for taking decisions for the next round. We do not explain the ecological benefits that the participants could receive at the start of the game, because we aim that the participants would learn from the dynamics during the game session.

In the first round, the participants start with a crop field to experience the economic and ecological consequences of monoculture crops at the plot scale. After the first round, the participants are free to choose another type of farming system. Each round in the game consists of five phases: (1) choosing the type of farming system by selecting plant species on the board; (2) paying the production cost and labor requirement to make sure that the default plot requirement is met; (3) opening dynamic cards to determine the weather (either wet or dry year); (4) receiving income and ecological consequences based on the water balance and soil erosion; and (5) evaluating the net benefit (Fig. 3). In this stage, the participants can consider whether they want to maintain the current system or change to another type of farming system. The external pressure scenarios were introduced in rounds 4, 7, 10, and 13 (Table 2). In those rounds, the income and ecological benefit might be affected because of those pressures (Appendix 3, Table A3.3). No scenario appears in the first three rounds, allowing the player to settle into the game setting and understand how the game works. A detailed description of main features, rules, and mechanics of the FORCES game is included in Appendix 3.

3.1.4. Exploration of game solution space

The FORCES game brings challenge to find synergies between obtaining sufficient income and causing minimal overall damage to the environment at the end of the game session. The balance (“optimum”) strategy is to be consistent on maintaining trees in the system during the rest of 14 rounds since tree-based systems: (1) provide ecological benefit (litter and water infiltration tokens) that can reduce production cost; and (2) increase income (less fluctuation) with less damage (soil erosion tokens) to the environment, avoiding a fine to secure the total income.

Fig. 3. Five phases of the game session in each round: 1) choosing plant species forms the type of farming system, 2) paying production cost and labor, 3) opening dynamic cards, 4) receiving income and ecological consequences, 5) evaluating the benefits for consideration for the next round.

The highest total income (but more fluctuation) can be achieved when the annual crop system is chosen during the whole game, but this will result in large ecological damage (Fig. 4).

3.1.5. *Game trial session*

During the trial session, the game elements, environment, and dynamics worked appropriately. The FORCES game was successfully tested by undergraduate students. Most of the participants enjoyed playing the game and exploring the options. However, we found that the game was more interactive and live when was played with farmers because they have real-life experience which fits with the objective of the game.

3.2. *Evaluation of the FORCES game performance*

3.2.1. *Application and performance of the FORCES game in different landscapes*

Based on fifty-five game sessions, the FORCES game was easily applied in three different landscapes by smallholder farmers of various gender, age, and socio-cultural backgrounds. The generic game setting (the use of the 'water balance' element) supported the translatability of the game to a different context. Water infiltration is linked to the specific issues in a landscape, such as the springs and ground water recharge in the Brantas Hulu sub-watershed and Rejoso watershed, while run-off triggers soil erosion that leads to sedimentation in the river in the Kali Konto sub-watershed. Those essential linkages were important to increase the relevance and facilitate various specific water issues in different locations. Specific game elements were adjusted to create the relevant environment and provide a realistic experience, i.e. (1) farming system options were determined based on common farming systems found; and (2) the variation of income was based on specific climate conditions. For the Brantas Hulu sub-watershed, we adapted the income variation to be locally relevant, where the income was higher in dry than in wet years which is different compared to the Kali Konto and Rejoso watershed. Based on farmer pre-interviews, most horticultural commodities in Brantas Hulu showed higher productivity in dry than in wet years. In response to this situation, the seasonal dynamics in the original version were kept as generic core, but the effect of climate variation was adjusted based on the local context. Without modifying the amount of income (Appendix 3, table A3.1), we swapped the amount of income in wet and dry years. Additionally, the external pressure scenarios in the

