WATERAGRI

D 1.3 Serious Game

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WP 1 Farming Community Engagement

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Abstract:	This report presents the concept and design of the serious game AgriLemma. The game is a physical board game designed to engage WATERAGRI stakeholders and increase their awareness about the WATERAGRI solutions and the complex trade-offs involved in using them. Furthermore, a summary of gameplay results is presented in the report, along with suggestions for future work.

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List of Abbreviations and Acronyms	
EU	European Union
WS	Workshop

1. Introduction

AgriLemma is a serious game about farming in Europe in the 21st century. A serious game is a game designed to achieve a purpose beyond entertainment, such as training, education, behavioural change or raising awareness. The name of the serious game AgriLemma comes from the words “Agriculture” and “Dilemma”. The game is a multi-player board game that simulates the world of the farmers, who are faced with the challenge of adapting to the growing pressures of climate change, water scarcity/abundance, and the institutional push for sustainable food production. The game captures the complexity of farming and aims to help stakeholders better understand trade-offs between outcomes of available options and appreciate technologies and solutions developed in the WATERAGRI project.

AgriLemma targets all WATERAGRI stakeholders: farmers or farm managers, agricultural chambers, farmer associations, water management organizations, consultants, media, researchers and policymakers. The aim of the serious game within the scope of the WATERAGRI project is two-fold:

- To engage stakeholders and increase awareness of the water retention and nutrient recovery solutions and
- To enable players to learn more about WATERAGRI technologies and solutions and appreciate the complex trade-offs that exist when using these.

Serious games were chosen as a means of engagement because they are fun and engaging and provide a sense of autonomy, competence and relatedness to players. Games allow us to simplify and model the complexity of the real-world and let players experiment with their choices when doing so in the real-world can be costly. A stakeholder can further understand how to adapt their choices and decisions under uncertain drivers such as climate change. Moreover, games are engaging and provide a good learning medium compared to more traditional forms of learning such as information campaigns, websites, marketing flyers or leaflets. Furthermore, they are an efficient tool to communicate with the general public and stakeholders who may not have the technical knowledge and background in the field of agricultural water management.

In the game AgriLemma, players step into the shoes of a farmer in Europe. They have their own farm with six fields to grow five types of crops: sugar beets, rapeseed, maize, potatoes, and chickpeas. To grow crops in the fields, they need resources such as water, nutrients, workers, and seeds. Players have to run, invest in and improve a farm in 8 seasons. The players are challenged to maximize their farm sustainability score, which is dependent on environmental, financial and social aspects of the farming conducted. Players can maximize the total score by ensuring that the farm's environmental impact is positive, workers are satisfied, and the farm is profitable. The players need to strategize and balance these goals while withstanding uncertainties of weather and events such as pest attacks.

This report presents the concept and design of the serious game AgriLemma and a summary of gameplay results. In section 2, we present the methodology followed for the game design. Section 3 presents the game round, objectives, mechanics, and paraphernalia. Section 4 presents a summary of gameplay results, and section 5 presents the conclusion and suggestions for future work.

2. AgriLemma Design

2.1. Game Design phases

AgriLemma was designed iteratively. The game was developed in 5 phases. Firstly, the objective and scope of the game were defined in Phase 1: *Design Specifications*; this was defined by the project proposal of WATERAGRI, wherein the game was envisaged as an engagement tool for stakeholders to become familiar with the technologies being developed in the project and explore the pros and cons of the solution. The medium of the engagement was decided as a board game tool to be able to support in-person workshops, facilitation and engagement activities.

In Phase 2, *Systems Analysis*, desk research was conducted. This phase started with a stakeholder analysis to understand the actors involved in farming in Europe, their objectives, resources, and interests. Online interviews were conducted from September to December 2020 with farmers and researchers involved in the project to gather information on common European crops, policies on farming in the EU, and uncertainties that farmers have to deal with. Information about the solutions was taken from factsheets developed by the solution providers. These factsheets contain information on each solution covering topics such as the design concept, technical information and results from case studies where the solutions were applied, costs and benefits of each solution, challenges and opportunities in implementing them, and contact details of the researchers and companies that developed these solutions.

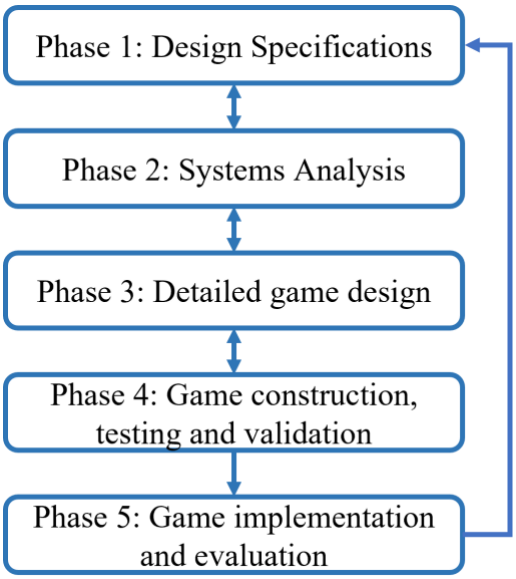

Figure 1: Serious game design phases (Peters & van der Westlaken, 2014; Mittal et al., 2022)

Phase 3: *Detailed Game Design* started with developing a prototype of the game on paper and translating the real-world elements from the systems analysis to gaming elements. To execute this, the matrix proposed by Peters & van der Westlaken (2014) was used, where each element from the systems analysis was mapped to a gaming element. For instance, the steps in the farming cycle were represented as steps in one round of the game, uncertainties were represented as event cards and weather cards, technologies were represented as technology cards, and critical inputs that are

required to sustain a farm were represented as resources – money, water and nutrients. This phase also involves further refining the game's boundaries and scope. For instance, a choice was made to only include farmers as the active player in the game while actions of other stakeholders were incorporated through uncertainties or policy events.

In Phase 4: *Game construction, validation, and testing,* the game is tested and debugged. This step is also useful to validate whether players can relate to the game's goals and whether the intended learning was communicated effectively through the game. The feedback received in this phase is used to improve the game, which involves going back to previous phases and simplifying different aspects of the game. AgriLemma underwent two iterations of prototyping and testing.

Lastly, in Phase 5, the game's final prototype was presented and demonstrated in the 4th WATERAGRI stakeholder consultation workshop held at the Delft University of Technology, The Netherlands, on 24th February 2023. The game's impact was evaluated by comparing responses to the pre-game and post-game questionnaires. A summary of the results from the workshop can be found in Chapter 5. More information about the workshop can be found in WATERAGRI Deliverable 1.7: Workshop 4 report.

2.2. Play, meaning and reality

While designing AgriLemma, three pillars or core components were considered: realism, play and meaning (Harteveld et al., 2010; Harteveld, 2011), as shown in Figure 2. The aim was to develop a serious game that balances all 3 components.

Realism refers to the real-world and how it is represented in the game. It stems from the subject matter that the game is based on. In AgriLemma, the world of farming and management of water and nutrients was captured through the farming cycle (sowing, cultivating and harvesting of crops), uncertainties such as weather and policies, and the results of the WATEAGRI solutions from the case study areas that were captured in the WATERAGRI factsheets.

The play represents the world of games. It refers to the mechanisms and rules of the game, aesthetics, and criteria for developing good games, such as fun, engagement, and immersion. Since farming is an individual endeavour/business, the game was developed as a competitive game so that farmers can take individual decisions regarding their farms. They were challenged to maintain their farm while keeping it economically, socially and environmentally sustainable. The game board was designed to represent individual player farms and couple it with score tracking so that players can get feedback on their performance. Players were encouraged to interact with each other by trading resources.

The last pillar of serious game design is *Meaning* which refers to the learnings that players can derive from the game. To make a game meaningful, it is critical to transfer the learnings from the game to the real-world, either through post-game discussion or debriefing, where players can reflect on their journey and experience of the game and draw conclusions for the real-world. In AgriLemma, the meaning was incorporated by representing the complexity of farming in the game to engage and challenge players - they were tasked to balance multiple sustainability goals while making multiple decisions on what resources to invest in and when and how to adapt to uncertainties. Since one of the aims of the game was to enable players to learn more about different WATERAGRI technologies

and solutions and appreciate the complex tradeoffs involved when selecting these solutions, the pros and cons of the solutions were presented on technology cards. The debriefing of the game was linked to the aims of the game – players were tested on the information they remember about the solutions, their awareness level about the solutions and their opinion on some statements about farming, impending climate change and the role of water retention and nutrient recovery solutions.

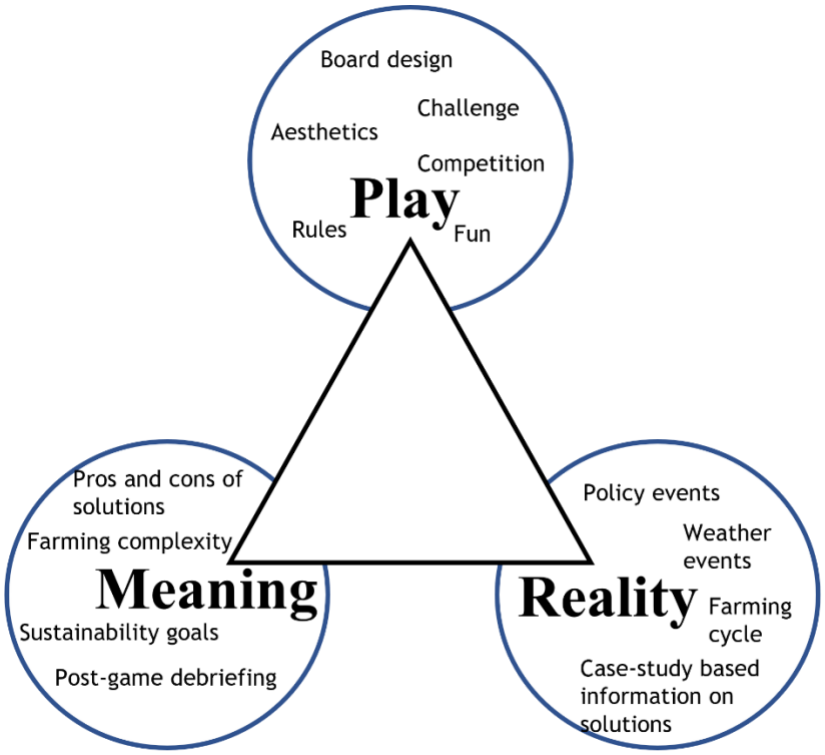

Figure 2: Balancing meaning, reality and play (Harteveld, 2011)

3. AgriLemma Game

AgriLemma is a board game aimed at increasing awareness about the water retention and nutrient retention solutions developed in the WATERAGRI project. The game aims to further engage diverse stakeholders and highlight the relevant tradeoffs in solution selection. AgriLemma stands out for its focus on specific technologies that can be used for agricultural water and nutrient management and experimenting with them in a gaming environment. The game is meant to be played by 2-4 players. However, this number can be extended to 8 by making 4 teams of 2 players. The game is competitive in nature, where players compete to get the highest overall score. The game takes approximately 2 hours to complete including the time to set up the game.

