# Reinforcement Learning Framework for Optimizing Planting Dates in Corn Yield under Climate Variability

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# Introduction

**Challenges in Agriculture**

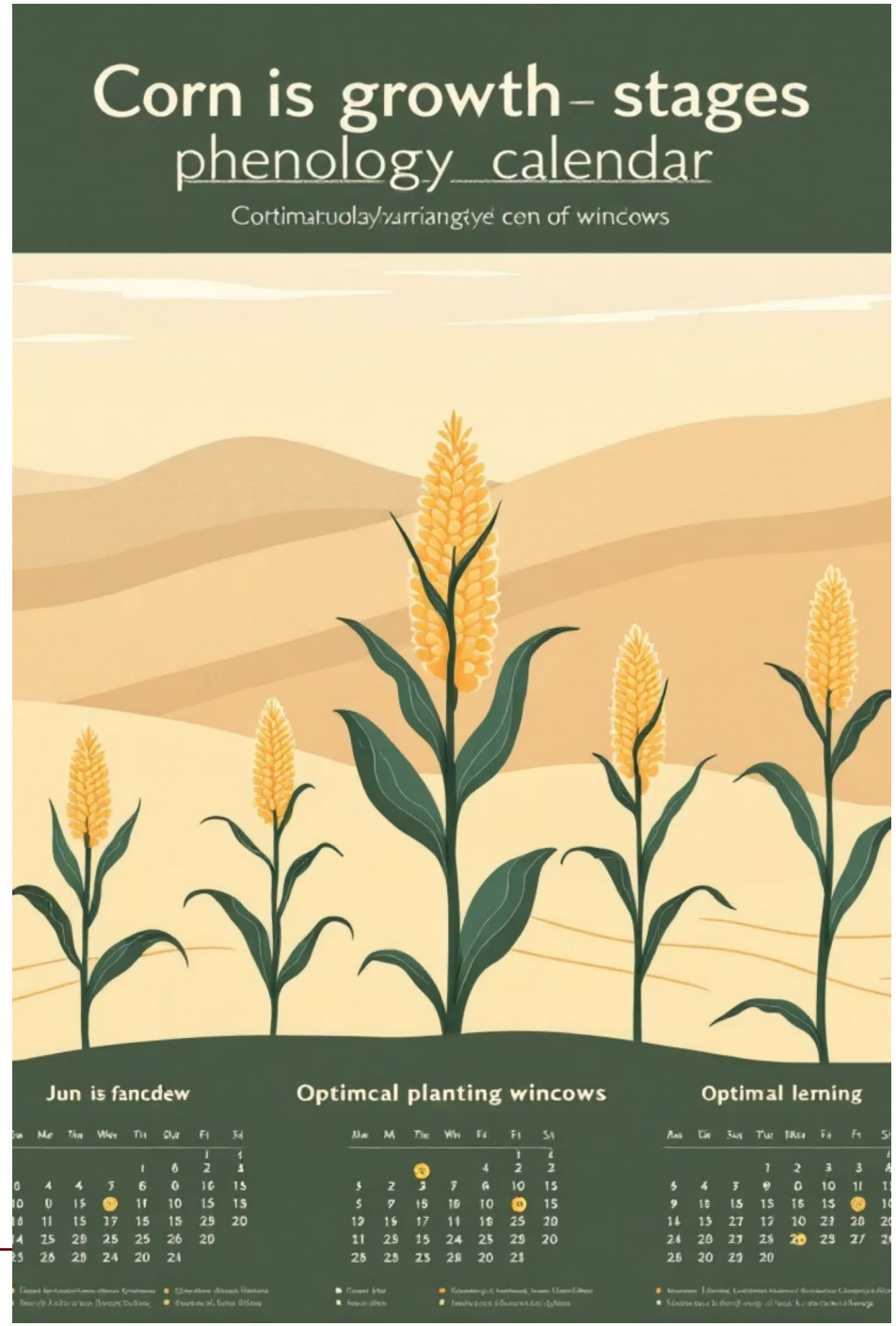
- **Climate uncertainty**: a growing challenge for agriculture.
- **Threats**: rising temperatures, extreme weather, unpredictable rain, droughts.
- **Need**: Flexible strategies for adapting agriculture to these emerging challenges and threats

# Introduction

## The Critical Role of Planting Date

### Why Planting Date Matters?

- Determines the **synchronization** between crop **phenology** and **seasonal climate**.
- Influences yield by **aligning** critical **growth stages** with optimal temperature, solar radiation, and soil moisture



# Introduction

## Determining the Planting Date

**EMPIRICAL METHODS**

Static Average: Simple, easy

**Limitations**: Fails in novel climates. Cannot adapt.

**PROCESS-BASED MODELS**

Mechanistic Growth Detailed

**Limitations**: Needs constant recalibration. Intensive computation

**REINFORCEMENT LEARNING**

Learns Optimal Actions: Adaptive, iterative.

Handles delayed rewards (harvest). Ideal for dynamic climate

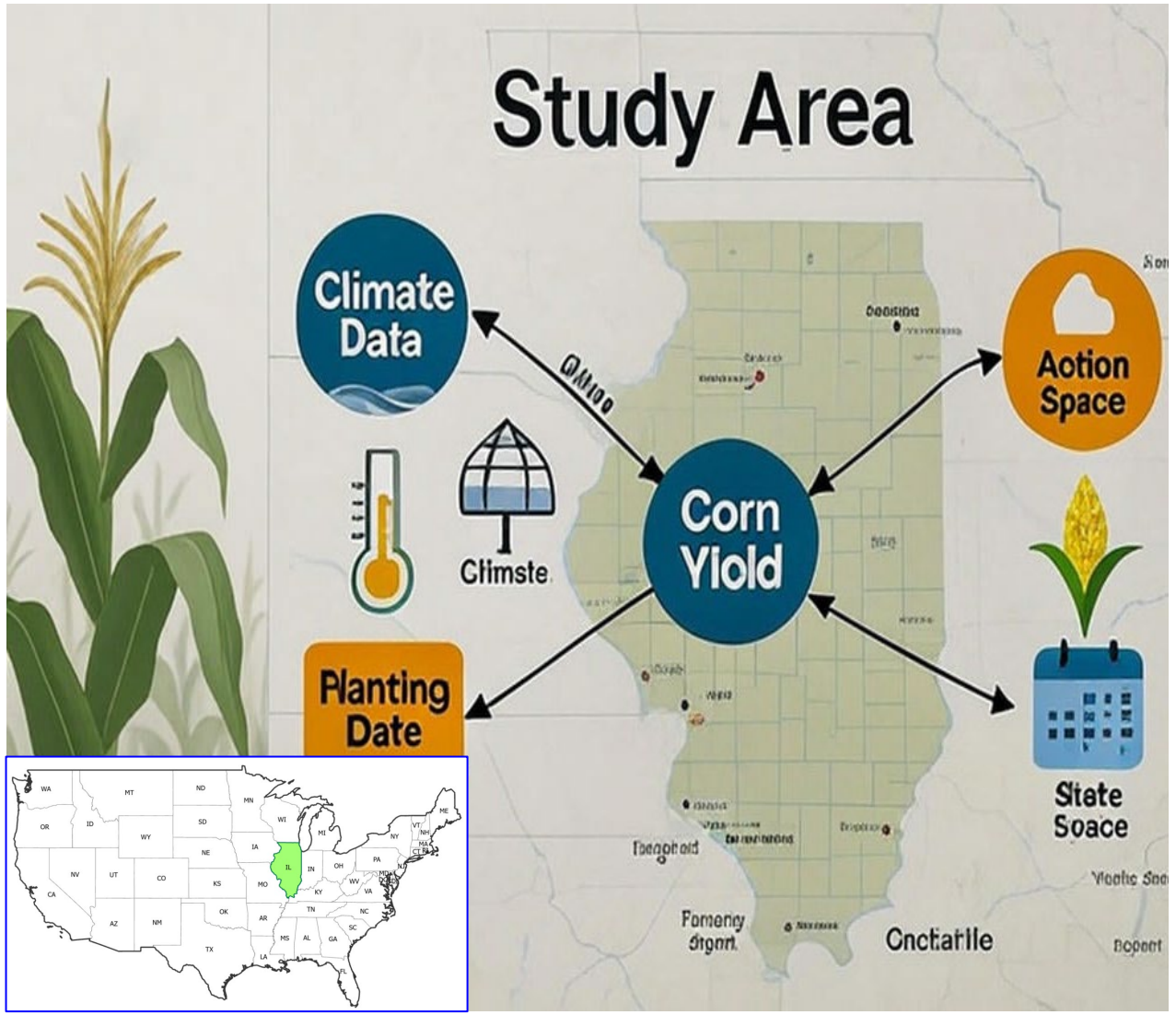
# Objectives

- Promote **adaptive agricultural strategies** to improve **corn** yield and resilience under climate uncertainty
- **Develop an RL-based framework** to optimize planting dates using climate, management, and soil data.
- **Integrate with the APEX crop model, ML models,** and future climate scenarios into the RL model for **climate-robust decision-making**.