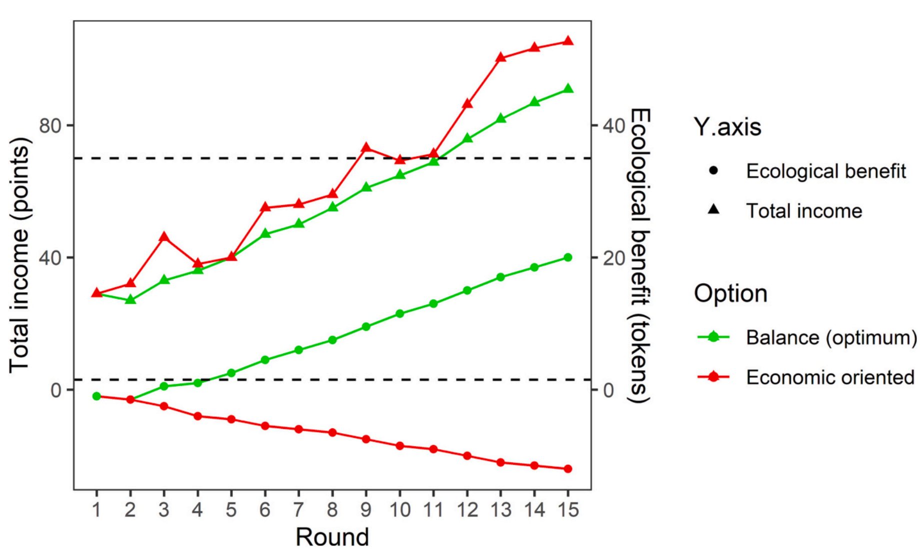


Fig. 4. The impact of the balanced ("optimum") and economically oriented strategy on total income and ecological benefits during 15 rounds of the FORCES game. Ecological benefits were the total amount of tokens derived from the litter and water tokens minus the soil tokens accumulated in the river. Total income referred to the net income generated in every round after harvesting and the production cost payment.

game could be easily adjusted to fit the local context, while keeping the generic core rules and mechanics. In this context, however, we implemented similar external pressures since we considered the generic core issues of these three landscapes together when developing the game, to be able to make the game outcome comparable.

The participants' choices in the game varied between participants which was most likely determined by the economic, ecological, sociocultural factors, and type of farmer. During the game sessions, participants exhibited varying degrees of persistence (13–90%) with average of 70% in farming system choices. Most of the participants changed their choices after the first four rounds and/or after the emergence of external pressures. The total income earned by participants ranged from 30 to 103 points, depending on their management strategies, with higher points often indicating worsened ecological consequences due to soil erosion. As the game progressed, participants became more careful in their decision-making, as they became aware of the impact of ecological consequences on their total income in each round because production costs could increase, and fines related to the contribution of soil sedimentation in the river should be paid. During the 55 game sessions, participants who persisted in maintaining crops systems (commonly crops farmers) had fluctuated income during the whole game rounds yet earned high income by the end of the game despite its ecological risk. Most of them failed to solve the challenge due to the incapability to prevent soil movement. Some participants (tree-based farmers) successfully tackled the game challenge by obtaining 88 points of total income which was not too far from participants who maintained crops (min 90 points), but they could keep the soil tokens in the plot until the end of game session plus producing more water infiltrations (17 water tokens). The consistent choices of mixed farming systems type since the beginning of game session seemed beneficial to accumulate sufficient but continuous income in each round. The benefit of long-term tree maintenance in mixed systems could reduce production cost, avoid fine due to soil erosion, and increase the system's resilience on securing income when facing drought, price fluctuation and social pressures. The increased pattern of number of tree and/or plant species (from two to eight species) was discovered in the last round particularly for participants who chose mixed systems. Unexpectedly, the consistent pattern was discovered in Kali Konto and Brantas Hulu that young participants

