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Exploring the effectiveness of serious games in strengthening smallholders' motivation to plant different trees on farms: evidence from rural Rwanda

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Abstract. Addressing the global challenges of climate change and biodiversity loss requires the widespread adoption of sustainable agricultural practices such as agroforestry. In many Sub-Saharan African countries, however, agroforestry adoption rates remain low among small-scale farmers, with insufficient knowledge about the benefits being a major barrier. To close this knowledge gap and increase farmers' motivation to plant different tree species on their farms, this study applies a Role-playing game (RPG) as an awareness-raising tool. 72 small-scale farmers from Rwanda played the RPG and participated in pre- and post-game surveys. A comparison of responses before and after playing demonstrates that the RPG increased farmers' knowledge and attitude toward most tree-related benefits. Moreover, playing the game significantly strengthened farmers' motivation to plant more tree species on their farms. The findings were supported by debriefing results, confirming that RPGs are an effective tool to raise farmers' awareness and motivation on sustainable land use management.

Keywords: agroforestry adoption, on-farm tree planting, ecosystem services, role-playing game, serious game.
JEL codes: Q15, Q51, Q54.

1. INTRODUCTION

Since 1960, more than half of the world's tropical forests have been destroyed and at present, deforestation continues to increase (IUCN, 2021). Deforestation and land degradation pose serious threats to ecosystem functioning and the human food system. Especially in Sub-Saharan Africa, where the prevalence of food insecurity and undernourishment is among the highest in the world (FAO et al., 2021; Ndoli et al., 2021), small-scale subsistence farmers are severely affected by the consequences of forest conversion (Meijer et al., 2015). Strengthening the resilience of ecosystems and human livelihoods, therefore, requires the urgent and widespread adoption of sustainable agricultural practices (FAO & UNEP, 2020). Agroforestry, one sustainable land-use practice with trees as an integral part of the farming systems,

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provides various benefits for human well-being and the environment, including provisioning, regulating, supporting, and cultural ecosystem services (Coulibaly et al., 2017; FAO, 2013b; FAO & UNEP, 2020; Gamfeldt et al., 2013; Garrity et al., 2010; Udawatta et al., 2019). Despite the numerous benefits of trees, however, adoption rates among smallholder farmers remain low in many Sub-Saharan African countries (Amare & Darr, 2020; Ndlovu & Borrass, 2021).

A large body of literature has already examined a variety of adoption barriers, which include lack of land tenure rights, high investment costs, limited access to credits, insufficient availability of planting material, high transaction costs, information asymmetries, and lack of institutional support (Amare & Darr, 2020; Arvola et al., 2020; Bettles et al., 2021; Jerneck & Olsson, 2013; Kang & Akinnifesi, 2000; Kehinde et al., 2022; Meijer, Catacutan, Sileshi, et al., 2015; Romero et al., 2019; Russell & Franzel, 2004).

Besides the importance to address such external barriers, researchers and policy-makers should not ignore the intrinsic motivation of smallholder farmers to adopt agroforestry systems. According to the Millennium Ecosystem Assessment (Millenium Ecosystem Assessment, 2005), ecosystem management depends on people's evaluation of the services provided by these ecosystems. It is therefore assumed that smallholder farmers are more willing to plant trees if they are aware of and positively evaluate the benefits of agroforestry systems. Nevertheless, smallholders value and plant trees predominantly for direct economic benefits such as product provision and income-generating opportunities (Ndayambaje et al., 2012). In contrast, they seem to disregard environmental benefits that are not directly observable in the short term (Karamage et al., 2016; Ndayambaje et al., 2012; Zubair & Garforth, 2006). This disregard may imply a lack of knowledge about the complex interactions within social-ecological systems (Lima & Bastos, 2019; Lima & Bastos, 2020). Insufficient knowledge about the linkages between ecosystem services and human well-being can therefore reduce farmers' motivation to plant trees (Coulibaly et al., 2017; FAO, 2013a), whereas increasing farmers' knowledge and perception can improve their motivation (Oduro et al., 2018). This assumption is confirmed, for example, by a study from Indonesia, in which an environmental information campaign increased the motivation of oil palm farmers to plant trees (Romero et al., 2018). To improve agroforestry adoption among smallholders, it is therefore important to close existing knowledge gaps and raise awareness of the benefits of trees (Bettles et al., 2021; Ndayambaje et al., 2021; Zhang et al., 2016).

