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HOW DISTRIBUTIONAL EQUITY AFFECTS EVOLUTIONARILY SUSTAINABLE LANDSCAPE MANAGEMENT

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Table of contents

Abstract

As the human population rapidly grows, ensuring food availability for everyone will require substantial agricultural intensification in a sustainable manner. This must however be achieved without negatively impacting ecosystems or stakeholders' (e.g. farmers) livelihoods. For stakeholders to engage in sustainable agricultural practices, it is important to evaluate “equity”, which represents a form of justice. Current literature indicates that individuals who express a perception of inequity are less likely to engage in sustainable landscape-management practices and to cooperate. This study explores distributional equity, concerning the distribution of cost and benefits between stakeholders, alongside other predictors and their association with landscape-management decisions by using behavioural games as an experiment. The game developed for this research lets participants assume the role of a farmer who needs to protect crops against pest attacks by choosing between different pest control methods. The pest control options rank naturally from least to most evolutionary-sustainable, based on the concern of their contribution to insect pesticide resistance. I predicted players' choice of pest control to be affected by their perceived performance in the game, mirroring the effect of distributional equity. Using an ordinal categorical mixed model for analysis, the results from 134 players showed only a small to non-existent effect of inequity on decision-making. This did not align with my predictions. The small effect from inequity suggests that it may not be an important predictor when choosing pest control methods or that players pay more attention to other predictors. Pest density and the complex interdependence of density, game-round and gender were all associated with pest control decisions, reinforcing current literature that emphasises that empowering women in agriculture may help achieving more sustainable agriculture.

Svenska

Den mänskliga befolkningen ökar snabbt och för att producera mat till alla kräver det en intensifiering av jordbruket på ett hållbart vis. Detta måste dock uppnås utan att negativt påverka ekosystem eller intressenters (till exempel lantbrukare) välstånd. För att intressenter ska engagera sig i hållbara jordbruksmetoder är det viktigt att utvärdera hur upplevd ”rättvisa” (equity) påverkar deras beteende. Forsking visar att individer som uttrycker en uppfattning om orättvisa i förhållande till sina grannar är mindre benägna att delta i hållbar jordbruksförvaltning samt att samarbeta. Denna studie utforskar närmare hur en form av rättvisa gällande fördelningen av kostnader och fördelar mellan intressenter (distributional equity) tillsammans med andra prediktorer kan påverka beslut om jordbruksförvaltning, genom användning av ett digitalt beteendespel. Spelet som utvecklats för denna studie låter deltagarna anta rollen som en bonde som behöver skydda grödor mot skadedjursattacker genom att välja mellan olika bekämpningsmetoder. Alternativen för bekämpningsmedel rangordnas från minst till mest evolutionärt och ekologiskt hållbara, baserat bland annat på risken för skadedjur att utveckla resistens mot bekämpningsmedlet. Min hypotes var att deltagarnas val av skadedjurskontroll skulle påverkas av deras upplevda prestation i spelet, vilket återspeglar effekten av orättvisa. Med användning av en statistisk model för analys visade resultaten från 134 deltagare endast en liten nästintill obefintlig effekt av graden av orättvisa med avseende på bekämpnings metod. Det resultatet överensstämde inte med min hypotes. Att ingen effekt hittades av orättvisa kan antyda på att rättvisa inte är så viktigt när de väljer skadedjurskontrollmetoder, eller att deltagare ägnar större uppmärksamhet åt andra prediktorer. Andra prediktorer så som skadedjurens intensitet och den komplexa samverkan mellan skadedjur, spelomgång och kön påverkade istället besluten om skadedjurskontroll. Mina resultat förstärker aktuell litteratur som betonar att inkludera kvinnor i jordbruket kan hjälpa till att uppnå ett mer hållbart jordbruk.

Introduction

The human population is estimated to reach almost 10 billion people by 2050, and providing everyone with food will require agricultural intensification (UN FAO, 2017). Importantly, this should not come at the expense of ecosystems or the livelihoods of stakeholders, e.g. farmers (Gould et al., 2018). Protecting Healthy Ecosystems and Eliminating Hunger are two of the 17 Sustainable Development Goals (SDGs) of The United Nations Agenda 2030. Reaching these goals simultaneously is possible but could generate conflicts between stakeholders with conflicting interests and is therefore considered one of today's “wicked problems” facing humanity (Gould et al., 2018). Wicked problems are difficult to tackle since they involve interests without one single solution.

Finding ways to approach such wicked problems demands interdisciplinary dialogue and may also require a change in stakeholders’ attitude towards conservation and cooperation. Stakeholders’ willingness to participate in conservation actions such as sustainable landscape-management depends on various social, psychological and economic factors (Dessart et al., 2019; Magarey et al., 2019). One factor known to affect stakeholders’ behaviour is “equity”, a term referring to fair treatment and the relative gain of individuals or groups (McDermott et al., 2013). Equity accounts for existing disparities and considers individuals and societies different needs by focusing on the relative gains of individuals or groups. Thus, equity aims to recognise and address differences to achieve fairness (Brosnan & Bshary, 2016; McDermott et al., 2013).

Equity and sustainability

Recognising that life and society are not always fair and acknowledging individuals’ different needs could result in a more equal and just outcome. Equity, and related terms like equality and justice, have a central part in the SDGs (e.g. in SDG 10 “Reduce inequality”) and have lately gotten more attention in conservation discussions regarding such as payments for ecosystem services and the consequences resulting from climate change (Grasso, 2007; Pascual et al., 2014). Engagement in conservation actions is influenced by individuals’ perception of inequity (Brosnan, S. F., & Bshary, R., 2016; Brosnan, S.F., 2023; Rakotonarivo et al., 2021). A study by Rakotonarivo et al., (2021b) set out to test the effect of incentive-based schemes on increasing farmers conservation actions such as protecting and not killing crop-damaging elephants. Their results showed that monetary payments significantly increased participation in conservation actions and further highlighted the importance of considering equity while creating polices for conservation strategies. Yet, what kind of equity is important and exactly how equity affects stakeholders’ behaviour is less clear (Leach et al., 2018).

Therefore, the primary objective of this study is to explore how stakeholders’ perception of inequity affects their decision-making. This is done by designing a digital experiment that allows for manipulation of the effect of inequity to test how it influences stakeholders' landscape-management.

McDermott and colleagues (2013) divide aspects of equity into three categories; Distributional, Procedural and Contextual, a useful distinction according to multiple other studies (Friedman et al., 2018; Pascual et al., 2014). Distributional equity is about the distribution of costs and benefits between various actors (e.g., individuals, communities, governments, and international stakeholders) and how the gain is divided. Procedural equity concerns the influence and inclusion in decision-making (e.g., in politics). Contextual equity acknowledge that the social context could be unjust due to historic beliefs and situations, such as landownership and historical colonisation. While equity is a multidimensional phenomenon and recognising that all dimensions are intertwined (Friedman et al., 2018; McDermott et al., 2013; Pascual et al., 2014) this study only focus on distributional equity, and in particular how gaining more or less than a social partner can impact stakeholders' decision-making.

Distributional equity

Distributional equity concerns the fair allocation of benefits and costs between stakeholders. A distributionally equitable approach strives towards a more just outcome by considering each person's needs and current state (McDermott et al., 2013). An individual's reaction or own preference for justice is known as inequity aversion (Brosnan & de Waal, 2014; Hopfensitz & Miquel-Florensa, 2017).

The reaction to an unfair situation could be reacting negatively to the sense of gaining less than a social partner, known as disadvantageous inequity aversion, but could also be in response to gaining more than a social partner, known as advantageous inequity aversion (Fehr & Schmidt, 1999). The tendency to compare relative gains and reject less profitable offers (disadvantageous inequity aversion) is not exclusive to humans or monkeys but also seen in certain bird species (Wascher & Bugnyar, 2013), wolves and domestic dogs (Essler et al., 2017), and other primates (Hopper et al., 2013; Verspeek & Stevens, 2023). In contrast, the reaction to gaining more than a social partner (advantageous inequity aversion) is much less studied, and has so far only been documented in humans older than five and chimpanzees, probably since it requires a highly developed cognitive ability (see also Brosnan & de Waal, 2014; Gao et al., 2018).

One potential mechanism that might explain why species with complex social behaviour have evolved a reaction to inequity could be that it is important for cooperation. Behaviour that favours cooperation is associated with higher fitness of individuals in social groups (Brosnan & de Waal, 2014; Fehr & Schmidt, 1999; Stevens & Hauser, 2004). An explanation to this behaviour could be that the individual that gets the less preferred award could in the long run benefit from rejecting it and look for a more equal outcome or partner to cooperate with in the future (Brosnan & de Waal, 2003). Cooperating helps individuals in a group or population to perform tasks such as foraging, parenting, defending territories specialising in different tasks better than they would have by themselves (Dugatkin, 1997). Cooperation, from an agricultural perspective, could also help addressing the wicked problem on how to protect the environment while making sure there is food for a growing population by improving crop protection.

One common approach to encourage participation in cooperative efforts and sustainable actions is to provide incentives to stakeholders to make cooperation profitable. Policy interventions are designed to promote behavioural change, and one of the ways they might work is to dispel aversion to new polices that arise from perceived inequity.

Challenges in modern agriculture

Some industrial approaches to modern agriculture have engendered substantial problems related to sustainability. For example, pest herbivores cause crop losses of up to 30 % before harvest which is obviously a global concern (Oerke & Dehne, 2004; WHO, 2019). Addressing this loss could help increase food production without exploiting more land for agriculture. Globally, various small-hold farmers have transformed into big-scale monocultures to scale up efficiency and produce food faster at a lower price. These farming ecosystem has become specialised to a small number of crops. Among the crops cultivated today, only three crops (wheat, rice and maize) contribute to 60 % of our daily direct calory and protein intake (FAO, 2019).

As a consequence, the species diversity of many landscapes has been substantially reduced by agricultural intensification. A homogenous environment in combination with an excessive use of a few pesticides can lead to less efficient crop protection if herbivorous pest develops resistance to pest controls (Hawkins et al., 2019). Tackling the problem with pesticide resistance and promoting more evolutionary-sustainable agriculture is a complex and multifaceted problem. However, considering two key elements have the potential to greatly enhance the sustainability of pest control: favouring biocontrol methods and embracing landscape diversity.

Biological control involves living organisms such as microorganisms, insects and parasitoids that naturally suppress pest populations. Using natural enemies offers advantages over chemical pesticides due to their generally heightened specificity and reduced environmental impact. Moreover, the genetic complexity of living organisms makes it harder for pests to develop resistance compared to the relatively simpler forms of chemicals compounds (Mangan et al., 2023). A recent study by Rodrigues et al. (2023) in Brazil argues that implementing biocontrol methods can additionally improve agricultural productivity, especially when considering an escalating risk of crop loss via pesticide resistance. However, even biopesticides can provoke resistance in pests if overused (Mangan et al., 2023), reinforcing the importance of implementing diversity among farmers to prevent overuse of a single pest control.

