

Building Climate-Resilient Digital Platform for Integrated, Multi-Scale Water Management: The CROP Approach

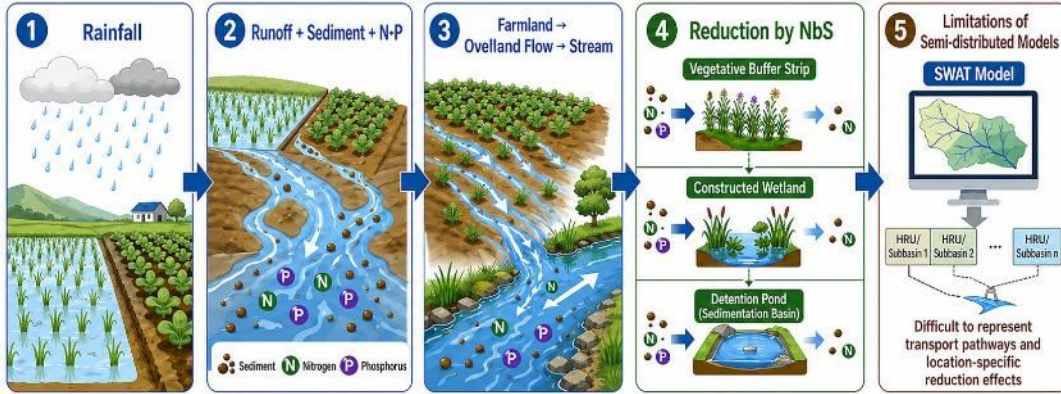


KGID
2026
SEJONG

Jaepil Cho, Executive Director
Integrated Watershed Management Institute (IWMI)
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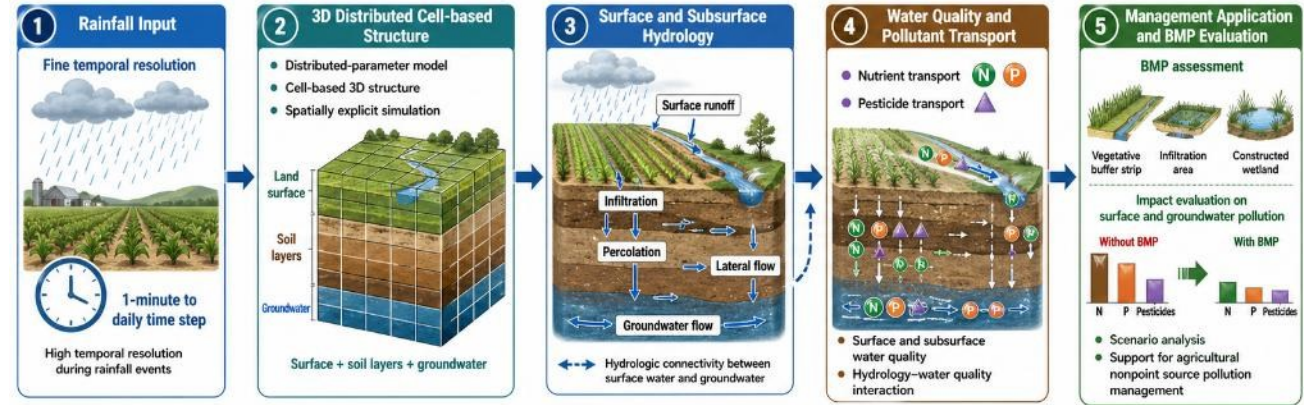
Why a Platform? — Responding to Growing Complexity

Agricultural Nonpoint Source Pollution Transport, NbS Reduction Effects, and the Limitations of the SWAT Model



DANSAT: A 3D Distributed Agricultural Non-point Source Assessment Model

A cell-based, physically based model for simulating surface and subsurface hydrology and water quality in agricultural fields