One approach to raising smallholders' awareness about environmental concerns is serious games, among them role-playing games (RPGs). RPGs simulate realistic issues in a safe learning environment, in which players can experience alternative actions that do not affect their real lives (Barreteau et al., 2007; Salvini et al., 2016; Villamor & Badmos, 2016). This experience allows players to better understand the consequences and linkages of their actions within complex social-ecological systems (Le Page et al., 2016; van Pelt et al., 2015; Villamor & Badmos, 2016).[1]

Accordingly, RPGs have been increasingly used in recent years to better understand human decision-making behavior, and increase players' knowledge of sustainable resource and land use management (Barreteau et al., 2007; den Haan & van der Voort, 2018; Falk & Meinzen-Dick, 2021; Hardy et al., 2020; Jean et al., 2018; Medema et al., 2016; Moreau et al., 2019). For example, the RPG conducted by Salvini et al. (2016) in Brazil increased farmers' awareness of the need to adopt climate-smart agricultural systems to strengthen their resilience to climate change.

The findings of previous studies, therefore, suggest that RPGs may also be appropriate instruments to raise awareness about the importance and advantages of agroforestry adoption. Thus, this paper aims to investigate whether an RPG can improve small-scale farmers' perception of the benefits of trees and their motivation to plant different tree species on their farms. Specifically, the study explores whether there are significant differences in attitude, knowledge, and intention regarding tree planting between a group of farmers who played the RPG and a group of farmers who did not play the game. The RPG of this study was applied in the Volcanic Highlands of the Northern Province of Rwanda. The area is characterized by high population density, land scarcity, and steep slope farming, which have resulted in high deforestation rates and susceptibility to soil erosion in the past (Ndoli et al., 2021; Stainback et al., 2012). Although the government of Rwanda promoted the implementation of the fast-growing, exotic Alnus

[1] RPGs aim to address real-world challenges and are therefore designed for a primary purpose beyond entertainment such as education, training, and information exchange (Medema et al., 2016). Particularly in the context of human-environment interactions, RPGs are used to improve stakeholders' understanding of different viewpoints and the consequences of their behavior on a system's functionioning. In addition to sharing perspectives and knowledge, their goal is also to strengthen collective action to change the current functioning of a system. Although RPGs are only simplified representations of difficult issues, they can still reflect the complexity of a system by incorporating relevant dynamics and interrelationships. This makes them an important tool for supporting social learning and collective decision-making processes (Bousquet et al., 2013)

and Eucalyptus species to reduce soil erosion, the diversity of trees in the Volcanic Highlands remains low (Iiyama et al., 2018; Mukuralinda et al., 2016). The Volcanic Highlands of Rwanda, therefore, represents an interesting case study to promote the planting of more different tree species.

This paper begins with information on the study area, data, and methods used in section 2; presents the results in section 3; follows with a discussion in section 4, and ends with a summary and conclusion in section 5.

2. DATA AND METHODS

2.1 Study area

The study was conducted in the Volcanic Highlands in the north of Rwanda, a small, landlocked country in Sub-Saharan Africa. The north of Rwanda is characterized by mountainous regions with altitudes of more than 2000 meters (Mukuralinda et al., 2016). During the two rainy seasons occurring between March and May/June and from September/October to December/January, annual precipitation accounts for more than 1200 mm (Ngarukiyimana et al., 2018). The population of Rwanda mainly consists of small-scale farmers who use almost 75% of the land for crop cultivation and cattle farming (Mukuralinda et al., 2016). Due to land scarcity and high population density, farmers occupy only less than one hectare of land, which is often located on steep slope areas. However, cultivation on steep slopes, high deforestation in the past, heavy rainfall, and increasing population densitiy exacerbate the already existing vulnerability to flooding, landslides, and soil erosion (Uwihirwe et al., 2020). These environmental hazards decrease the availability of fertile soil for food production, impairing farm productivity and crop yield, which severely affects the farming population's livelihood (Ndoli et al., 2021; Stainback et al., 2012; WFP & VAM, 2018).