3.1. Game round

Players go through 8 rounds in AgriLemma. Each round represents one farming season which is further divided into the following five steps:

1. *Invest*: In this step, players can make investments in their farms. They can hire workers, buy development cards (max 2), crops, and technology cards. The crops bought in this round can be directly put on the fields (this represents sowing them).
2. *Uncertainties*: In this step, players have to draw one weather card and one event card. The weather card determines how much water is available in the season, while the event card determines government policies, crop diseases, and other uncertain events. In this step, players can also receive the benefits provided by the technology cards.
3. *Trade and Cultivate*: In this step, players must provide nutrients and water to crops sown in their field. They can trade them with other players if they do not have sufficient resources. However, if required resources cannot be arranged, the crop dies, and they must remove it from their field.
4. *Harvest*: After cultivation, players can harvest their fields in this round. Players can harvest up to 2 fields without a worker and receive the yield amount. For harvesting more fields, they either need a worker or a farm machinery development card.
5. *Payments and Scoring*: In the last step of a round, players must make payments – they need to pay the workers deployed on the field and pay the maintenance costs of tech cards. If workers cannot be paid, then they must keep the workers, but their social points will decrease by 1. Once the payments are made, players can adjust their social, environmental and financial scores.

As players progress through the steps in a round, they must advance the round-steps-tracker further, and once a round is completed, then the round tracker must be advanced to the next round (see Page 1 and Page 2 of the game manual for pictures and placement of the round-tracker and round-steps-tracker).

3.2. Game objective and scoring

Players have to run, invest in and improve a farm in 8 seasons. The objective of the game is to maximize a score which represents the overall sustainability of the farm incorporating aspects such as environmental health and environmental impact of the farm, worker satisfaction, and profitability, which results from ensuring that sufficient nutrients and water are available for the crops grown in the farm. The players need to strategize and balance all these goals to maximize the farm sustainability score while withstanding uncertainties of weather and events such as pest attacks.

The farm total sustainability score is calculated as the sum of the following:

- **Environmental points:** Players earn environmental points by investing in sustainable technologies or diversifying their crops.
- **Social points:** Players can earn social points by generating livelihoods through labourer employment, providing them with consistent sources of income or investing in technologies.
- **Financial points:** Players can earn financial points by generating profit. This equals the amount of money left with the players after the payments step in each round. If players become bankrupt, they can take a one-time loan of 5 coins from the bank (with an interest of 1 coin). At the end of the game, players must subtract this loan from their financial points. If they become bankrupt again, then the player loses and has to exit the game. The resources left at the end of the game can be monetized and added to the financial score as follows:

- 1 Water = 0.25 coins
- 1 Nutrient = 0.25 coins
- Any technology = 1 coin
- Any development card = 1 coin
- 1 worker = 1 coin.

Play ends when 8 rounds are over. The player with the maximum farm sustainability score at the end of the game wins. In case of a tie, apply the following tie-breakers in order:

- The player with the most technologies wins
- The player with the highest environmental sustainability score wins
- The player with the highest social sustainability score wins.

3.3. Game mechanics

Some of the key mechanisms incorporated in the game are described below:

- **Competition:** Farming is an individual business or enterprise, so the game's basic structure is kept as competitive. However, the resources used in farming can exist in surplus or shortage, so farmers are provided with the opportunity to trade resources and set a price for them.
- **Phased cultivation process:** The rounds in the game follow a crop production cycle. Each round in the game represents a season where the farmer sows the crop, provides it with the required nutrients and water, manages the climate uncertainties and then finally harvests the crops and sells them and pays maintenance and dues for any technologies or resources such as workers that were deployed in the farming business.
- **WATERAGRI solutions/technologies**: Incorporated as technology cards.
- **Weather and other uncertainties**: Farmers are faced with multiple uncertainties that are outside their control. These could be the changing weather conditions and actions taken by other stakeholders, such as policy decisions. These uncertainties are incorporated into the game's event cards, weather cards, and technology dice.
- **Resources:** Farmers need resources to run a farm. These are crops to sow, workers to deploy on the field, water and nutrients for the crop, and additional options such as crop insurance and farm machinery.
- **Progress tracker:** The farm's progress is tracked on 3 scoring trackers: economic, social and environmental sustainability.

3.4. Game paraphernalia

3.4.1. Game board and setup

In AgriLemma, players step into the shoes of a farmer. They are in charge of one farm on the board that consists of 6 fields, which are represented by same-coloured rectangles on the game board (see Figure 3). Players can sow a crop on two of six fields without any other inputs (i.e. by doing the work themselves). However, as they expand the production on their farm, they either need farm machinery or a worker to sow a crop on the remaining 4 fields. Each player has the same starting conditions; they start with 5 nutrients, 5 water, and 40 money tokens.

The scores of players are tracked on 3 scoring meters that can be found at the edge of the game board. Each player is given 3 pawns matching the colour of their field to track their individual scores on the 3 scoring meters. Players start with a score of 40 financial points, 10 environmental points, and 10 social points.

Other elements on the board include event cards, weather cards, the number of game rounds and the steps within to help players track their progress through the game. Instructions on where to place the cards on the board and the initial position of player tokens are provided in the game manual (see Page 2 of Appendix 7.1.1).

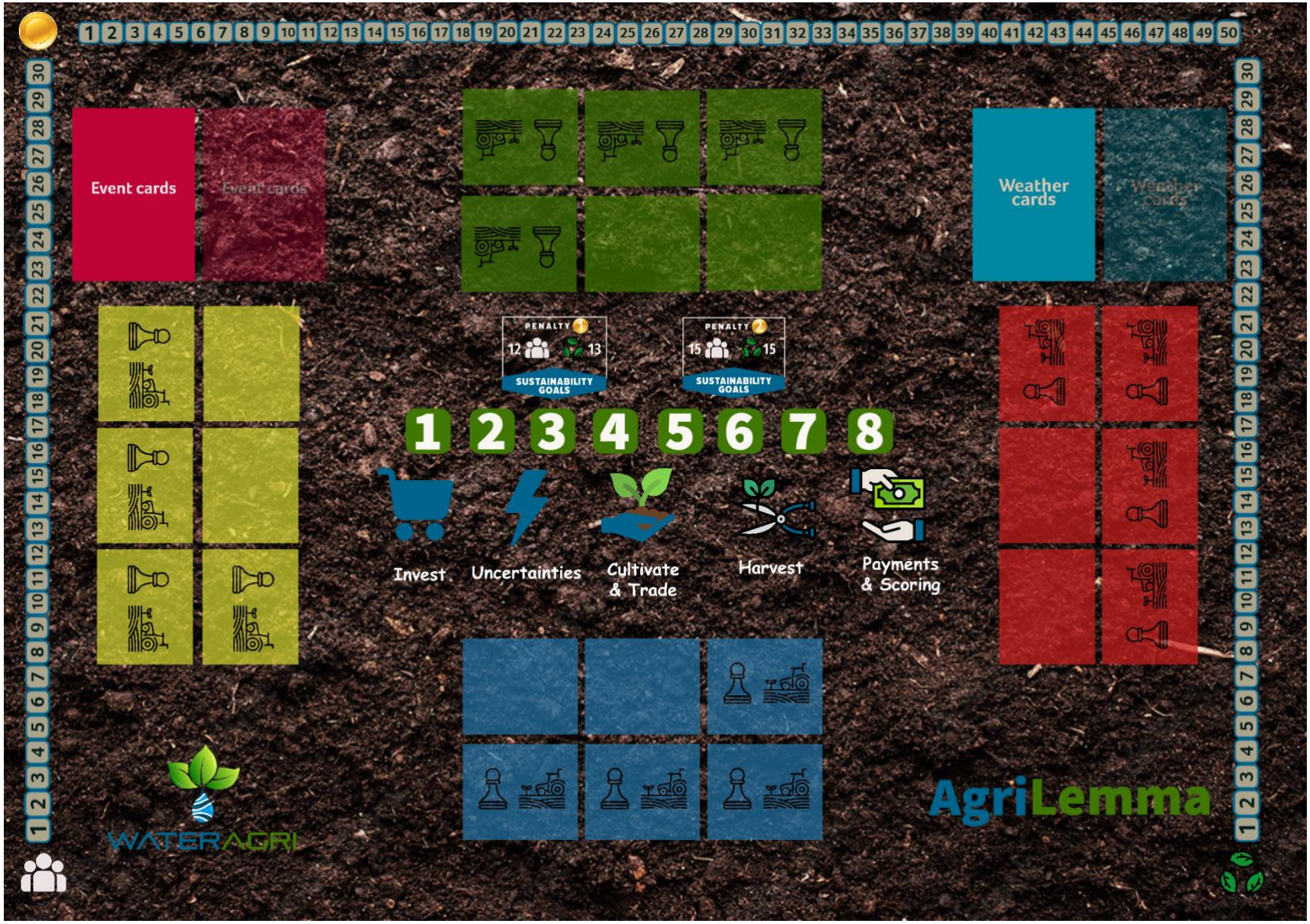

Figure 3: AgriLemma game board

3.4.2. Game currency

Players can use the game currency to buy and trade resources such as nutrients and water, investments such as crops, tech cards, and development cards, and hire workers. The game currency is represented by money tokens (see Page 4 of the game manual in Appendix 7.1.1 for all the game paraphernalia).