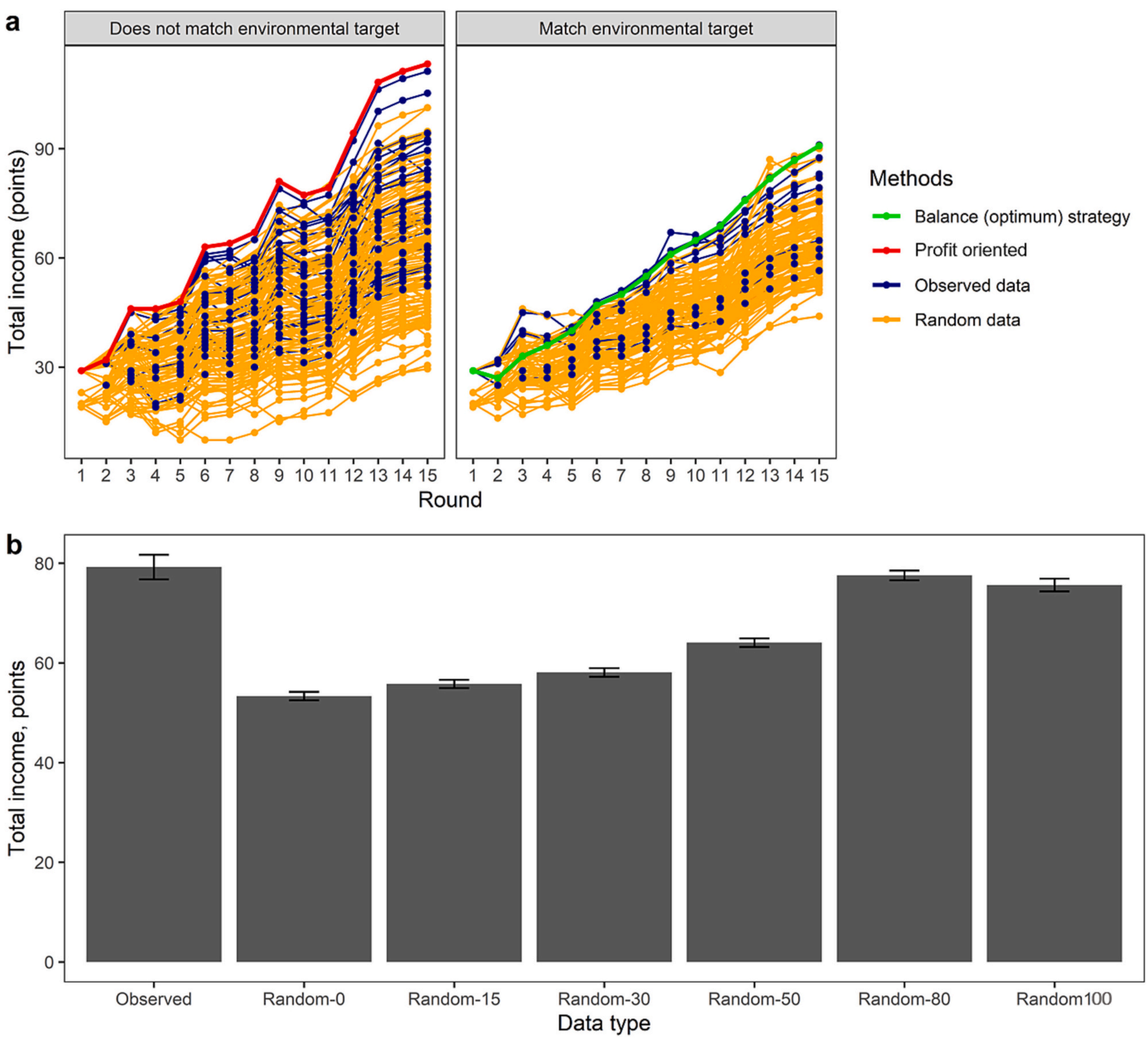


Fig. 5. a) Game outcomes or the participants ($n = 55$) and random-walk choice analysis ($n = 250$) on farming system choices during 15 game rounds of the FORCES game. To solve the challenge, participants need to synchronize economic and ecological interest; b) Total income obtained based on the participants' choices (observed data) versus random choices with various levels of persistence in choices (Random-0 to Random100 = random choices with 0% persistence up to random choices with 100% persistence).

preferred to choose monocrops systems and tended to obtain high income by the end of the game but produce more soil erosions with less water infiltration.

In terms of performance, the FORCES game could translate the challenge of finding synergy between maintaining economic production and ecological services through its game elements and dynamics. Not all observed participants choices and their impact on the economics matched the environmental target (Fig. 5a). Around 30 % of the total participants accomplished the challenge by pursuing economic interest while maintaining the basic plot conditions with little soil erosion. We found that the observed choices differed from fully random choices (Fig. 5b), which indicates that participants did not take random decisions on farming system selection during the game session. We found that persistence in farming system choice across game rounds improved the result of random choices, with the best result at 80% persistence in choices across game rounds. Based on the observation data, participants with highly consistent choices in selecting mixed farming systems received long-term economic and ecological benefits because of having trees in their systems (Fig. 5a, Appendix 4).

3.2.2. Realistic representation of game dynamics and outcome

We used empirical data during the game development process to provide realistic dynamics, which resulted in a causal link between system components, representative of the real-world situation. Based on qualitative commentary data analysis during and after the game session (post-game interview), almost 75% of the participants indicated that the game provided a realistic experience through (1) the climate dynamics in the game, which determine income variation, representing the uncertainty in the real-world situation (65%); and (2) external pressures particularly related to price fluctuations (35%). Fifty five percent of participants found the game "very realistic" while the rest found the game "realistic". The common expression from participants that emerged during the gameplay was "*Why does this game seem to be real? I experienced a similar situation recently/last year*".