2.2 Data collection and analysis

For this study, data were collected from 72 smallholder farmers. The gender ratio of the sample selected for this study is balanced and consists of about 50% male and 50% female farmers. They have a mean age of 38 years and invested 8 years in education (Table 1). The average household size is six persons, about half of whom are dependent on other household members. Respondents own approximately 0.6 ha of land and generate two-thirds of their income through agricultural activities. Most farmers are members of agricultural cooperatives and have learned about agroforestry through previous projects. On average, they have planted three different tree species on their farms.

Table 1. Farmer and household information.

Socioeconomic variables	Mean values	Standard deviation
Female respondents (%)	49.32	
Age	38.15	10.76
Years of education	8.29	3.71
Household size	6.25	2.24
Dependency ratio [1] (%)	48.33	
Size of land (ha)	0.73	0.76
Annual income (RWF)	629,383.8	683,957.8
Share of agricultural income (%)	64.84	
Cooperative membership (%)	70.83	
Social interactions [2]	6.43	16.88
Experience with agroforestry (%)	73.61	
Number of tree species planted on farms	3.11	1.74
Risk affinity [3] (%)	88.89	

Notes: If mean values are shown, standard deviations are given in parentheses.
[1] Dependency ratio defined as share of dependent household members who are not counted as labor force due to young/old age or diseases in relation to total household size.
[2] Social interactions defined as number of people with whom respondents discuss their agricultural decisions.
[3] Risk affinity (binary variable) measured by stated willingness to plant a tree even if the yield is uncertain.
*** p<0.01; ** p<0.05; *p <0.1.

We conducted a mixed-method approach that includes both quantitative and qualitative data collection procedures. Figure 1 provides an overview of the single steps of our data collection processes. First, for the quantitative data collection approach, all farmers answered a pre-game survey that contained questions following the Theory of Planned Behaviour (TPB) developed by Ajzen (1991). This theory states that an individual's behavior is guided by intrinsic beliefs. Whether an individual performs a certain behavior or not depends mainly on the individual's behavioral intention. Intention, in turn, is composed of three components, namely attitude, subjective norms, and perceived behavioral control. Attitude refers to the individual's perception of the consequences of certain behavior and whether the individual evaluates the behavior as favorable or unfavorable. Perceived behavioral control relates to the individual's perception of possible obstacles and the extent to which the person assesses the performance of the behavior as easy or difficult. Subjective norms take into account whether other people would approve or disapprove of the performance of the behavior and the extent

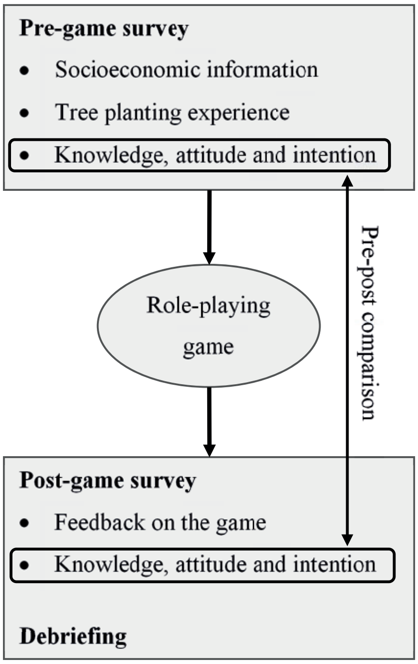

Figure 1. Data collection procedure.

to which the opinion of other people influences an individual's decision to perform a given behavior.

Since this study investigates the impact of an RPG to raise awareness and enhance, respectively change farmers' viewpoints towards positive perceptions of tree planting, we only include TPB constructs that are not affected by external factors. Since subjective norm is determined by the opinion of family members, friends, and other farmers, and perceived behavioral control is influenced by external adoption barriers such as insufficient access to markets, unavailability of tree seedlings, and small land area, we only include questions related to farmers' attitude and intention. In addition to these two original TPB constructs, we also include knowledge as an additional construct (Anebagilu et al., 2021; Maleksaeidi & Keshavarz, 2019).

We measure each construct by several indicator questions. Attitude includes eleven indicator questions and knowledge includes three indicator questions. As proposed by Meijer et al. (2015), the indicator questions of attitude are determined by multiplying the two measurement components salient belief and outcome evaluation. In our study context, salient belief describes farmers' expected outcome of diverse tree planting and outcome evaluation defines the personal assessment of this outcome. Concerning knowledge indicators, the first component specifies whether respondents think that specific knowledge of agroforestry is required to plant more tree species on farms and the second part describes whether respondents have this knowledge. All questions were asked on a five-point Likert scale. Both measurement components of attitude and knowledge indicators are multiplied, which resulted in a maximum final score of 25.

