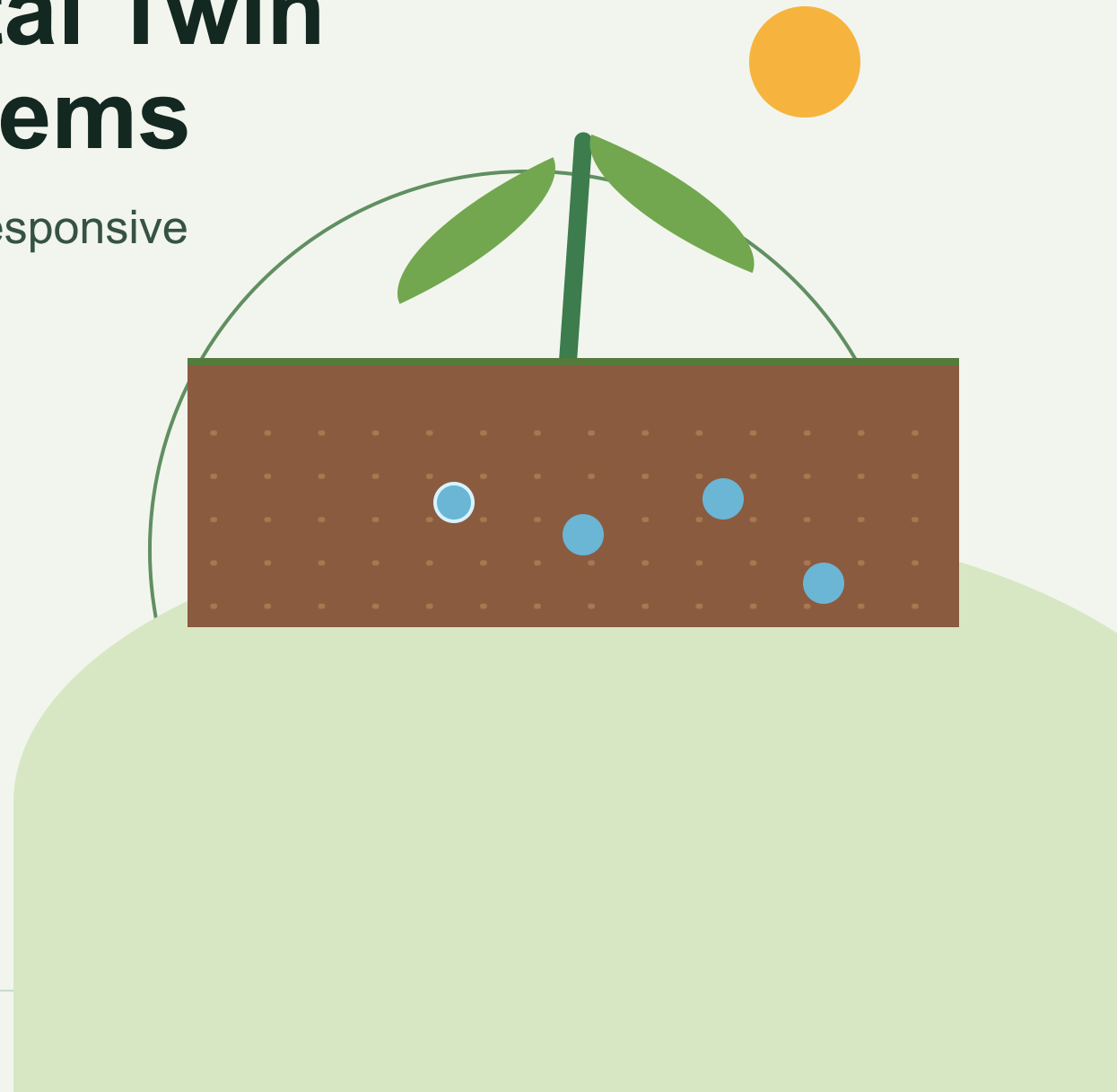


Physics-Informed Digital Twin for Intelligent Soil Systems

Water-efficient precision agriculture using stimuli-responsive hydrogels and hybrid state models.