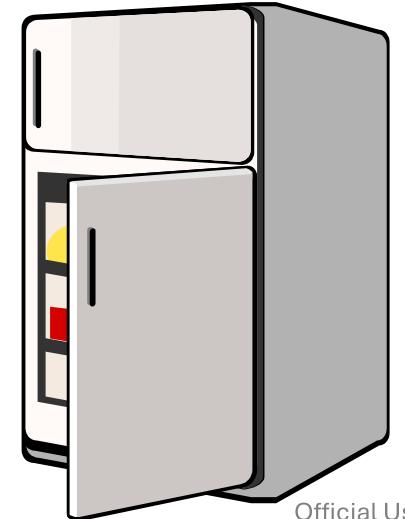
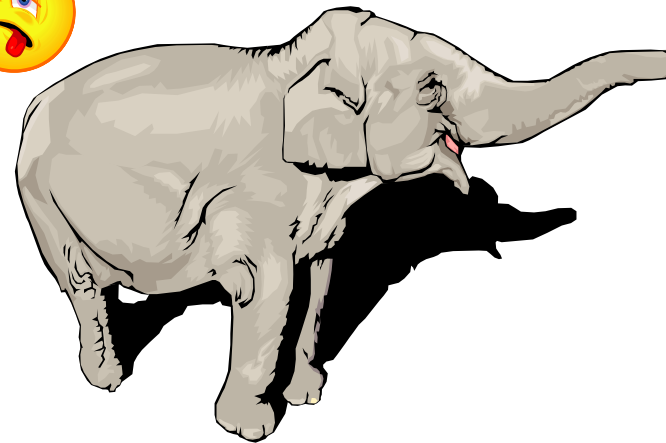
Assessment of agricultural nonpoint source pollution should consider not only runoff quantity, but also pollutant transport pathways and the reduction effects of NbS.



DANSAT represents agricultural fields as spatially distributed 3D cells and simulates rainfall-driven surface and subsurface hydrology and water quality processes, making it useful for evaluating BMP effects on nonpoint source pollution.







How to put an elephant in a fridge?

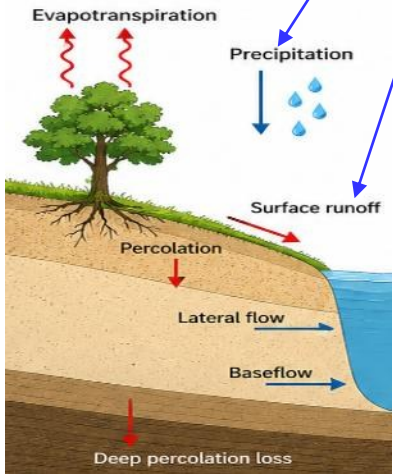
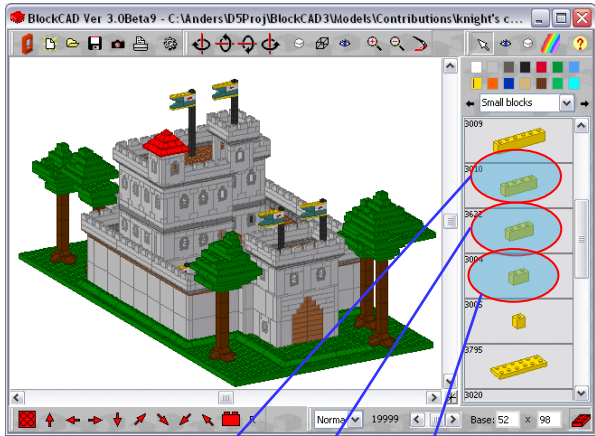