Favouring biocontrol methods and landscape diversity as a way to combat pesticide resistance becomes especially important in regions dominated by large monocultures and huge-scale production of food (typical in highly productive agricultural regions of North and South America, and developing farm economies in parts of Asia and Africa). In such regions, creating in-farm diversity might be comparatively difficult due to economic pressures favouring efficiencies at large scale. One way to enhance diversity without compromising farm-level efficiencies would be to encourage stakeholder cooperation, such that even if individuals specialise on one farming condition, neighbouring farms do so differently in a way that diversifies the wider landscape.

Pesticide resistance develops over time due to persistent exposure to a homogenous environment and the same pest control methods. However, maintaining resistance often comes at a fitness cost, such as increased metabolism, implying that resistance can be counteracted by enhancing diversity in the landscape (Kliot, A. & Ghanim, M., 2012). Achieving diversity at the landscape scale, however, may require a change in stakeholder behaviour and a willingness to cooperate.

Multiple places in the world are facing challenges with pesticide resistance. My study sets out to study landscape-management in Brazil. There are various reasons why studying landscape-management decisions in Brazil is of importance. First, Brazil is a world-leading exporter of crops such as soybeans, maize, and sugarcane (Embrapa, 2021). Brazil is one of the important countries in the ongoing agricultural expansion worldwide, happening particularly in the global south (Alexandratos & Bruinsma, 2012). Additionally, research and development of biocontrol products is rapidly evolving in Brazil with promising new alternatives being available on the market (Embrapa, 2019). However, like many other countries with big agricultural intensification, monocultures and the use of pest control, Brazil has encountered challenges with pesticide resistance. The historical culture of using synthetic pest control may affect the progress and behaviour in this area to change to more sustainable alternatives (Parra, J., 2014).

Behavioural games to studying stakeholders decision-making

Studying human behaviour in dynamic social-ecological systems could be challenging and costly. Nevertheless, learning about factors that influence stakeholders' behaviour is important for creating impactful policies that promote cooperation and sustainable agriculture. One way to study human behaviour in an ethical way is by using framed field experiments known as behavioural games (Bell et al., 2023; Oni et al., in prep; Rakotonarivo et al., 2021a&b; Valerolopez et al., in prep; Yang et al., 2022). Behavioural games in research are controlled experiments that simulate real-world scenarios that let players interact and participate in a study. This approach becomes extra valuable when studying wicked problems where stakeholders with conflicting interests may struggle to collaborate towards shared conservation goals and where real-life experiment could result in ethical issues and high economic expenses (Duthie et al., 2021; Redpath et al., 2018)

Rakotonarivo et al., (2021b) developed and used a behavioural game which provided the foundational basis for my project. Their game involved four participants at a time who needed to act regarding landscape-management and conservation. Complementing their game with a questionnaire, their results highlighted the importance of addressing equity to achieve better conservation goals and protecting locals' livelihoods. This result was later confirmed by Oni et al., (in prep.) who re-analysed the same data set from Rakotonarivo and specifically tested whether equity affected cooperation for conservation objectives. However, Oni et al's study was unable to distinguish whether equity was a cause or a consequence of changes in the game, and they recommended manipulative experiments to isolate the potentially important role of inequity aversion in driving stakeholder behaviour.

Motivated by the findings from Rakotonarivo and Oni, my study develops a new behavioural game tailored specifically to assess the isolated impact of distributional equity on decision-making alongside other predictors of behaviour. My game is a single-player game where each player takes the role of a farmer who needs to manage their land by protecting crops against pest outbreaks. To protect crops against pests the player needs to choose from the available pest control options, ranked from most sustainable to least sustainable, and play over various game-rounds.

Aim

The objective with my study is to test the impact of fairness on decision-making processes in landscape-management. More specifically, I will examine how distributional equity affects the choice of pest control methods, and if this effect increases when experiencing higher levels of inequity. In my study, this will be done by answering the following questions:

- Does distributional equity affect attitudes towards evolutionarily sustainable landscape-management practices?
- Does the effect of distributional equity increase with inequity?

Material and methods

I investigated stakeholders' behaviour in social-ecological systems by using behavioural games as a data collection tool. I was mainly interested in how perceived performance in the game affected players landscape-management decisions. More specifically, I quantified how distributional equity affects attitudes towards engaging in more evolutionary sustainable landscape-management.

Game design and development

I developed the game and conducted analysis using R Statistical Software (v4.2.2; R Core Team, 2022). Furthermore, I used R package Shiny (v1.7.4; Chang et al., 2022) to code and design my game (Shiny is a platform to create interactive web applications). The development and trial period of my game spanned from September to March 2022-2023. The importance of adjusting the game in collaboration with stakeholders was shown by Valero Lopez et al. (in prep). Making the game more abstract, such as not defining the species of crops or pests, made it easier for farmers to relate the game-settings to their own reality. During the trial sessions, I worked closely with agriculture advisors from Centre for Agricultural and Biosciences International (CABI), The Brazilian Agricultural Research Corporation (EMBRAPA), stakeholder groups and university researchers to adjust my games' representation of reality.

My single-player game aimed to test various predictors that might influence landscape-management decisions, focusing on distributional equity. To test the isolated effect of distributional equity, my game manipulated players perception of personal performance relative to peers by manipulating the score table in the game. The score table displayed the players' score and those of nine digital neighbours which allowed for comparison and indicator of relative performance. To mimic distributional equity and how this might change with increased inequity, the game manipulated the score table by assigning each player to two treatment groups which alternated the players perception of personal performance.

Treatments and predictors

The first treatment group manipulated the players rank in the score table. The rank symbolised how profit was distributed between players to mimic distributional equity. The two levels of rank a player could be assigned to was “loser" and "winner." Players assigned loser did always end up at the bottom or near the bottom of the score table, or if you like, were less profitable than their neighbours. In contrast, winners consistently ended up in the top or near-top scores and were more profitable than their neighbours. The idea was to visualise how equally distributed profits were between the neighbouring farms.

However, the effect of distributional equity is expected to only influence behaviour if there also exists a perception of inequity. Imagine a winner and a loser, one with marginal higher profit than the other but where the difference is extremely small. In this scenario there inequity does not exist or is very low, even someone is a winner and another a loser (Fig. 1). To create a perception of inequity, the difference between a winner and a loser needs to be such that it creates a feeling of unfairness. Therefore, a second treatment group was introduced in the game: score disparity.

Score disparity manipulated how evenly score was distributed between players. The two levels of score disparity that each player could be assigned to were “low disparity”, where all players scored similarly, and “high disparity”, were the difference between top-ranked player and bottom-ranked were large (Fig. 1). A low disparity in scores indicated that profit had been distributed relatively evenly wheras high disparity in scores implied an uneven allocation of profit where the winners are doing much better than the losers. When inequity is high, the influence of rank is expected to be stronger than when inequity is low. Within each treatment group, players were randomly assigned to one of the two levels. This design resulted in four distinct treatment combinations: Loser & Low Disparity, Loser & High Disparity, Winner & Low Disparity, and Winner & High Disparity (Fig. 1).

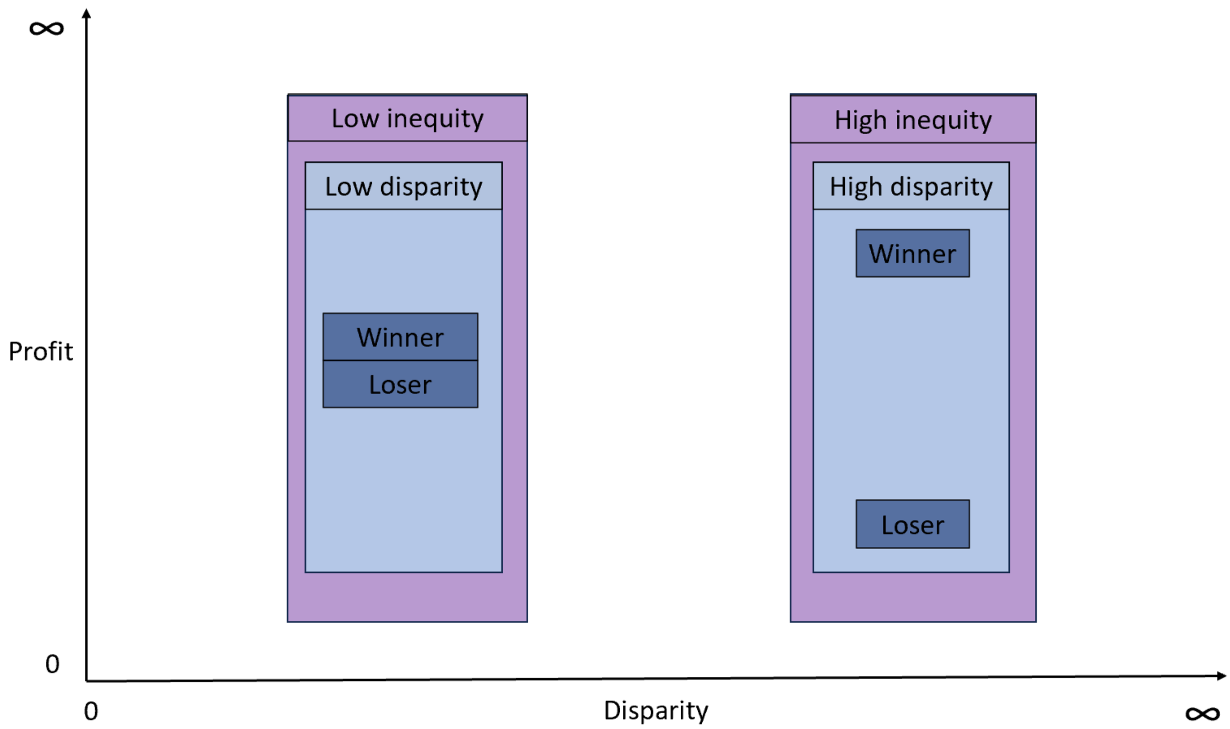

Fig. 1. Illustrating profit (Y-axis) and disparity in scores (X-axis). Treatment groups rank and score disparity are shown in the light and dark blue boxes. The first treatment group, rank, is represented within the dark blue boxes with two levels: winner and loser. The second treatment group, score disparity, is shown by the light blue boxes, featuring low disparity and high disparity as its two levels. Each player is assigned to one of the two levels within each treatment group. In the low disparity group, only minor differences between winners and losers exists, symbolising low inequity as indicated by the purple box. Conversely, the high disparity group exhibits a substantial gap between winners and losers, resulting in high inequity.