# Study Area and Data

## Why Illinois?

- **Major corn-growing region:** >75% of Illinois land in agriculture.
- **Extensive data:** CEAP surveys provide long-term management and yield records
- **High productivity** but significant yield variability
- **Variable climate:** Humid continental with precipitation as a key constraint
- **Rainfed agriculture dominates**; precipitation is a key constraint



# Study Area and Data

## Cropland Data

- **Cropland:** 208 corn farmland sites with no-rotation
- **Management:** CEAP-I (2006) & CEAP-II (2016)

## Climate Data

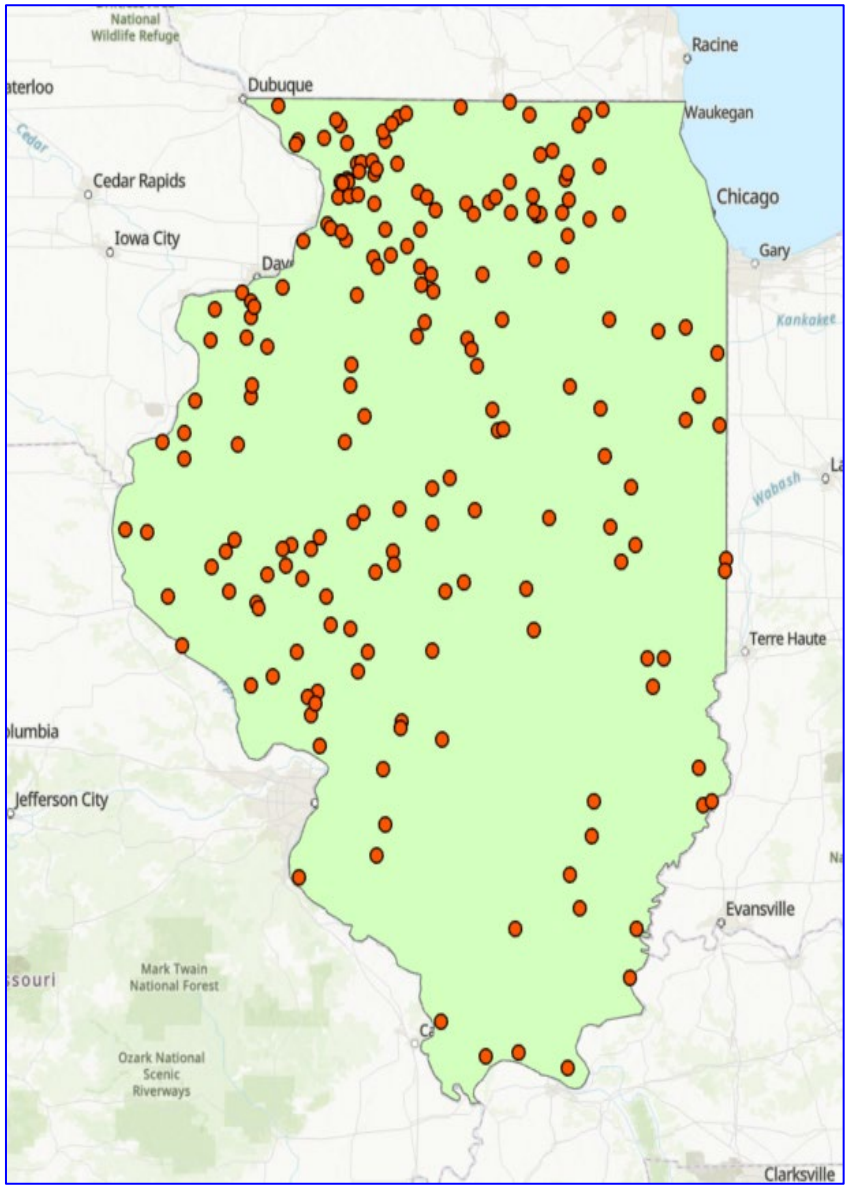
- **Historical data**: from MACAv2-METDATA dataset (University of Idaho)
- **Future projections:** Global Circulation Model (GCM) CNRM-CM (**RCP 4.5 & RCP 8.5**)

## Soil Data

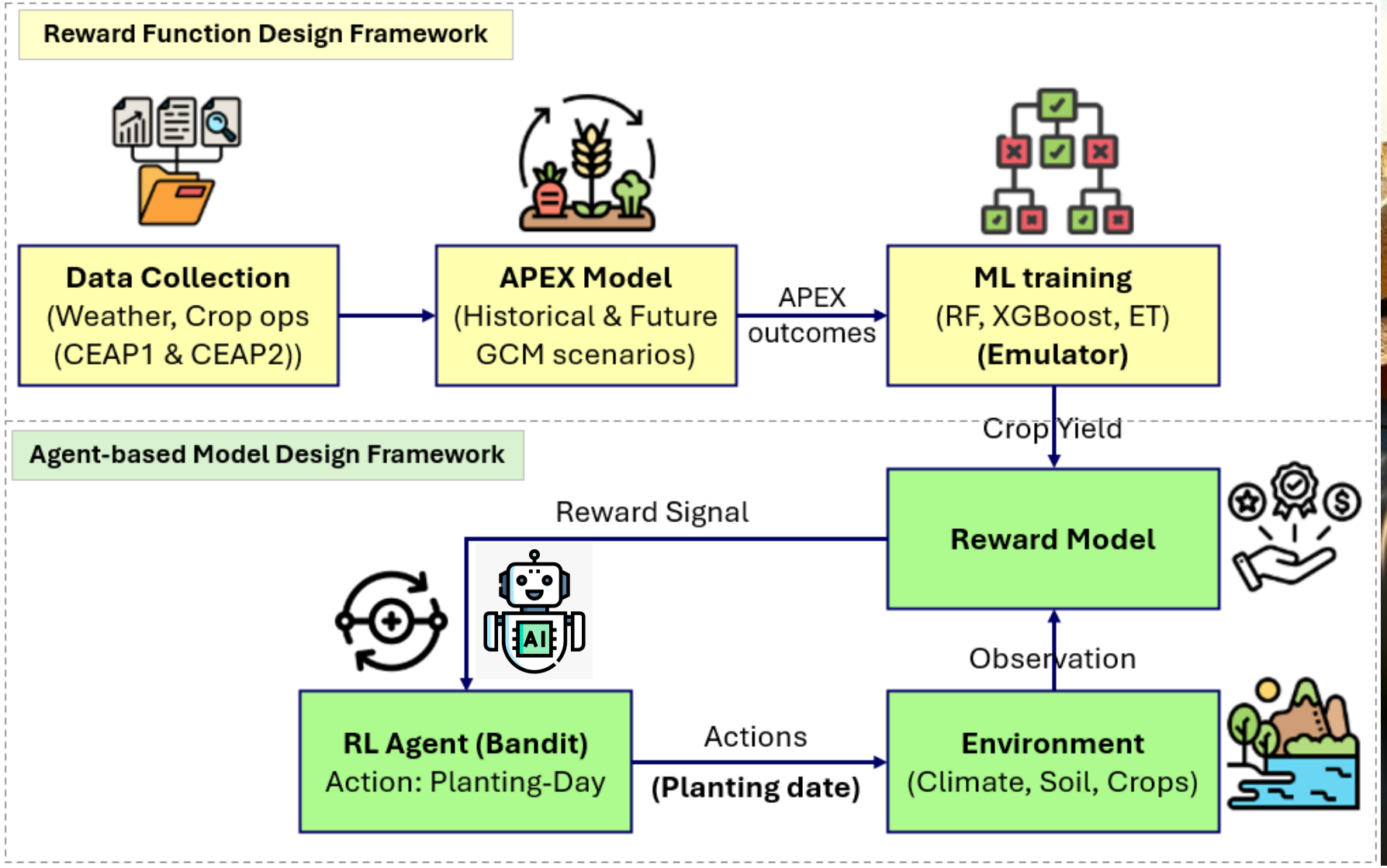
- **CEAP** soils database

## Timeframes

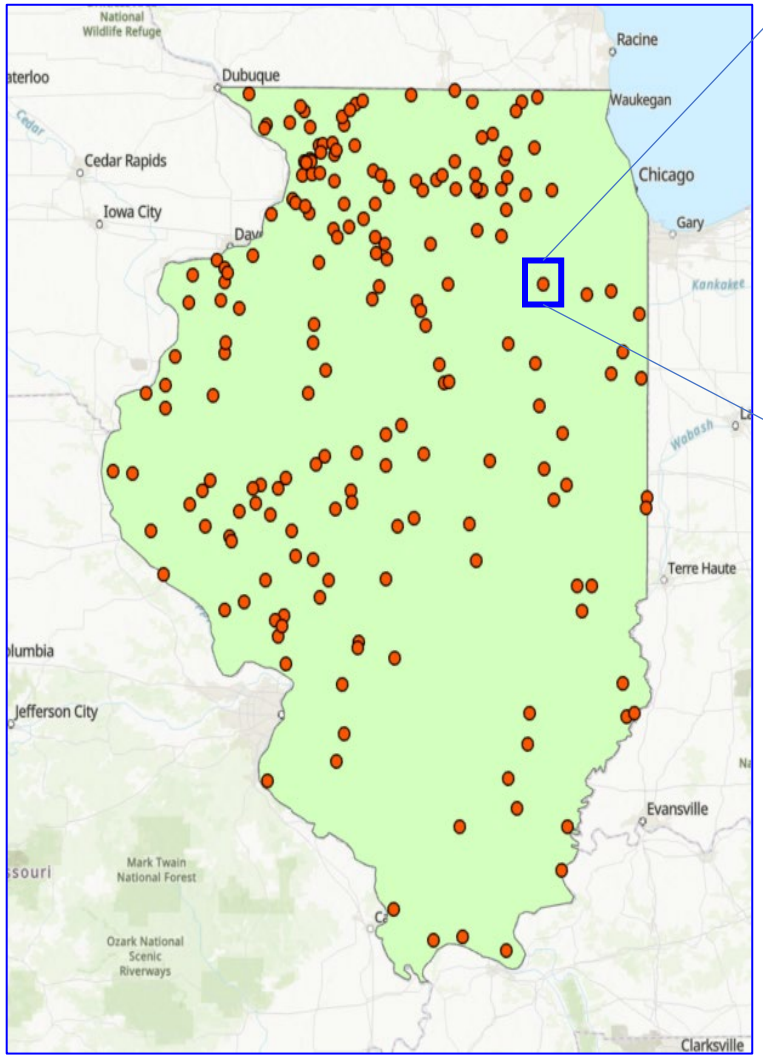
- **Historical:** 1986 – 2025
- **Short-term:** 2026 – 2049
- **Mid-term:** 2050 – 2074
- **Long-term:** 2075 – 2099