Direction 1: From standalone tools to integrated decision support platforms

Watershed Modeling Platforms: Comparison of OMS3, OpenMI, CSDMS, and NextGen

Examples of existing platforms for modular and integrated watershed modeling

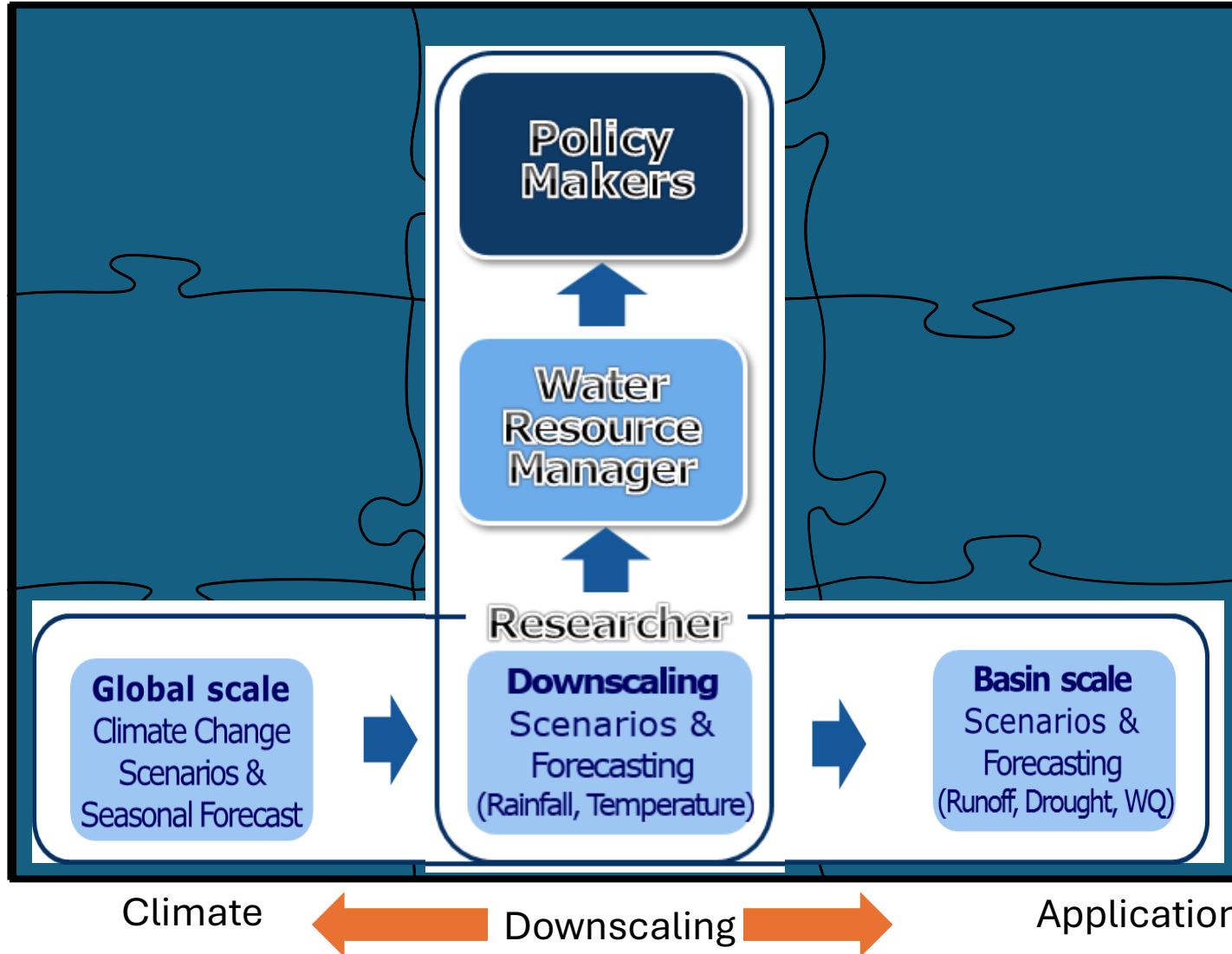
Platform	Core Concept	Typical Use / Modules	Strengths	Limitations
 OMS3	Object Modeling System; modular framework for assembling environmental and watershed models	PRMS, AgES, custom hydrology and agro-environmental workflows	Flexible modular design; problem-specific model assembly; reproducible workflows	Steeper setup; requires technical expertise to configure components
 OpenMI	Open standard/interface for linking different models and exchanging data during runtime	Hydrology, hydraulics, groundwater, water quality, ecology models	Strong interoperability; supports dynamic coupling of independent models	Model wrapping and standard compliance can require extra integration effort
 CSDMS	Community modeling framework and workbench for Earth-surface and hydrologic systems	BMI-enabled community models, coupling tools, shared model repository	Open-source ecosystem; model sharing and reproducibility; strong research community	More research-oriented; operational deployment depends on the selected model stack
 NextGen	Next Generation Water Modeling Framework for national-scale and flexible hydrologic modeling	National Water Model evolution, modular hydrologic components, catchment-based simulation	Highly extensible; supports large-scale integration and modern modular architecture	Still evolving; setup and operational implementation can be complex



Break it down into modular steps!

