

## INTRODUCTION

Simulation-based game framework to enhance engineering students' decision-making skills by requiring players to balance resource use, economic considerations, and socio-environmental impacts to achieve long-term sustainability, aligned with the **Engineering for One Planet (EOP)** learning outcomes

- System Thinking
- Social Responsibility
- Environmental Impact Assessment
- Critical Thinking

Backend analysis using explainable AI to assess decision quality and reinforce sustainability learning objectives.

Supports the Sustainable Systems Engineering minor in the College of Engineering at GMU, and master's level data analytics engineering program.

- OR 531 *Introduction to Analytics and Modeling (pilot implementation)*,
- SYST 496 *Sustainable Systems Methods Practicum*
- SYST 414 *Systems Thinking*,
- SYST 473 *Decisions and Risk Analysis*,
- EVPP 434 *Food-Energy-Water-Climate Nexus*.

## APPROACH

### Building Water Resilience in Drought-Prone Agricultural Regions

#### Web-based Architecture

- Presentation layer, game flow layer, game logic layer, and data layer

#### Game Mechanics

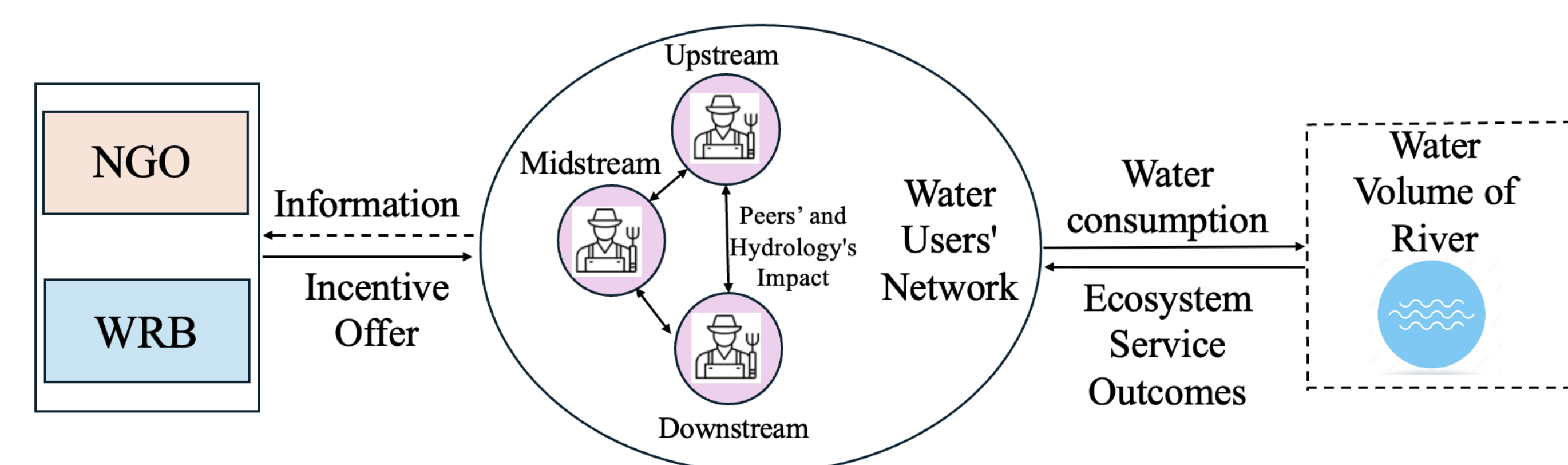
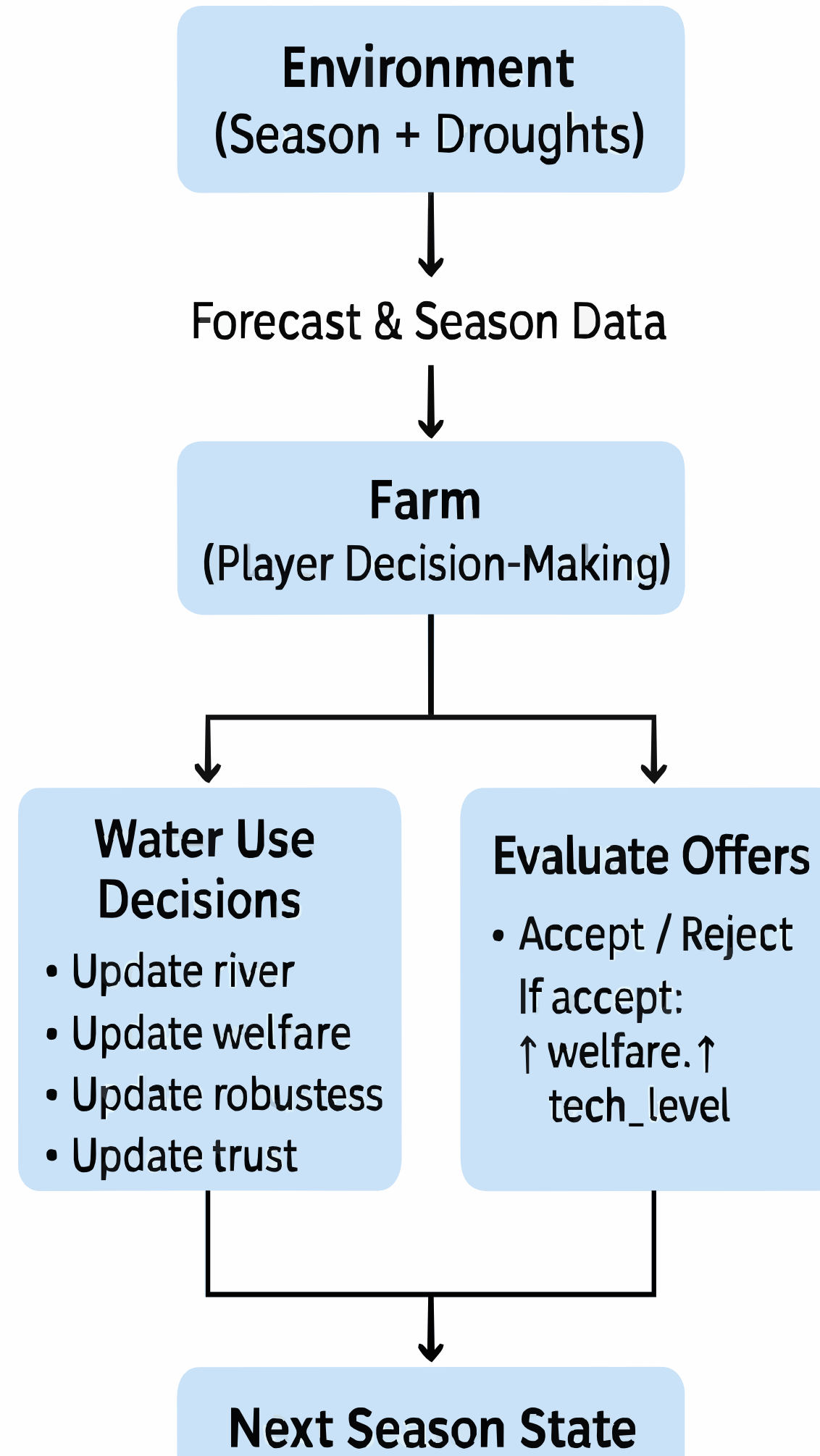
- 8-Season Drought Scenario:** Players experience long-term consequences of water use decisions
- Three Farmers:** Upstream, midstream, and downstream locations demonstrate interdependencies
- Dual Incentive System:** NGO offers monetary incentives; WRB provides cost-sharing for efficiency equipment
- Trust Dynamics:** Modeled using sigmoid functions; evolves based on player decisions and peer influence
- Multi-language Support:** Available in English, Portuguese, and Spanish for broader accessibility

#### Technical Implementation

- Platform: Godot Engine (cross-platform, open-source)
- Backend: Firebase for real-time data collection and analysis