After answering the pre-game survey, all respondents participated in an applied RPG, which is further described in chapter 3.3. Afterward, participants conducted a post-game survey that contains the same questions on farmers' knowledge, attitude, and intention as the pre-game survey. In addition, the post-game survey also includes questions that are directly related to the game's outcome. To gain a more comprehensive understanding of the effectiveness of the game based on qualitative data, debriefings were held after the game sessions to discuss the results of the game. Game debriefings allow players to deepen their knowledge, increase mutual understanding between participants and translate their experiences into learning outcomes (Crookall, 2010; Eisenack, 2013; Mendler de Suarez et al., 2012; Meya & Eisenack, 2018).

The descriptive data were analyzed using Stata 14.2. Paired t-test was used to compare players' responses before and after the game.

2.3 Role-playing game

The role-playing game used in this study is based on the "Upstream Downstream" game developed by the Partners for Resilience (PfR) program to build community resilience and reduce disaster risk (Mendler de Suarez et al., 2012). To increase farmers' knowledge of the multiple benefits of trees and to improve their perception of agroforestry systems, the game was adapted and expanded for the specific context of the study region. Players take on the role of subsistence farmers in mountainous areas who are at risk of crop failure due to heavy rainfall and flooding. To deal with shocks and maintain livelihoods, farmers have the option to cut down trees and sell wood, which in turn increases the risk of flooding in subsequent turns. For this study, two more elements were added to the game: the inclusion of trees of different species and the addition of scenarios related to various ecosystem services. Each game session consisted of eleven rounds and took about two hours.

The game board depicts a steep hillside landscape along a river and is divided into a mountainous upstream area and a flatland downstream area. While the upstream area has a higher tree density, trees are less common in the downstream area. Each farmer cultivates two neighboring plots that differ in terms of crop yield and flood risk. The game includes three different types of trees: fruit trees, timber trees, and indigenous trees. Each tree species exhibits different characteristics (e.g., morphological characteristics such as height, leaf appearance, and flowering) that result in different contributions to economic and environmental benefits. Trees define the dynamic linkages between upstream and downstream farmers and determine the severity of precipitation's effect on crop and yield losses. The number of trees planted by upstream farmers can increase the damage threshold and thus reduce flood risk. Specifically framed scenarios reflect the different ecosystem services provided by different tree species (fruits, timber, soil fertility, pest control, pollination, climate regulation, and tourism). The scenarios reflect players' livelihoods in a resilient environment depending on the tree number and species diversity growing in their fields. The first three rounds were played without scenarios to ensure participants' understanding and familiarity with the rules of the game.

Table 2. Tree species planted by farmers.

Tree species	Farmers who planted corresponding trees (%)	Most important planting reasons for farmers
Alnus	75.00	Stakes for climbing beans, soil fertility, soil erosion protection, timber, firewood
Avocado	61.11	Fruits, income
Eucalyptus	50.00	Timber, firewood, stakes for climbing beans, soil erosion control
Tamarillo	37.50	Fruits, income
Papaya	16.67	Fruits
Acacia	16.67	Soil erosion control, soil fertility, firewood, timber
Vernonia	13.89	Stakes for climbing beans, fodder, culture, medicine, soil fertility, soil erosion protection
Grevillea	9.72	Timber, stakes for climbing beans, soil erosion control, firewood
Erythrina	6.94	Soil fertility

3. RESULTS

3.1 Tree planting

The most frequently planted tree species by farmers from the study area and their reasons for planting are provided in Table 2. Most smallholders implemented Alnus, Avocado, Eucalyptus, and Tamarillo trees on their farms, which account for more than 70% of trees on their farms. A majority of these tree species provide multiple benefits but farmers' planting reasons for ecological purposes are rather monotonous.