Prepared for presentation use

Direction 2: bridging climate information across scales and decision levels



Vertical Linkage

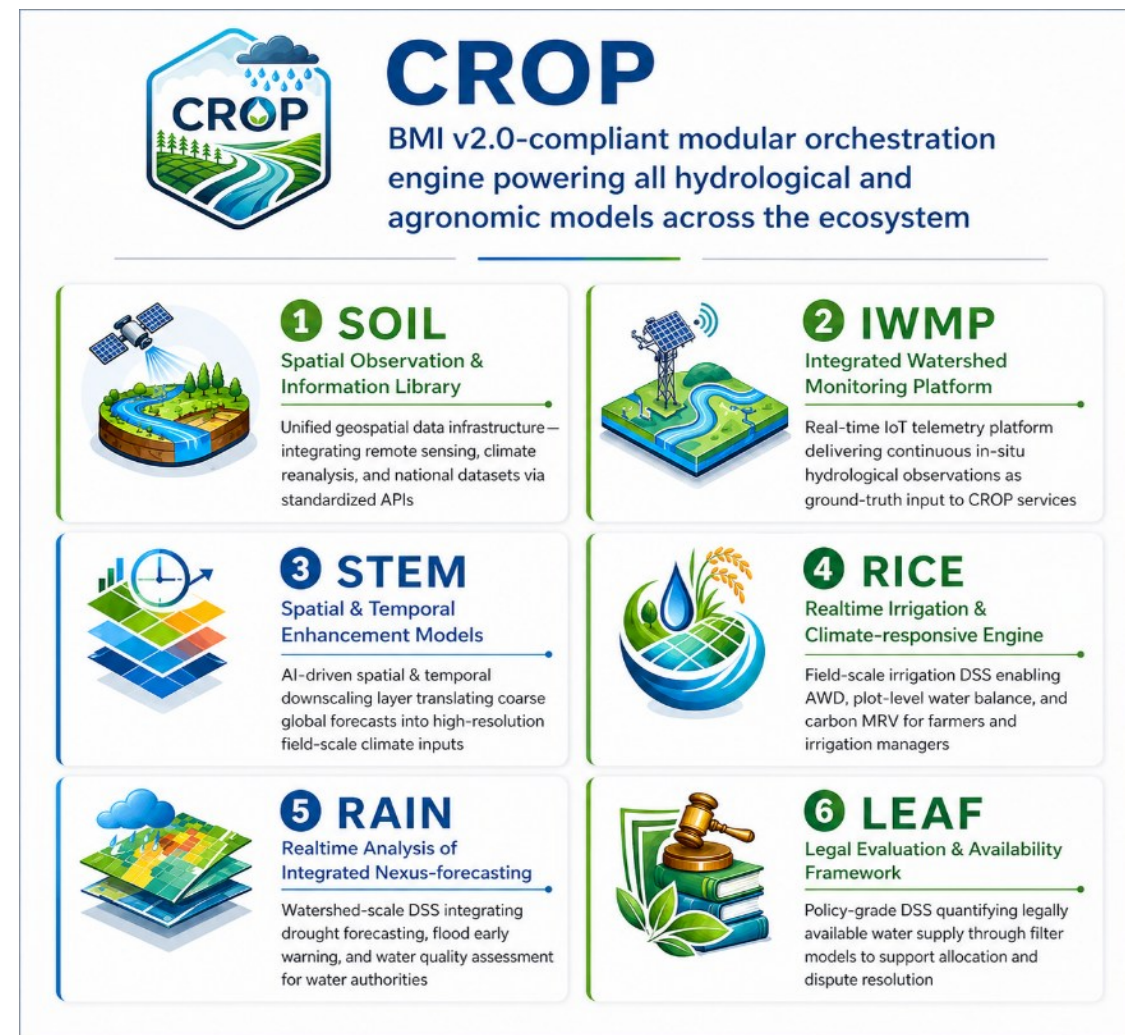
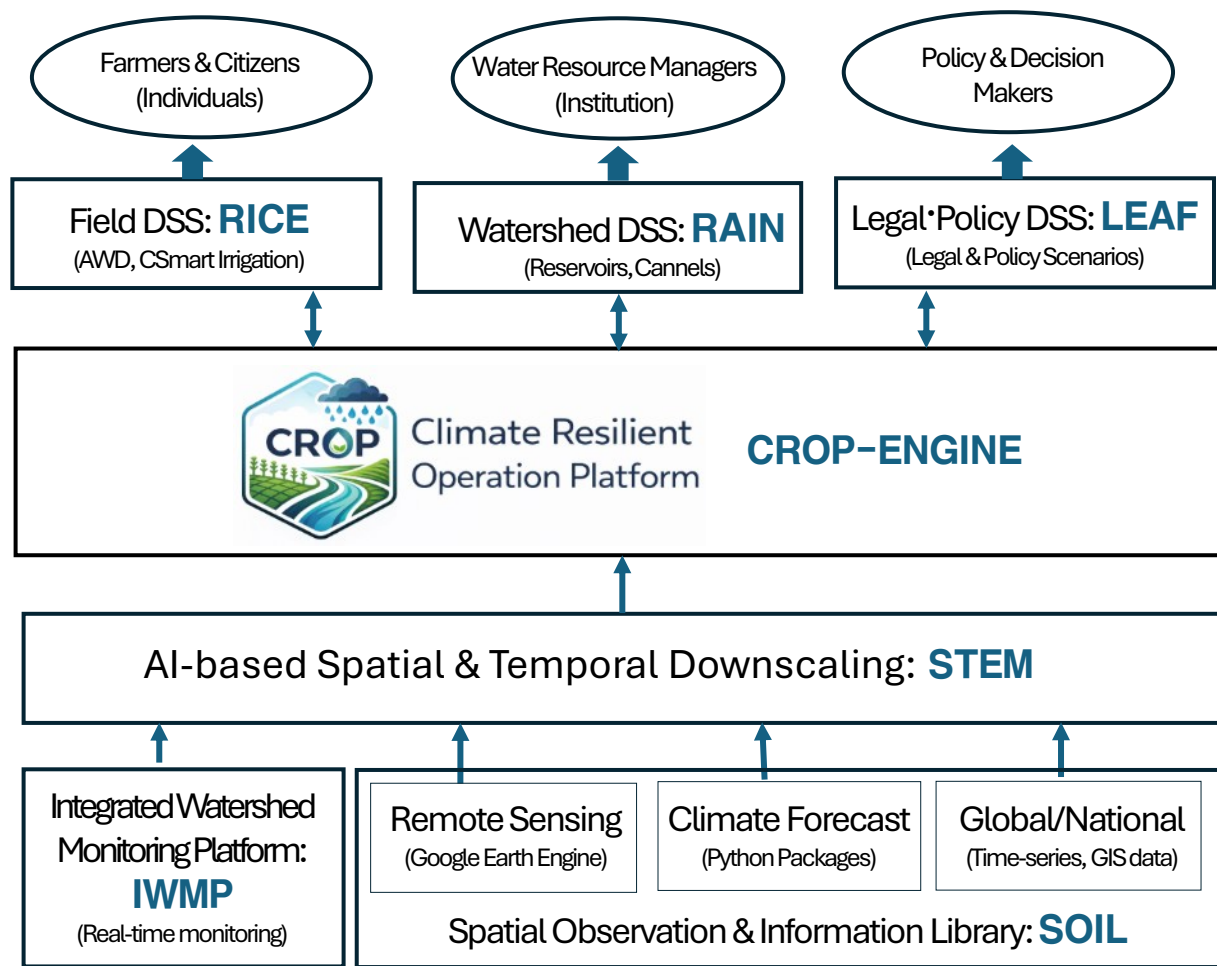
Scientific information produced by **researchers** should be translated into practical tools for **water resource managers**, and then into clear decision-support messages for **decision makers and policy makers**.