Based on the post-game interview, 71% of the participants mentioned that the realistic game setting influenced their decision-making during the gameplay. It triggered participants to make similar choices as in real life. However, the rest of the participants explained that their decisions in the game were inspired by what they would like to have or based on their personal preferences. Overall, around 40% of the participants managed to solve the challenge by the end of the game session. When we compared the choices of farming system type in the last round of game sessions with the actual participants' farming systems, we found that only 30% of the participants selected different farming system as they had in real-life. It indicates that only a few farmers decided or committed to changing their farming system, even though only in the context of gameplay. Only a few of these participants could solve the game challenge. Furthermore, the rest of the participants (70%) preferred their real-life farming system choices by the end of the game, potentially as part of their strategy to address the game challenge. Notably, 80% of these participants were tree-based farmers who demonstrated a higher ability to solve the game challenge. This suggests that these participants recognized the vital role of trees in achieving a balance between income and ecological function within the game's context.

3.2.3. The evaluation of the FORCES game from the participants perspective

The participants feedback on the FORCES game varied among locations, but we found no relationship with participants gender and age. The average total score of game evaluation did not differ across locations but differed between categories of evaluation. Overall, participants indicated that the length of the game varied between sufficient to a bit too long. Most of the participants (85%) agreed that the game setting was easy to understand with enough complexity, fun and that it provided realistic visualization and dynamics (Fig. 6). The rest of the participating farmers indicated that the game was a little bit boring and needed more complexity. Eleven percent of the participants, mostly crop farmers, criticized the absence of income variation among annual crop species in the game. They mentioned that the total income for crops should be distinguished by its species, instead of having the same number for all crops. A few participants suggested to include more complexity to the land-use type options that consider commodity-based variation in the game. Among the participants who failed to solve the challenge, approximately 24% of these participants felt motivated and initiatively wanted to play the FORCES game for the second time because they seemed eager (1) to test the strategy discussed during the debriefing session, particularly regarding the long-term choice between mixed vs monocrop systems, and (2) to explore the possibility of minimizing the trade-off between income and environmental services. On the other hand, the remaining participants might not have shown this initiative, possibly because they had accepted the information and had other commitments, such as returning to their field to work.

3.2.4. Knowledge gain through playing the FORCES game

We found that the game supported knowledge building for the participants (Fig. 6) through experiencing the game dynamics, particularly through the link between farming system choices and socio-eco-hydrological systems. Based on the self-assessment of participants during the post-game interview, approximately 90% of the participants in