The only ecological purposes for farmers to plant trees are soil erosion control and soil fertility improvement, with Alnus and Eucalyptus being the most preferred species to provide these benefits. Since Alnus and Eucalyptus are widely known as fast-growing species (Cyamweshi et al., 2021; Kuria et al., 2017), farmers of our study have planted them for timber production, stakes for climbing beans, and firewood. In contrast, they grow fruit tree species such as Avocado, Tamarillo, and Papaya exclusively for food production and income generation. Although agroforestry systems in Rwanda are dominated by exotic tree species, some farmlands also include indigenous species such as *Vernonia amygdalina* and *Erythrina abyssinica* (Mukuralinda et al., 2016). For example, 14% of farmers in our study region implemented Vernonia trees, with cultural backgrounds, use as fodder, and medicinal purposes being particularly important reasons for planting. Overall, our results show that most farmers are highly willing to plant more trees in the future, even if growth and yield are uncertain.

3.2 Game feedback

Players' feedback on the game is illustrated in Figure 2. The results indicate that, although 38 players perceived the duration of the game as too long and one-third considered the game as too complicated, nearly all participants liked the game and had fun while playing. In addition, more than 75% of all participants agreed that the RPG represents their reality. In contrast, about 20% were uncertain about the game's ability to represent farmers' daily life, and only two players mentioned that the game was not representative. Despite this criticism, all farmers have expressed that they have learned something from the game. When asked farmers about their strategies followed during the game, 97% of farmers mentioned profit maximization, 51% indicated environmental protection, and 28% increased biodiversity. Results of the post-game survey furthermore show that, except for one farmer, all players consider it important to plant more trees in real life. Of these farmers, everyone emphasized the need to increase tree diversity on their farms and stated a higher willingness to plant trees in the future after they have played the game. The debriefing results also support the post-game survey responses of the farmers. For example, one player explained: "While playing the game, I diversified trees to support biodiversity. Now that I know the values of all trees, I would like to buy more species." Another farmer mentioned "What I learned is that indigenous trees are also important. I did not value them before but now,

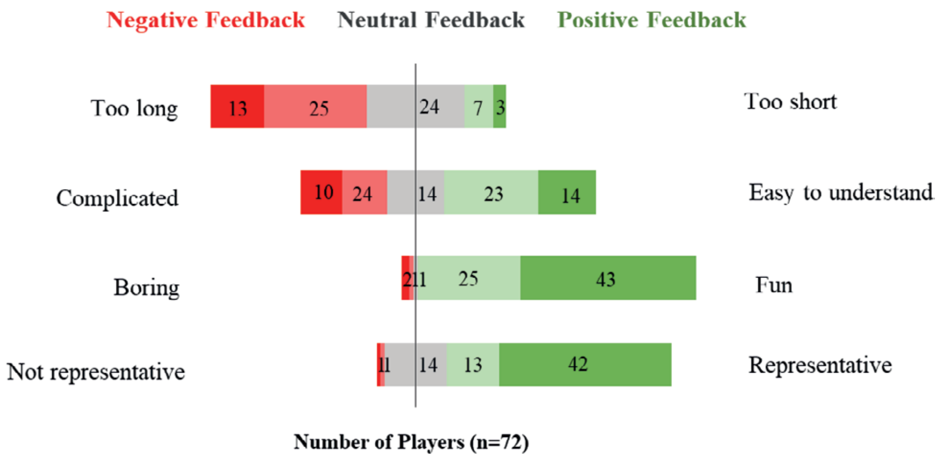

Figure 2. Players' feedback on the game. Note: Illustration adapted from Orduña Alegría et al. (2020).