#### Visual Feedback

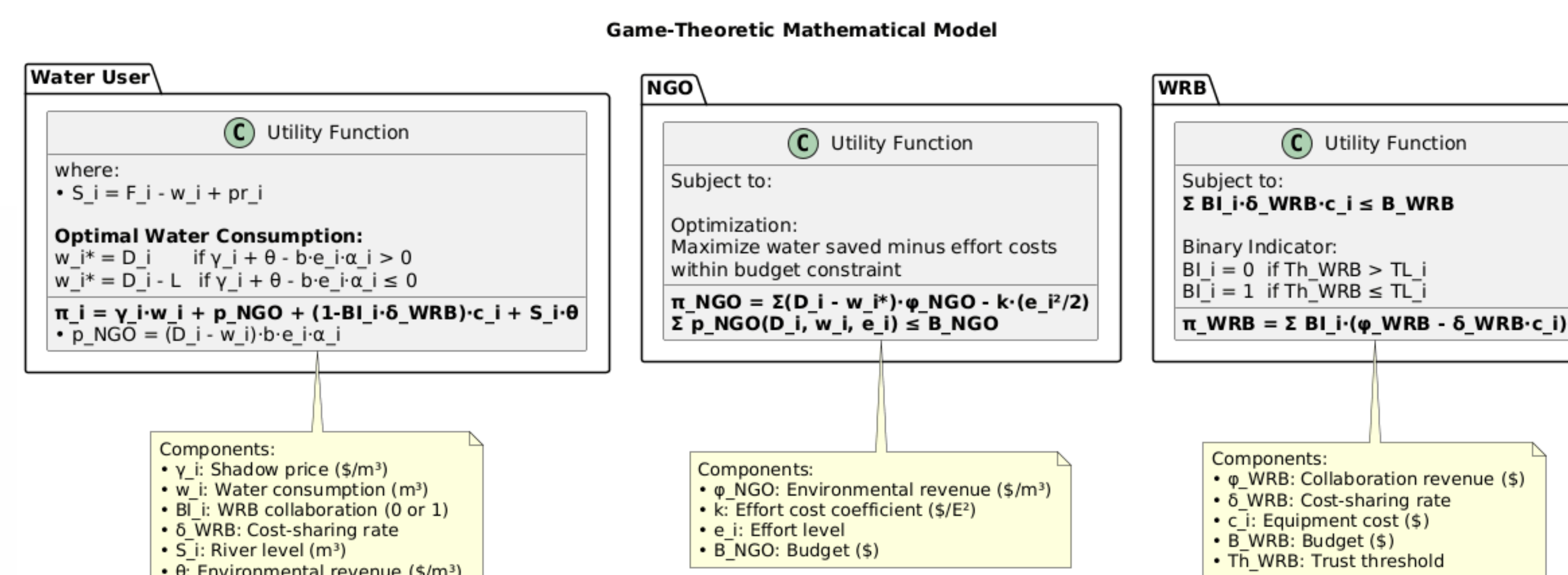
- Dynamic crop health, river levels, performance dashboards



## EVALUATION AND IMPACT



### Game-Theoretic Model for Optimal Policies



### Study Design

- Comprehensive and accessible tutorial
- Sample size: 69 master's students in OR 531
- Method: summative evaluation using pre- and post-surveys assessed learning gains in systems thinking (4 questions), environmental impact assessment (4 questions), critical thinking (3 questions), and social responsibility (4 questions), two open-ended questions
- Analysis: Paired t-tests, text mining of open-ended responses



### Statistical Significance

- All four learning outcome categories showed significant improvement (p-value < 0.05)

### Sample Student comments

"The trust dynamics helped me understand why long-term relationships matter in resource management."

