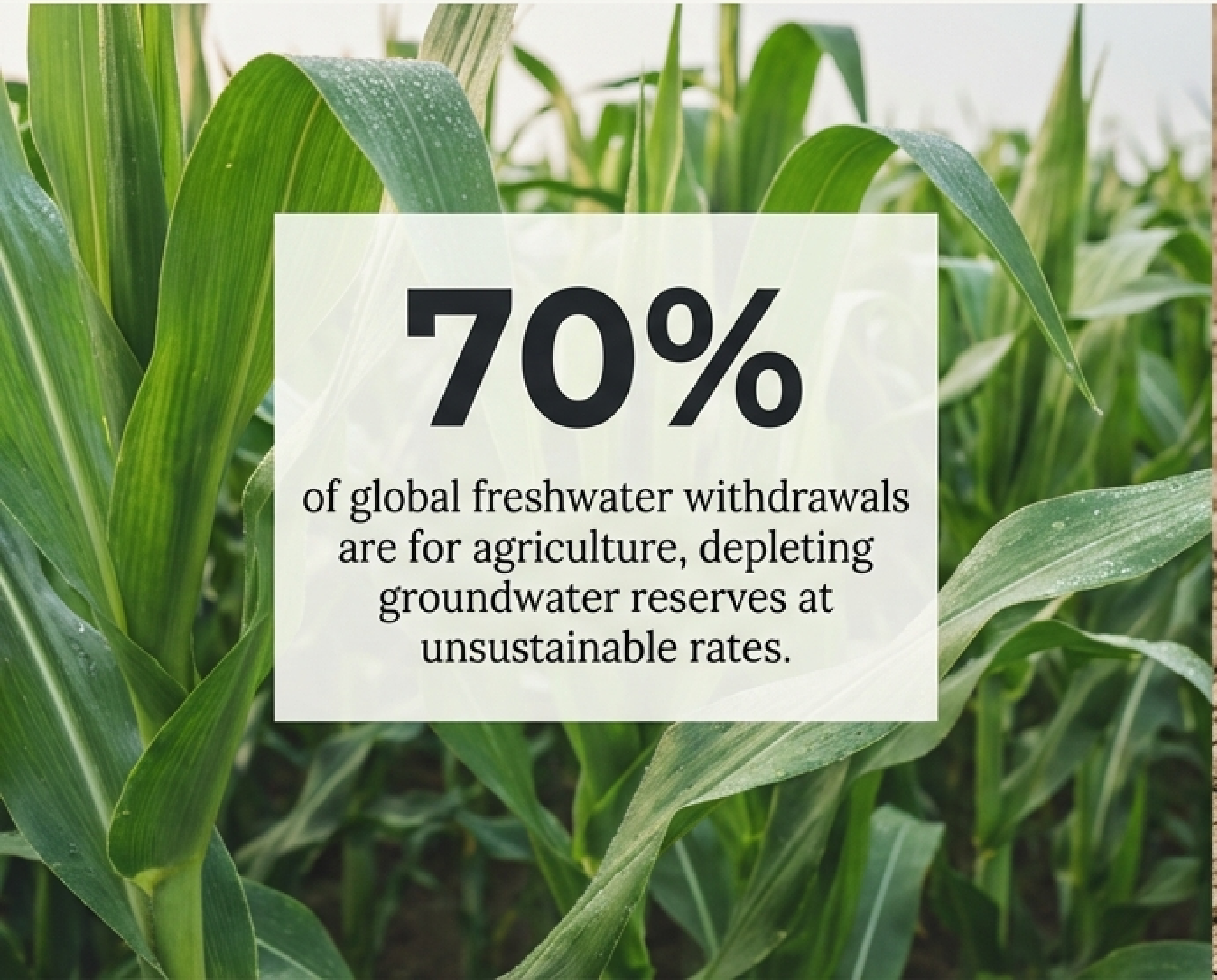
Smarter Water: A Reinforcement Learning Showdown for Sustainable Farming