3.4.3. Game resources

Players need water and nutrients to cultivate crops in their fields (see page 4 of the game manual in Appendix 7.1.1). In each round, players draw a weather card to find out how many nutrients and water resources are naturally available in that round. If players do not have enough resources during the game, these can also be bought from the bank.

3.4.4. Investments

Using the money tokens, players can invest in various things – technologies, crops, works, and developments. Players are provided with a reference card describing all these investments (see Appendix 7.1). The investments are explained below. Using the money tokens, players can invest in a variety of things – technologies, crops, workers, and development cards.

3.4.4.1. Technology cards

Technology cards are opportunities to invest in the farm. There are 10 different technologies incorporated in the game, and each technology has associated fixed costs and maintenance costs. These costs are marked on the card's top left and right corners (see Figure 4). Players need to pay the fixed cost when buying the card, and the maintenance cost must be paid in each subsequent round. If players cannot pay maintenance costs, they must roll the technology dice (see Section 3.4.5.3). Each technology can have an impact on nutrients or water savings, social and environmental scores, and the possibility of predicting uncertainties. The impact of technology cards can be positive or negative and be a one-off or/and a recurrent benefit. The impact description can be found at the card's bottom left and right corners (see Figure 4). For instance, in Figure 4, players get a one-off impact of +1 environmental score and -2 social score and a recurrent benefit of 1 water saving per round, i.e., they need to give 1 less water token in total for the cultivation of the plants. The benefits and maintenance/recurrent costs of the technology can be either per field or for the whole farm (assume the whole farm if 'per field' is not specified). Players can buy as many technologies as they want, and each technology can be bought multiple times (see Appendix 7.1.3 for all technology cards).

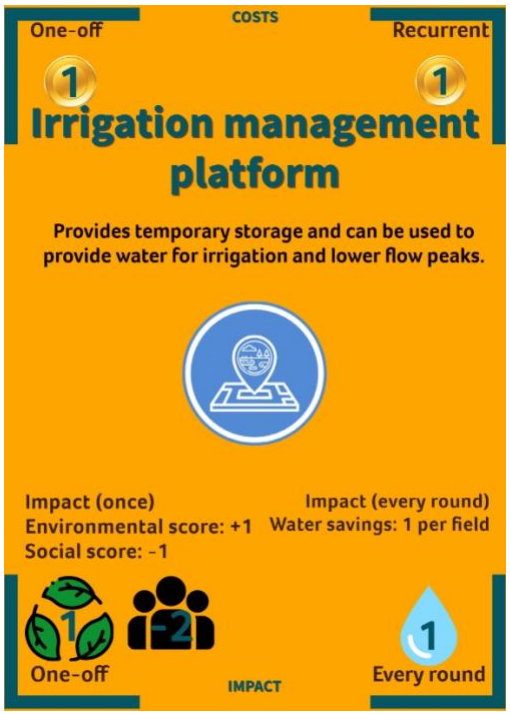

Figure 4: Example of a technology card

3.4.4.2. Crops

Players can buy crops in step 1 of each round by paying money tokens (see the top left corner of Figure 5) and placing them on their fields, representing the crop sowing in the real world. Each crop requires a specific amount of water and nutrient inputs which are written on the left side of the crop card (see Figure 5). Once the crop is cultivated in step 3 of a round, i.e., it is provided with the required water and nutrient tokens, it can be harvested in step 4 of a round. Players get a monetary yield from the crop, which is marked on the right side of the crop card.

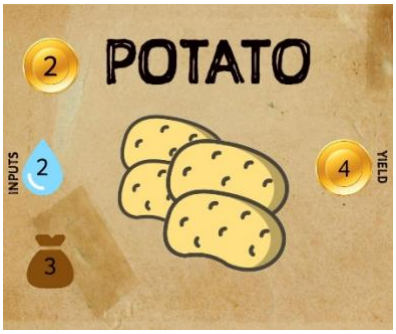

Figure 5: Example of a crop card

3.4.4.3. Workers

Labourers are required to harvest four out of six fields. These are represented as white pawns in the game. The hiring cost of a worker is 1 money token (representing hiring and contract costs), and recurrent payment is 1 money token (representing the worker's salary and related costs). If the player has the money to pay, then they need to pay the worker, and the worker cannot be fired. If they don't

have money tokens, they can keep the worker, but they will lose 1 social point for each round they cannot pay the worker.

3.4.4.4. Development cards

Development cards provide additional benefits to the farmers. For instance, players can buy crop insurance for 3 money tokens that can make them immune to uncertainties or bad weather (see Figure 6). A maximum of 2 development cards can be bought in a round. Once development cards are used, or the specified benefits are obtained, they need to be discarded (see Appendix 7.1.5 for all development cards).

Figure 6: Example of a development card

3.4.5. Uncertainties

3.4.5.1. Weather cards

The cultivation of crops depends on good weather – an appropriate temperature and availability of rain and nutrients in the fields. Climate changes have direct consequences on future weather hence also the production of crops. This factor is highly uncertain and outside the control of farmers. They must continuously adapt to changing weather conditions. In AgriLemma, weather uncertainty is incorporated as weather cards (for example, see Figure 7). These vary from extreme weather (drought, hailstorms, heatwaves) to normal/good weather conditions. The weather cards determine how much water (from rain) and nutrients are available to each farmer for the given season (i.e. a round). In addition, extreme weather conditions may further destroy crops, reducing the yield per field. For instance, during a drought, farmers get 1 less coin for each harvested crop. There are a total of 15 weather cards in the game, out of which five different types exist: extreme heatwave (x2), summer drought (x2), fair weather (x4), normal weather (x4), and hailstorms (x3).

Figure 7: Example of a weather card

3.4.5.2. Event cards

Apart from the weather, agriculture involves many other uncertainties. These include changing market conditions and consumer preferences that impact the prices of crops. Apart from that, regulations around farming may change, for instance, the permissible environmental impact or the availability of subsidies for farmers. Moreover, new diseases, pests or plagues may affect crop production. These uncertainties are incorporated as event cards in the AgriLemma game. An example of the event card is shown in Figure 8. For instance, in the event card "Monoculture mayhem" (see Figure 9), if farmers do not diversify their crops, it can lead to an outbreak of pests and diseases which may destroy crops. There are 15 event cards in the game (see Appendix 7.1.7 for the description of all event cards), of which there are 10 different cards, and some are repeated twice.

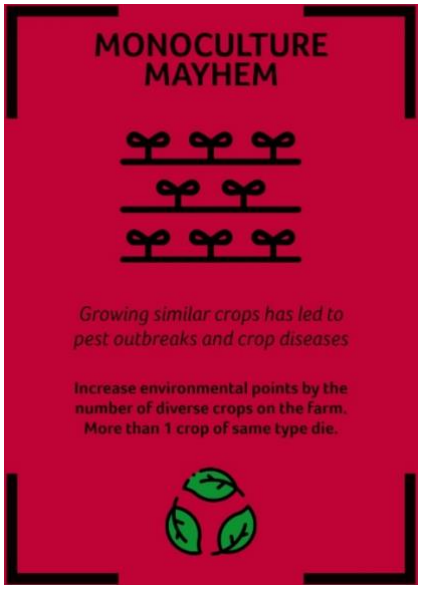

Figure 8: Example of an event card

3.4.5.3. Technology dice

If the maintenance of a technology/solution is not done regularly, there is a high chance that the technology can fail. If the players can no longer pay the maintenance costs of the technology, then they will need to throw a dice for each technology they own. The technology failure dice has a 50% chance of failure/success. If the technology failure dice shows numbers 1-3, players need to lose the technology and buy it again. If it shows numbers 4-6, players can continue using the technology.

4. Game Playing Results

Multiple sessions were organized to test the initial prototypes of AgriLemma and receive feedback. In November 2020, the game's first prototype was tested with 15 MSc students at TU Delft. In April 2022, the game's second version was presented at the WATERAGRI general assembly in Vienna, and three gameplay sessions were conducted with internal WATERAGRI stakeholders. Another gaming session was organized with farmers in Gleisdorf, Austria, where the game was played with 2 farmers external to the project.

The final prototype of AgriLemma was presented at the 4th WATERAGRI stakeholder consultation workshop in Delft, The Netherlands, on 24th February 2023. The instructions to download and prepare the materials for this prototype have been provided in Appendix 7.2. The workshop was attended by 13 people, of which 3 were the workshop organizers and 10 were workshop participants. Out of the 10 participants, 9 were members of the WATERAGRI consortium, while 1 participant was not affiliated with WATERAGRI but still worked in the field of agricultural water management and nature-based solutions. Questionnaires were deployed before and after the game to test the impact of the game. In this section, a summary of the results of the workshop is presented. For more details on analysing the questionnaire data and the precise results, please refer to the WATERAGRI Deliverable 1.7: Workshop 4 report.

Figure 9: Gameplay session in progress with participants of the 4th WATERAGRI stakeholder consultation workshop at TU Delft

In terms of the first aim of the game – increasing awareness of the WATERAGRI solutions, the game performed marginally well. There was a 3 - 14 % increase in the awareness of the solutions after playing the game (as assessed by players). We also tested a change in players' opinions on eight statements about farming, the urgency to do something about water and nutrient scarcity, and adapting to climate change. Two statements stood out for which the percentage change was high. There was a 22% decrease in favour of the statement "I am prepared to deal with the uncertainties in farming" after playing the game. This indicates that the game demonstrated the complexity of farming and managing water and nutrients and made the players re-think their preparedness to deal with the uncertainties of weather, government policies, and diseases. Similarly, there was a 14% increase in favour of the statement, "I am aware of the benefits and impacts of the nutrient retention solutions". This indicates that the game improved the knowledge of related WATERGRI solutions and that it was possible to partially communicate the corresponding benefits.

Players also shared their learnings from the game. When asked to describe one solution and its main trade-offs, 9 out of 10 players described farm-constructed wetlands and listed their trade-offs – high costs versus benefits of water retention, nutrient retention, sustainable impact, ecosystem services, and prevention of water pollution. Players further mentioned that the game supported systematic thinking and helped them to combine trade-offs among different factors that affect farming. They also learned that it is difficult to plan and prepare for uncertainties in farming, which they thought resembled reality well.