Horizontal Linkage

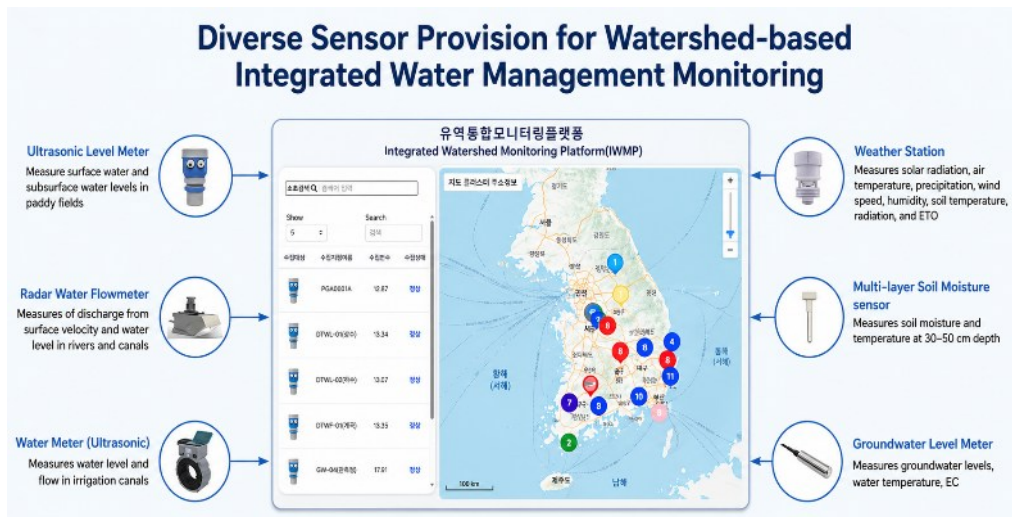
Through temporal and spatial downscaling, climate data can be converted into practical information such as **rainfall and temperature**, which can then support basin-level applications including **runoff analysis, drought assessment, and water quality management**.

Climate Resilient Operation Platform (CROP) Platform

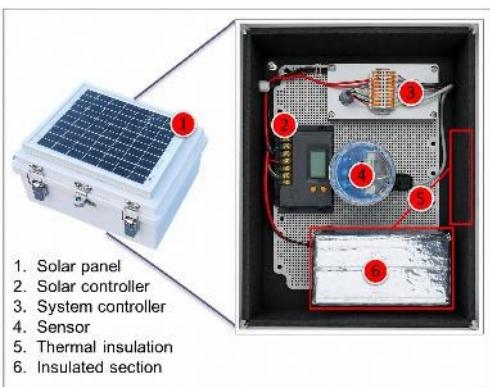
Integrated architecture spanning data ingestion, AI downscaling, modeling, and decision support



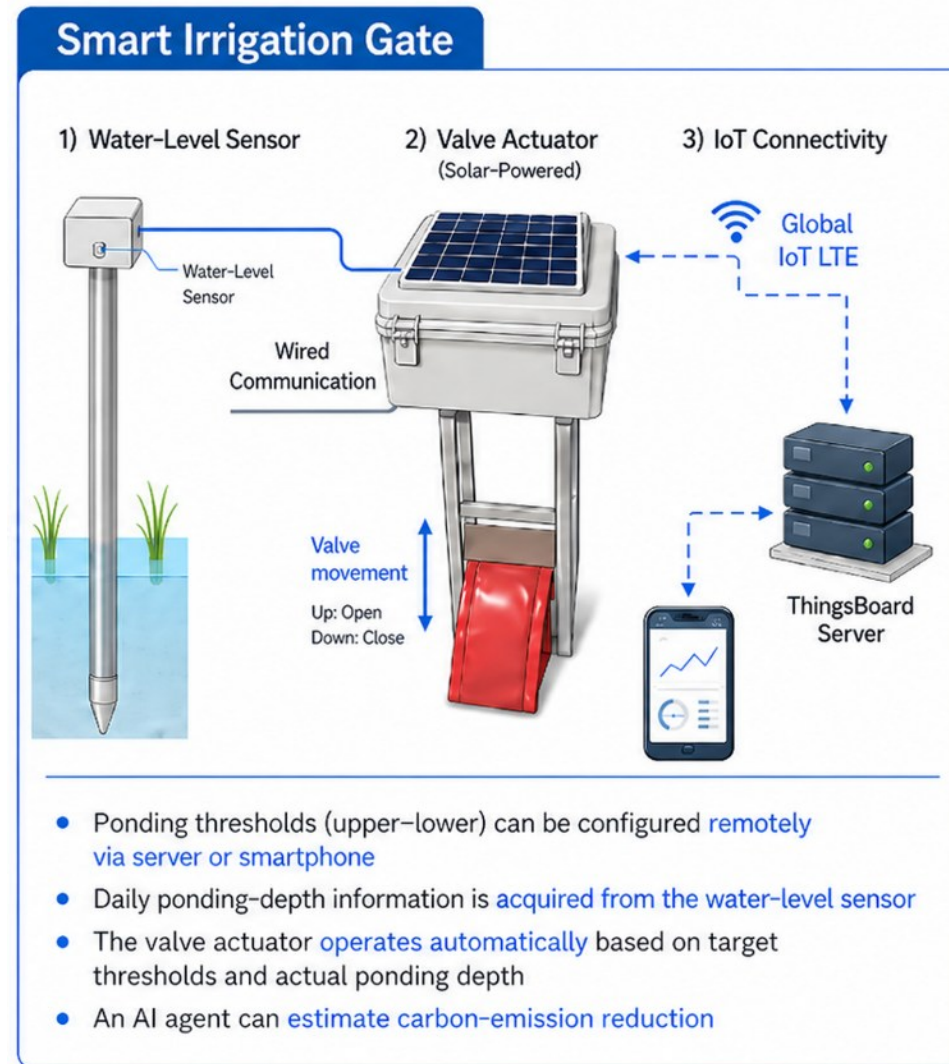
IWMP — Integrated Watershed Monitoring Platform &