I expected players' strategies to correlate with their perceptions of personal performance and in-game inequity. Specifically, I hypothesised that individuals experiencing lower profits when faced with high inequity would exhibit a reaction to inequity. This reaction might manifest as reduced motivation to cooperate and participate in sustainable actions as a response to disadvantageous inequity aversion. On the other hand, those who are more profitable and outperform other players in the high disparity group might be more inclined to cooperate. This willingness to help less profitable individuals during times of high inequity would be a response to advantageous inequity aversion.

In this study, I expected individuals to respond to the rank treatment only when assigned to the high score disparity level. In cases where inequity plays a vital role, players in the high inequity group are expected to behave differently than those in the low inequity group (Fig. 1).

Notably, player choices and strategies within the game affected their own score, but because the treatments adjusted the values of digital neighbours they had only a minor impact on the score table compared to the assigned treatments. Moreover, by manipulating how players perceived their own performance, it allowed for testing if inequity truly influenced player decisions and to determine whether inequity aversion happened as a cause or a consequence, a question raised by Oni et al., (in prep).

At the start of the game, players provided demographic information including age, gender, profession, and state (the Brazilian state in which the player lived), all of which were potential predictors of variation in landscape-management. Furthermore, each game session consisted of four game-rounds with different game conditions such as crops changing colour due to pest attacks and pest density fluctuating due to reproduction and because of pest control choices (Fig. 3.) I expected these changes in the game to have potential influence on landscape-management. Therefore, I included two in-game predictors “game-round” and “pest density”.

Due to difficulties in getting complex models to converge, I summarised the age, profession, and state of participants descriptively and did not include these variables as predictors in models of pest control decisions. Those models rather included gender, game-round, and pest density. I predicted women to select more sustainable pest control option than men, and to opt for the cooperation option more than men, given that existing literature suggests women tend to be more cooperative than men (Espinosa & Kovářík, 2015; Ray et al., 2017). I expected game-round to play a role in pest control decisions due to the observed changes in crops due to pest attacks. Lastly, I expected an increase in pest density to correlate with less sustainable pest control choices and that this association would differ between men and women, with men opting for less sustainable choices as a more frequent response.

Study area and Game session

I conducted field studies in Brazil and invited farmers, students, and people working with agriculture to participate in the study (Fig. 2). I recruited participants for the study through my network in Brazil, where I was hosted by the Centre for Applied Biosciences International (hereafter CABI), a multinational non-for-profit organisation that seeks to promote sustainable agriculture and biodiversity while reducing inequality and poverty. In addition, I recruited participants by visiting farmers, cooperatives, biocontrol factories, events for agricultures, participating in meetings, doing an interactive research at a Brazilian agriculture company, talking to local agricultural newspaper, presenting my project at university, and recruiting a champion (a person who has contacts within the agricultural sector and then helps recruiting people for the study) in Bahia state where I could not visit. In addition to this, I created a YouTube video (https://youtu.be/eL0aOwm3eZ8?si=7Hm2E2znjmcg-3Yu) explaining the background of the study and how to play the game. With this I encouraged players to share the game with others that had a connection with agriculture.

Fig. 2. Map of Brazil highlighting the home states of study participants; Bahia, Mato Grosso do Sul, Minas Gerais, Paraná and São Paulo.

Plantas versus Pragas game

My game was designed to be adaptable to various agricultural contexts and maintain a high level of generality (link to the game used in this study: https://maljohansson.shinyapps.io/Agriculture_game-main/). The game was initially created in both English and Portuguese versions. The English version was employed only at the outset of the co-development phase, whereas the Portuguese version was fully developed and deployed during my field study in Brazil. The Portuguese version of my game was called Plantas versus Pragas (Portuguese for Plants versus Pests). Plantas versus Pragas was played either on a smartphone or on a computer and was divided into three parts. First, players could register and provide demographic information (such as gender, age, profession, and state) and give consent to participate in the study. The second part of the game consisted of the instructions on how to play the game. The third part was the game where players assumed the role of a farmer who needed to protect crops from pest outbreaks over four game-rounds.

The game mechanics were designed to be simple, allowing stakeholders to participate in the study without help or lot of background information (see Attachment 2. Game instructions). In the fictional game world, the crops and pests were presented symbolically and could therefore fit different types of agriculture. My single-player game involved the player managing nine land squares (each representing a field on the farm) and earning a living through selling crops (Fig. 3). During each round of play, pests colonise land and destroy crops, resulting in reduced yields. To maximize yield, which contributed to the player's score, the player needed to select a pest control method for each of the nine fields to protect the crops from varying levels of pest density.

Each game session consisted of four rounds and was designed to represent two agricultural years. The reason four rounds were chosen was to make the game quick enough to play while still getting enough information to conduct analysis. In round one, the player began with 100 units of yield in each field. After selecting pest controls for each field, the game progressed to round two, which still was a part of the first crop harvest (to reflect the fact that farmers need to engage in several bouts of pest control during each growing season). In round two, affected fields changed colour from green to brown, mirroring crop loss due to pest attacks, and pest density changed due to reproduction of pests and the effects of pest control (Fig. 3). Again, the player needed to select pest control methods for all fields before moving on to the second harvest and round three. Round three represented the start of the second planting cycle, starting anew with 100 units of yield in each field again to ensure no player ended up at a negative yield score. The final round of the game, round four, had similar conditions to game-round two in the first planting cycle. The reason for including different cycles with two rounds in each was to simulate the association of pest control and pest attacks across separate harvests.

The player objective for Plantas versus Pragas was to maximize the score, which was increased by yield that was not consumed by pests and decreased as a function of expenditure on pest control. More specifically, player score was calculated by taking the yield score and subtracting the cost of pest control and the damage by pest for each land-square, adding score of all the squares together and taking the mean (as in Rakotonarivo et al., 2021). After each round the player could compare their score to those of digital neighbours. By protecting the crops from pests, the player decreased crop losses which increased yield score. However, remember that due to the treatment (rank and score disparity), the players' actions only have a minor effect on the ranking in score table, because digital neighbours were manipulated to be mostly above or below the focal player, and dispersed to a lesser or greater degree.

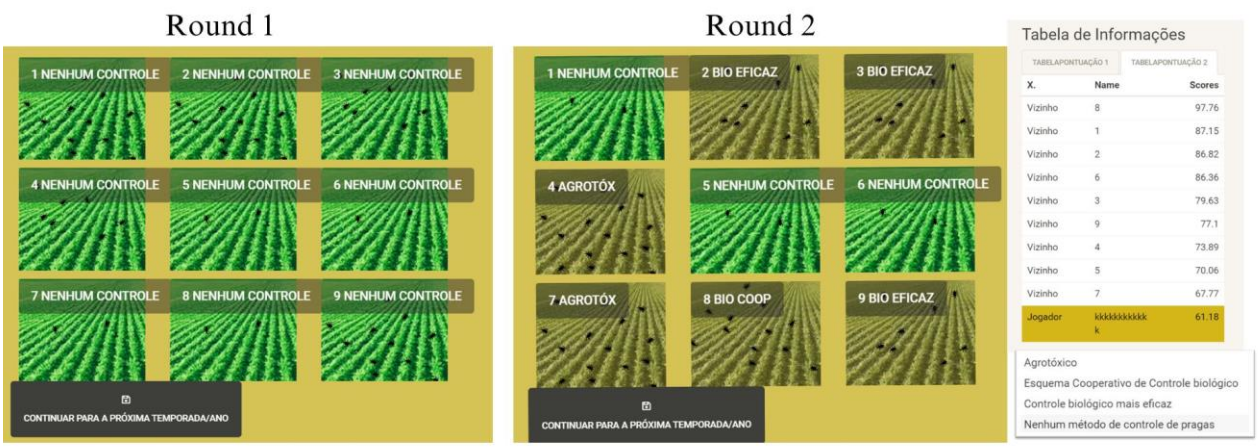

Fig. 3. A screengrab from the Portuguese version of the game Plantas versus Pragas showing the first two (out of four) game-rounds. Each of the nine land-squares are infested by a different severity of pests throughout each planting cycle and the player needs to choose one of the four available options to protect the crops. In round two, crops that are negatively affected by pest attack have changed from green to brown colour. In the score table to the right the player can tell how well they are doing compared to neighbours.

Pest control options

Protecting crops from pests is necessary in agriculture and the way it is done can be considered more or less sustainable depending on the perspective. In this study, the sustainability focus is on the perspectives of ecology and evolution, such as how protecting crops contributes to pesticide resistance and how harmful it is for the environment. In my game, the player's task was to choose a pest control for each land-square to protect their crops from pest attack. Each control option had a different impact on pest density and a different cost.

The four available pest control options in my game were: "Synthetic control", which was initially highly effective but could harm off-target insects and contribute to resistance evolution. The second option, "Most effective biocontrol", was the most effective biopesticide available on the market but slightly more expensive than the synthetic control. Biopesticides were considered less harmful but could still provoke resistance when used in excess. As a result, some authors have proposed introducing a concept called "Biocontrol scheme", in which diversity is enhanced among farmers to reduce landscape-wide resistance evolution (Mangan et al., 2023). This requires neighbouring farmers participating in the scheme to agree to use different biocontrol methods to ensure no control is overused. Therefore, the third option in my game was the "Biocontrol Scheme". When participating in the scheme, the government paid half of the cost of the biocontrol to encourage participation which made this the cheapest control in the game. Finally, a player could choose to not apply any pest control as the fourth option "No pest control" which of course was for free.

I improved the narrative in the game, reduced text in pop-up windows after discovering that players often ignored lengthy text, simplified the game's navigation and adjusted the game's length to four game-rounds instead of six to increase the likelihood of stakeholders completing it.

Game parameters, such as pest control costs and subsidies, were adjusted and tested in collaboration with people from CABI and EMBRAPA, and various stakeholders in Brazil. Due to issues related to internet connectivity in the field, a unique password system was implemented for each player, enabling them to resume interrupted sessions. No official questionnaire was used after the game, however, I took notes during the debriefing and discussions which were held with participants when possible after playing the game (see attachment 1).

Hypothesis

I expected distributional equity to be important in such as players ranked as winners should be more willing to choose sustainable pest control options than losers. Moreover, I predicted that the effect of players rank should be influenced by the disparity in score (Low or High), such that rank only had a significant effect on decision-making when disparity in score was high, mimicking high inequity (the effect of personal rank should diminish as the disparity in scores becomes low) (Fig. 1).