Regarding game experience, players rated the game above 4 (on a scale of 1 to 5) on aspects of fun, engagement and learning of complex trade-offs in selecting WATERAGRI solutions. Game realism, the extent of learning, and clarity of rules were rated between 3 and 4. Lastly, players felt that the game was not too difficult to follow but not easy to win.

Players provided a lot of feedback on further improving the game. Some of the suggestions mentioned frequently were:

1. Adding more event cards and weather cards to the game to make it more dynamic when played multiple times
2. Providing more money to the players at the start of the game so that they are better equipped to utilize more fields on the farm
3. Adding a rule to monetize remaining resources at the end of the game and converting them into financial points
4. Increasing collaboration among the players by allowing them to share investment costs or resources
5. Improve the balance of benefits gained from technologies in the game. Currently, the benefits seem skewed towards constructed wetlands as it is difficult to earn similar social and environmental points from other technologies.
6. Introducing technologies at the beginning of the game and adding more information about them in the game manual or on the technology cards (for instance, a barcode that can be scanned and leads the player to the webpage of the solution on the wateragri website)
7. Diversifying technology cards beyond the ones developed in the WATERAGRI project. Some potential solutions/farming approaches that could be added are cover-crop technologies, agroforestry, conventional agriculture with high use of fertiliser and pesticides

8. Adding more realism in the game by differentiating between crops based on their ability to withstand weather changes, incorporating soil types, and allowing technology cards and the parameters of the crops to be adapted for local and or regional context

Points 1-3 of the above feedback have been incorporated into the game's design, as presented in the deliverable D1.3: Game Design. The game will be further tested with these changes in the upcoming WATERAGRI general assembly in Budapest in April 2023. The remaining suggestions would need further development and testing, which is outside the scope of game development within the WATERAGRI project. Beyond the project's end, we recommend practitioners and interested stakeholders who wish to use the game to further invest time and resources into upgrading and adapting the prototype to their requirements.

5. Conclusion

This report presents the serious game AgriLemma. The game is designed to increase awareness of the water and nutrient retention technologies and solutions developed as part of the WATERAGRI project. Furthermore, through the game, we aim to highlight the complex trade-offs of the solutions and their economic, social and environmental impact. The game targets various stakeholders – farmers or farm managers, agricultural chambers, farmer associations, water management organizations, media, researchers, and policymakers. The game was developed over a period of 3 years with multiple iterations incorporating feedback from interim test sessions with internal and external stakeholders.

The final prototype of the game was presented on 24th February 2023 at the 4th WATERAGRI stakeholder consultation workshop, which was attended by 13 participants. Three game sessions were organized with players, and the game was received well. The results of the pre-game and post-game questionnaire showed improvements in the awareness of solutions and the attitude towards the urgency of adapting to farming uncertainties.

Before the project's end, future work should focus on translating the game to different languages to make it more accessible to WATERAGRI stakeholders. Case study representatives are encouraged to help with the translation. A lot of constructive feedback was also received to further improve the game. Although this is outside the project's scope, future work beyond the project could be focused on improving the presentation of technology cards, incorporating more technology solutions in the game beyond those being developed in the WATERAGRI project, and integrating mechanisms to increase collaboration among players. The game can be further adapted to the local context of different farming regions by incorporating soil type, local weather conditions, and local farming practices.

6. References

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Harteveld, C., Guimarães, R., Mayer, I. S., & Bidarra, R. (2010). Balancing play, meaning and reality: The design philosophy of LEVEE patroller. *Simulation and Gaming*, *41*(3), 316–340. https://doi.org/https://doi-org.tudelft.idm.oclc.org/10.1177%2F1046878108331237

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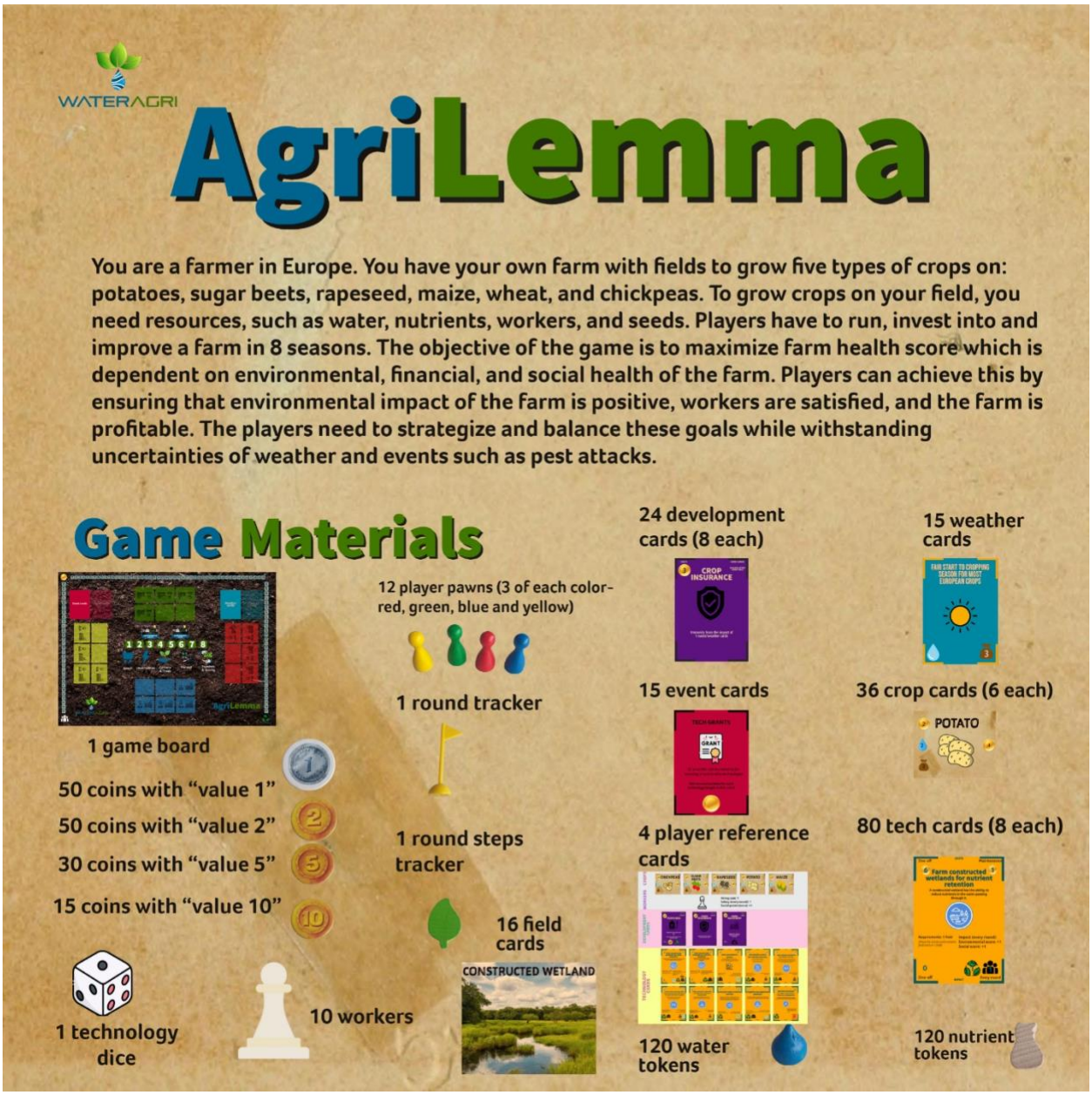
7. Appendix

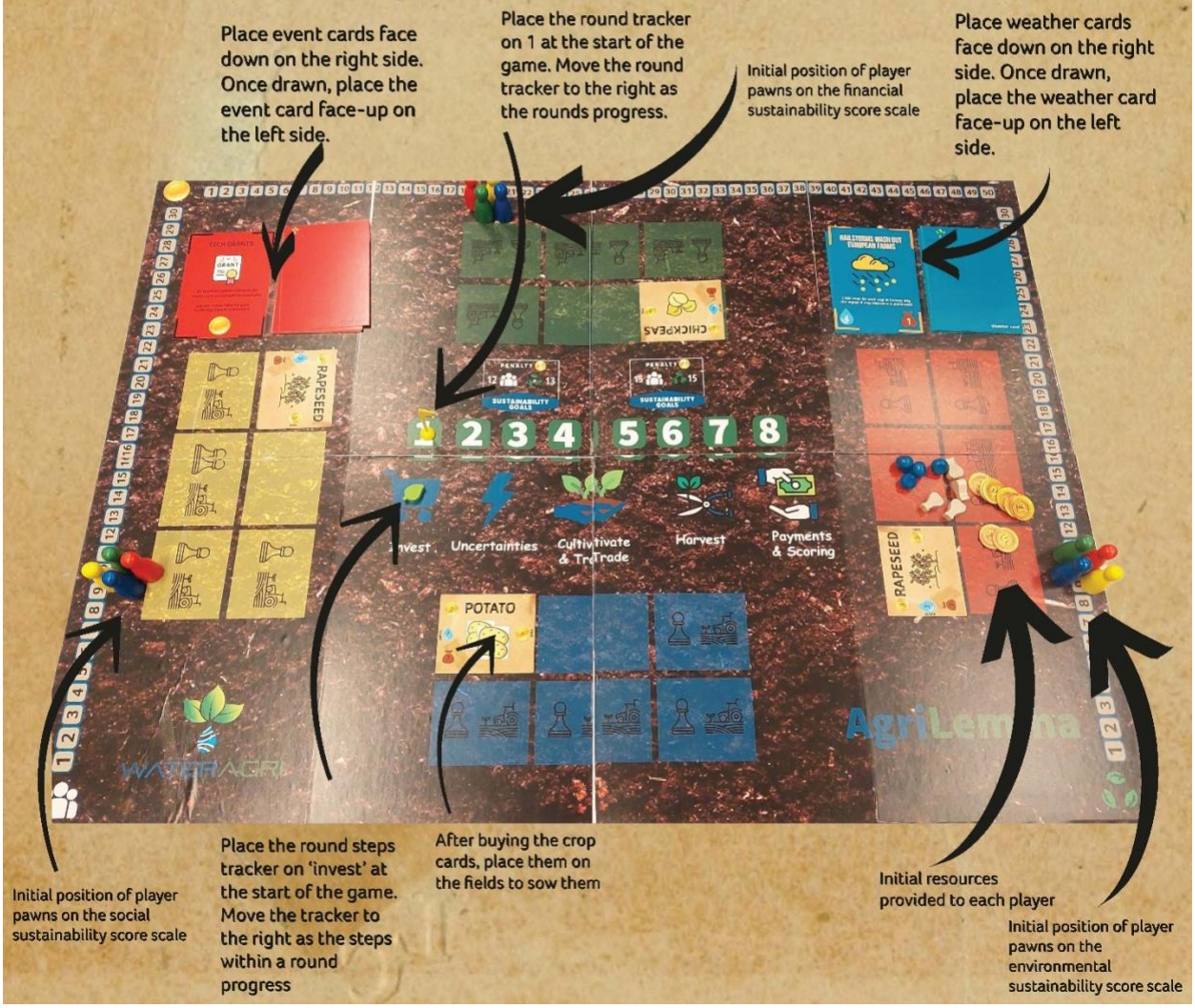
7.1. Game materials

7.1.1. Game manual



Game Setup

- Each player is in charge of one farm on the board that consists of 6 fields.
- Each farm has the same starting conditions.
- Players start with 5 nutrients, 5 water, 40 money tokens
- If there are more than 4 players, teams of 2 can be made and they can collectively play as one player.