- ❖ Simple configuration that can be **maintained by non-expert farmers**
- ❖ **Cheap communication cost** using a Global IoT SIM (\$15 for 10 years)



Agricultural Water Supplier (KRC)

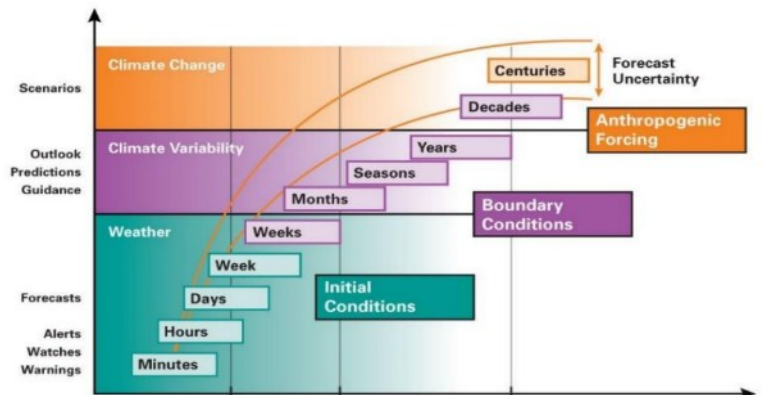
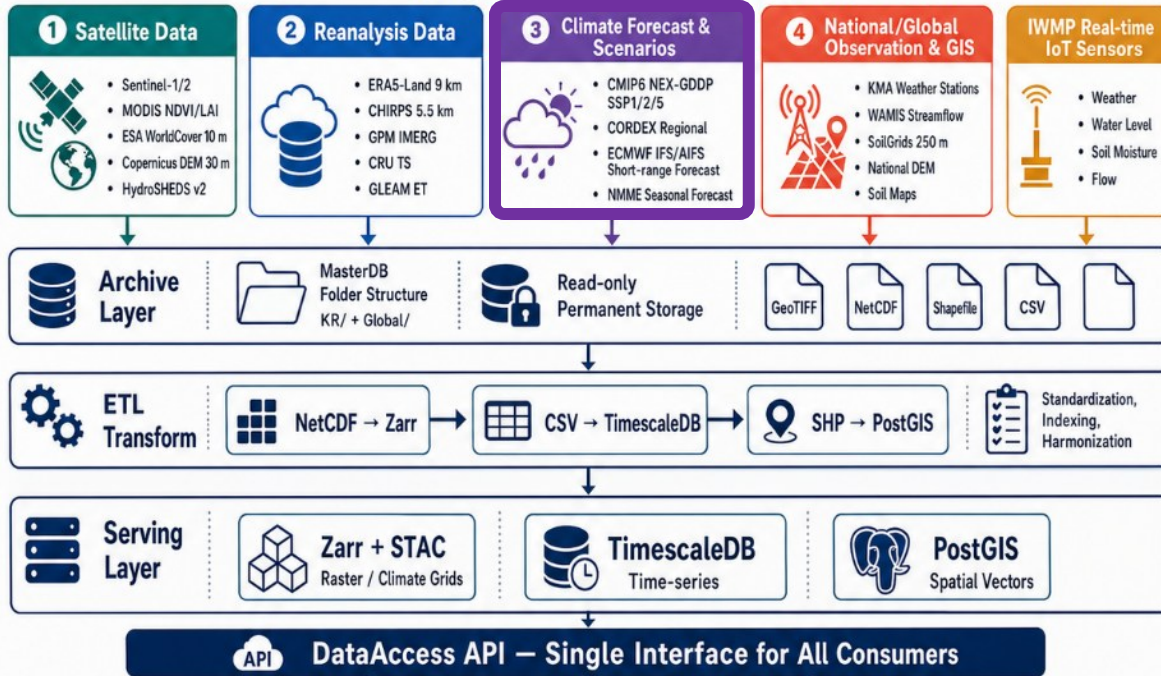