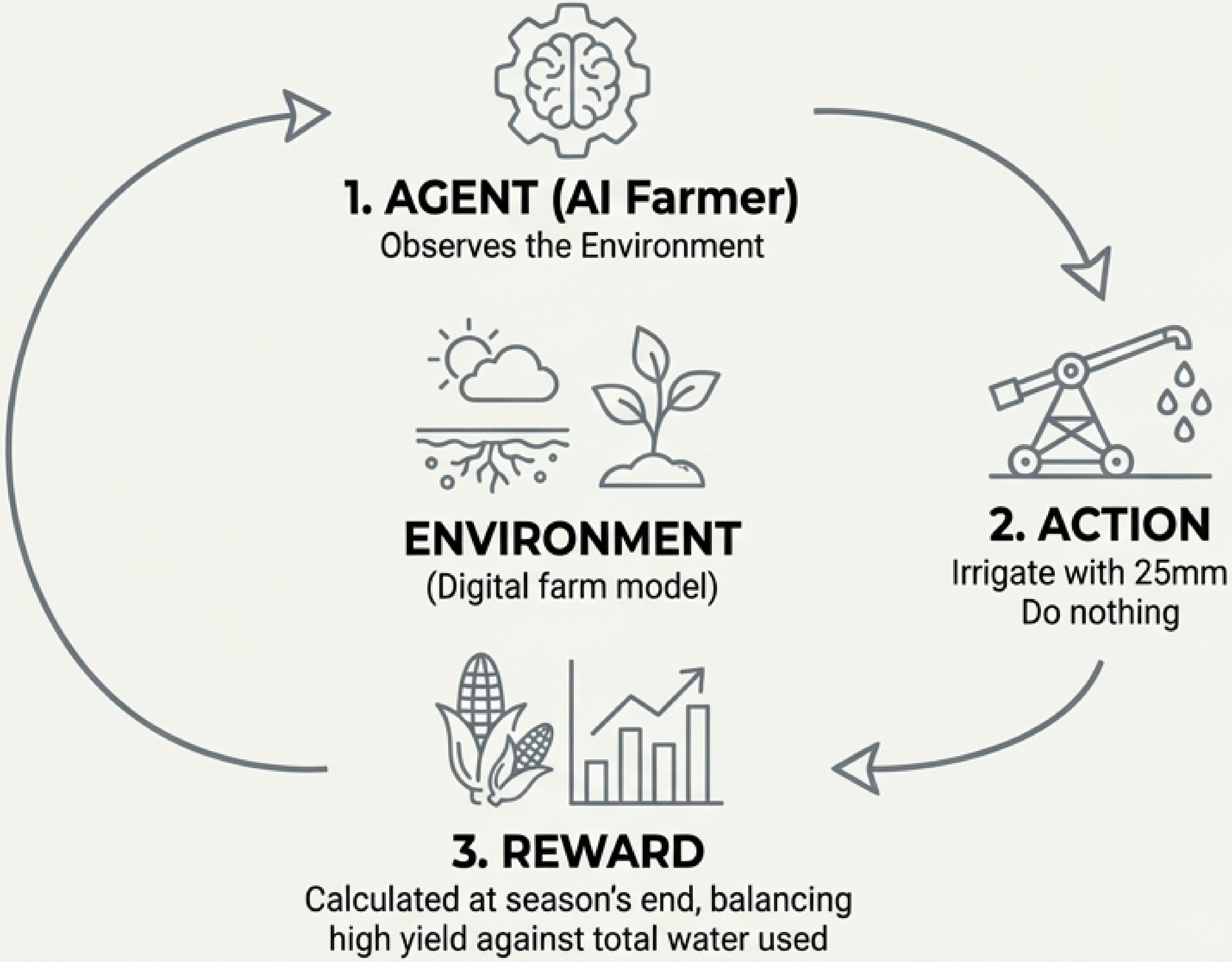
Comparing Profit-Driven (PPO) vs. Efficiency-Focused (A2C) AI for Optimizing Maize Irrigation

Agriculture faces a critical challenge: produce 50% more food while using dramatically less water.