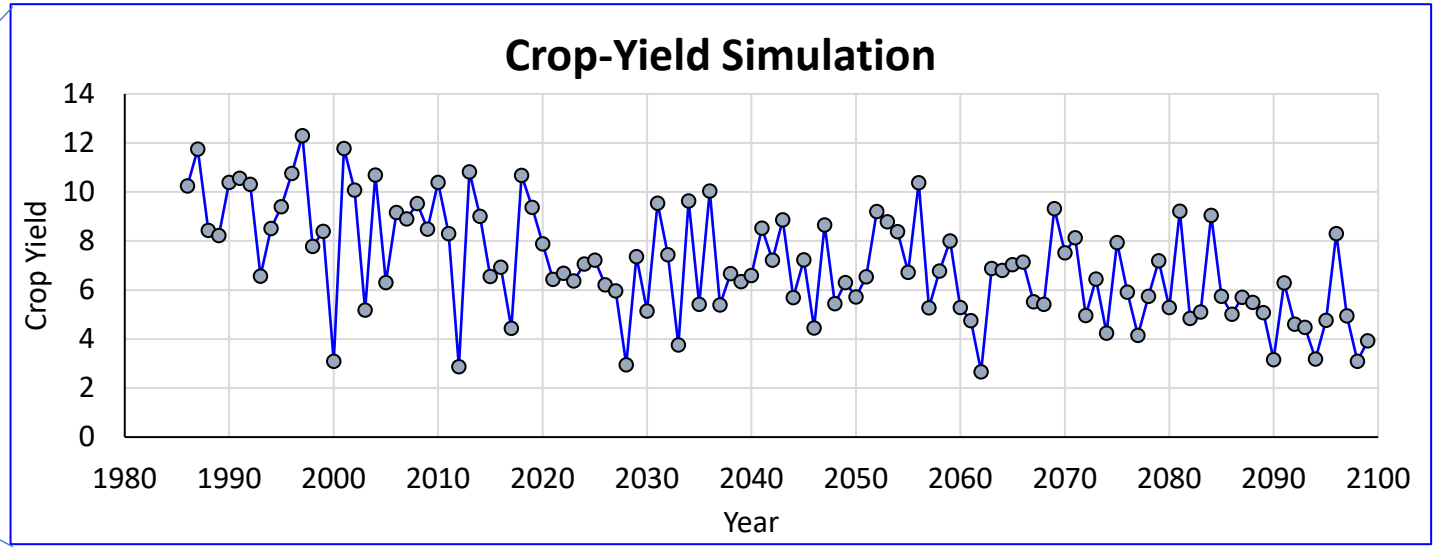


# Methodological Framework




# Results:
## APEX Modeling

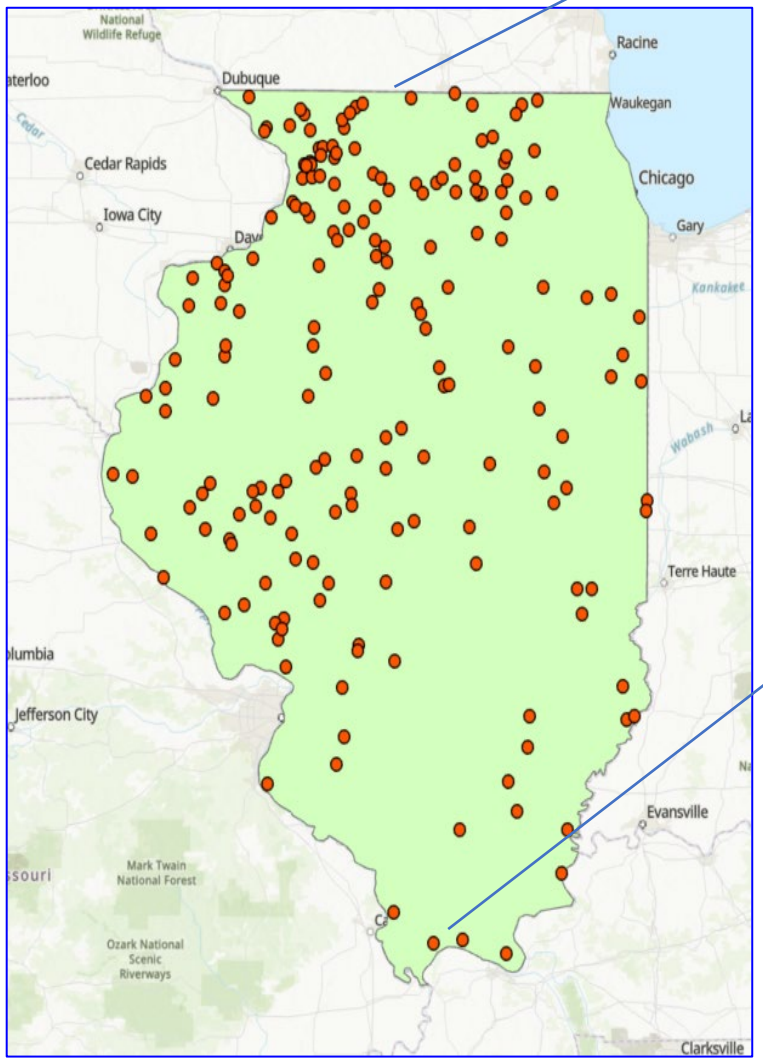


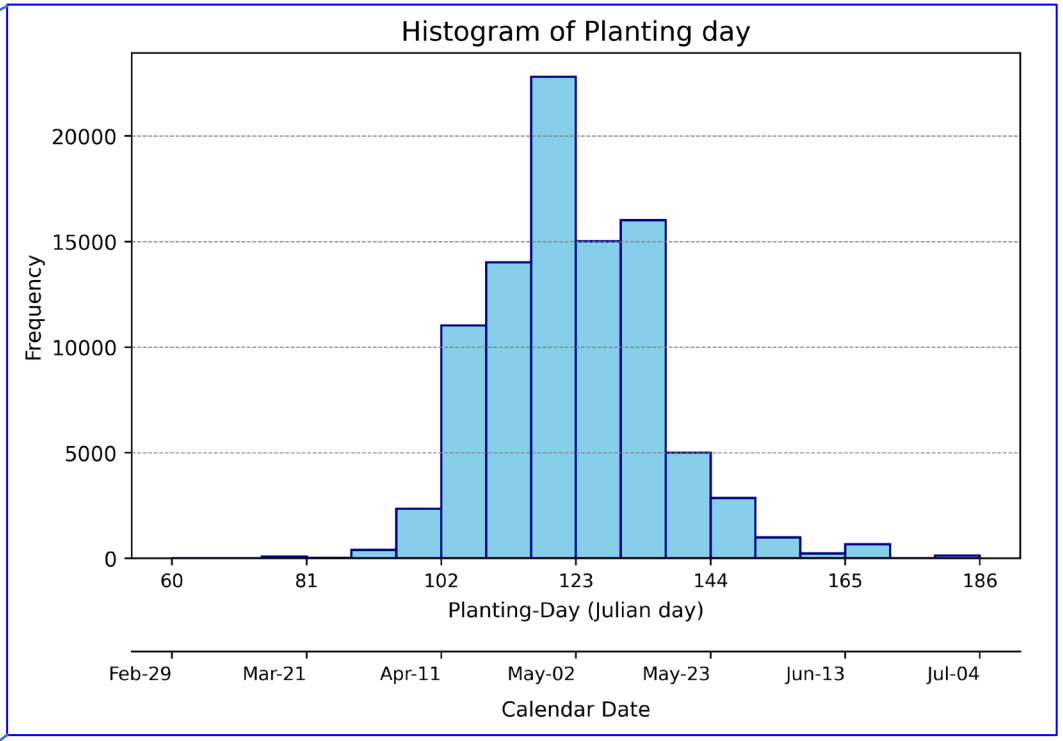




**Study Period Overview**

- **Model setup:** 1950–2099
- **Model stabilization:** 1950–1970
- **Evaluation period:** 1986–2099