Statistics and analysis

To compare probabilities of selecting each pest control choice, I used ordinal categorical models, which are a kind of generalised extension to linear models similar to binomial logistic models, implemented using the "ordinal" package (v2022.11-16; Christensen, R. H. B., 2022) in R Statistical Software (v4.2.2; R Core Team, 2022). The ordinal categorical model is used when the response variable has more than two categories, like in my study where I have different levels of pest control choices as response variable. The pest control options in my study ranked naturally from least to most sustainable in evolutionary terms (synthetic control, most effective biocontrol, biocontrol scheme, no pest control).

Age, profession, and state were only included as demographic categories to describe the data set and not analysed in the model due to these being of least interest for affecting pest control choice and to avoid making the model too complex and causing model convergence issues. The following predictors were included in my model: rank treatment, score disparity treatment, gender, game-round and pest density. A random effect for individual player was included to account for the nonindependence of observations from individuals (Table 1). I created an ordinal categorical model and included an interaction between the experimental treatments since I wanted to test if the effect of rank depended on score disparity as a way to mimic inequity. To assess the importance of other interactions, I iteratively removed each of them, starting with the least significant, and compared all updated models to the model from which each was simplified using likelihood-ratio tests (Heinze et al., 2018).

Table 1. Predictors and levels included in an ordinal categorical mixed model of pest control behaviour within a simulated game world, Plantas vs pragas (see text and compare with Table 2. in the Results which contains the single best model summary). Rank and score disparity were treatments in the experimental game that were included to mimic inequity, thought to influence decision-making. Individual player identity accounted for the differences in players. This predictor was included as a random effect in the model to account for multiple observations of pest control being made by each participant. Gender was included as a demographic predictor expected to influence pest control decisions. Pest density and game-round were in-game predictors constantly changing in the game.

Predictors	**Levels**
Rank	Winner | Loser (Assigned treatment)
Score disparity	High | Low (Assigned treatment)
Gender	Man | Women
Pest density	Low | High
Game-round	2 | 3 | 4 (Game-round 1 was not included in the model since the players choices are not yet affected by treatments)
Individual player identity	Unique level for each player (Random effect). Included to account for multiple observations of pest control for each participant.

Thresholds

In an ordinal categorical model, the response variable consists of multiple levels where each level is separated by a threshold that demarcates the relative probabilities for each of several categorical outcomes. In addition to examining the association between predictors and decision-making, I wanted to explore if any of the predictors could also influence the thresholds between pest control choices (the thresholds can reasonably respond to some of the predictors). The ordinal model fits probabilities to the transitions between these levels, without assuming that the thresholds are evenly spaced, and allows us to estimate the effects of predictor variables on both the probability of any discrete outcome as well as the spacing between the outcomes. I explored whether the predictors listed above affected thresholds by iteratively testing whether more complex models (with variable thresholds depending on the focal predictor) provided more explanatory power than simpler models (where fixed effects only affected the overall response and not the spacing between choices) using likelihood-ratio tests.

My data consisted of multiple choices from each player, and it is likely that decision from one player is more similar than to those of other players. To avoid overfitting and assure independence of observations I included “Individual player identity” as a random effect in the model. Additionally, to visualise how each choice from the player might be influenced by fluctuations in other predictors all graphs was done to show model predictors, since visualising each data point with all different values from other predictors would be impossible.

Results

Demographic results

The final dataset comprises 134 participants engaged in the Plantas versus Pragas game from March to June 2023. I excluded game sessions that were incomplete, lacked data, or lacked affirmative consent, along with any data from English versions and test rounds in the game. I further excluded the first game-round since there was no effect from the treatments (the score table was not visible in the first game-round, hence no effect of rank and score disparity could be seen). Lastly, I included only participants that chose gender as either male or female due to small sample size in other categories (N = 3). This final data set consisted of 27 individual pest control decisions from each player. The participants came from five states in Brazil: Bahia (14), Mato Grosso do Sul (8), Minas Gerais (1), São Paulo (27) and Paraná (84). Out of the 134 individuals 59 % were men (N = 79) and 41 % women (N = 55). Participants were between 18 and 78 years old, with an average age of 35 years.

During the recruitment process I strived to get a representation from many stakeholders in the agriculture sector. From the 134 people that were included in the analysis the participants were food producers (33), working in the production industry but not as producers (20), working as conservation workers or managers (3) and students in agriculture (39). The remaining participants (39) did not choose any of these four categories of profession, but instead specified their profession in other fields such as agronomy engineering, researchers in agriculture or working consultants.

The data consisted of a total 3609 individual pest control choices. The results showed that synthetic pest control was chosen with a proportion of 0.187 (95% binomial CI: 0.175 - 0.200), most efficient biocontrol with 0.210 (0.197 - 0.223), biocontrol scheme 0.254 (0.240 - 0.268) and no pest control 0.350 (0.334 - 0.365). Among the 134 players, 27 individuals never used synthetic pest control throughout the entire game. Interestingly, no participant exclusively used synthetic controls for all fields in all game-rounds, but 24 players exclusively used synthetic pest control for all fields within a single game-round, and one player did this for two entire game-rounds.

During the debriefing after the game, several stakeholders who frequently chose synthetic control mentioned that this response reflects what they think is the best available option on the market in Brazil today. However, multiple stakeholders acknowledged concerns about pesticide resistance and environmental harm. In reality, a common approach is to use a combination of biocontrol and synthetic control within individual fields (note this was not a possible pest control choice for any field within the game). Participants in the study also expressed concerns about balancing the health implications for their children and families due to exposure to harmful chemicals while highlighting the responsibility to protect crops and produce food for their communities (see Attachment 1. Notes from the post-game debriefing).

104 players did at least once choose the cooperation pest control option (biocontrol scheme). Various participants expressed interest in the idea of cooperation among farmers to create landscape-scale diversity. However, other participants also expressed concerns over this option and that it would not work in Brazil due to corruption and a lack of trust (see Attachment 1. Notes from the post-game debriefing).

Model

The results from the ordinal categorical mixed model revealed that 65.5% of the variance in pest control choices (Variance = 1.90; NB residual variance in generalised models is fixed at 1) could be attributed to individual player identity. Individual player identity was incorporated as a random effect because each player contributed with multiple observations (pest control decisions), and observations from the same individual were expected to be more similar than those from different individuals.

During model construction, the inclusion of predictors was based on literature and the model simplification method. Comparing models with and without predictors revealed the inclusion of pest density, gender and game-round significantly improved the models. These predictors were expected to influence decision-making and potentially impact threshold levels for pest control choices. Model comparison showed that pest density and gender had a significant influence on thresholds, while game-round only minimally influenced thresholds. Therefore, results from the model comparison showed the best model to be where game-round along with the treatments (rank and score disparity) had a uniform influence across all levels (fixed effects) and gender and pest density to influence threshold values which allowed for variable influenece on the pest control levels (nominal predictors).

Treatments and predictors

I predicted that players' choice of pest control methods would be influenced by their assigned rank level, especially when score disparity was high, reflecting the impact of inequity. In the high disparity treatment group, I expected winners to choose more sustainable pest control options than losers. To assess the validity of rank treatment as category winner and loser, I compared players' actual ranks (between 1-10) with their assigned ranks (only shown as winner or loser), but no difference in results was detected. Consequently, in order to simplify the presentation, the assigned treatments were utilized in all analyses rather than the ranks themselves.

The models revealed only a marginally nonsignificant interaction effect between the rank treatment and score disparity (see Table 2. for model summary). I would expect losers in the high disparity group to choose less sustainable pest control choices but instead a marginally higher frequency of choosing sustainable pest control could be seen in this group. This contradicted my expectations even if the effect from the treatments was very small (Fig. 4). The minimal influence of the treatment interaction suggests that, in my experiments, the treatments had limited predictive power regarding participants' decisions.

Table 2. Results from an ordinal categorical mixed model showing the effects from coefficients and thresholds on pest control decisions. The four pest control decisions Synthetic, Most efficient biocontrol, Biocontrol scheme and No pest control are categorically ranked and make up the response variable in the model. Coefficients are fixed effects equally influencing all levels of pest control choices and do not influence the spacing between choices. The thresholds can influence both the levels of pest control and the spacing between them, showing the probabilities to the transitions between the different levels of pest controls. These coefficients are visualized in Fig. 4-6 below. Random effect included in the model was Individual player identity (differences in players).

Coefficients	**estimate**	**std.error**	**statistic**	**p.value**
Rank Loser	-0.391	0.394	-0.992	0.321
Score disparity High	-0.472	0.395	-1.195	0.232
Game-round 2	1.043	0.081	12.839	<0.001
Game-round 4	1.025	0.082	12.565	<0.001
Rank Loser:Score disparity High	0.956	0.519	1.842	0.065

Thresholds	**estimate**	**std.error**	**statistic**	**p.value**
Synthetic | Most efficient biocontrol .(Intercept)	-1.389	0.311	-4.467	<0.001
Most efficient biocontrol | Biocontrol scheme .(Intercept)	-0.056	0.309	-0.183	0.855
Biocontrol scheme | No pest control .(Intercept)	1.445	0.311	4.651	<0.001

Synthetic | Most efficient biocontrol .Pest density	0.609	0.065	9.374	<0.001
Most efficient biocontrol | Biocontrol scheme .Pest density	0.404	0.055	7.382	<0.001
Biocontrol scheme | No pest control .Pest density	0.424	0.06	7.128	<0.001
Synthetic | Most efficient biocontrol .Women	-0.313	0.268	-1.171	0.242
Most efficient biocontrol | Biocontrol scheme . Women	-0.169	0.259	-0.654	0.513
Biocontrol scheme | No pest control .Women	-0.207	0.26	-0.798	0.425
Synthetic | Most efficient biocontrol .Pest density:Women	-0.199	0.105	-1.896	0.058
Most efficient biocontrol | Biocontrol scheme .Pest density:Women	-0.043	0.085	-0.501	0.616
Biocontrol scheme | No pest control .Pest density:Woman	0.087	0.092	0.949	0.343

Coefficient	**Variance**
Individual player identity	1.90

Visualising individual data points in a graph would be impractical, given that each player made 27 individual choices all with varying pest density levels. Consequently, following graphs in this study will depict model predictors to convey data patterns and illustrate the association between predictors and pest control methods. When predictors do not interact, the data patterns remain consistent across different predictor levels which is why one graph is sufficient to illustrate the data patterns for all levels of the predictors.