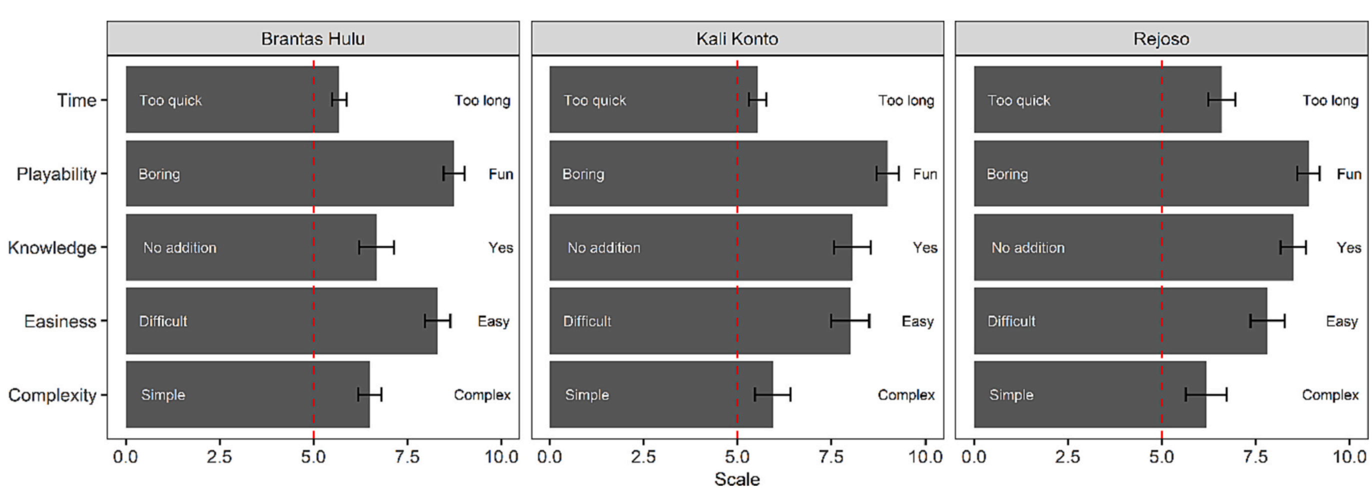


Fig. 6. Game evaluation based on participants point of view in three different locations in East Java, Indonesia derived from score-based closed question from post-game survey (mean ± standard error, $n = 55$).

Kali Konto and Rejoso found that the game was beneficial for gaining insight on the risk of agricultural practices for both economic and environmental aspects, while for only 70% of the participants in Brantas Hulu this was the case. Based on the open question from post-game interviews, after playing the FORCES game, participants indicated to have gained insight on (1) the benefit of maintaining mixed systems (trees) to provide soil protection (29%), (2) management choices in response to trade-offs between economic benefit and ecological function (29%), (3) the risk of farming system choice on income provision, related to climate change and social conflicts (18%), (4) the effect of maintaining trees and crops on ecological benefit and erosion (12%), and (5) the stability of the farming system with regard to providing continuous income (12%) (Appendix 5). Benefits, risks, choices, and trade-offs were the keywords that emerged as the most frequent words mentioned by the participants during the game sessions. These keywords matched the result content from the post-game interviews. Some participants said to have become aware that poor land management could bring negative consequences for the environment in the long term. According to the recorded data, approximately 18% of the participants in Brantas Hulu indicated that they were already aware of the environmental impacts of intensive farming systems. It could explain the disparity of the knowledge gained between Brantas Hulu and other landscapes. We unexpectedly found a significant and positive association between the level of easiness and additional knowledge gained by the participants ($R^2 = 0.26$, $P < 0.001$, Fig. 7). It indicated that a relatively simple game might support the participants' learning process because it is easy to comprehend. Thus, the important messages can be absorbed without being distracted by unnecessary details in a more complex game design.

4. Discussion

4.1. The balanced design of FORCES games and its application across landscapes

We aimed to design the FORCES game to be applied in different locations by balancing the game design between generic and specific elements. Based on our results, the FORCES game was easy to apply and adapt, which indicates that it has sufficient balance between generic and specific elements. It indicates that the DPSIR framework and ARDI methods could be effectively combined in the game development process. This is in agreement with Malmir et al. (2021) who combined the DPSIR framework for different context (numerical modelling). The water balance as the generic element that can be linked with many specific water issues (water recharge, soil erosion and sedimentation) facilitates game adaptability to different locations. Specific game elements such as the type of farming system, and the variation in income and climate were adjustable to the local context, providing realistic dynamics that trigger participants engagement. A balance of generic and specific elements can avoid oversimplification and complexity, induce realistic game dynamics, and evoke information processing mechanisms that increase the ability of game players to process information (Cannon et al., 2009). Based on the self-reflection of participants after playing the game, we unexpectedly found that the score on easiness of the game tended to positively relate to knowledge gain. It indicates that the FORCES game design has succeeded in presenting an easy-to-understand context, but still with sufficient complexity so that the causal relationship that participants must see to learn from the game is still achieved.