Game Start

The player with the most experience in the farming/water sector starts the game.

Game Round

Invest

- Hire workers, buy development cards (max 2), crops, and tech cards

Uncertainties

- Draw a weather card
- Draw an event card
- Implement/get impact of event, weather and tech cards.

Cultivate & Trade

- Provide nutrients and water to crops sown in your field
- If the player does not have sufficient resources, try to trade them with other players. If required resources cannot be arranged, remove the crop from the field.

Harvest

- Harvest up to 2 fields without the worker and receive the yield amount. For harvesting more, deploy one worker per field.

Payments & Scoring

- Pay the workers, maintenance cost of tech cards
- If workers cannot be paid, then you may keep the workers and decrease social points by 1.
- Adjust social, environmental, and financial score

Game currency

The game currency is represented by money tokens. Players can use this to buy and trade resources such as crops, tech cards, and development cards, and hire workers.

Resources

Water and nutrients are required to grow and cultivate the crops. In each round, players draw a weather card to see how much water and nutrients are available in this round for each player.
If players run out of water and nutrients, they can buy them from the bank.

Resource trading

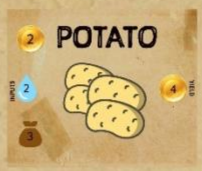
Players can trade resources with each other. Players can trade resources for resources or resources for money. They can negotiate the terms of selling and buying.

Bankruptcy

If players run out of money, they can take a one-time loan of 5 coins from the bank. At the end of the game, players must subtract this loan from their financial points. If they become bankrupt again, then the player loses and has to exit the game.

Items to invest in

Development cards provide additional benefit to the farmers. A maximum of 2 development cards can be bought in a round. Once development cards are used or the specified benefits are obtained, they must be discarded



Players can choose from 6 crops to grow on their fields: maize, wheat, rapeseed, sugar beets, chickpeas and potatoes. Crops need water and nutrients to grow and provide a monetary benefit at harvest

Workers are required to harvest the fields. Hiring cost of a worker is 1 money token and payment (every round) is 1 money token. PLayers get one social point for hiring a worker. If players do not have the money to pay the workers, then they can keep the worker for that round but they will lose 1 social point in that round.

Technology cards are opportunities to invest in the farm. These provide players with nutrients or water savings, and the possibility to predict uncertainties. These cards have social/environmental consequences that impact the environmental and social score.

- Players can buy multiple technologies
- Each technology can be bought as many times as the player wants.
- Players need to pay the maintenance of some technologies every round. If players cannot pay the maintenance cost, they have to roll the technology dice.
- In the round that you buy the card you pay the "one-off" fee (fixed costs) and in subsequent rounds, you pay the "maintenance cost"

Uncertainties

Weather

Weather is a huge factor in how the crop will grow. Extreme temperature and precipitation can prevent crops from growing, destroy them orreduce yields

Events

Like weather, these are additional factors that are outside the control of the farmer. The uncertainties inherent in global markets, pest attacks, government policies, etc. can cause impact farm health.

Technology failure

Technology failure dice: If the maintenance of a technology/solution is not done regularly, there is a high chance that the technology can fail. The technology failure dice has a 50% chance of failure/success. If the technology failure dice shows fail (red), players need to lose the technology and buy it again. If it shows "no fail" (green), they can continue using the technology.

GameEnd

Game ends when 8 rounds are over

Score Tallying

The objective of the game is to maximize farm health score which is calculated as

Environmental points + Social points + Profit

Players earn environmental points by investing in sustainable technologies, or diversifying their crops

Players can earn social points by generating livelihoods through employment of workers providing them a consistent sources of income, or investing in technologies.

Players can earn financial points by generating profit. This is equal to the amount of money left with the players after the payments step in each round.

Winning Conditions

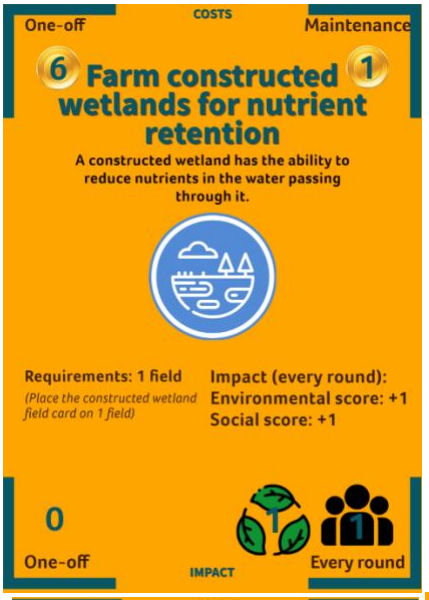
The player with the maximum farm health score at the end of the game wins

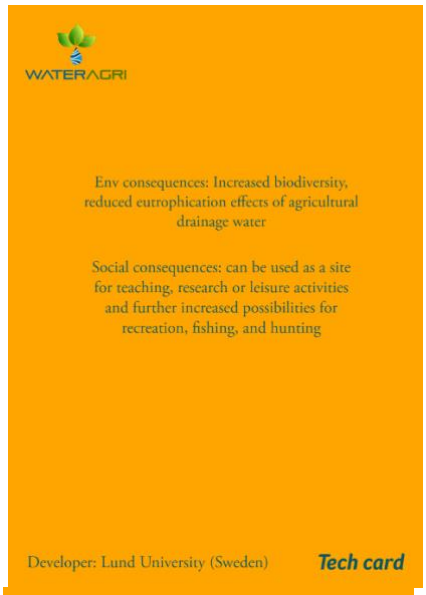
In case of a tie, apply the following tie breakers in order:

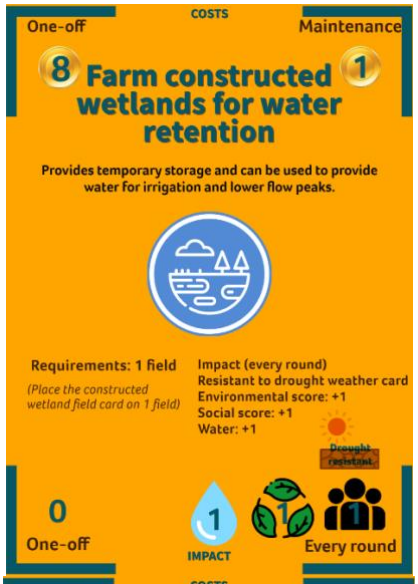
1. **The player with the most technologies wins**
2. **The player with the highest environmental sustainability score wins**
3. **The player with the highest social sustainability score wins**