Ministry of Agriculture & Farmers Welfare

Industry Guidance: Chatake Innworks Pvt. Ltd. - Apollo AgriVerse



Farmers must make irrigation decisions with incomplete visibility of the root zone.

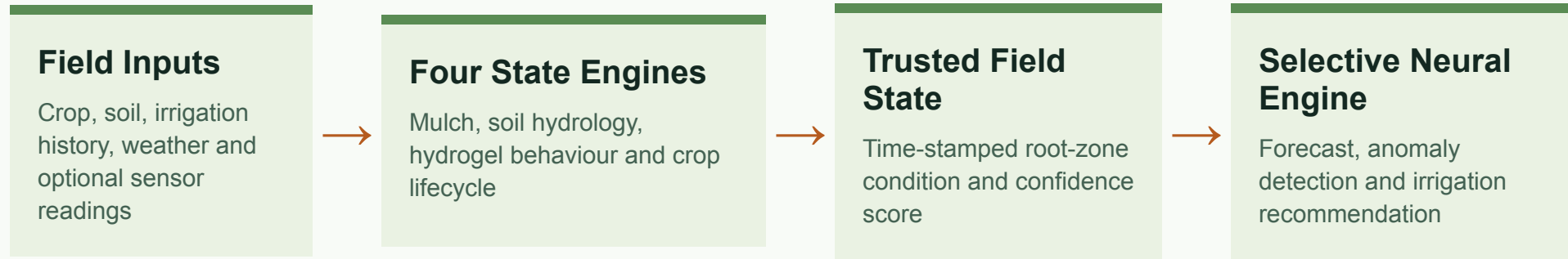
- 1 Erratic rainfall and heat make fixed irrigation schedules unreliable.
- 2 Sensors can be noisy, unavailable or fail in real fields.
- 3 Pure AI may recommend actions that do not respect soil and crop physics.
- 4 Conventional soil does not actively buffer water near the roots.

What is missing?

A resilient, explainable recommendation - not another data screen.

The system must continue estimating field state even when a reading is uncertain, then make its confidence visible.

Apollo AgriVerse combines material intelligence with a physics-informed digital twin.



Why this architecture: physics keeps the state plausible during imperfect telemetry; ML is used selectively for prediction and uncertainty rather than as a black box.

The prototype demonstrates a decision, not merely a dashboard.

1. Configure

Crop, soil, weather scenario and treatment.