Defining the generic core issues and dynamics in a wider range of circumstances played an integral role in the development of the FORCES game, as the game is targeted for generic application. The development of generic games in the context of social-ecological systems, although still limited in number, has garnered increased interest while the middle ground between stylized and locally fine-tune game design is missing. The FORCES game contributes to filling the gap on the need of generic-specific balance of serious games particularly for the context of sustainable (agro)forestry management. This balance is needed to raise participants' engagement, providing locally relevant situations where players could recognize the context. This way, participants' interaction with the game could be more interesting, where the choices in the game might be represented closer to real-life choices. Thus, an individual farmer's decision-making may be better understood. A recent sustainable livestock farming system game such as La Grange (Dernat et al., 2023) that focused on crop-livestock production was designed as generic game that can be played elsewhere with less preparations (no data needed) to play. However, in the context of the FORCES game, where the integration of annual (crop) and perennials was allowed, small preparation was needed before it could be properly applied. The FORCES game required pre-survey before game play as the relevancy of the game elements (such as the type of plants and trees; including core dynamic: season variations) are matters to provide close to real-life game experience. Pre-survey in this context does not mean requiring a lot of (research) data to make the game work but only to ensure the relevance (qualitatively checks) of the elements used and the dynamics presented by asking one or several local communities for cross checking. Without the pre-survey step, the FORCES game could still be played but with less local relevance as consequences. This adjustment indeed increased the complexity, but we maintained the balance to make it generic enough and avoid too much abstraction. An abstract game, however, with many simplifications, or too specific game based on one specific case study can be unsuitable for adaptation to other locations. The FORCES design facilitates game reusability to different locations which allow site-specific element to be included still. Not many single case-study-based games is reported that can be easily adapted and implemented in other locations, but some authors have successfully explored and implemented their game beyond the original location (Barnaud et al., 2007; Speelman et al., 2014; Le Page et al., 2016; Andreotti et al., 2020; Pfeifer et al., 2021). Such games are desired to make more efficient use of resources and optimize research investment of game development which currently rely on long-term research investment based on a single context (van Noordwijk et al., 2020).

Despite the FORCES had limited social interaction due to a single player setting unlike other serious games that can be used in the context of water issues (Daré et al., 2018; Ferchichi et al., 2020; Assefa et al., 2021), this game offers: (1) realistic representation through the 3D

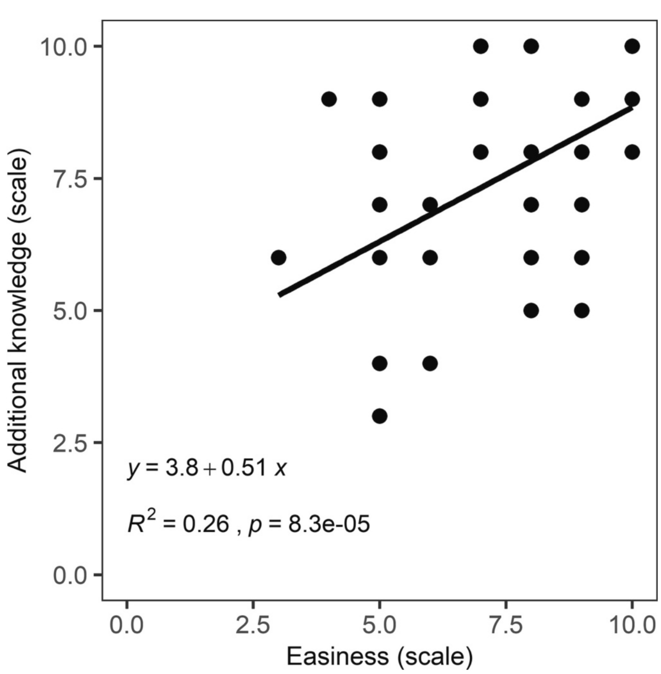


Fig. 7. The association between game easiness and knowledge enhancement based on the self-assessment of the players (n = 55).

board game which allow to trigger participants' engagement; (2) low-tech which is handy to bring in remote area with limited access to network or internet; (3) the balance of generic and specific setting which maintain the relevance of local context and easy to apply and adjusted to different locations; and (4) although it only focusses at plot level, it allows focus on deeper individual understanding about the trade-offs issues between maintaining economic and ecological services which appear to be the important learning element of the FORCES game. In terms of the design, the FORCES game allows relational values to be expressed in the game as most of games more focus on involving instrumental characteristics while relational value also become important aspect to be included in the game design (Janssen et al., 2023; van Noordwijk et al., 2023a). This point was indicated through the involvement of socio-cultural factors that were captured behind participants' choices that derived from the FORCES game session. In the context of natural resource management issue cycles, the FORCES game falls under the first phase of issue tension cycle of agenda setting domain since this game facilitated awareness-raising about trade-off issue. In this context, the game development is suggested to be designed based on the different tension of issue cycles (Rodela and Speelman, 2023). This game could be useful as an initial step for the range of participatory project approach to facilitate individual understanding about the trade-off in social-ecological system before they could collaborate or interact with other stakeholders in other game at landscapes level in the next issue cycles. When participants possess prior knowledge of the system's functioning, achieving another agenda for the game, such as collaboration, may be more readily accomplished.