# Results:
## Planting Date Setting

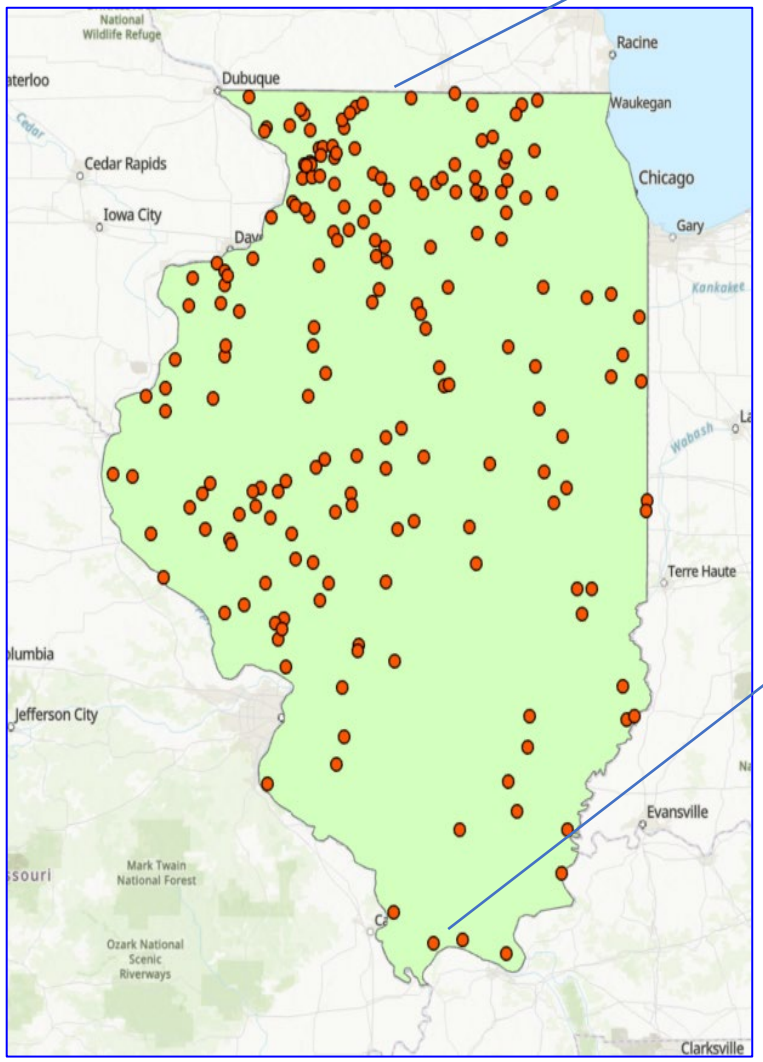


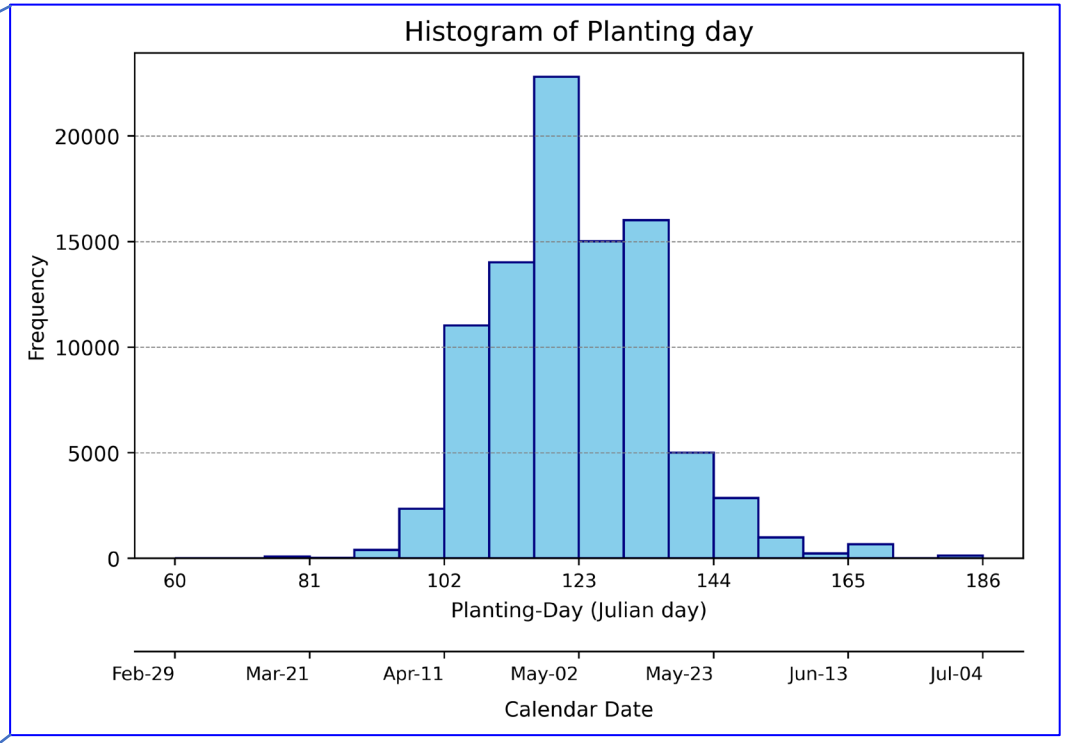




- **Frequent planting dates:** April 12 – May 24 (Julian days 102-144)
- **Weekly grouping:** Six one-week intervals
- **Why weekly:**
  - Captures key agronomic variations with less daily noise
  - Increases sample size per group (better statistical stability)
  - Enhances interpretability and alignment with real-world practices.
- **Supported by literature:** Weekly or biweekly intervals commonly used

# Results:

## Planting Date Setting for RL




### Actions in the Reinforcement Learning

- **Action 1** → Week 1 (Apr-12 to Apr-18)
- **Action 2** → Week 2 (Apr-19 to Apr-25)
- **Action 3** → Week 3 (Apr-26 to May-02)
- **Action 4** → Week 4 (May-03 to May-09)
- **Action 5** → Week 5 (May-10 to May-16)
- **Action 6** → Week 6 (May-17 to May-23)

# Results:
## ML Modeling (APEX Emulator)

### ML Models

- Random Forest (RF)
- Extra-Tree Regressor (ET)
- XGBoost Regressor (XGB) ✓

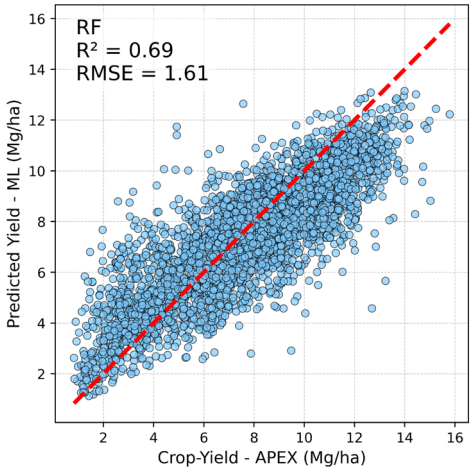
### Predictors

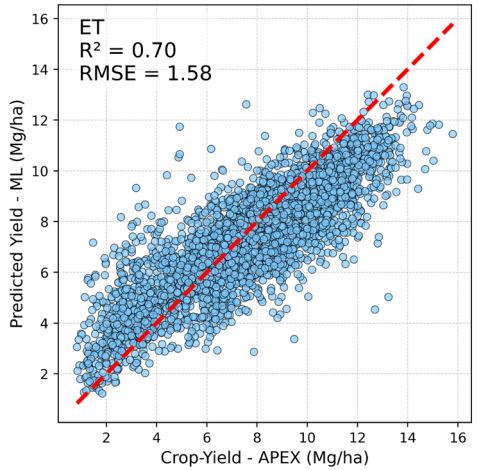
- Planting date (week)
- Growing Degree Days
- Precipitation during growth
- Latitude, Longitude
- Soil Organic Carbon

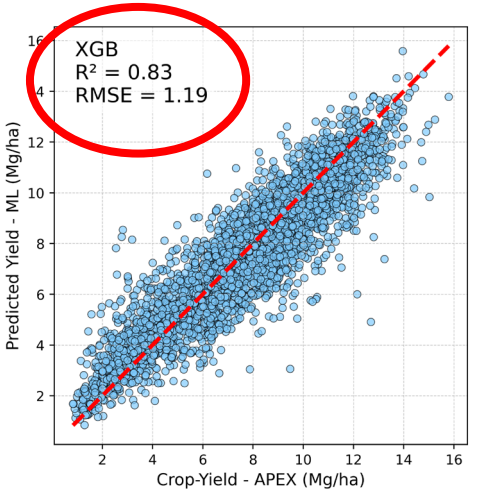
### Target

- Crop yield (Corn Yield)