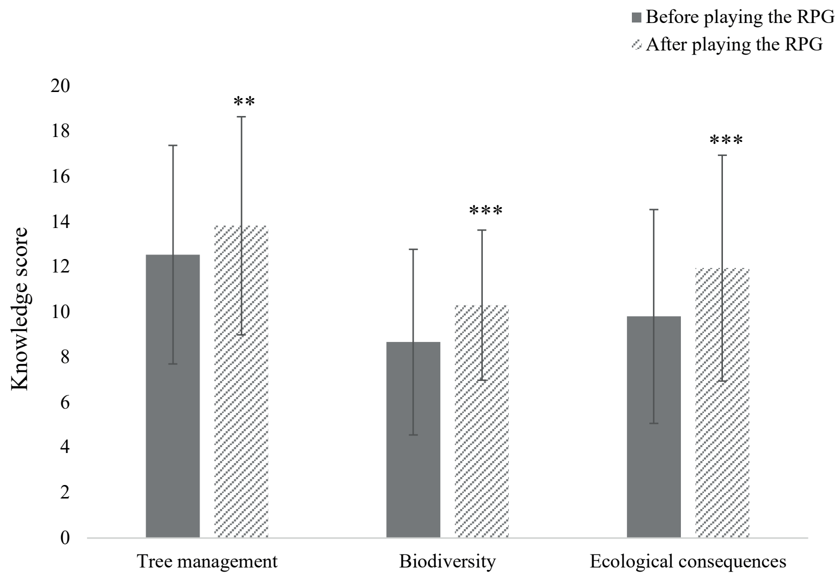

Figure 3. Comparison of farmers' knowledge score before and after playing the RPG. Notes: Mean values and standard deviations are shown. Maximum possible value of perception score is 25. *** p<0.01; ** p<0.05; *p <0.1.

after this game, I will start planting them on my farm." When players were asked why farmers do not mix trees with crops, they replied, "It is a poor mindset" and "lack of knowledge". This finding suggests that the RPG applied in this study is a useful tool to increase farmers' knowledge about the benefits of trees and improve their motivation to plant more different species.

3.3 Comparison of pre-game and post-game survey

Figure 3 shows the results of farmers' knowledge scores before and after playing the RPG. The higher score values for all knowledge indicators imply that the RPG significantly affected farmers' awareness of knowledge requirements and skills related to agroforestry. Specifically, playing the RPG increased farmers' views on the knowledge needed for tree management. The higher awareness can be explained by the fact that farmers learned about the importance of the choice of tree species and the planting density on their farms. For example, the way players managed their trees affected not only their own livelihood in the game but also that of other players. The more trees players cut on their farms, the higher the likelihood that other players also suffer from flooding and soil erosion, leading to loss of crop yield and removal

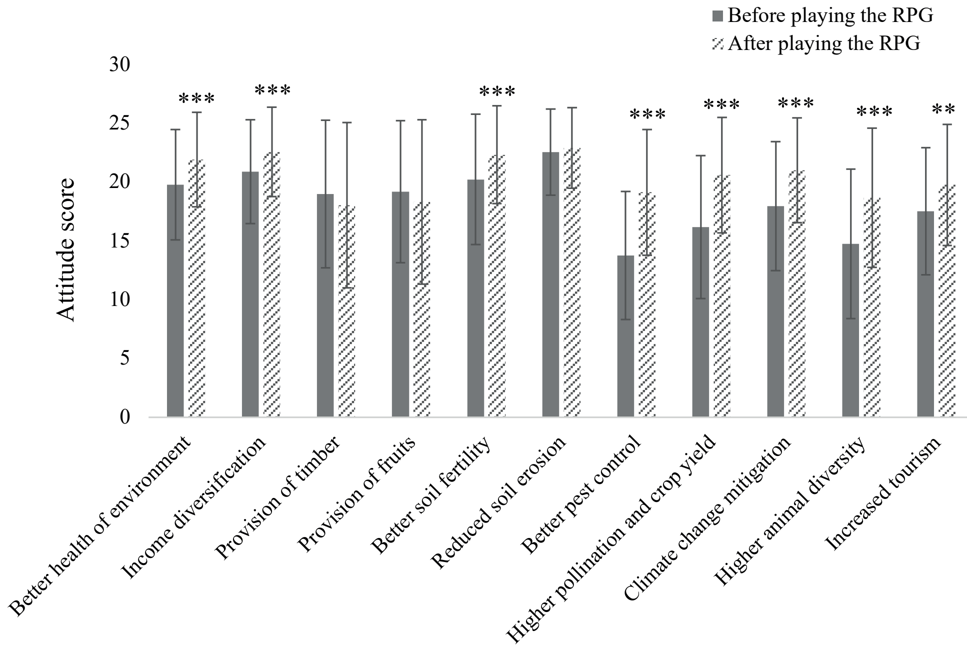

Figure 4. Comparison of farmers' attitude scores before and after playing the RPG. Notes: Mean values and standard deviations are shown. Maximum possible value of intention score is 25. *** p<0.01; ** p<0.05; *p <0.1.