Reinforcement Learning (RL) offers a new path forward, training AI agents to make optimal, long-term decisions.

In agriculture, RL is uniquely suited to handle challenges like sparse actions (decisions aren't made every second) and delayed rewards (the result is only clear at the end of the season).



We compare two leading RL strategies, each with a different philosophy for success.

PPO

The Profit Maximizer

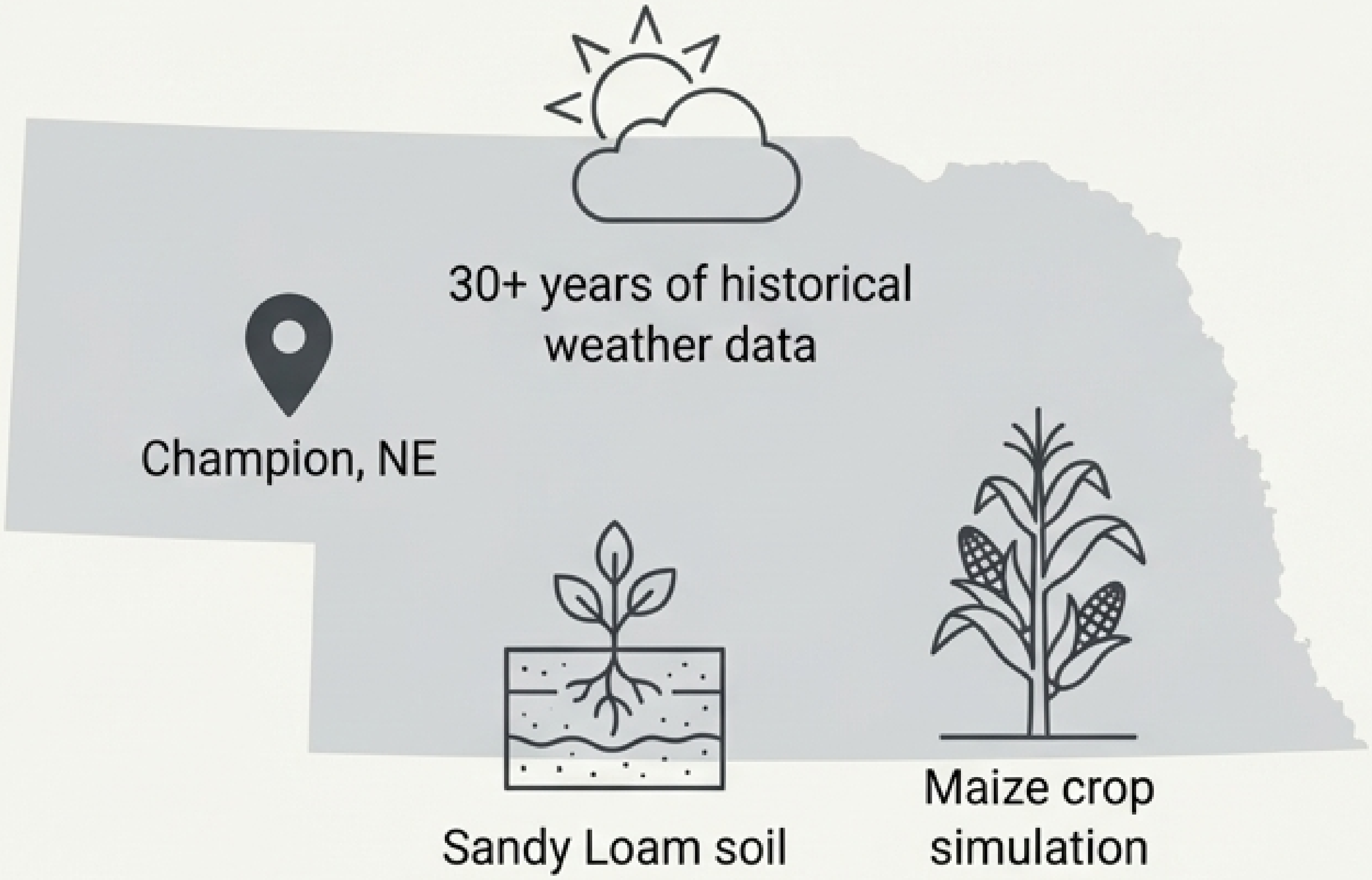
A robust, established algorithm that excels at finding the most profitable balance between yield and resource cost.