4.2. The importance of a realistic representation in game design

The models, combining simplified and empirical components may cause more confusion (Sun et al., 2016). However, in the context of FORCES, maintaining a balance between generic and specific game design and the integration of empirical data as a basis for establishing game rules and mechanics was essential to bring realistic dynamics during the sessions without an overly complicated design. Empirical data was used in our game design to generate realistic causal links between the elements of socio-ecological systems, as was done by Perrotton et al. (2017) who relied on empirical data to design the prototype of the Kulayijana game in Zimbabwe. Accurate causal links between components may facilitate the learning process for participants based on the consequences of their choices that they may face in the real world. A game with realistic dynamics may trigger participants to take actions like their real-life decisions during gameplay, resulting in a more reliable game outcome (Weisberg, 2006, 2007; Speelman et al., 2017). We found that most participants choices during the gameplay were closely linked to participants choices in real life, in agreement with results of Dare and Barreteau (2003); Levitt and List (2007). Realistic games can be used as a research tool to (1) understand how participants behave in taking decisions and responding to given dynamics; and (2) explore participants choices. The participant, however, has entire control over how they behave and take decisions while exploring their desired strategy (Speelman et al., 2017).

The impact of game on participants' learning process that was supported by the realistic representation of the game dynamic may be limited to the short term and may not necessarily result in behavior change (Janssen et al., 2023). Despite the FORCES game could rise awareness about the risks associated with different management choices, the effect of the game on tree/plant or farming system type in real life could not be ensured, thus, it should be further explored. A positive impact on games (Meinzen-Dick et al., 2018; Bartels et al., 2022) and similar participative tools (Lairez et al., 2020) was reported in real-life choices. However, the follow-ups steps in this context are essential to be considered to encourage farmers into action (Dernat et al., 2022a).

4.3. Evaluation of the FORCES game in achieving the objectives

The FORCES game received positive feedback and appreciation from most participants in all landscapes because it triggered participants' engagement and interest. Despite only less than half participants could solve the challenge to attain synergy between economic and ecological benefits, some participants requested to re-play the game to satisfy their curiosity. It indicates that participants could capture, process, and learn from the information and dynamics given and that it motivated them to explore their choices beyond what they did in the real-world. Participants' knowledge gain, engagement and interests are the signs that the game has sufficient complexity in its design (Cannon et al., 2009). However, "farming system type" as a generic element that was maintained to avoid a too complicated design in the FORCES game did not seem complex enough for a few participants who showed high persistence in the choice for certain farming systems (crops systems) with no desire to explore beyond their preference. The degree of unpredictability and attendant risk are mentioned to be the reasons why people are reluctant to invest in a game (Hofstede et al., 2010). In this context, inviting farmers to participate to play the FORCES game voluntarily was not an easy task, particularly as "a game" was frequently associated with children and was not common in the local culture. However, we used the term "simulation" rather than "a game" to attract "adult" farmers' participation with a long introductory period to build good relations and trust before the game session, preparing an enjoyable and secure environment for participants to play. It could partly become the reason why many participants mentioned they enjoyed playing the FORCES game. Such an environment is essential to support implicit and unconscious learning, and emotional and cognitive aspect which are part of learning process through a game (Hofstede et al., 2010).

Based on the game outcome from the study cases, the FORCES game could potentially be utilized as a research tool to generate qualitative and quantitative data. For example, the choice on tree species and farming system derived from game session can be quantitatively analyzed, such as its diversity (number of species) and persistence. The use of game to generate research data as we found in this study was similar to Kuntashula and Mafongoya (2005), who developed the Bao game to generate quantitative data to evaluate the role of legume tree in agroforestry in Eastern Zambia. The economic, ecological, and socio-cultural consideration of participants when choosing trees and farming system during the game session provided essential information to understand the rationale behind the decision-making and how it changes over time. From the case studies, we found that the choices of farmers differed across participants' categories (type of farmer and age), indicated by specific farmer preferences for tree and farming system type when searching for synergy on minimizing the tradeoff issues. As the policies (i.e., conservation programs) are mostly implemented in top-down fashion without considering local preferences, the effectiveness of these programs is limited to the project duration. The local preferences derived from game sessions hold significant importance as input for policymakers to reconcile a top-down perspective with a bottom-up farmer-understanding approach and minimize conflicts due to the mismatch of preferences. A unique combination of tree and plant species that emerged during the game, from a scientific perspective can be used to facilitate co-inquiry, which involves farmers' experiences in the knowledge co-creation process and can lead to research questions that are contextually relevant and result in actionable outcomes (Dumont et al., 2020; Frank et al., 2022). Furthermore, involving farmers in the design, decision-making and evaluation of the conservation programs, for example, by combining serious game and agent-based model (ABM), could facilitate knowledge sharing between farmer and policymaker (Joffre et al., 2015), contributing to more efficient, sound, and inclusive pathways toward long-term sustainable agriculture (Lujan Soto et al., 2021).