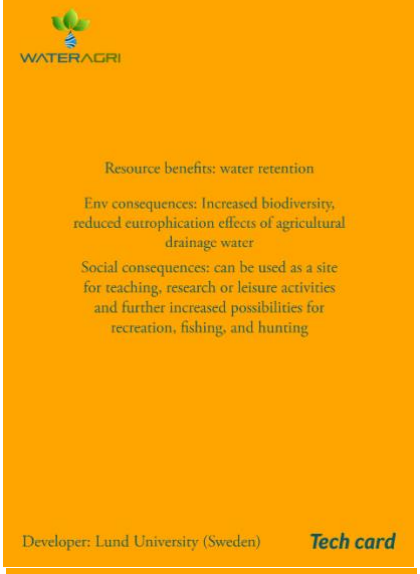
7.1.2. Reference card

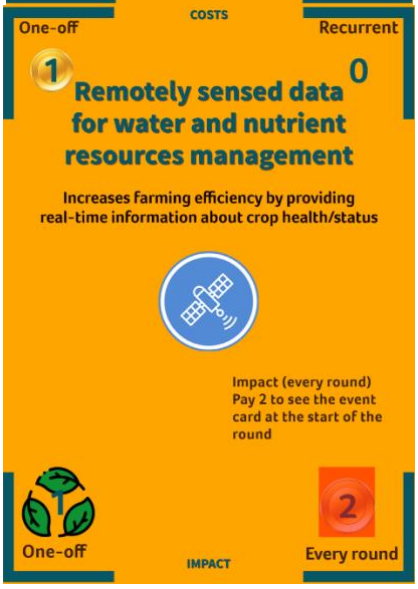
7.1.3. Technology cards

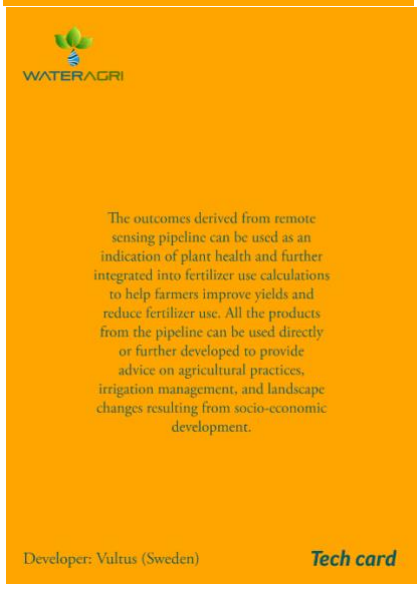


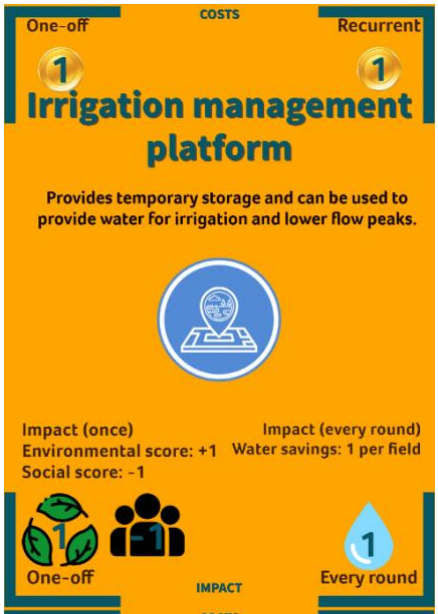


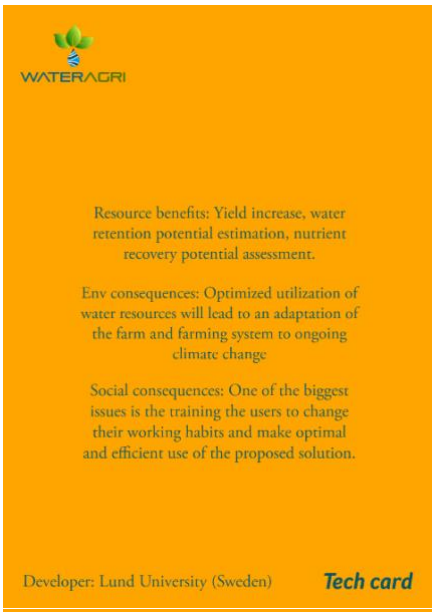




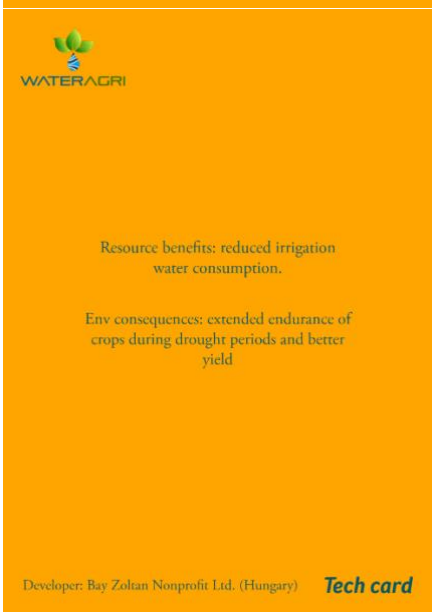


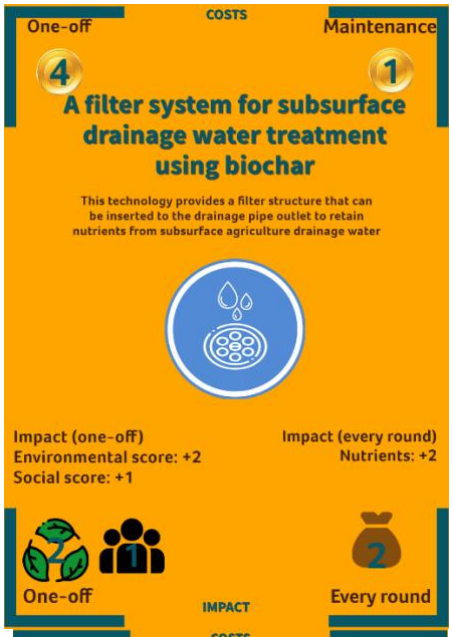


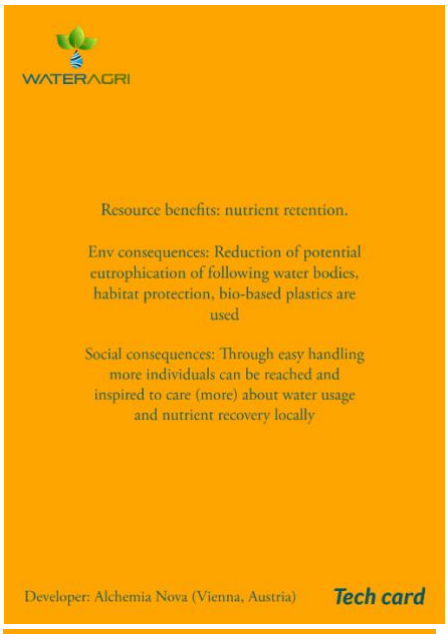

COSTS
One-off
Recurrent
1
1
Irrigation management platform
Provides temporary storage and can be used to provide water for irrigation and lower flow peaks.
Impact (once)
Environmental score: +1
Social score: -1
Impact (every round)
Water savings: 1 per field
1
-1
1
One-off
IMPACT
Every round

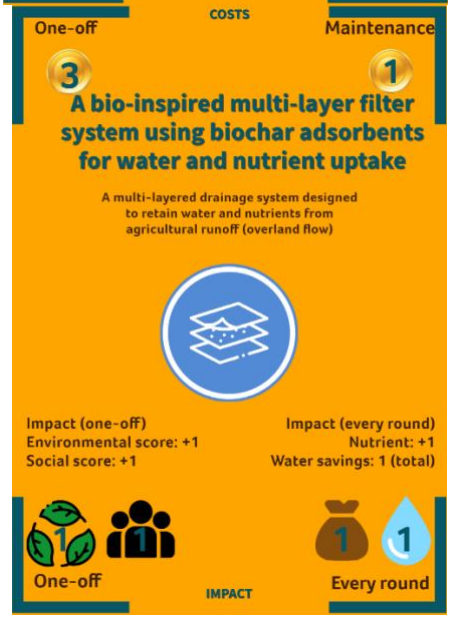

WATERAGRI
Resource benefits: Yield increase, water retention potential estimation, nutrient recovery potential assessment.
Env consequences: Optimized utilization of water resources will lead to an adaptation of the farm and farming system to ongoing climate change
Social consequences: One of the biggest issues is the training the users to change their working habits and make optimal and efficient use of the proposed solution.
Developer: Lund University (Sweden)
Tech card

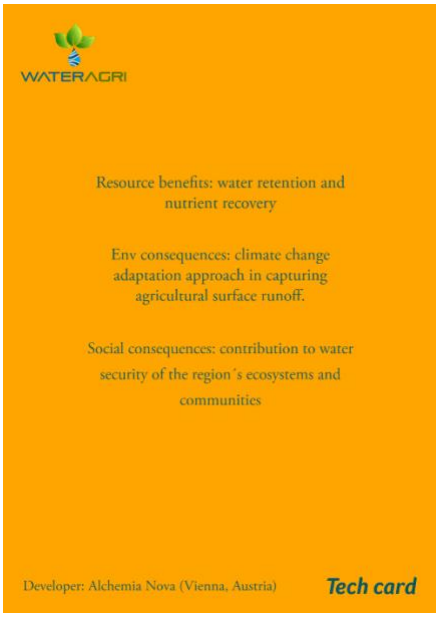

COSTS
One-off
Recurrent
1
1 per field
Enhanced water retainer concept
An organic soil conditioner liquid that that can be added to the soil surface to help plants to take-up water, reduce evaporation from bare soils and thus diminish the effects of drought and dehydration
Impact (one-off)
Environmental score: +1
Impact (every round)
Water savings: 1 per field
1
1
One-off
IMPACT
Every round

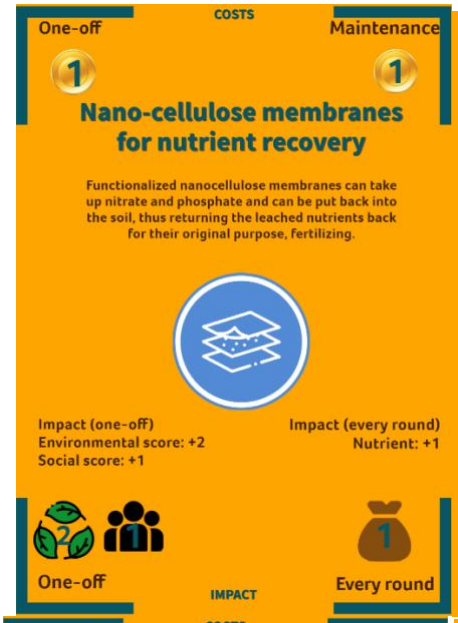

WATERAGRI
Resource benefits: reduced irrigation water consumption.
Env consequences: extended endurance of crops during drought periods and better yield
Developer: Bay Zoltan Nonprofit Ltd. (Hungary)
Tech card

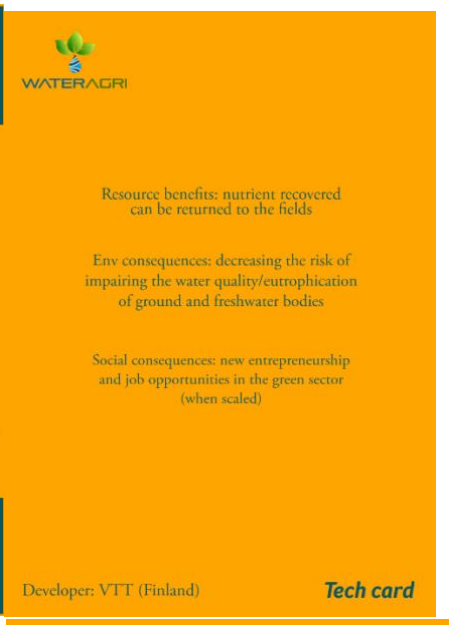

COSTS
One-off
Maintenance
4
1
A filter system for subsurface drainage water treatment using biochar
This technology provides a filter structure that can be inserted to the drainage pipe outlet to retain nutrients from subsurface agriculture drainage water
Impact (one-off)
Environmental score: +2
Social score: +1
Impact (every round)
Nutrients: +2
1
2
One-off
IMPACT
Every round


WATERAGRI
Resource benefits: nutrient retention.
Env consequences: Reduction of potential eutrophication of following water bodies, habitat protection, bio-based plastics are used
Social consequences: Through easy handling more individuals can be reached and inspired to care (more) about water usage and nutrient recovery locally
Developer: Alchemia Nova (Vienna, Austria)
Tech card