For predictors that expect to influence each other such as the two treatment groups (rank and score disparity) I introduced an interaction term. An interaction term is fitted since rank is expected to influence decisions primarily when disparity is high, the effect of rank depends on score disparity. On the other side, concerning for example the association between the treatment groups and pest control decisions, I anticipated the treatments to affect men and women in a similar way and therefore I did not introduce an interaction term between gender and treatments. Consequently, visualising graphs for men or women when showing the effect of treatments results in similar patterns regarding the association between treatment groups and individual pest control choices (Fig. 4).

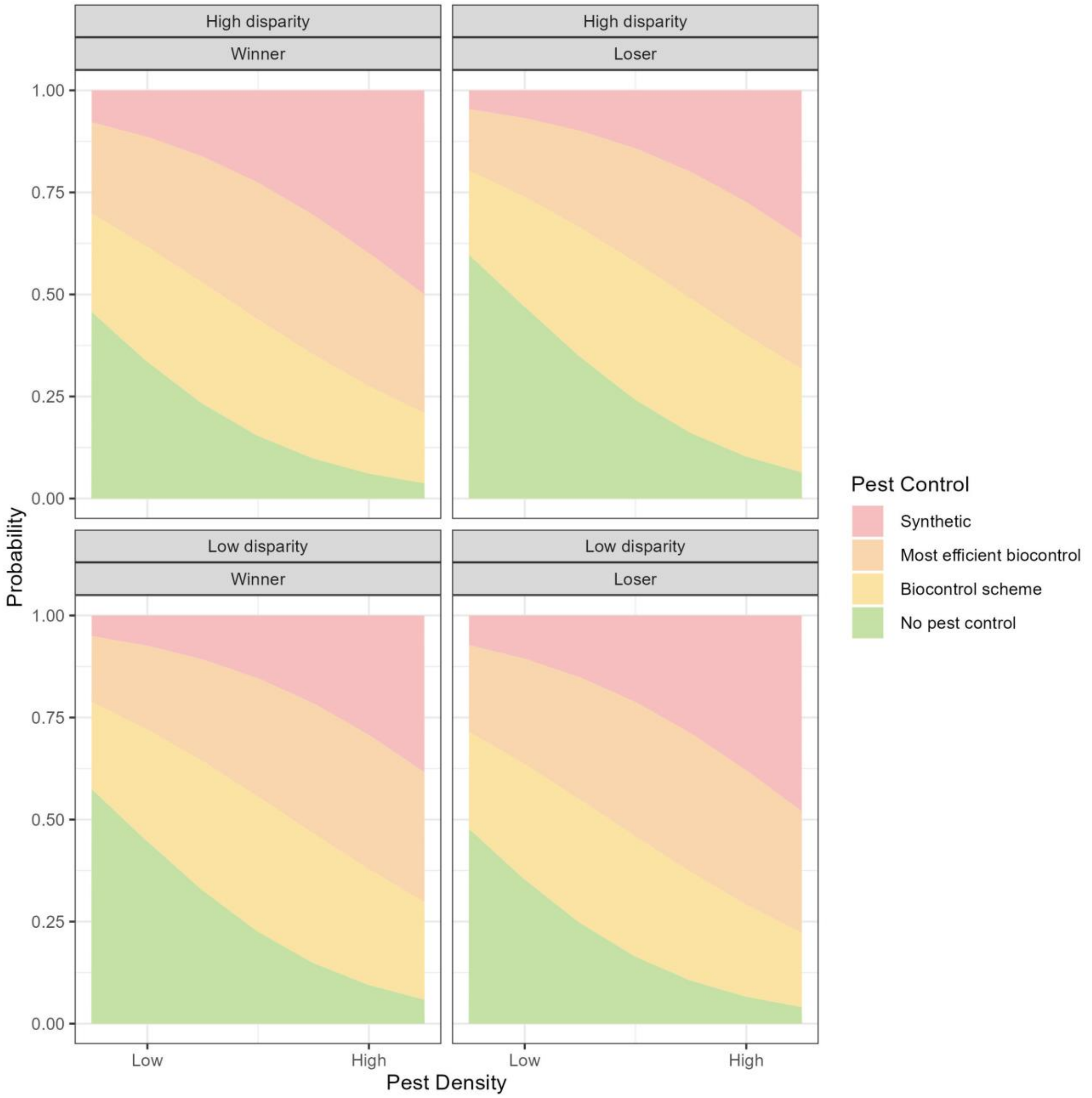

Fig. 4. Probability of choosing each pest control method (on the y-axis) as a function of the treatments rank and disparity (in panels) and pest density (on the x-axis). The colours illustrate the probability of choosing each pest control option, stacked one upon the other, ranging from least sustainable (Synthetic, in red) to most sustainable (No pest control, in green). The estimates here apply to women in game-round 2, but because there are no interactions between those predictors and the treatments, the patterns are similar for all the levels in these predictors.

While the treatments rank and score disparity showed only a minor impact on decision-making, I could observe substantial effects from other predictors. I introduced an interaction term between gender and pest density, anticipating that an increase in pest density would result in less sustainable pest control choices, with men showing a stronger response to the increase in pest density. The results indeed showed that when pest density increased, men demonstrated a much steeper transition towards synthetic control than women (Fig. 5). Both men and women preferred less sustainable pest control choices with rising pest density as indicated by the positive values associated with pest density across all thresholds and visualised in Fig. 5. (see Table 2. for coefficients and threshold values).

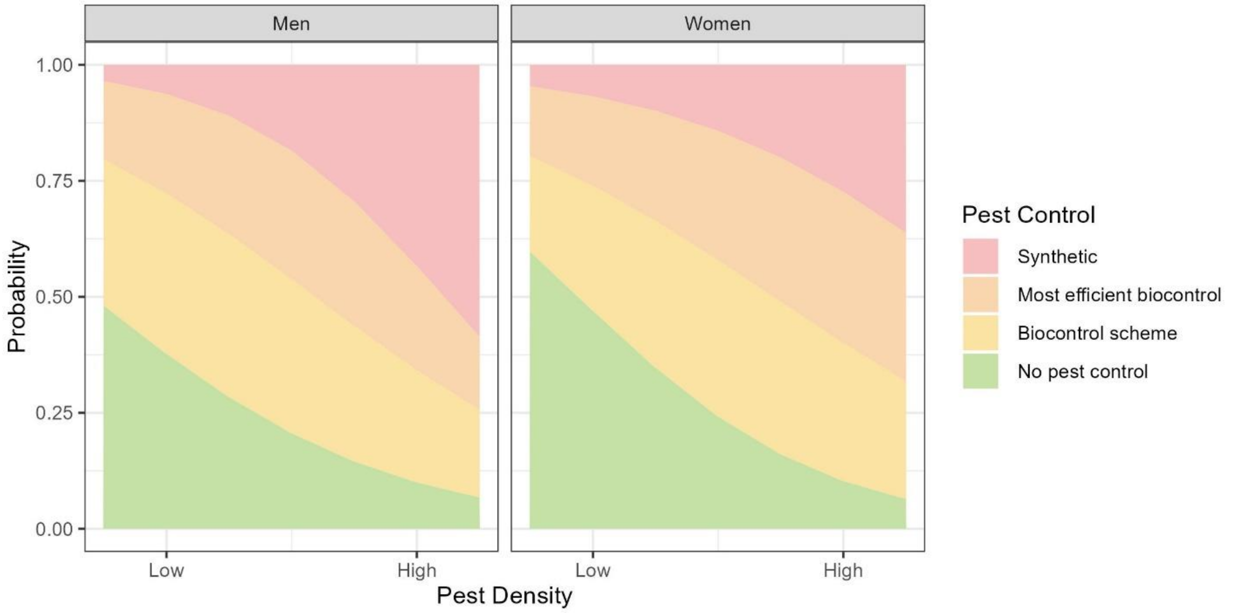

Fig. 5. Probability of choosing each pest control method (on the y-axis) as a function of gender (in panels) and pest density (on the x-axis). The colours represent the probability of choosing each pest control option, stacked one upon the other, ranging from least sustainable (Synthetic, in red) to most sustainable (No pest control, in green). The estimates here apply to the individuals in the treatment group High disparity & Loser in game-round 2, but because there are no interactions between those predictors, the patterns are similar for all levels in these predictors.

Another predictor I anticipated would impact decision-making was game-round, as the game settings differ across the digitally depicted seasons (referred to as game-rounds). In Fig. 6., it is evident that round 2 and round 4 are not very similar, despite occurring at second round in each year and displaying the fields after the association between pest attack and pest controls (Fig. 3). Conversely, game-rounds 3 and 4 more closely resemble each other.

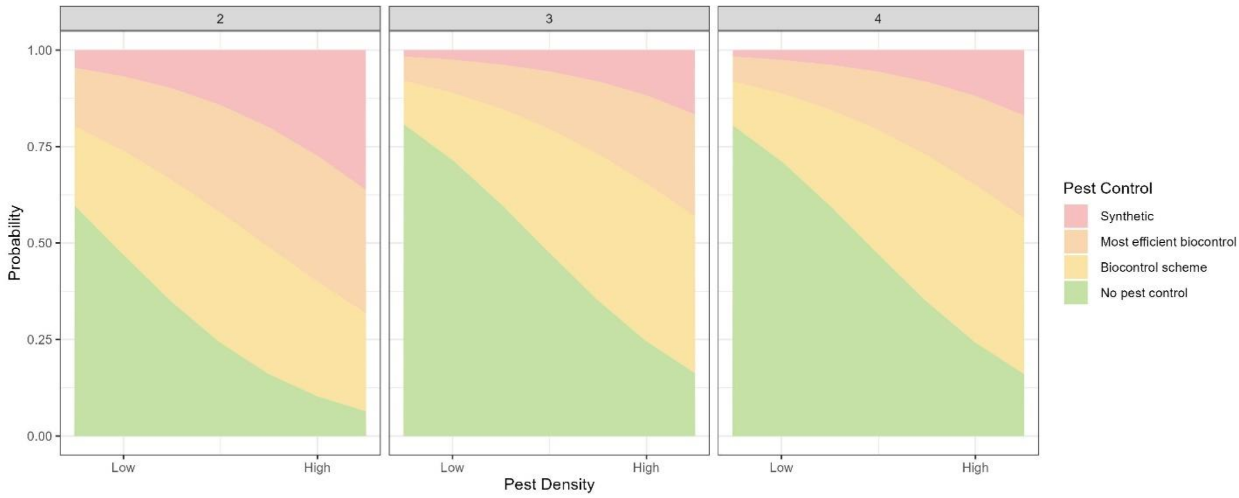

Fig. 6. Probability of choosing each pest control method (on the y-axis) as a function of game-round (in panels) and pest density (on the x-axis). Game round 2 and 4 represent the second seasons in a year, whereas game-round 3 represents the first season. The colours represent the probability of choosing each pest control option, stacked one upon the other, ranging from least sustainable (Synthetic, in red) to most sustainable (No pest control, in green). The estimates here apply to the women in the treatment group High disparity & Loser, but because there are no interactions between those predictors the patterns are similar for all levels of these predictors.