Figure 5. Comparison of farmers' intention scores before and after playing the RPG. Notes: Mean values and standard deviations are shown. Maximum possible value of intention score is 5. *** p<0.01; ** p<0.05; *p <0.1.

of young trees. Likewise in a game debriefing, one player concluded "If farmers hardly mix trees with crops and they manage their trees poorly, they suffer crop and tree losses". At the same time, players noticed that the choice of tree species and the planting density also depend on external circumstances, such as farmland size, crop species cultivated, and tree-crop competition. For example, some farmers explained, "Planting too many trees on small farming plots will decrease crop yield". Thus, the debriefing results underline the finding that the RPG significantly increased players' awareness of the knowledge required to manage and benefit from trees. The game also significantly reinforced respondents' opinion that planting trees requires knowledge and that they have the required knowledge about the ecological consequences of trees and their impact on biodiversity.

Similar to knowledge scores, farmers significantly increased their attitude toward various benefits of trees after playing the game (Figure 4). Most of the changes in attitude scores relate to indirect environmental services. Farmers revealed a significantly more positive perception, especially in terms of better environmental health, improved soil fertility, better pest control, increased pollination, climate protection, greater wildlife diversity, and tourism attraction. While farmers now also increasingly perceive trees as an opportunity for income diversification, the game did not significantly change farmers' attitudes regarding the potential of trees to provide fruits and timber and to reduce soil erosion.

Figure 5 illustrates the games' impact on the intention of farmers to plant more diverse trees on farms in the future. Concerning both farmers' stated intention and their self-assessed likelihood of planting diverse trees in the next three years, score values increased significantly after playing the game. Although the farmers were already highly motivated to plant trees before playing the game, the significant increase in their intention scores implies that the RPG is an effective and meaningful tool to further stimulate the intrinsic motivation of participants.

4. DISCUSSION

This study explored the potential of an RPG to raise smallholder farmers' awareness of the benefits of trees and increase their motivation to plant more different tree species on their farms. The results manifest our hypothesis that after playing the RPG, farmers significantly increased their awareness of the knowledge needed to plant different tree species on farms. After gameplay, farmers are more aware that tree planting requires knowledge about both tree management and the consequences of planting. Indeed, agroforestry adoption and management is more knowledge-intensive and requires more education and experience than conventional agricultural systems (Barrett et al., 2002; Mercer, 2004). Our result that farmers increased their awareness of knowledge requirements coincides with findings from other studies that revealed higher awareness among participants after gameplay (Moreau et al., 2019; Salvini et al., 2016). One example is the study by Salvini et al. (2016), which investigated the impact of an RPG on social learning and collective action among Brazilian farmers toward the adoption of Climate Smart Agricultural (CSA) practices. They found that the RPG increased farmers' awareness in terms of higher resource investments needed to implement CSA.

The RPG applied in this study furthermore strengthened farmers' positive attitudes towards the majority of tree-related benefits. The increasing positive perceptions towards most environmental benefits might stem from the game scenarios that raised farmers' awareness of the harmful environmental consequences of not planting trees or planting few trees, especially when tree diversity is low. Similarly, coffee farmers who played a RPG in Brazil learned about the positive environmental effects of agroforestry in terms of higher resilience to droughts compared to traditional farming systems (Salvini et al., 2016). Concerning knowledge acquisition, one player from our study declared during a debriefing session "The only way to learn about the consequences is through experience." As concluded in other studies, serious games create a safe environment in which players experience and learn from the consequences of their actions (Hardy et al., 2020; Mayer, 2009; van Noordwijk et al., 2020; Villamor & Badmos, 2016). RPGs, therefore, offer players the possibility to make decisions and explore alternative actions without taking real-life risks.

However, farmers of our study did not significantly change their attitude toward the potential of tree planting to decrease soil erosion and provide timber and fruits. The unchanged attitude towards these benefits can be explained by our finding that in real life, farmers have already planted most of the trees on their farms for soil erosion control and product provision. This result is in line with findings of Ndayambaje et al. (2012), who also noted that farmers in Rwanda have planted trees in the past primarily for economic reasons.

Although farmers' attitudes towards some tree-related benefits did not improve, the game still significantly increased their motivation to plant more different tree species on their farms. Our finding that the RPG increased farmers' intention to plant more different tree species on farms is in line with previous studies showing that serious games can lead to motivational or behavioral change (Janakiraman et al., 2021; Meinzen-Dick et al., 2018; Meya & Eisenack, 2018; Salvini et al., 2016). According to Meinzen-Dick et al. (2018), an applied RPG on watershed management increased farmers' motivation in India to adopt water registers in their real life and resulted in the introduction of rules for more sustainable groundwater use. Salvini et al. (2016) found that after gameplay, some farmers increased the area used for agroforestry systems on their land, while farmers who have not implemented agroforestry systems at the time of the study adopted coffee agroforestry and silvopastoral system after playing the game.