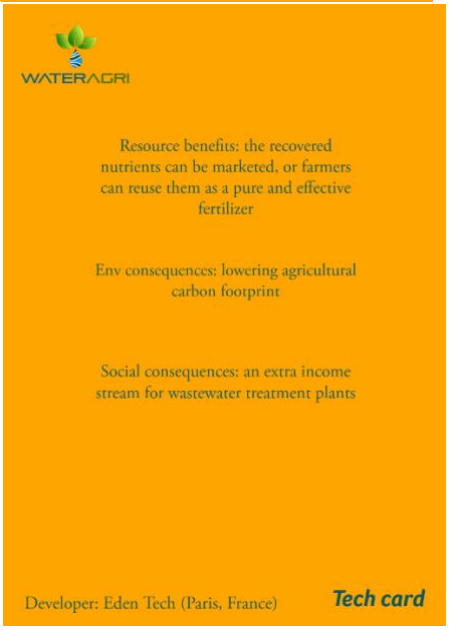

One-off
COSTS
Maintenance
3
1
A bio-inspired multi-layer filter system using biochar adsorbents for water and nutrient uptake
A multi-layered drainage system designed to retain water and nutrients from agricultural runoff (overland flow)
Impact (one-off)
Environmental score: +1
Social score: +1
Impact (every round)
Nutrient: +1
Water savings: 1 (total)
1
1
1
1
One-off
IMPACT
Every round

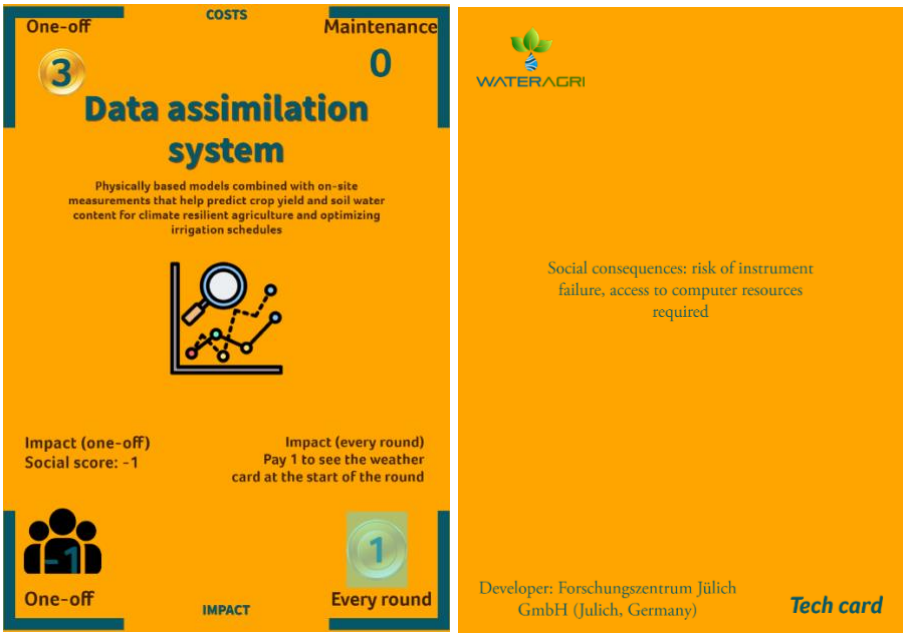

WATERAGRI
Resource benefits: water retention and nutrient recovery
Env consequences: climate change adaptation approach in capturing agricultural surface runoff.
Social consequences: contribution to water security of the region´s ecosystems and communities
Developer: Alchemia Nova (Vienna, Austria)
Tech card


COSTS
One-off
Maintenance
1
1
Nano-cellulose membranes for nutrient recovery
Functionalized nanocellulose membranes can take up nitrate and phosphate and can be put back into the soil, thus returning the leached nutrients back for their original purpose, fertilizing.
Impact (one-off)
Environmental score: +2
Social score: +1
Impact (every round)
Nutrient: +1
2
1
1
One-off
IMPACT
Every round

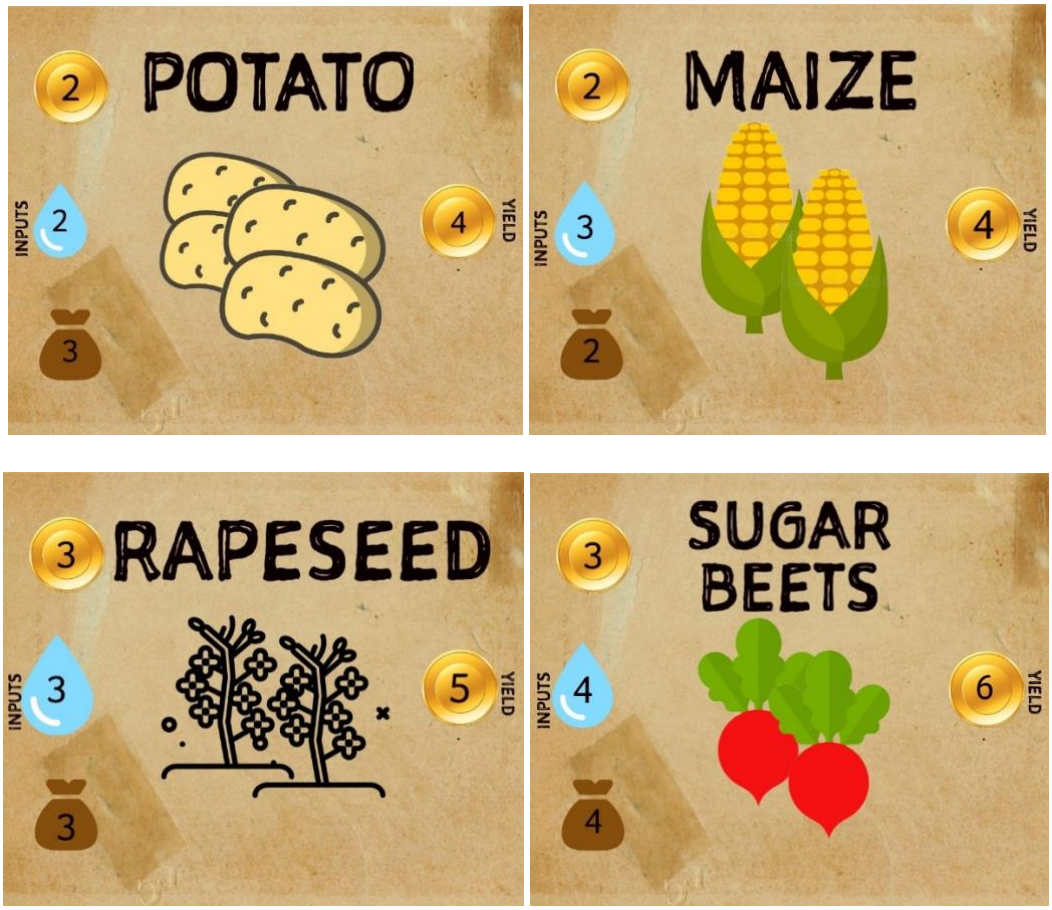

WATERAGRI
Resource benefits: nutrient recovered can be returned to the fields
Env consequences: decreasing the risk of impairing the water quality/eutrophication of ground and freshwater bodies
Social consequences: new entrepreneurship and job opportunities in the green sector (when scaled)
Developer: VTT (Finland)
Tech card


One-off
COSTS
1
2
Microfluidic system for nutrient recovery
This innovative solution utilizes microfluidic networks and adsorbent microbeads to recover nutrients from agricultural wastewater.
Impact (one-off)
Environmental score: +1
Social score: +1
Impact (every round)
Nutrient: +2
1
2
One-off
IMPACT
Every round


WATERAGRI
Resource benefits: the recovered nutrients can be marketed, or farmers can reuse them as a pure and effective fertilizer
Env consequences: lowering agricultural carbon footprint
Social consequences: an extra income stream for wastewater treatment plants
Developer: Eden Tech (Paris, France)
Tech card