Discussion

I created a behavioural game called Plantas versus Pragas to explore what influences stakeholders' landscape-management decisions regarding pest control methods. I tested how distributional equity alongside other predictors such as pest density, gender and game-round influenced pest control methods that ranked from least to most sustainable. Among 134 participants, 104 opted at least once for the cooperation option (biocontrol scheme), indicating a high willingness in participants to engage in sustainable agriculture. Further, only 18% of all the fields were treated with synthetic pest control. Analysis revealed that 66% of variation in pest control choices were explained by individual player identity (differences between players). Remaining differences in pest control choice were mostly influenced by predictors pest density, gender, and game-round. Surprisingly, treatments (rank and score disparity, designed to simulate inequity) showed no strong impact on decision-making.

Game validation

Post-game discussions and debriefings with participants provided valuable insights in games' effectiveness as a research tool. Employing games to study social-ecological systems has gotten more popular lately and various games and platforms already exists (Janssen et al., 2014). Behavioural games can help gaining insights into ongoing challenges and attitudes from stakeholders. My game was developed and designed to fit different agricultural scenarios and be as general as possible, based on suggestions from ValeroLopez et al., (in prep.). My study was conducted in Brazil, but the design of the game allows for it to be used in different countries and translated into other languages. Feedback from stakeholders participating in the study were positive regarding behavioural games, and considered a good approach to improve communication with stakeholders and local communities. Communication and inclusion are shown to be important for stakeholders' inclination towards cooperative activities (Taleghani, M. & Mehdizade, M., 2016).

Descriptive results from my study revealed that synthetic pest control was the least chosen option and most of the players chose to engage in the cooperation action with neighbours at least once. This demonstrates a willingness in stakeholders to engage in more sustainable agriculture and highlights the importance of providing necessary tools, policy instruments, and security for people to be able to do this in real-life.

In-game predictors such as game-round and pest density had a notable influence on decision-making, suggesting that players interacted with the game. Players further commented on the impact of rank on their decision-making, suggesting they paid attention to the score table. However, it remains uncertain to what extent they perceived the manipulation of high or low score disparity and their perception of inequity.

Findings from model analysis

Findings from the analysis revealed that pest control choice was tightly linked to individual player identity. This may be explained by peoples' different beliefs and interest or other predictors that were not included in my model such as age, profession, wealth (Sargent et al., 2022), education (Bell et al., 2023), ecological differences (Prediger et al., 2011). One reason for not including more predictors was to assure convergence of the model. However, data was plotted to assure an even spread of gender, age, and profession.

Another plausible explanation for the significant impact of player identity relates to how players perceived the game. For example, in discussions held after the game participants discussed whether the no pest control option indicated set aside land to combat pesticide resistance or if it was simply a choice to use when pests' infestation was low.

Lastly, if players in-game decisions mirrored what they hypothetically thought would be the best choice or if it mirrored what they thought was the best choice that would be available at this moment in Brazil. Games are seen as valuable tools to study complex situations (Redpath et al., 2018), however as in any experiment participants might respond differently to an experiment as to a real-life situation (Jackson., 2012).

Effect of treatments on decision-making

The game Plantas versus Pragas, inspired by Oni et al. (in prep.) and Rakotonarivo et al. (2021b), was especially designed to test the effect of distributional equity on decision-making. To explore the direct effect of inequity, I introduced two treatments involving rank and score disparity manipulation. This allowed for manipulating players' perception of inequity (by manipulation personal performance) and to test its potential influence on pest control decisions. The treatments were expected to affect the pest control decision such that losers in rank would be less likely to choose one of the sustainable pest control methods than winners. Additionally, this effect was expected to be especially important when score disparity was high, making the difference between a winner and a loser more notable and creating a scenario of high inequity. Surprisingly, however, results from the game did not provide strong evidence supporting the influence inequity on decision-making. The lack of a strong significant effect could potentially be explained by one of following arguments:

Perceived personal performance in the game was relatively unimportant. It is possible that participants did not let their perceived individual performance in the game affect their pest control methods, but instead only opted for the pest control they believed to their knowledge would be the best option available on the market.

It may also be that the game did not manage to effectively mimic inequity. Experiments, such as behavioural games, involves a balance between simplifying to be able to test specific predictors and maintaining complexity of reality (Duthie et al., 2021; Redpath et al., 2018). Post-game comments from players regarding their personal rankings indicated that participants paid attention to the score table. Nevertheless, the extent to which the treatment manipulation successfully mimicked the sense of inequity to the players remains uncertain, which could mean that the game underestimated the importance of inequity in influencing decisions.

Another possible explanation is that distributional equity is not as important as predicted by other work (Oni et al., in prep; Rakotonarivo et al., 2021b). Engaging in sustainable landscape-management and cooperations may be more influenced by other predictors (Prediger et al., 2011; Sargent et al., 2022).

To promote cooperation and sustainable landscape-management many policy interventions are formed to address inequity issues. Several studies suggest that equity plays an important role in affecting cooperation attitudes and engagement in conservation efforts (Rakotonarivo et al., 2021b; Oni et al., in prep). Importantly, my study found no support for equity being an important predictor to influence landscape-management decisions such as cooperative actions and sustainable pest control management.

A recent study by Bell et al., (2023) considered seven behavioural games and did not find any results that monetary payments are effective on their own to promote conservation actions. Incentives and polices remain important to favour engagement in more sustainable agriculture (Tilman et al., 2002). Research published on sustainable agriculture during the last 30 years has exponentially increased and highlights the importance of understanding what influences participation and attitudes in sustainable landscape management to achieve goals like eradicating hunger and protecting the environment (Aznar-Sánchez et al., 2019; The United Nations' Agenda 2030).

Predictors that may influence decision-making

Following the recommendations from Oni et als' (in prep) study, Plantas versus pragas allowed for in-field variations, with nine unique fields capturing fluctuating pest densities. The game was therefore able to capture the impact from pest density on pest control choices.

As pest density increased, people tended to opt for less sustainable pest control methods, confirming the predictions. Post-game discussions with stakeholders supported these findings (Attachment 1). At lower pest densities, stakeholders expressed a willingness to explore biocontrol and the cooperative alternative, but as pest density increased, many leaned towards more synthetic pest control. This shift was sometimes explained in the discussions after the game to be due to a perceived lack of effectiveness in biocontrol and more familiarity with synthetic pest control options. A study on small-scale farmers in Kenya by Constantine et al. (2020) set out to explore why farmers did not use more biocontrol. They found that farmers reported a lack of trust in the effectiveness of biocontrol, along with higher costs, longer time to show effectiveness, and limited availability influenced as reasons not to use biocontrol.

Additionally, my study revealed a significant difference between genders on the use of pest control methods, with women tending to choose more sustainable pest control options than men. Moreover, results showed that women reacted less to an increase in pest density. This aligns with other studies highlighting the value of including women to create more sustainable outcomes and engage in cooperation activities (Bell et al., 2023; Masuda et al., 2022). However, it's important to note that differences associated with gender can be influenced through various mechanisms. We need more studies testing the impact of gender, and exploring these mechanisms in a way that can suggest improving the sustainability of all farmers, regardless of gender (Bell et al., 2023).

Lastly, game-rounds significantly influenced pest control decisions. Players might adapt different pest control methods due to the visual changes represented by crop colour shifts due to pest damage. One potential explanation for players pest control methods to differ with game-round is related to the players' treatments. For instance, one possibility is that fixing player ranks led to changes in later game rounds regardless of the stage in the planting cycle, as farmers grew desperate to experiment (if losing) or willing to experiment (if winning) in a way that made round 4 rather different from round 2. Longer games with more rounds would be needed to explore such effects.

Suggestions for future studies

Experimental studies testing the isolated effect of distributional equity on decision-making has to my knowledge never been done. Considering that my results found no strong effect of inequity on decision-making highlights the need of future research to keep on studying the direct effects of inequity. I suggest more experimental studies where manipulation of personal performance could be followed up by post-game questions to confirm players perception of inequity. Further, with more data it would be possible to add other demographic predictors (e.g. age, wealth or profession) to the model which could help further disentangle the differences in pest control explained by individual characteristics.

It would be interesting to test how various predictors might influence behaviour differently depending on individual preferences in pest control choice before treatments. This could be done by examining the first game-round, where players are still not exposed to the treatments and then compare if players that start out sustainable are influenced by the treatments in the same way as players who do not start out as sustainable.

Implementations

This study provide valuable insights in game design to study human behaviour. Even a quite simple game can successfully contribute to the knowledge of which predictors that might be important to assess when forming policy instruments. This study further contributed to the research field that shows how games can be used a tool to initiate conversations with stakeholders and an appreciation for including stakeholders in research.

The results from this study further supported the hypothesis that women tend to be more sustainable than men. It is important to know how response to pest attacks and participation in cooperative action might vary between men and women to be able to create more sustainable agriculture. Knowing that gender might influence decision-making could be important while forming polices and incentives targeted to promote cooperation.

Conclusion

This study developed and used a behavioural game that simulated landscape-management in agriculture to test the effect of distributional equity on pest control decisions. Inequity was expected to be an important predictor influencing the choice of sustainable pest control methods. However, no strong effect from inequity on pest control decisions was found. Instead, results showed that the individual differences between players was strongly associated with the choice of pest control. Further, predictors such as gender and pest density also influenced pest control decisions. Considering sustainability from an ecologic and evolutionary perspective, women opted for more sustainable pest control methods than men which aligns with results from other studies. Furthermore, findings from my study provide useful insights in design and development of behavioural games and is one of the first experimental studies to test the direct effect of distributional equity on decision-making.

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Appendix 1. Popular science article

How does being unfairly treated affect our behaviour?

The human population grows rapidly, and more food needs to be produced to feed everyone. However, healthy ecosystems should not be destroyed to make this possible. This calls for a sustainable approach to agriculture that benefits both farmers and the environment.

One way to improve agriculture would be to make crop protection more sustainable and efficient. 30 % of today's crops are lost even before harvest, mainly due to plant eating pests. Conventional methods often rely on pesticides, yet an excessive use of few pest controls has given rise to a pesticide resistance. Consequently, crop protection is not as effective, resulting in diminished agricultural yields.

One solution is adopting more sustainable pest control methods like biological controls, which are living organisms that are less harmful than synthetic pest control and more challenging for pests to develop resistance to compared to. Additionally, enhancing landscape diversity through the use of various biological pest controls instead of overusing just a few can further counteract pesticide resistance.