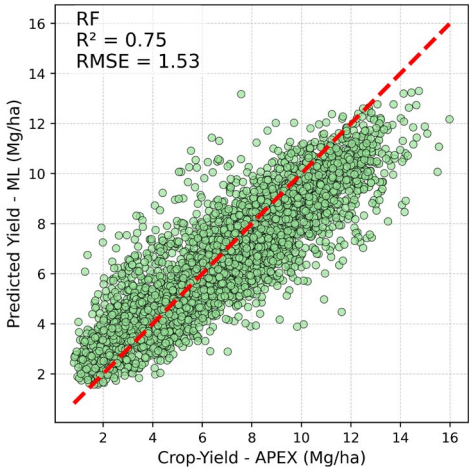
**RCP 4.5**

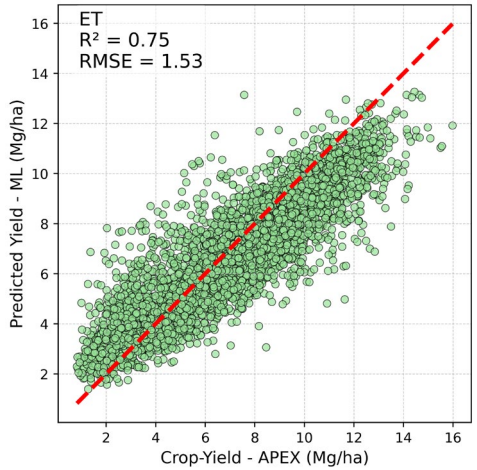


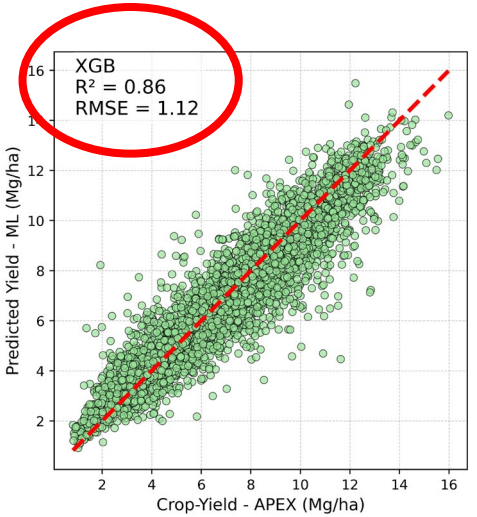




**RCP 8.5**

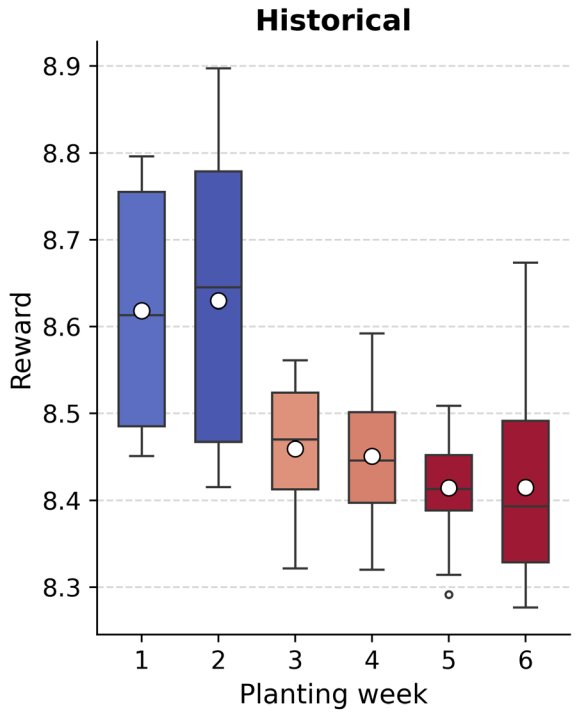


# Results

## Historical Corn Yield

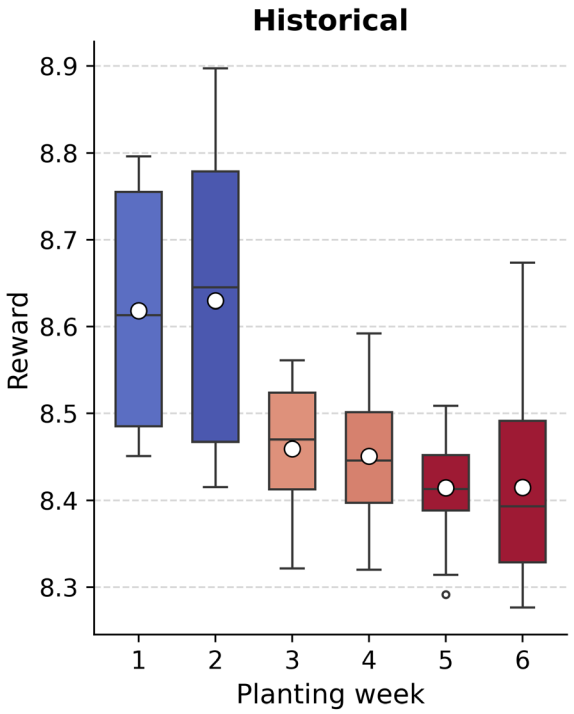



**Optimal Planting Week (Historical):**

- Week 1 & Week 2
- Slightly higher yield in week 2
- Average optimal reward (yield) = 8.6 Mg/ha