2. Simulate

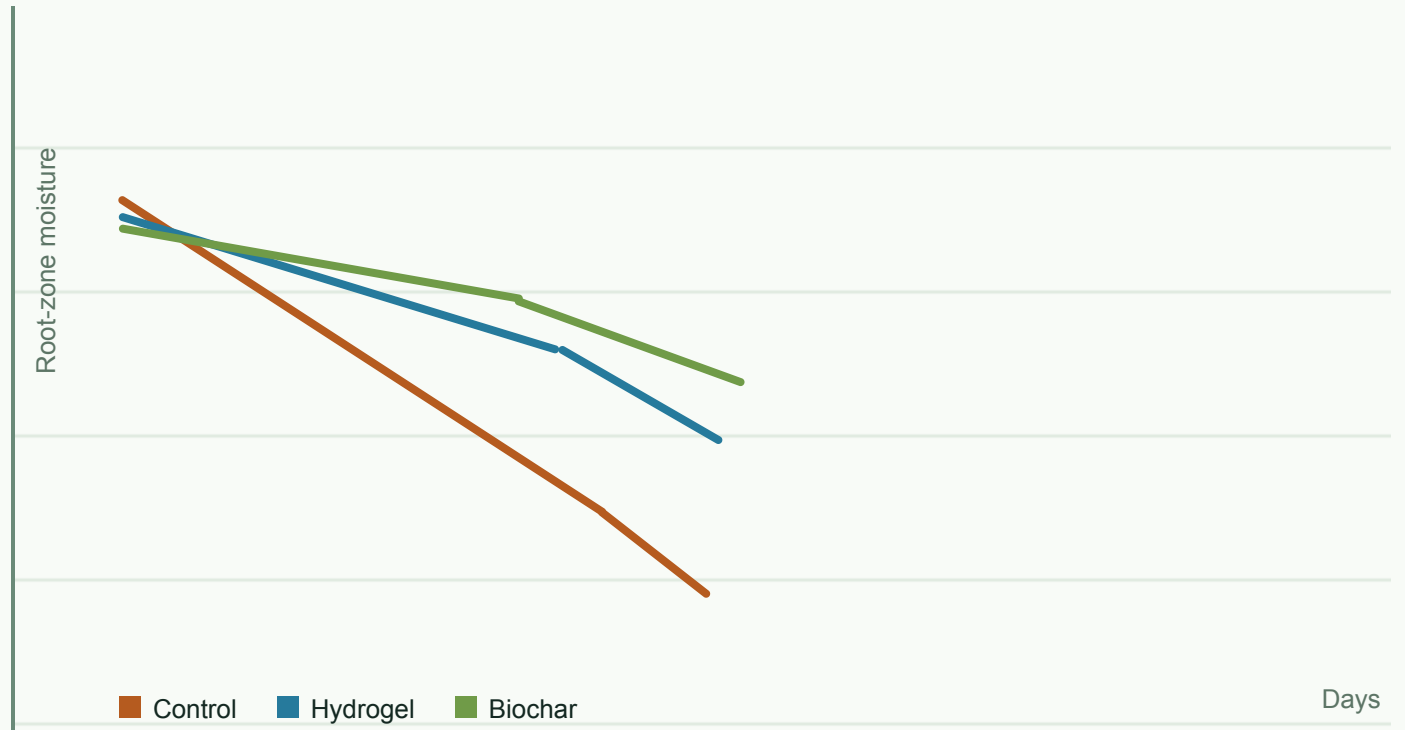
Seven to fourteen days of water balance and crop demand.

3. Compare

Control, hydrogel, biochar and combined treatment.

4. Recommend

Irrigate now, delay, partial cycle or inspect a sensor.



Demo story: in a hot, low-rainfall scenario, the control plot reaches stress first. The system recommends a partial, timed irrigation where the modelled hydrogel buffer still holds water. *All displayed results are simulated MVP scenarios until field validation.*

The innovation is a transparent hybrid decision system - not a claim that one material solves every soil problem.

Feasible now

- Software-first MVP using simulated and manual data.
- Low-cost future hardware path: moisture, temperature, EC and one valve.
- State engine works through missing data and reports confidence.
- Every irrigation action shows the variables that caused it.

Test, then prove

- Hydrogel: local water reservoir with finite storage and release.
- Biochar: comparator for longer-term soil hydraulic and nutrient effects.
- Field protocol: control, hydrogel, biochar and combined treatment.
- Measure water productivity, crop response, cost and usability.

Hydrogel and biochar are complementary, testable interventions. The correct answer depends on crop, soil, irrigation regime and economics.

From SIH demonstration to a field-verifiable Apollo AgriVerse module.

01 / HACKATHON

Digital twin MVP

Scenario engine, transparent recommendation and recorded demo.

02 / VALIDATION

Controlled experiment

Compare control, hydrogel, biochar and combined treatment.

03 / PILOT

Local field proof

Calibrate with one crop, one soil profile and agronomist review.

04 / SCALE

Farmer workflow

Simple advice, economics, local language and irrigation integration.

Priyan
Product & integration

Divyanshi
Soil & material research

Zidane
State engine

Rudra
Crop & weather

Mubeen
UI & demo

Siddhanth
ML, QA & documentation