A2C

The Efficiency Champion

A nimble, resource-conscious algorithm that aims to produce the absolute most from every unit of input.

The algorithms were tested in a high-fidelity simulation of a maize farm in Champion, Nebraska.



Simulation Parameters

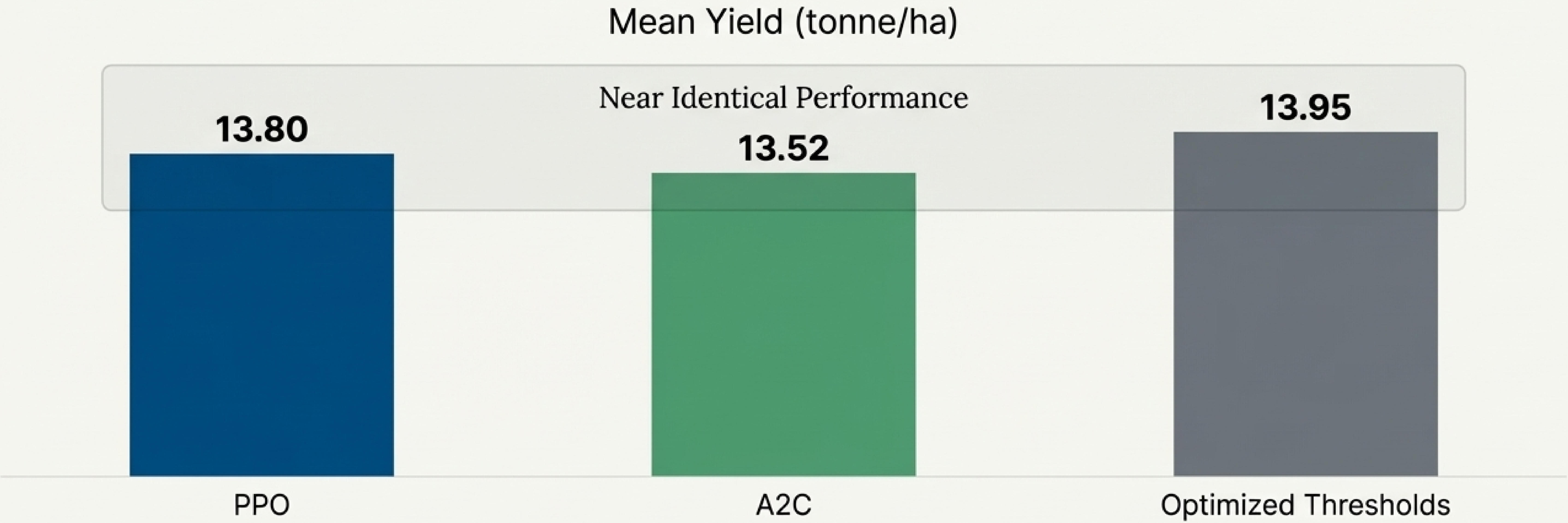
ENVIRONMENT MODEL: AquaCrop-OSPy, a simulation focused on crop yield response to water.

THE TASK: The AI agent makes a daily decision: apply 25mm of water or do nothing.

THE GOAL: Maximize an end-of-season reward that heavily rewards final yield but penalizes cumulative water use.