Imagine you as a farmer who together with your neighbours started to do this, favouring biocontrol and deciding that each of you should use a different biocontrol to create diversity in the landscape and making sure no single pest control is overused. However, over time some of the farmers in the collective start to get higher profits than you. Since you have all committed to using different biopest control methods, some methods are naturally more effective than others, creating an unequal outcome.

Research says feeling treated unfairly or seeing your neighbours do better can have a negative influence on participation in cooperation and eco-friendly farming. When your livelihood depends on it, would you still choose to cooperate and participate in this new form of sustainable agriculture?

To test this theory, this study conducted a digital experiment where participants had to protect crops from pests by choosing different pest control methods ranking from most to least sustainable while being exposed to different levels of injustice. My results found that the different levels of injustice did not strongly affect players' pest control methods.

However, players choices were influenced by other predictors in the study such as being a man or a woman. Women in general tended to use more sustainable pest control methods than men. Perhaps, individual perceptions of fairness have less impact on decision making than previously thought.

Appendix 2. Supplementary figures

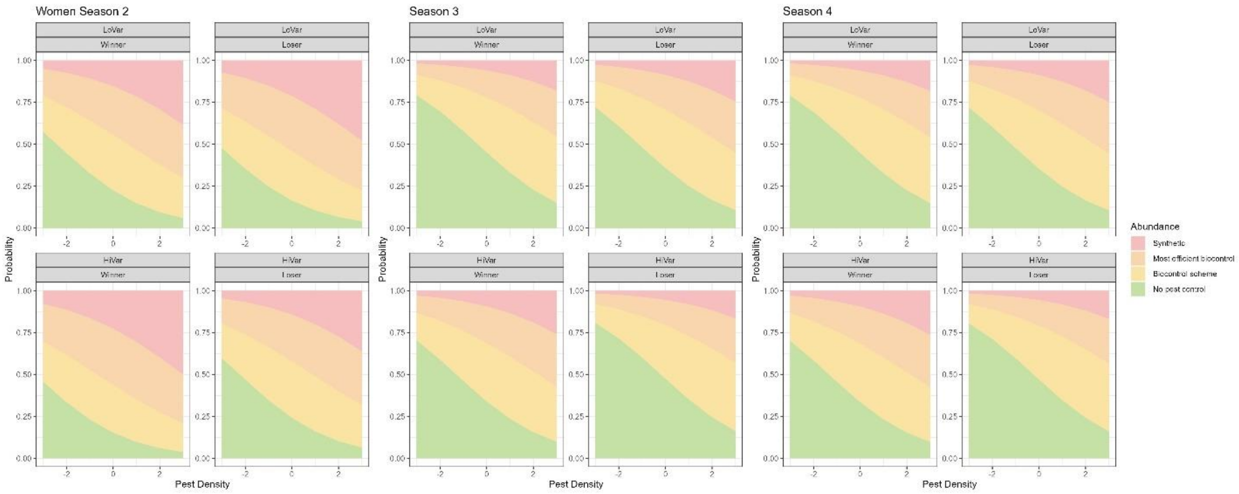

Figure. A2.1 Probability of choosing each pest control method (on the y-axis) as a function of treatments and game-round (Season) (in panels) and pest density (on the x-axis). Game round two had similar conditions to game-round four in the first planting cycle, whereas game-round 3 represents the second planting cycle in harvest. The colours represent the probability of choosing each pest control option, stacked one upon the other, ranging from least sustainable (Synthetic, in red) to most sustainable (No pest control, in green). The estimates here apply to women.

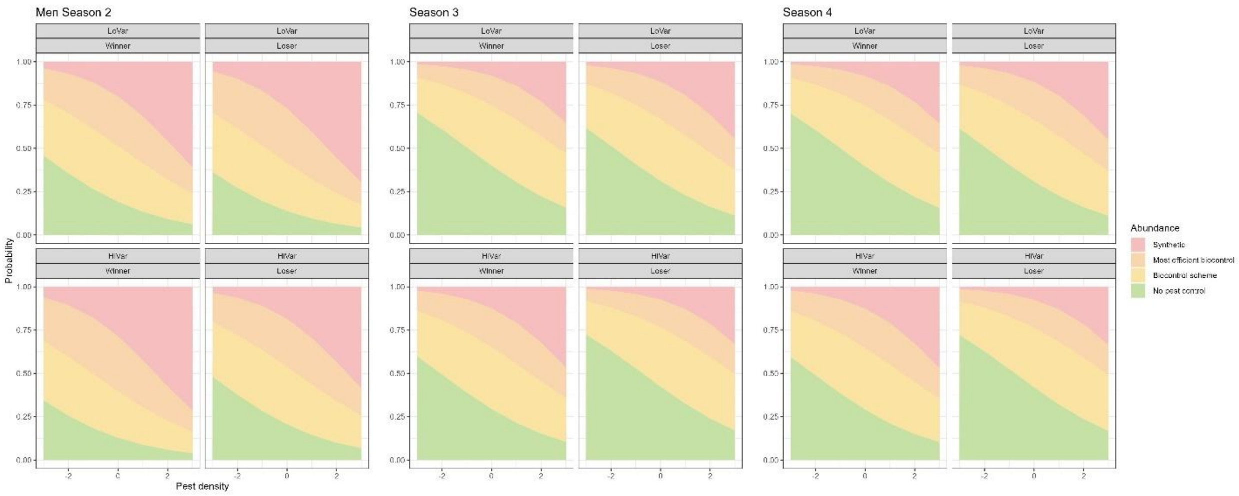

Figure. A2.2 Probability of choosing each pest control method (on the y-axis) as a function of treatments and game-round (Season) (in panels) and pest density (on the x-axis). Game round two had similar conditions to game-round four in the first planting cycle, whereas game-round 3 represents the second planting cycle in harvest. The colours represent the probability of choosing each pest control option, stacked one upon the other, ranging from least sustainable (Synthetic, in red) to most sustainable (No pest control, in green). The estimates here apply to men.

Attachment 1. Notes from the post-game debriefing

Notes during post-game discussions with participants. Notes in English are roughly translated from Portuguese.

“We don’t want our kids to grow up exposed to a lot of chemicals, but we also have a responsibility to produce food for our people”

“The older generation want to use synthetic control because they know how it works and it is not as dependent on the weather changes as biocontrol.”

“I like the cooperative idea, but there are no such things that works in Brazil.”

“The game is a good tool, it works like a bridge between the university and the farmers. What sometimes works in theory won’t work in reality.”

“I’m afraid biocontrol won’t work as well because the climate is unstable and unpredictable.”

“You can forget the cooperative idea in Brazil, it would never work. It is all corrupt.”

“My son have to work at the neighbouring farm where he needs to apply chemicals because at our family farm where we don’t use chemicals we don’t make sufficient money to support ourself. He doesn’t want to work there, but he has no other option to earn money.”

“We do not talk about the risk with cancer from applying chemical pesticides because we do not have any other choice to sustain ourself than to use chemicals”.

Attachment 2. Game instructions

Links to the game and video instructions (in Portuguese)
Game: https://maljohansson.shinyapps.io/Agriculture_game-main/

YouTube video about the study and the game: https://youtu.be/eL0aOwm3eZ8

YouTube video on how to play on a smartphone: https://youtu.be/7ccv8YEQSt8

Text in the game. In the study only the Portuguese version of the game was used. Changes during the trial period was not made for the English version hence some differences might occur.

Consent page. All participants need to read and agree to the terms and conditions.

Portuguese

1. Informações do Participante

Esta página contém informações importantes sobre a pesquisa. Por favor, leia-o antes de concordar em participar da pesquisa e se registrar na plataforma.

2. Fundo e objetivos do projeto

NOSSO JOGO é parte de uma pesquisa sobre gerenciamento de recursos naturais realizada por Luc Bussière, Malin Johansson e Celia Oni na Universidade de Gotemburgo, em colaboração com uma equipe de cientistas internacionais. Queremos investigar os fatores sociais e econômicos que afetam a disposição dos agricultores em adotar proteção sustentável de cultivos. O jogo levará cerca de 15 minutos para jogar.

3. Por que fui convidado a participar?

Você foi convidado a participar dos jogos devido à sua experiência em agricultura ou devido ao seu interesse na resolução de conflitos entre produção de alimentos e ambientes saudáveis.

4. Eu tenho que participar?

A participação é voluntária. Você pode interromper o jogo a qualquer momento.

Existem algum risco potencial em participar?

Não há riscos previsíveis em participar do jogo.

5. Existem algum benefício em participar?

Não haverá pagamento por participar neste projeto. No entanto, você estará contribuindo para a pesquisa sobre um dos problemas mais difíceis enfrentados pela humanidade, que diz respeito a como maximizar a produção de alimentos e a prosperidade individual enquanto se conservam os habitats naturais.

6. Base legal para o processamento de dados pessoais

Nós não coletaremos nenhuma informação privada. Os dados coletados a partir do jogo e do formulário de registro serão processados de acordo com a Regulamentação Geral de Proteção de Dados da UE (GDPR) e a Lei Geral de Proteção de Dados (LGPD) do Brasil. Sob a GDPR, a base legal para o processamento de seus dados pessoais será interesse público / autoridade oficial da Universidade de Gotemburgo.

7. O que acontece com os dados que forneço?

Os dados são armazenados no servidor do jogo em um arquivo protegido por senha e podem ser usados após anonimização em publicações acadêmicas. Seu endereço IP não será armazenado.

Os dados que coletamos de você podem ser transferidos e armazenados ou processados em um destino fora da Área Econômica Europeia (EEE). Ao enviar seus dados, você concorda com essa transferência, armazenamento ou processamento.

Os dados de pesquisa serão mantidos por 1 ano em um drive de dados de pesquisa seguro no servidor do OUR GAME e, em seguida, serão depositados nos servidores da Universidade de Gotemburgo por 10 anos.

8. A pesquisa será publicada?

A pesquisa será publicada em relatórios de projetos e periódicos acadêmicos. Você não será identificável em nenhum relatório/publicação.

9. Quem está organizando e financiando a pesquisa?

O trabalho é financiado pela Universidade de Gotemburgo com ajuda da Agência Sueca de Cooperação para o Desenvolvimento Internacional, SIDA.

10. Com quem devo entrar em contato se eu tiver preocupações com este estudo ou quiser reclamar?

Por favor, entre em contato com:

Luc Bussière, Professor Adjunto na Universidade de Gotemburgo

luc.bussiere@bioenv.gu.se

11. Consentimento Eletrônico

Ao clicar em "Continuar", você concorda que:

● Você leu e entendeu as informações acima

● Você tem 18 anos ou mais

● Você concorda voluntariamente em participar.