Although most studies emphasize the effectiveness of serious games to increase awareness of certain issues among participants, there are some studies criticizing that the knowledge gained through gameplay is not sufficient to alter stakeholders' behavior (Ducrot et al., 2015; Lamarque et al., 2014). In this context, Lamarque et al. (2014) conducted an RPG with farmers to investigate how knowledge and valuation of ecosystem services influence their land-use decisions. However, the authors found that other external factors such as socioeconomic and topographic characteristics influence farmers' land-use decisions and outweigh the effects of ecosystem service valuation.

These contrasting study results highlight both the strengths and weaknesses of serious games. Although the application of serious games is an appropriate participatory method to reduce knowledge gaps and shift viewpoints, games represent only a simplified version of players' real life. In reality, they face additional challenges affecting their land-use decisions. To capture the entire socio-ecological system with all its elements, complex interactions and possible actions in the game is almost impossible and would lead to the game becoming unmanageable. To maximize the impact of a game while ensuring its representativeness and fun atmosphere, stakeholders should already be involved in the early design and testing stages of the game.

5. CONCLUSION

The purpose of the present study was to examine the impact of an applied RPG on small-scale farmers' knowledge, perception, and motivation to increase the planting of different tree species in a highly deforested area of the Volcanic Highlands in Rwanda. Comparisons of pre-game and post-game survey responses revealed that farmers significantly increased their awareness of the knowledge requirements for tree planting. Furthermore, the game significantly improved players' attitudes toward a wide range of tree-related benefits. After playing the game, participants expressed a significantly higher intention to plant more different tree species on their farms. Various statements made by farmers during the game debriefing sessions also confirmed the learning effect achieved through the game. Thus, this study provides empirical evidence of the effectiveness of RPGs in improving farmers' intrinsic motivation to adopt agroforestry.

Our study implies that insufficient awareness among smallholder farmers of the benefits of trees is an important barrier to tree planting that needs to be addressed. This paper, therefore, calls for more support to farmers to close existing knowledge gaps and promote agroforestry adoption. We recommend the use of serious games, which, as has been shown in this and other studies, are an auspicious tool to stimulate learning and support decision-making processes in sustainable land-use management, biodiversity conservation, and climate change mitigation (e.g. Andreotti et al., 2020; Meinzen-Dick et al., 2018; Salvini et al., 2016; Souchère et al., 2010).

As players criticized the duration and complexity of the RPG in this study, we suggest the participation of relevant stakeholders in every step of the development process of serious games. Early involvement would not only result in serious games that are fun and easy to understand but also helps researchers and policymakers to identify complex problems, constraining conditions, and feasible solutions to policy-relevant sustainability issues where actions are needed. In particular, the inclusion of a larger diversity of stakeholders can lead to both a greater expansion of personal views and knowledge and a commom understanding of the research gaps that need to be addressed (Menozzi et al., 2017). Stakeholder involvement is therefore key to successful game development and implementation (Barreteau et al., 2014). Overall, the strengths of RPGs to exchange knowledge, improve mutual understanding and collectively develop solutions make them a promising bottom-up instrument, which might be more efficient than conventional top-down approaches.

This study also comes with some limitations. First, we were interested in investigating the game's impact on farmers' intrinsic motivation but we have not considered whether a motivational change also leads to a change in farmers' actual tree-planting behavior. Overall, studies assessing the long-term effect of serious games and the translation of motivational changes into participants' real behavior are rare (Meya & Eisenack, 2018), offering scope for future research. Second, we have only examined farmers' intrinsic motivation as a superordinate factor and knowledge and attitude as subordinate components being influenced by the game. Beyond these components, farmers' motivation is also determined by their other intrinsic factors (e.g. subjective norms and perceived behavioral control) and extrinsic factors (e.g. farmers' socioeconomic and agroecological context). Thus, future research should focus on a combination of extrinsic and intrinsic determinants to better understand farmers' motivation and decision-making behavior in agroforestry adoption.

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