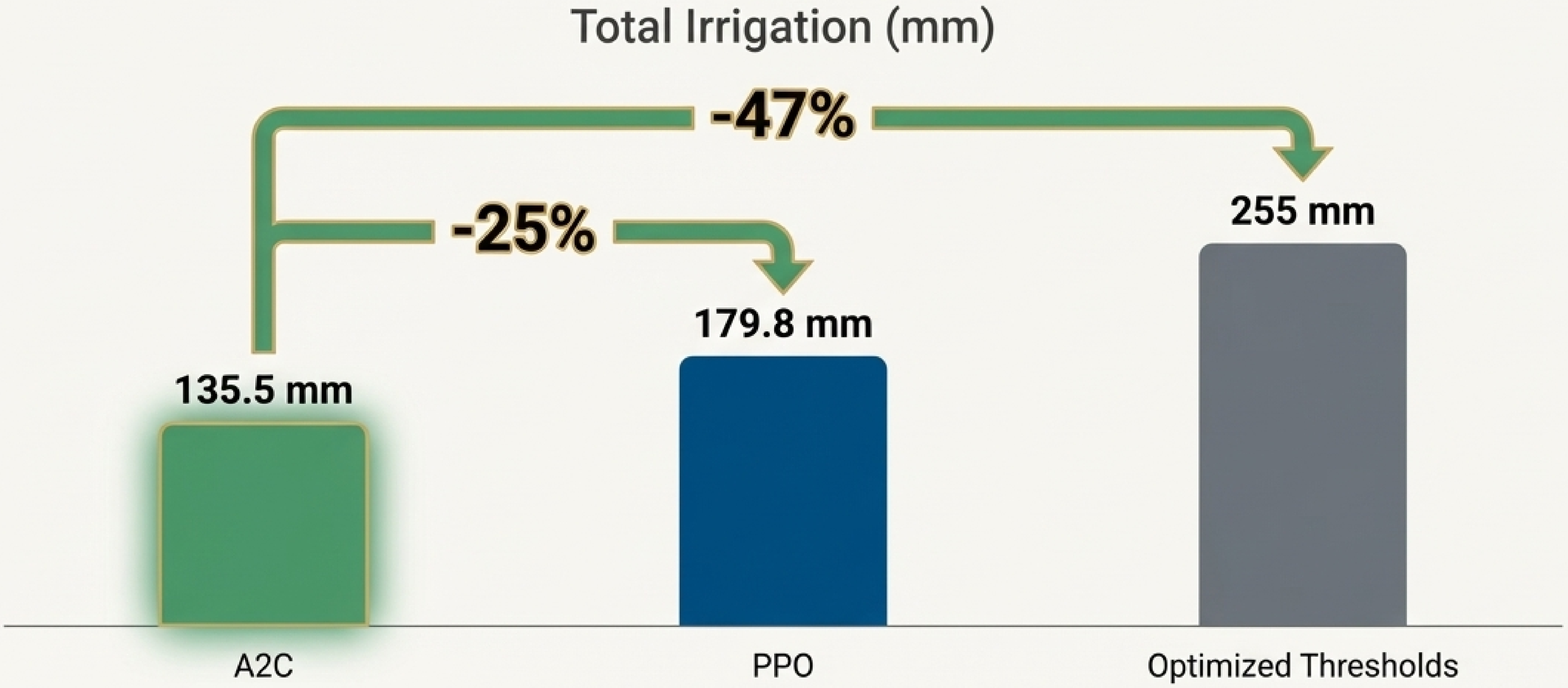
Both AI agents learn to maintain high yields, performing on par with water-intensive conventional methods

While PPO is slightly ahead, the yield difference between PPO, A2C, and the best conventional strategy (Thresholds) is negligible. All successfully learn to maintain high productivity.