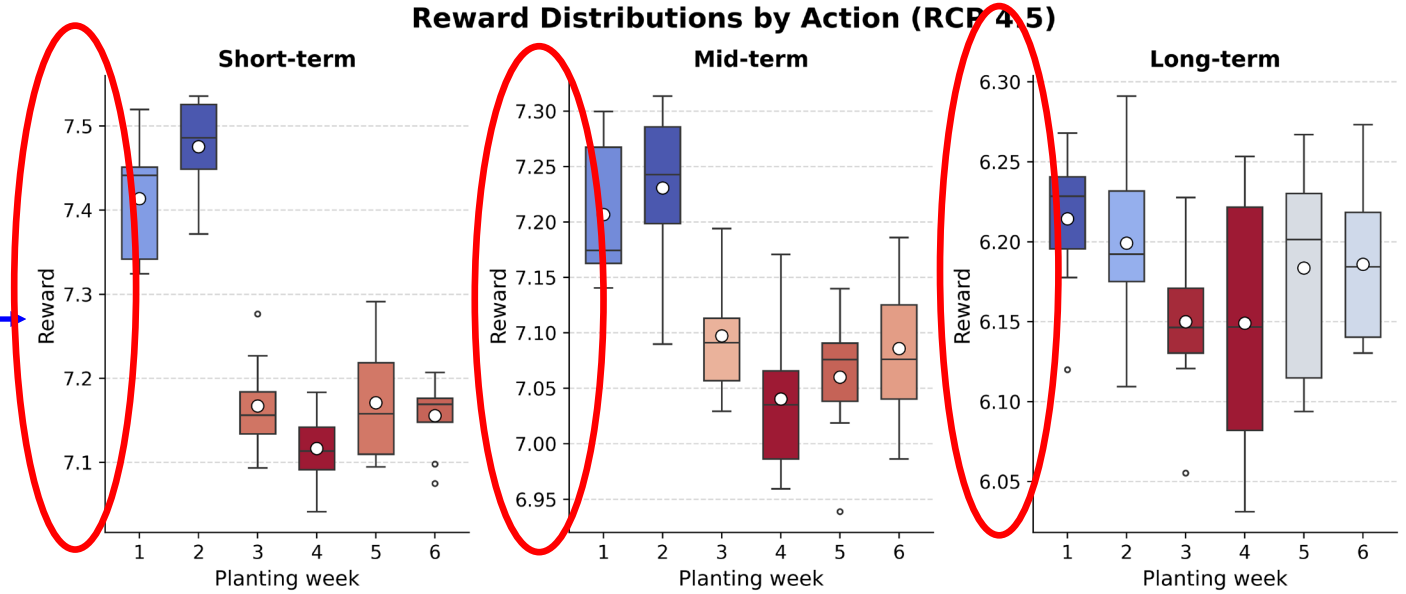
# Results

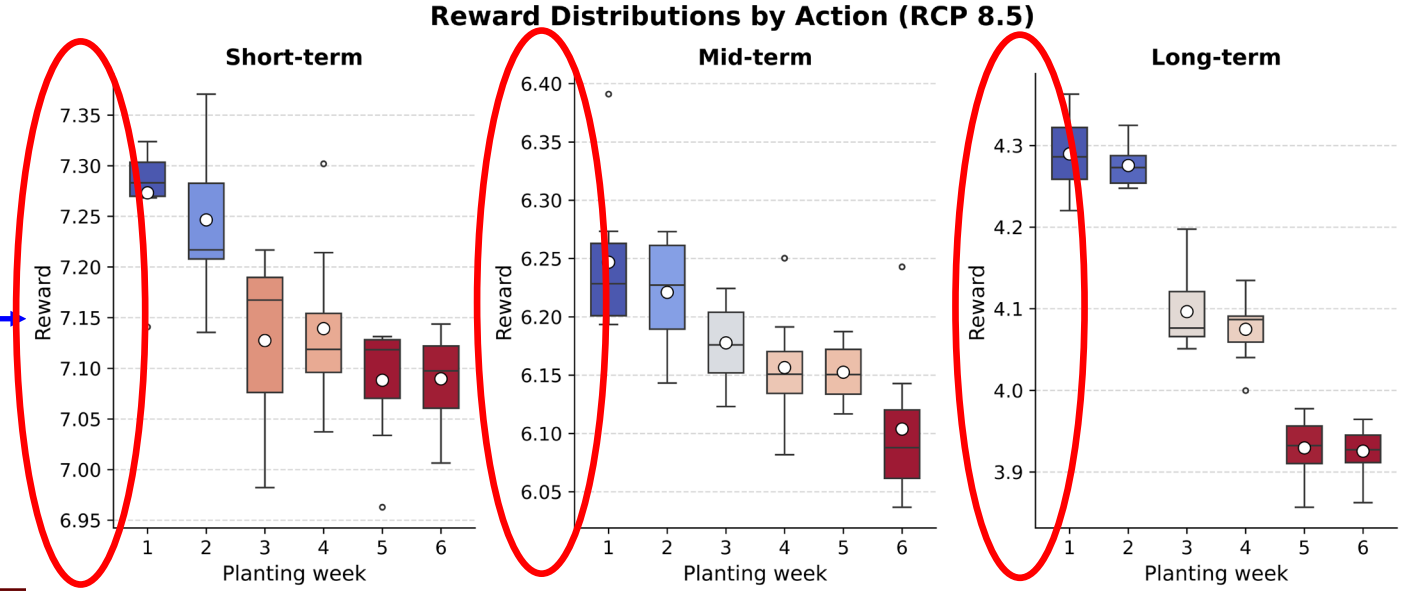
## Corn Yield Trend




RCP 4.5

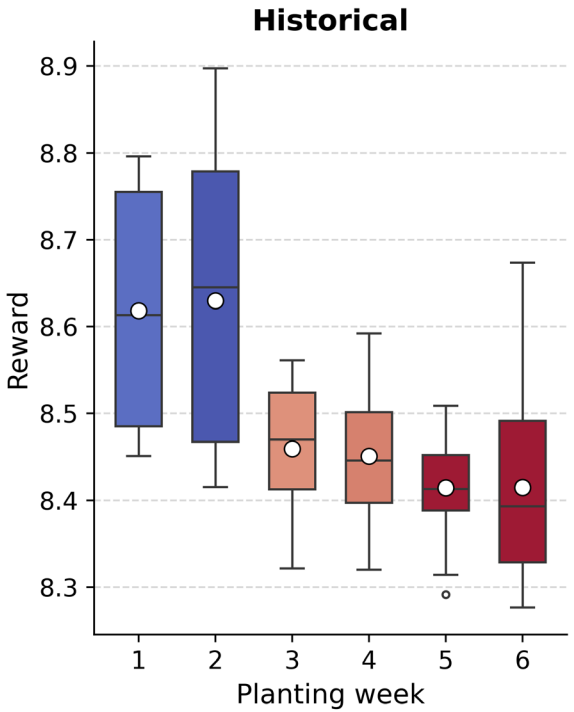
RCP 8.5



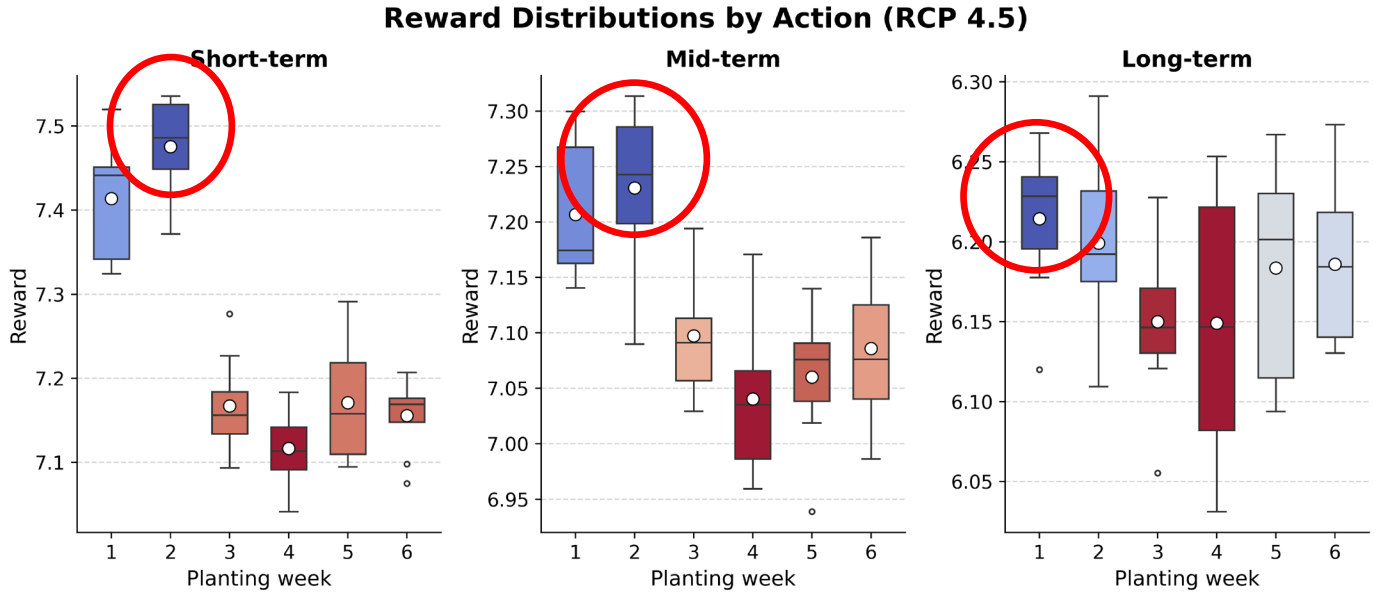
# Results

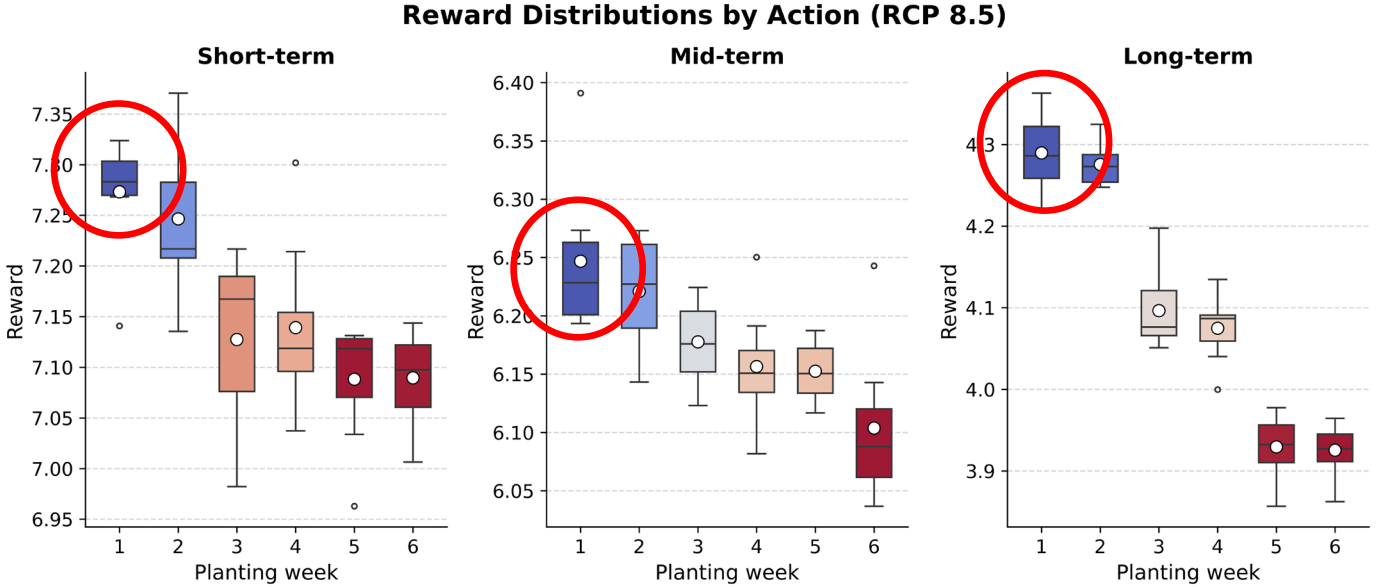
## Optimal Planting Week




RCP 4.5

RCP 8.5



# Conclusions

**Corn Production**

- Corn yields are expected to decline under future climate change scenarios

**Planting Date**

- **RCP 4.5**
  - Near & mid future → Week 2 may remain optimal
  - Long term future → Planting one week earlier could provide better results
- **RCP 8.5**
  - Planting one week earlier appears optimal in all future periods

In short, our results highlight the importance of adjusting planting dates to adapt to future climate scenarios

# Thanks for your attention

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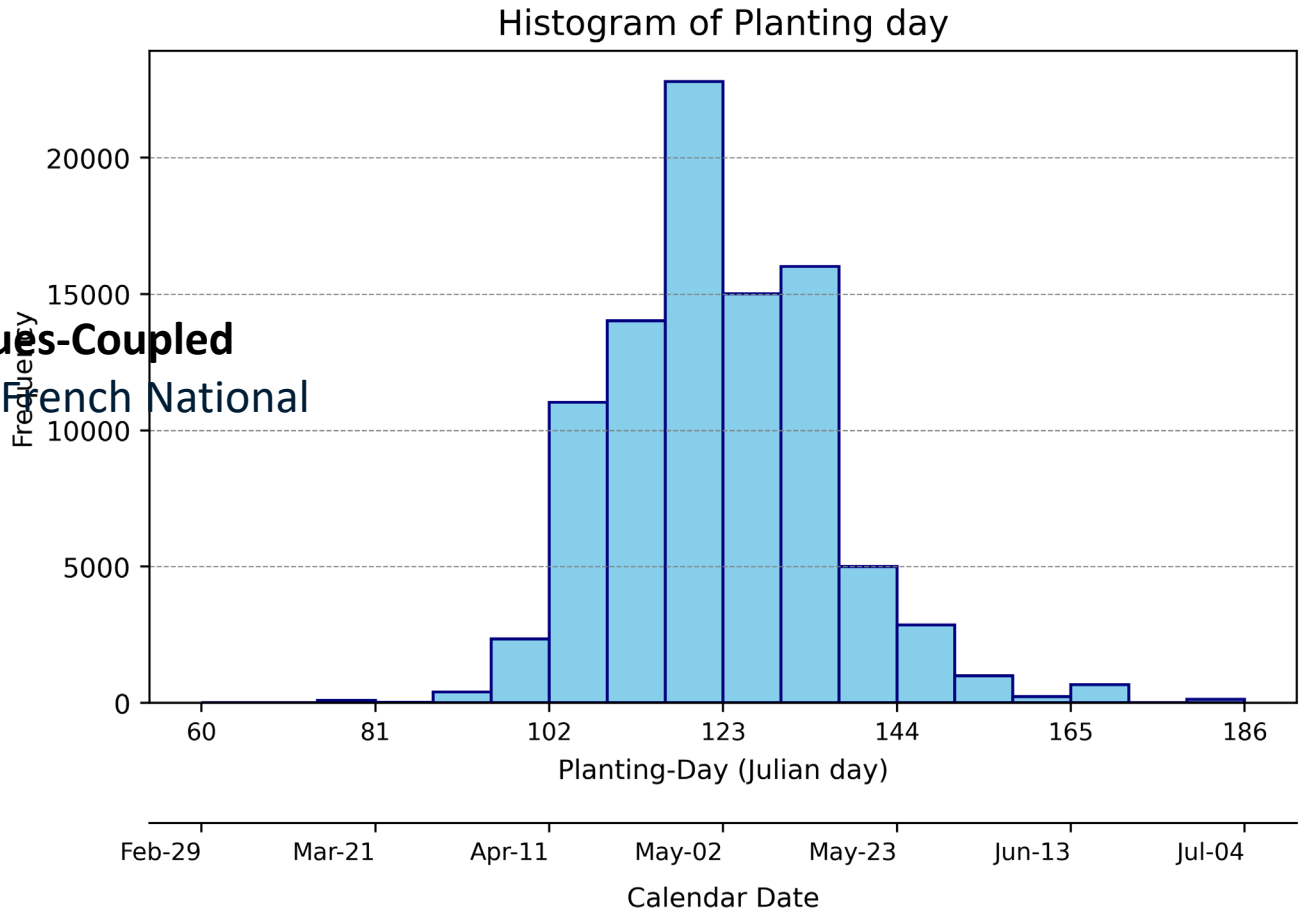
**Texas A&M AgriLife**

# Extra slides

# Results

Discretizacion de planting days in semansa

**Centre National de Recherches Météorologiques-Coupled Model**. It is a climate model developed by the French National Centre for Meteorological Research (CNRM)



# Methodological Framework

## APEX Crop Modeling

The APEX model simulates crop growth and yield dynamics under various climatic scenarios, calibrated against observed yield data.