4.4. Limitations

We reflected on the limitations of this study based on the three steps that we raised in the introduction section. Firstly, in terms of the game design, as a single-player game, the FORCES game could not facilitate social interaction. Social elements in this game were presented in a more abstracted way than in many other games which aim for collective action where direct communication with peers is needed. Secondly, regarding game reusability, the FORCES game was applied and transferred to different locations for research purposes. Even though the researchers indicated the easiness of reusing the game, it might not necessarily be the case for other local stakeholders who would like to reuse the game. Regarding this context, the FORCES game is under consideration to be used by the local agency as a complementary participatory tool in addition to the extension program to get a better understanding of farmers' preferences and raise awareness of trade-off issues of economic and ecological benefits. It would open the opportunity for the researcher to further evaluate the reusability of this game in the future thoroughly. Lastly, in terms of the representation of game result interpretation, more game sessions may be needed to obtain a more comprehensive representation of the game impacts.

4.5. Opportunities and future improvement of the game

The FORCES can be defined as a closed game because it has a relatively large set of rules and a countable set of solutions that can be discovered using analytical techniques. Closed games are commonly used in an experimental set-up that allows the replication of results with various groups of participants (Falk and Heckman, 2009; Janssen, 2010). Such games are utilized to test specific hypotheses on the underlying factors and processes of decision-making, including the behavior of players (Castillo et al., 2011; Garcia-Barrios, 2011; Speelman et al., 2014). In the FORCES game, however, the "open" game outcome can emerge through the plant species composition choice, which freely depends on the participants. The unexpected, preferred plant combination might emerge, and become the prospective management option. Such an outcome can then be explored as an input for further model simulations (e.g., in ABM), supporting the search of best practices for sustainable agroforestry management (Villamor et al., 2023). Considering the positive impact of the FORCES game on participants' insight after the game session, long-term evaluation may be necessarily important to assess the long-term impact of this game on participants' real life. However, to really encourage farmers into action, follow-up steps such as farmer assistance through extension activities after game session, for example, might be essentially required. Thus, a deeper quantitative analysis before and after playing the game (including the game outcome) needs to be performed (Teague et al., 2021) to provide concrete evidence on the impact of the FORCES game on participants' knowledge.

Beyond the current practice, the FORCES game may be played as a multiplayer game in the future which enables increased social interaction, exchange information, and discussion among players, allowing participants to be inspired on future decision-making. Based on this study, the FORCES game is suitable as a tool to explore decision-making and allow reflection for farmers on their own decision-making, which can trigger awareness about the trade-offs and explore available farmer management options to find synergy between maintaining production and ecological services for more sustainable management practices (research).

5. Conclusions

An innovative approach through adaptive game design could help addressing the complexity of socio-ecological issues by raising awareness of identified common problems, improving people's insight into the environmental consequences of their actions, and exploring the range of options in a relaxed and fun environment. The FORCES game was developed as a tool to explore decision-making and represent a search for synergy between maintaining agricultural productivity, diversity, and ecological functions in the complex socio-ecological system context toward a sustainable production system. The balance of generic issues and sufficient relevant specification in the FORCES game design allows this game to be applied in, and translated to, different landscapes. The integration of empirical data in the FORCES game supported the provision of realistic dynamics, facilitated the experiential learning process from the direct socio-ecological consequences that participants may face in the real world and triggered participants to make similar choices as in real life. While a single player design limited direct social interaction, the FORCES game allowed relational values to be recognized from participants responses. Based on the game evaluation, the FORCES game, designed with sufficient complexity and specification, invoked participants' engagement and interest to solve the game challenge and explore the management options. We hope that this game provides an adaptive and innovative approach to support a participatory way to explore decision-making to search for better strategy for maintaining production and more sustainable management practices that provide ecological services.

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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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2023.103782.

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