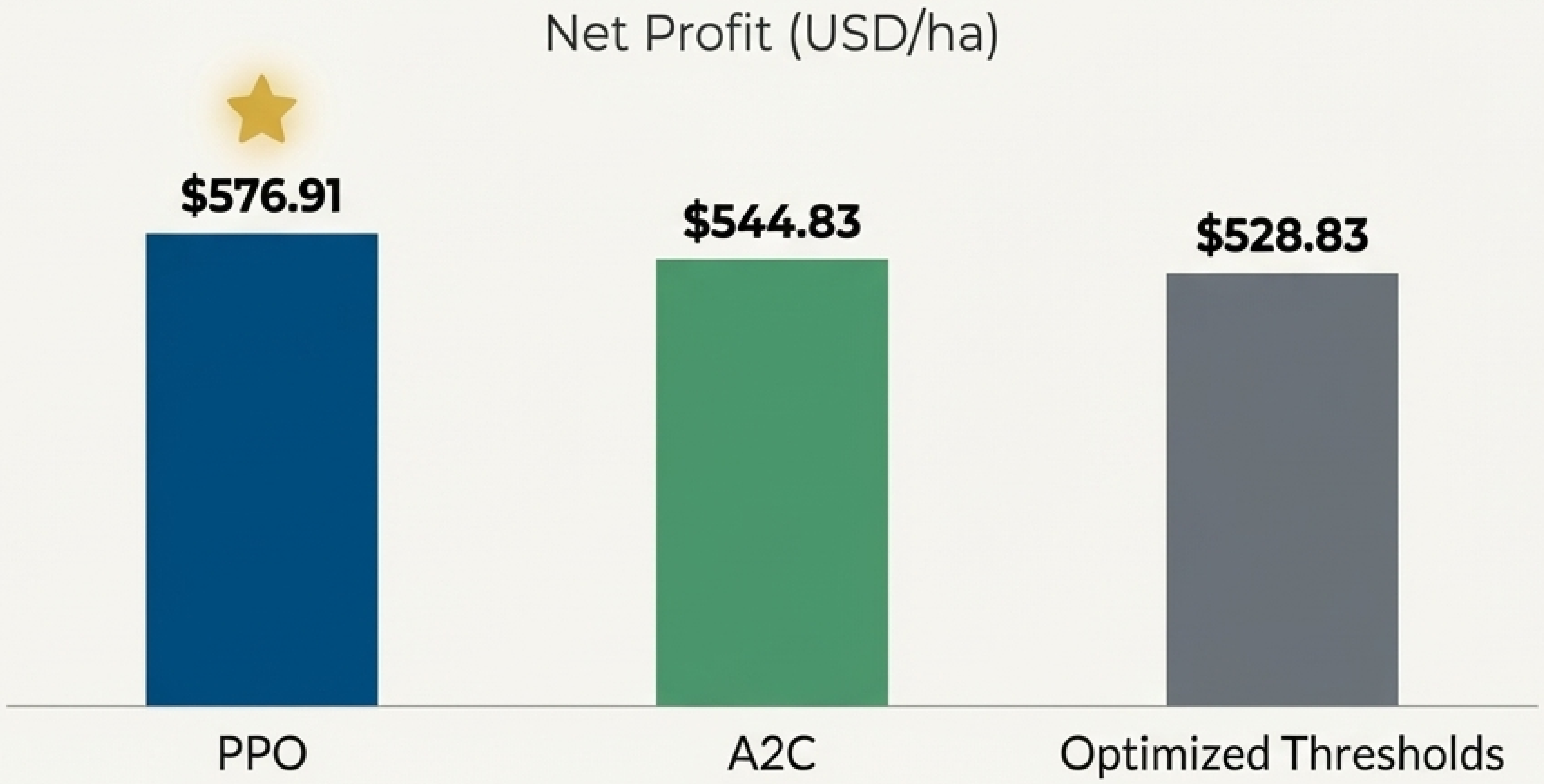
A2C demonstrates radical water conservation, using 47% less irrigation than the best-optimized conventional strategy.

A2C uses dramatically less water than any other irrigated strategy. This is its core strength.