English

Participant Information

This page contains important information about the research. Please read it before agreeing to take part in the research and registering on the platform.

1. Background and aims of the project

Plants versus Pests is a part of research on natural resource management being conducted by Luc Bussière, Malin Johansson and Celia Oni at the University of Gothenburg, in collaboration with a team of international scientists. We want to investigate the social and economic factors affecting the willingness of farmers to adopt sustainable crop protection. The game will take approximately 15 minutes to play.

2. Why have I been invited to take part?

You have been invited to take part in the games because of your experience in agriculture or because of your interest in the resolution of conflicts between food production and healthy environments.

3. Do I have to take part?

Participation is voluntary. You can stop the game at any time.

4. Are there any potential risks in taking part?

There are no foreseeable risks in taking part in the game.

5. Are there any benefits to taking part?

There will be no payment for taking part in this project. However, you will be contributing to research on one of the most difficult problems facing humanity, which concerns how to maximise food production and individual prosperity while conserving natural habitats.

6. Legal basis for processing personal data

We will not collect any private information. The data collected from the game and the registration form will be processed in accordance with the EU's General Data Protection Regulation (GDPR) and the Brazilian Lei Geral de Proteção de Dados (LGPD). Under GDPR the legal basis for processing your personal data will be public interest/the official authority of the University of Gothenburg.

7. What happens to the data I provide?

Data is stored on the game server in a password-protected file and may be used after anonymising in academic publications. Your IP address will not be stored.

The data that we collect from you may be transferred and stored or processed at, a destination outside the European Economic Area (EEA). By submitting your data, you agree to this transfer, storing or processing.

The research data will be kept for 1 year on a secure research data drive on the server of the Plants versus Pests and then will be lodged in the University of Gothenburg servers for 10 years.

8. Will the research be published?

The research will be published in project reports and academic journals. You will not be identifiable in any report/publication.

9. Who is organising and funding the research?

The work is funded by the University of Gothenburg with assistance from the Swedish International Development Cooperation Agency, SIDA.

10. Who do I contact if I have concerns about this study or I wish to complain?

Please contact:

Luc Bussière, Senior lecturer at the University of Gothenburg

luc.bussiere@bioenv.gu.se

Electronic consent

By clicking “Continue”, you agree that:

You have read and understood the above information

You are 18 years old or older

You voluntarily agree to participate

Register page

Portuguese

Registro

Nome de usuário (Seu nome não será armazenado para fins de pesquisa. Se preferir, sinta-se à vontade para usar um alias.)

Senha (Você precisará lembrar esta senha para acessar o jogo se ficar desconectado)

Questionário

Eu me identifico como...

● Homem

● Mulher

● Transgênero

● Outro

● Prefiro não divulgar

Idade:

País/Estado onde você reside atualmente:

Qual é sua atual função ou ocupação? (Se houver mais de uma, selecione a principal)

● Trabalhando principalmente como produtor de alimentos

● Trabalhador na indústria de produção de alimentos, mas não como produtor

● Trabalhador ou gerente de conservação

● Estudante em conservação, meio ambiente ou agricultura

● Outro: (Se você selecionou outro, por favor, especifique)

English

Registration

Username (Your name will not be stored for research purposes. If you prefer, feel free to use an alias.)

Password (You will need to remember this password for accessing the game if you get disconnected)

Questionnaire

I identify as...

Man

Woman

Transgender

Other

Prefer not to disclose

Age:

Country/State where you currently reside:

What is your current role or occupation? (If more than one, please select the main one)

Primarily working as a food producer

Worker in the food production industry but not as a producer

Conservation worker or manager

Student in conservation, environment or agriculture

Other: (If you selected other, please specify)

Instructions in the game

Portuguese

Bem-vindo ao jogo Plantas versus Pragas

Neste jogo, você é um agricultor que possui 9 parcelas de terra e os produtos cultivados são sua principal fonte de renda.

As pragas atacam os seus cultivos, ocasionando perdas de produtividade. O nível de dano ocasionado depende da densidade de pragas em cada parcela. Para cada parcela, você decidirá qual método de controle será empregado.

Em cada parcela, você pode escolher uma das quatro opções:

Agrotóxico

Esquema Cooperativo de controle biológico

Controle biológico mais eficaz

Nenhum método de controle de pragas

O agrotóxico como método para controle de pragas é inicialmente muito eficaz, mas a sua má utilização pode resultar na evolução de resistência. Biopesticidas também podem provocar resistência, mas uma forma de reduzir este risco é usar biopesticidas diferentes em lavouras adjacentes. Um novo esquema foi introduzido para favorecer a sustentabilidade, promover a diversidade e reduzir o risco da resistência a pesticidas. Este esquema envolve o uso coordenado de técnicas de controle de pragas, de maneira que os agricultores adjacentes não usem o mesmo biopesticida. Se você concordar em participar do esquema, será atribuído aleatoriamente uma opção de biopesticida, que poderá ser a marca líder e mais eficaz, ou uma das 4 opções ligeiramente menos eficazes. Como recompensa por participar do esquema, o governo pagará metade do custo do controle de pragas.

English

Welcome to Plants versus Pests.

In this game, you are a farmer with 9 squares of land and make your living by selling crops.

Pests are able to colonise your land and eat your crops, which reduces your yield. How much damage they cause depends on the density of pests in each land square. For every square, you need to decide what form of pest control to use.

In each land square you can choose one of four options:

Synthetic pest control

Scheme biocontrol

Most effective biocontrol

No pest control

Synthetic pest control is highly effective initially, but high levels of use harm off-target insects and lead to resistance evolution. Biopesticides can also provoke resistance, but one way to reduce this risk is to use different biopesticides in adjacent fields. A new scheme has been introduced to favour sustainability, promote diversity and reduce the risk of pesticide resistance. This scheme involves coordinating pest control use across the landscape so that adjacent farmers do not use the same biopesticide. If you agree to participate, you will be assigned a biopesticide option at random from the scheme, which might be the leading and most effective brand, or could be one of four slightly less effective options. As a reward for participating in the scheme, the government will pay half the cost of pest control if you choose to participate.

Game setup instructions. Cost and subsidies for each pest control.

Portuguese

Custos e redução de gastos com controle de pragas para cada parcela a cada tomada de decisão

- Agrotóxicos: custo (10 unidades)
- Esquema cooperativo de controle biológico: custo (15 unidades). No entanto, como você decidiu cooperar, você recebe um desconto no controle de pragas e, portanto, o custo é reduzido (7.5 unidades)
- Controle biológico mais eficaz (não como parte do esquema cooperativo): custo (15 unidades)
- Nenhum método de controle de pragas – gratuito

English

Synthetic pest control: cost (10 units)

Scheme biocontrol: cost (15 units). However, since you decide to cooperate you get a discount on the pest control and therefore the cost is reduced to (7.5 units)

Most effective biocontrol brand (not as part of the scheme): cost (15 units)

No pest control - free Portuguese

Configuração do jogo

Pop-up instructions between each game-round

Portuguese

A temporada terminou!

Não esqueça de verificar o quão bem você está se saindo em comparação com seus vizinhos e prepare-se para a próxima temporada!

A cada temporada, as plantas mudarão de cor de acordo com a perda de produtividade ocasionada pelo ataque da praga. A cor verde indica que não ocorreram perdas de produtividade, o amarelo indica produtividade ligeiramente inferior e o marrom indica que a produtividade foi significativamente afetada pelo ataque de pragas.

English

Season ended!

Make sure to check how well you are doing compared to your neighbors and get ready for next season!

Every season, the plants will change colour according to the amount of remaining yield after the pest attack. The green colour indicates full harvest, yellow indicates slightly lower harvest, and brown indicates that the harvest has been significantly affected by pests.

Post-game pop-up window

Portuguese

Bom trabalho! O jogo terminou!

Verifique os seus resultados!

English

GOOD JOB! The Game has ended

Look at the side Tables to see your results

Needs a translation

Exit page

Portuguese

Saída da página (aparece quando o jogo termina)

Obrigada! Seus dados foram registrados e sua participação é muito importante.

Caso tenha curiosidade sobre nosso projeto, aqui estão algumas informações:

Nossa pergunta central está relacionada a fatores que afetam a disposição para adotar práticas mais sustentáveis para a proteção dos cultivos.

O jogo é baseado em uma pesquisa em andamento desenvolvida por Luc Bussière, Malin Johansson e Celia Oni na Universidade de Gotemburgo e por uma equipe internacional de cientistas, mas o jogo não é uma simulação de um cenário agrícola real.

Se você tiver alguma dúvida sobre essa pesquisa, entre em contato com XXXXXXX@gmail.com

Se você deseja receber uma atualização quando completarmos a coleta de dados (no verão de 2023), envie um e-mail para XXXXXXX@gmail.com

English

Your data have been recorded, and your time has been very much appreciated.

In case you are curious about our research, here are some notes:

Our research question concerns factors affecting willingness to adopt sustainable crop protection.

The game is based on ongoing research developed by Luc Bussière, Malin Johansson and Celia Oni at the University of Gothenburg and an international team of scientists, but the game itself is not a simulation of any specific real-life farming scenario.

- If you have any questions about this survey, please contact XXXXXXX@gmail.com

- If you wish to receive an update when we have completed data collection (in summer 2023), please send an email to XXXXXXX@gmail.com

Attachment 3. Text for participant recruitment

Text was shared on WhatsApp or Email to possible participants.
Olá! Eu sou Malin, uma estudante de biologia da Suécia, atualmente realizando minha tese de mestrado sobre agricultura sustentável aqui no Brasil. Desenvolvi um jogo online chamado "Plantas versus Pragas" para coletar dados sobre atitudes em relação ao controle de pragas e cooperação. Esta pesquisa interativa convida você a participar devido à sua experiência e conhecimento em agricultura.

No jogo, você será um agricultor que precisa proteger suas plantações de pragas, utilizando diferentes métodos de controle. As pragas tentarão invadir suas terras e consumir suas plantas, o que resultará em uma diminuição na sua colheita e pontuação.

Crei meu jogo com o objetivo de nos ajudar a compreender como podemos promover a segurança alimentar, garantir a subsistência dos agricultores e preservar o meio ambiente para as próximas gerações.

Agradeço imensamente por sua participação e peço que compartilhe esta pesquisa com as pessoas que trabalham na área agrícola. Muito obrigada / Malin

Jogo: https://maljohansson.shinyapps.io/Agriculture_game-main/

Vídeo sobre o jogo: https://youtu.be/eL0aOwm3eZ8

Celular: https://youtu.be/7ccv8YEQSt8