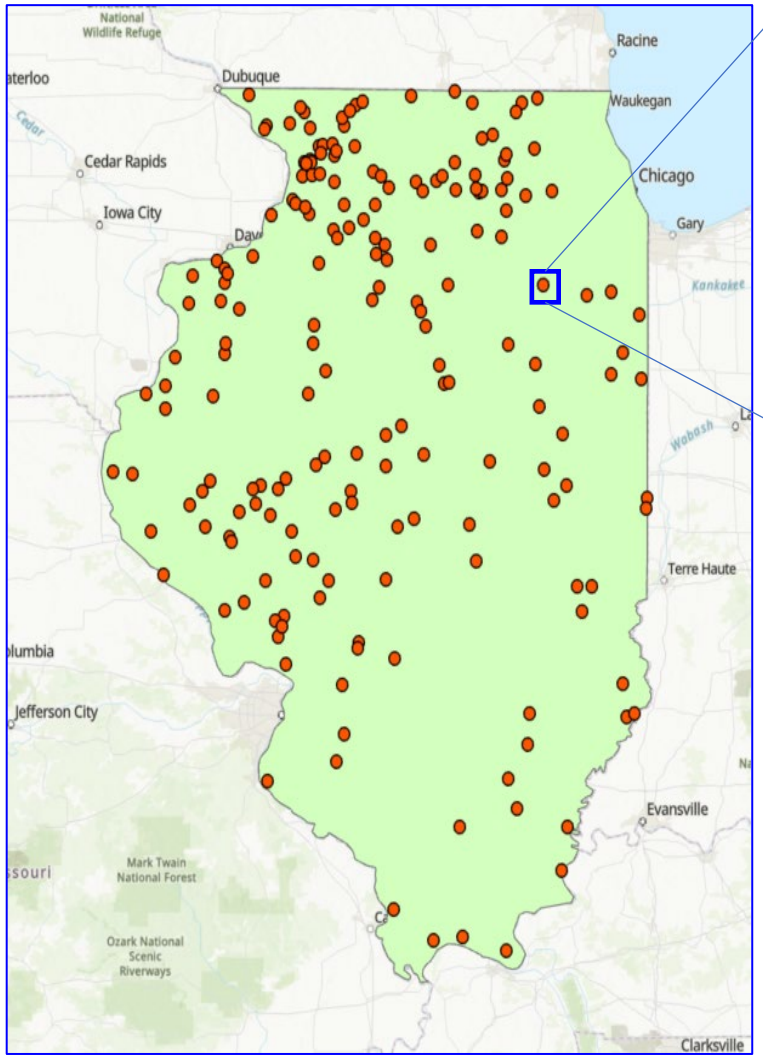
## Machine Learning Emulation

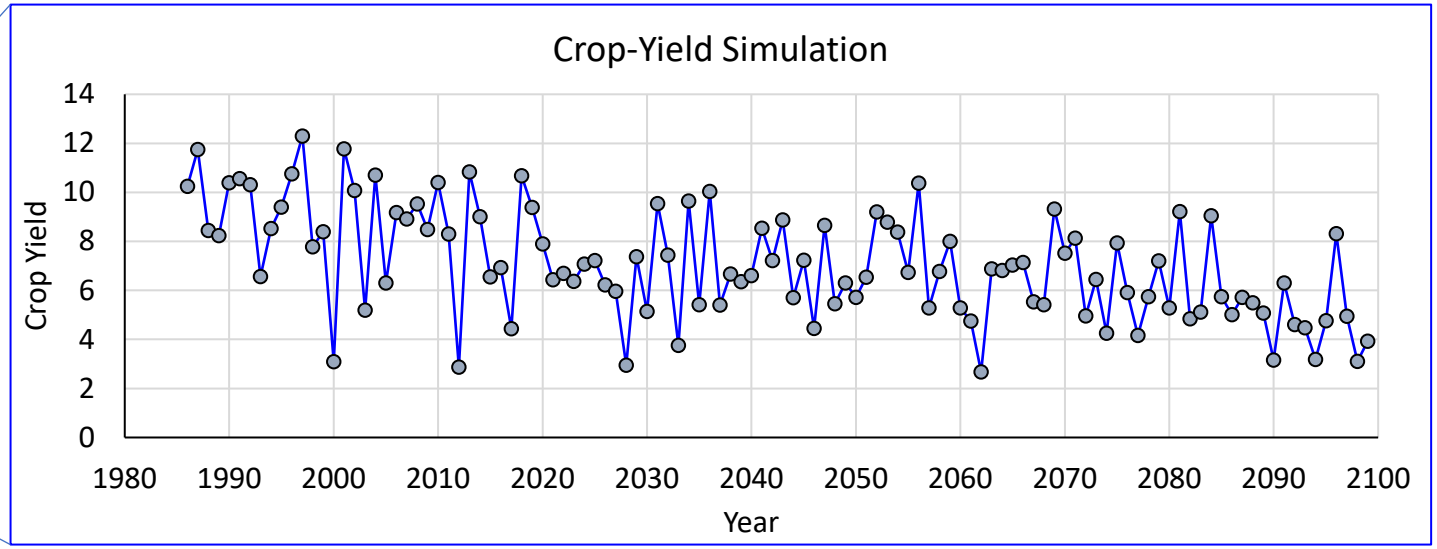
Machine Learning models are trained on APEX outputs, enhancing decision-making accuracy for planting dates through improved simulations.

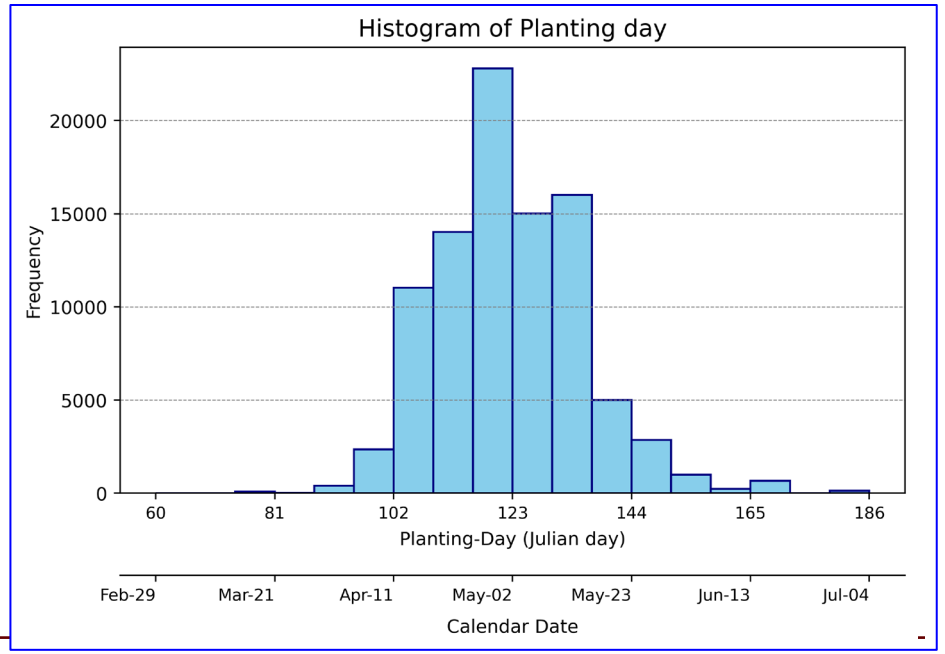
## Reinforcement Learning Optimization

A multi-armed bandit framework is utilized to optimize yield via adaptive strategies for planting dates, responding to climatic changes.

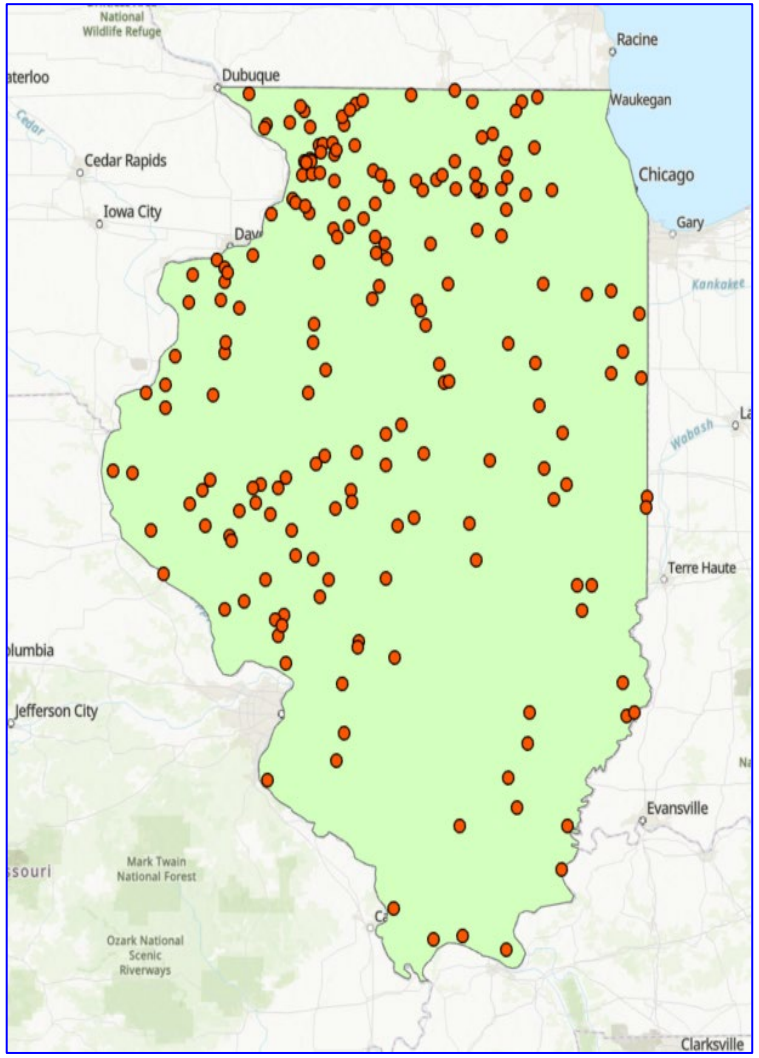
# Results

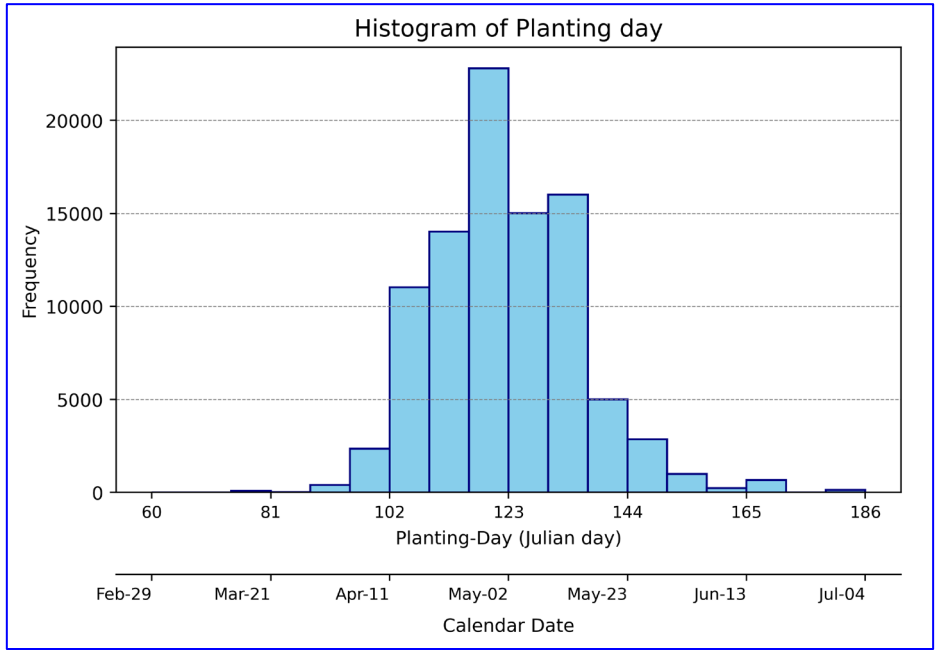

National Wildlife Refuge
Racine
Dubuque
Waukegan
Cedar Rapids
Chicago
Iowa City
Gary
Terre Haute
Jefferson City
Evansville
Mark Twain National Forest
Ozark National Scenic Riverways
Clarksville