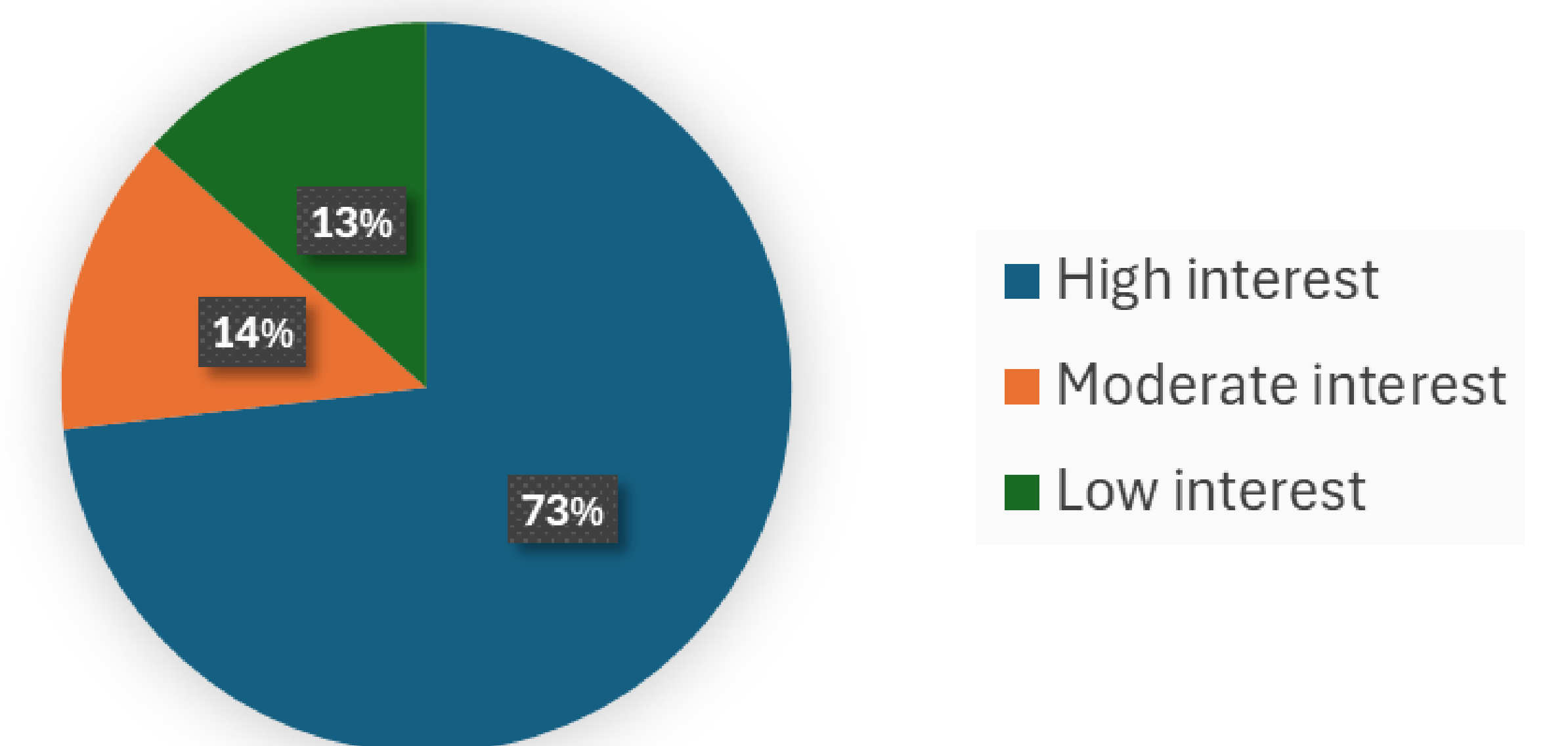
"Seeing my crops wither made the consequences real - numbers alone wouldn't have had the same impact."

"I initially over-consumed water but shifted strategies when I saw how my upstream decisions affected downstream farmers."

"The simulation showed me that small choices with limited information can greatly change future outcomes."

## PLAN FOR SCALING UP

### AI-Resilience-Sustainability Interface



### Refinements in Progress

- Additional drought scenarios with varying severity
- Performance comparison dashboard improvements
- Update the simulation module and scenarios for other application areas, such as evacuation planning in the face of a hurricane

### Scaling Strategies at GMU

- Integration with additional STEM courses
  - OR/SYST 335 and OR 635: Discrete Systems Simulation (undergraduate & graduate levels)
- Data collection for complementary statistical analysis at the undergraduate and graduate levels, considering the varying technical backgrounds of students, to enable a meaningful evaluation of the simulation framework
- Development of an instructor's guide with learning objectives and discussion prompts
- Disseminate materials through Dr. Mohebbi's website, ISE website, and social media for broader adoption and engagement



### Outreach Activities beyond GMU

- Showcase simulation games at VA high schools
- Disseminate materials to colleagues in Brazil and Latin America
- Open educational resource (OER) publication

## ACKNOWLEDGMENTS

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## REFERENCES

- Momeni, B., & Mohebbi, S. (2025). Differential game theoretic models for designing water conservation incentives. *Decision Analysis*, 22(2), 120-146.
- The Lemelson Foundation. (2022). The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education (2022). Retrieved [December 18, 2025].