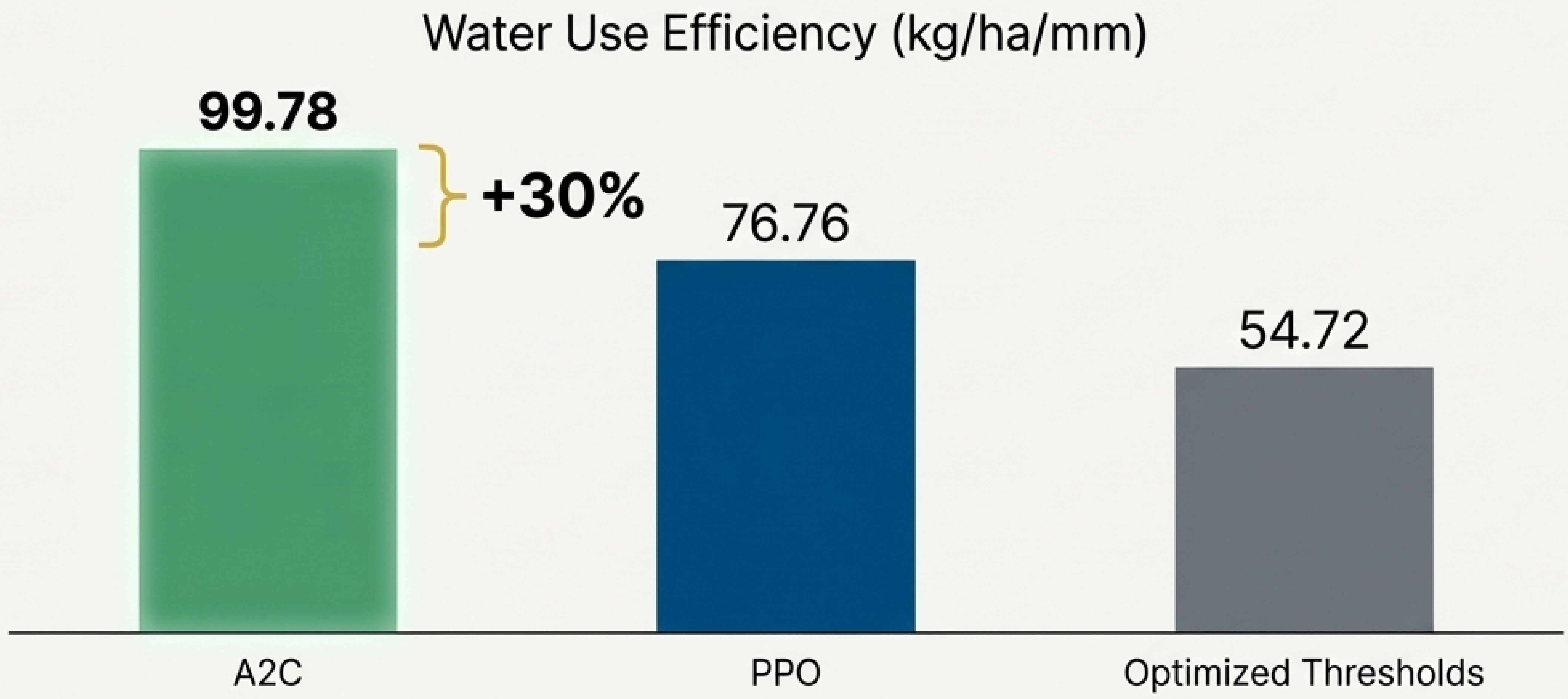
PPO's balanced approach delivers the highest net profit, confirming its strength as an economic optimizer.

By using slightly more water to secure a slightly higher yield, PPO generates the best economic return. However, A2C remains highly profitable, outperforming all conventional methods.



A2C is the undisputed champion of efficiency, producing 30% more crop per millimeter of water than PPO.

This metric (kg/ha/mm) reveals how effectively each strategy converts water into yield. A2C's score is vastly superior to all others.