Crop-Yield Simulation
Crop Yield
0
2
4
6
8
10
12
14
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year


Histogram of Planting day
Frequency
0
5000
10000
15000
20000
60
81
102
123
144
165
186
Planting-Day (Julian day)
Feb-29
Mar-21
Apr-11
May-02
May-23
Jun-13
Jul-04
Calendar Date

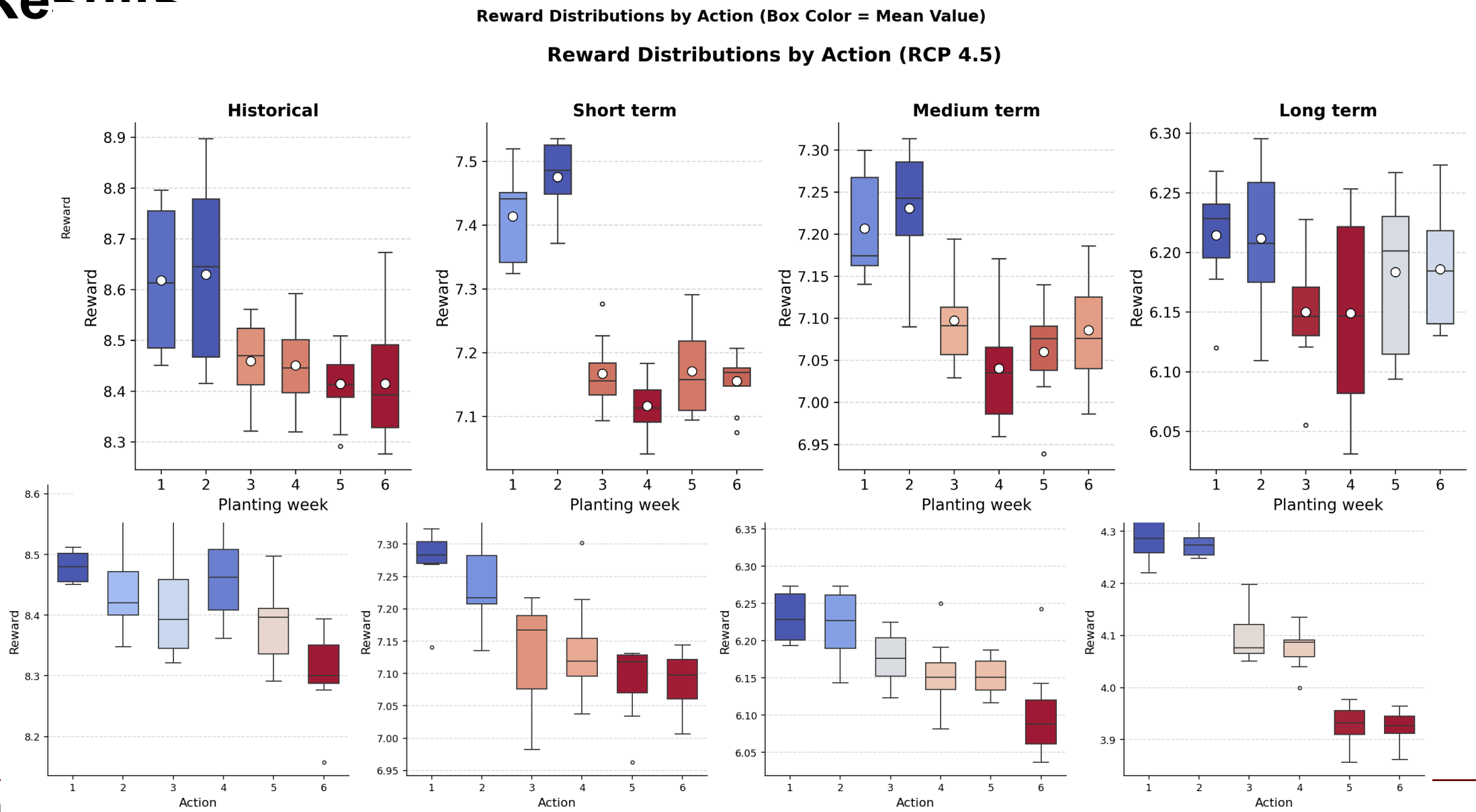
# Results



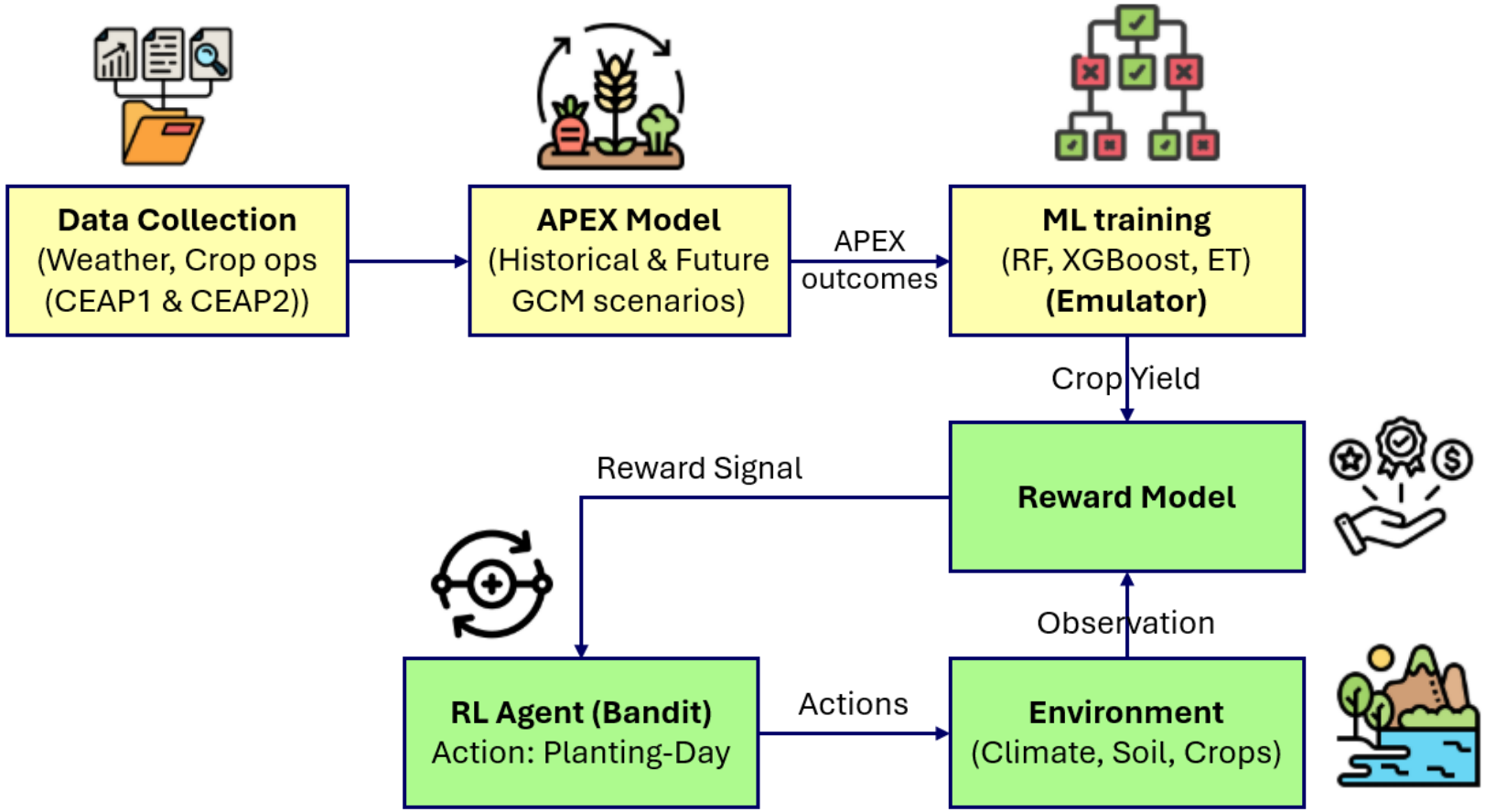




- **Planting window:** April 12–May 24 (Julian days 102–144), consistent with USDA guidelines.
- **Weekly grouping:** Six one-week intervals.
- **Why weekly:**
- Captures key agronomic variation with less noise.
- Improves statistical stability and real-world interpretability.
- **Supported by literature:** Weekly or biweekly intervals commonly used to define 9–24 day *optimal planting windows*

# Results


Reward Distributions by Action (Box Color = Mean Value)
Reward Distributions by Action (RCP 4.5)
Historical
Short term
Medium term
Long term
Reward
Planting week
Action

# Methodological Framework




# Conclusions

- **Historical Optimal Planting Week:** Weeks 1–2, slightly higher yield in week 2
- **Corn yields decline** under both RCP 4.5 and RCP 8.5 climate scenarios
- **RCP 8.5 yields are consistently lower** than RCP 4.5, with the gap widening toward the long-term horizon

# Conclusions

**Optimal Planting Week Under Future Scenarios**

**Under RCP 4.5:**

- Short- & mid-term → Week 2 optimal
- Long-term → Week 1 becomes optimal (suggesting earlier planting)

**Under RCP 8.5:**

- Week 1 optimal across all periods (suggesting earlier planting dates under harsher climates)

# Acknowledgment & Disclaimer

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