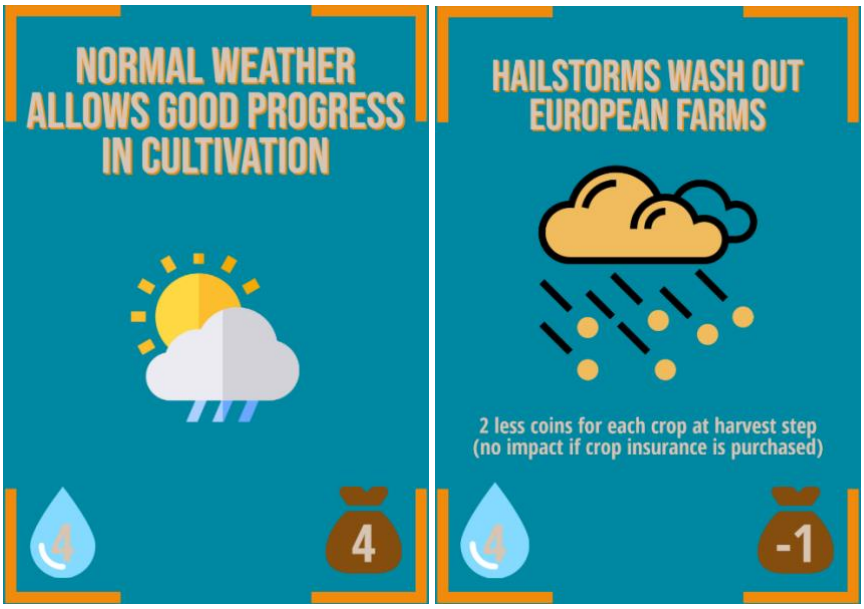


7.1.4. Crop cards

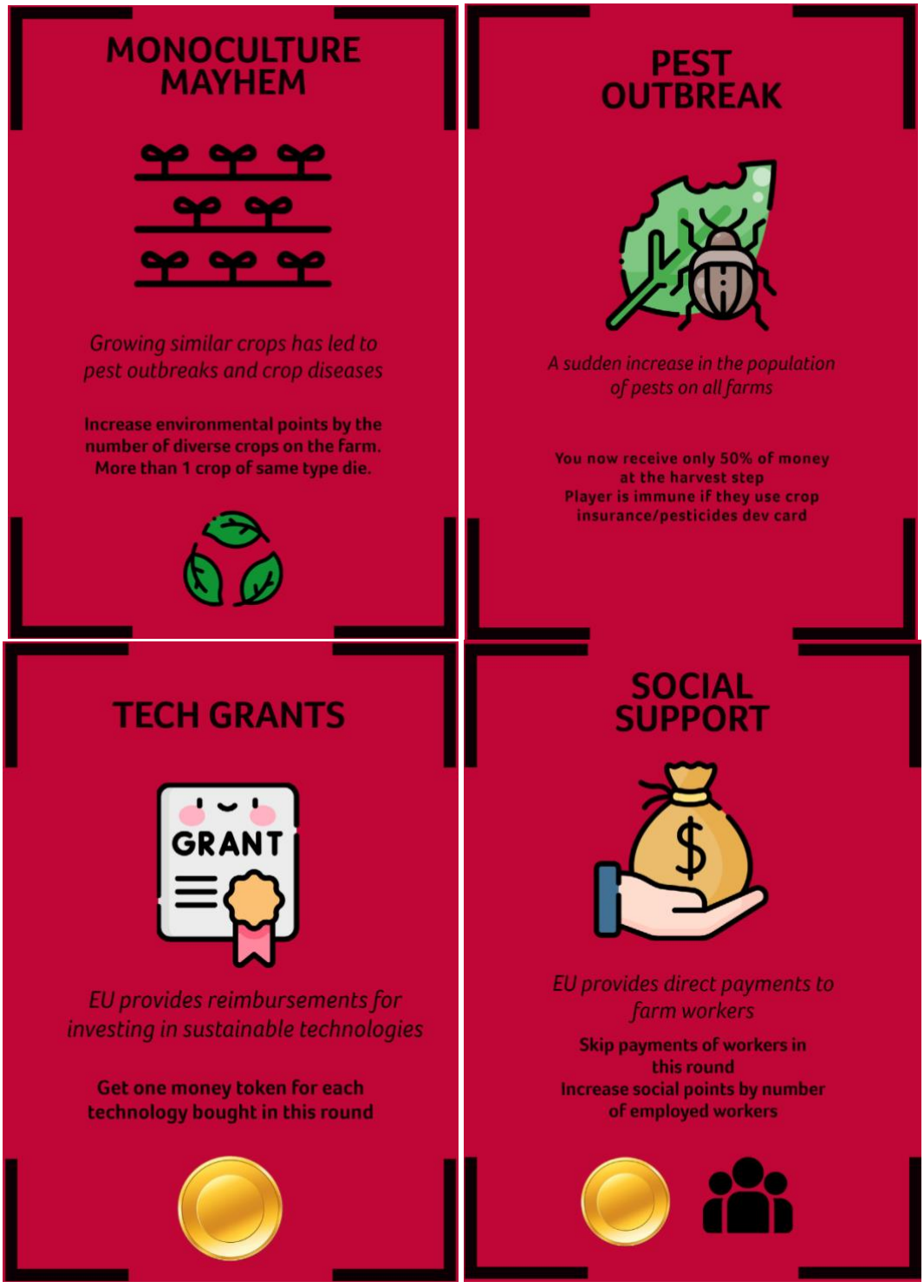


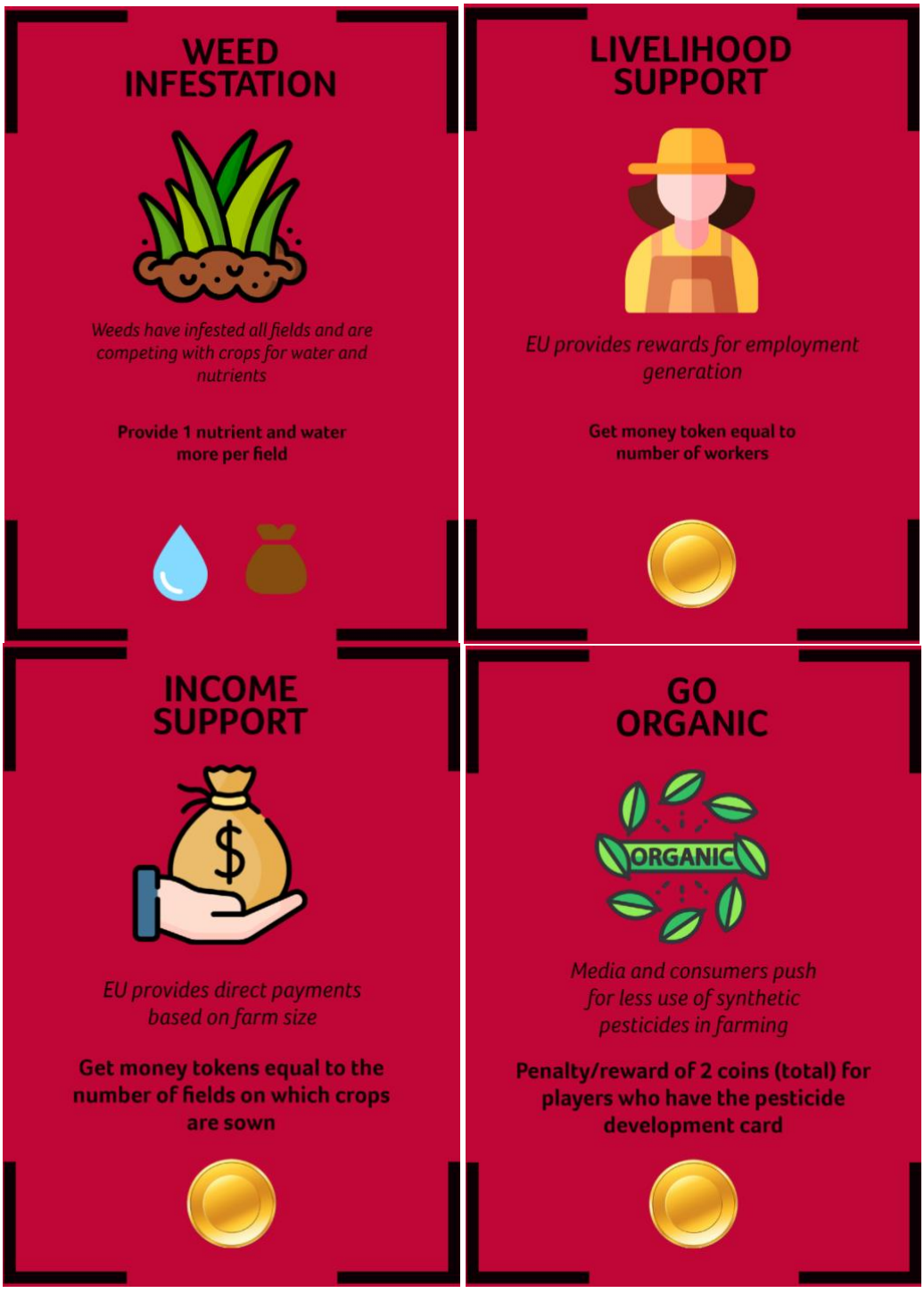
7.1.5. Development cards

7.1.6. Weather cards


NORMAL WEATHER ALLOWS GOOD PROGRESS IN CULTIVATION
4
4
HAILSTORMS WASH OUT EUROPEAN FARMS
2 less coins for each crop at harvest step
(no impact if crop insurance is purchased)
4
-1

7.1.7. Event cards




WEED INFESTATION
Weeds have infested all fields and are competing with crops for water and nutrients
Provide 1 nutrient and water more per field
LIVELIHOOD SUPPORT
EU provides rewards for employment generation
Get money token equal to number of workers
INCOME SUPPORT
EU provides direct payments based on farm size
Get money tokens equal to the number of fields on which crops are sown
GO ORGANIC
ORGANIC
Media and consumers push for less use of synthetic pesticides in farming
Penalty/reward of 2 coins (total) for players who have the pesticide development card

7.2. Game download and use

The serious game AgriLemma consists of different materials and paraphernalia. To organize a game session, stakeholders must print some materials and arrange the physical tokens independently. The following printable materials can be downloaded from the WATERAGRI website (available in May 2023):

1. Game board (x1) – original size 80mm x 600 mm
2. Game manuals (one for each player and one for the facilitator)
3. Reference cards (one for each player and one for the facilitator)
4. Technology cards (80 cards in total – 8 x 10 types of technologies)
5. Crop cards (36 crop cards in total – 6 x 6 types of crop cards)
6. Development cards (24 development cards in total – 8 x 3 types of development cards)
7. Weather cards (15 in total - extreme heatwave (x2), summer drought (x2), fair weather (x4), normal weather (x4), and hailstorms (x3).)
8. Event cards (15 in total – monoculture mayhem x 2, pest outbreak x2, tech grants x 2, social support x 1, weed infestation x 2, livelihood support x 1, income support x 1, go organic x 1, loans x 1, crop disaster x 2)
9. Wetland cards – 16 cards to be given to the player when they buy a wetland technology

The PDFs available on the WATERAGRI website contain the required number of items for each of the cards. Users can download, print, and cut the cards to prepare the materials. If people want to adapt the game to their requirements, editable versions of these cards can be requested by emailing a.mittal@tudelft.nl.

In addition to the above printable materials, other objects need to be obtained:

Item	Quantity	Image	Remarks
Round tracker	1		The shape of the tracker need not be the same. Feel free to use any token
Round step tracker	1		The shape of the tracker need not be the same. Feel free to use any token
Player pawns	4 red pawns 4 blue pawns 4 yellow pawns 4 green pawns		
Worker pawns	10		Feel free to use any colour other than red, green, yellow and blue (to avoid confusion with the play pawns)
Technology dice	1		Any six-sided dice will do
Water tokens	120		Feel free to use any blue-coloured token, e.g., blue cubes
Nutrient tokens	120		Feel free to use any brown-coloured token, e.g., brown cubes
Money coins	50 coins of value 1 50 coins of value 2 30 coins of value 5 15 coins of value 10		Instead of coins, poker chips or notes can also be used

These can be bought from local game shops or ordered online. Two examples of web stores that have a good selection are https://www.spelspul.nl/gb/ and https://www.spielematerial.de/en/. Please note this is not an exhaustive list, and we do not intend to promote these websites exclusively.