The results reveal a clear trade-off: PPO wins on profit, while A2C wins on sustainability.

There is no single ‘best’ algorithm; there is the right tool for the right job.

Highest Profit PPO $576.91 /ha	Lowest Water Use A2C 135.5 mm
Highest Water Efficiency A2C 99.78 kg/ha/mm	Highest Yield Near Tie

The right AI strategy depends entirely on the agricultural context and primary objective.

Choose PPO when...

The Profit Maximizer

- ✓ Maximizing profit is the primary objective.
- ✓ Water availability is moderate and costs are manageable.
- ✓ Stable, robust performance is critical.

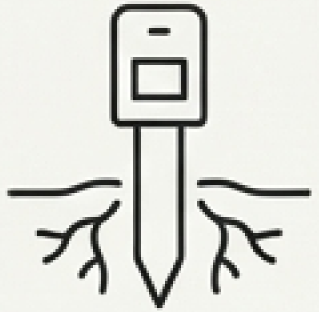
Choose A2C when...

The Efficiency Champion

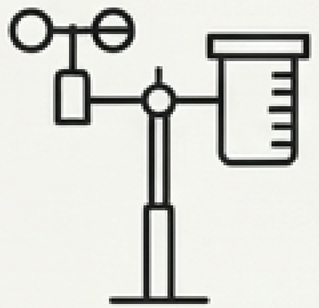
- ✓ Water is scarce, expensive, or heavily regulated.
- ✓ Sustainability and water conservation are the top priorities.
- ✓ The goal is to achieve the highest possible water use efficiency.

These AI-driven strategies translate from simulation to the field, offering significant environmental benefits.

INPUTS



IoT Sensors: Soil Moisture

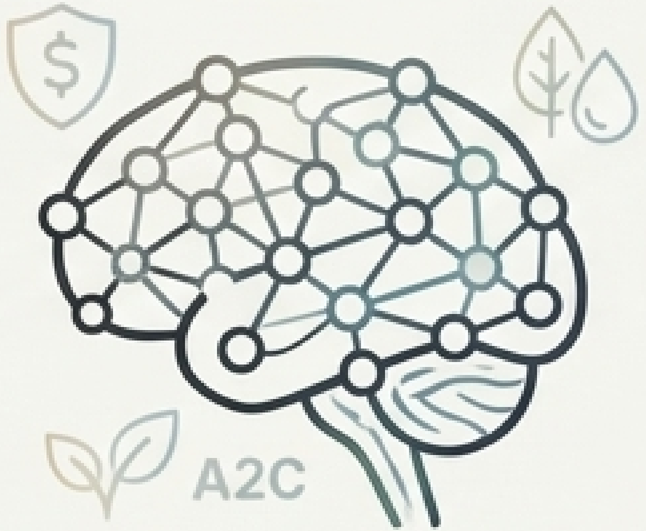


IoT Sensors: Weather Data

DECISION

AI Brain

RL Decision Engine



Real-time, automated decision-making

ACTION & IMPACT

Reduced groundwater depletion.

Lower energy consumption from pumping.

Decreased nutrient runoff and soil erosion.

NotebookLM

RL-powered irrigation is a transformative tool for balancing food security with environmental stewardship.

Summary of Key Findings

1. **Superior Performance:** Both RL agents vastly outperform conventional strategies in efficiency and profitability.
2. **A Clear Choice:** A distinct trade-off emerges: PPO (in #004E89) is the choice for maximizing profit, while A2C (in #4C9F70) is the choice for maximizing water conservation.

Future Research Directions

- Field trial validation
- Application to new crops and diverse climate conditions
- Integration of real-time weather forecasting

Research Credits & Resources

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Acknowledgments

The original framework by Alkaff et al., the AquaCrop-OSPy model, and the Stable-Baselines3 library.

Code Availability

https://github.com/alkaffulm/aquacropgymnasium

Thank You

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