Agricultural Water User (Farmers)

SOIL — Spatial Observation & Information Library

CROP-SOIL: Spatial Observation & Information Library

Geospatial Data Pipeline Platform



Climate information supports different levels of water resources decision-making from real-time operation to long-term adaptation planning.

Climate Information Time Scale	Typical Information	Water Resources Decision Use
Minutes–Hours	Heavy rainfall alerts, flash flood warnings, real-time weather	Flood warning, gate operation, pump operation, emergency response
Days–1 Week	Short-term weather forecast	Reservoir pre-release , river flood preparedness, irrigation scheduling, field operation planning
Weeks–Months	Subseasonal outlook , rainfall and temperature tendency	Drought monitoring, water allocation adjustment , irrigation demand planning, reservoir storage management
Seasons	Seasonal forecast , wet/dry season outlook	Seasonal irrigation planning, crop-water planning, drought preparedness, reservoir operation strategy
Years	Interannual climate variability, ENSO-related outlook	Annual water supply planning, basin water balance assessment , drought risk management
Decades	Climate variability trends, regional climate projections	Infrastructure investment, dam and reservoir planning, long-term water security strategy
Centuries	Climate change scenarios , anthropogenic forcing	Climate change adaptation policy , national water strategy, resilient infrastructure design

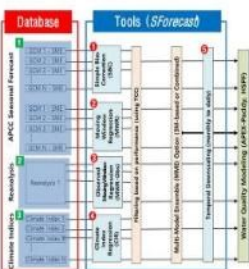
STEM — Spatial & Temporal Enhancement Models

AI-powered downscaling from global climate signals to field-scale inputs

• R-Packages

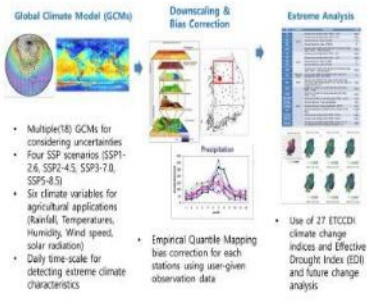
Sforecast(station-based)

- Hybrid seasonal forecasting based on APCC forecast, reanalysis, and climate indices.
- Deterministic forecast information are provided for each weather stations.



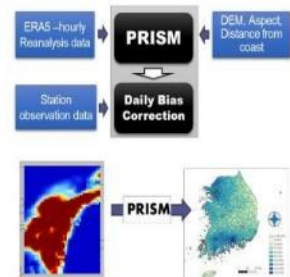
SQM

- Weather station-based statistical downscaling package for CMIP6 (SSP scenarios)



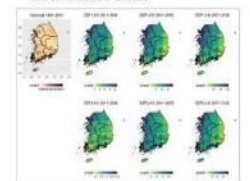
ObsGrid

- Creating long-term grid-based observation data
- ✓ ERAS: 1979–present; 6 variables (rainfall, temperatures, Wind speed, humidity, solar radiation); 25 km resolution



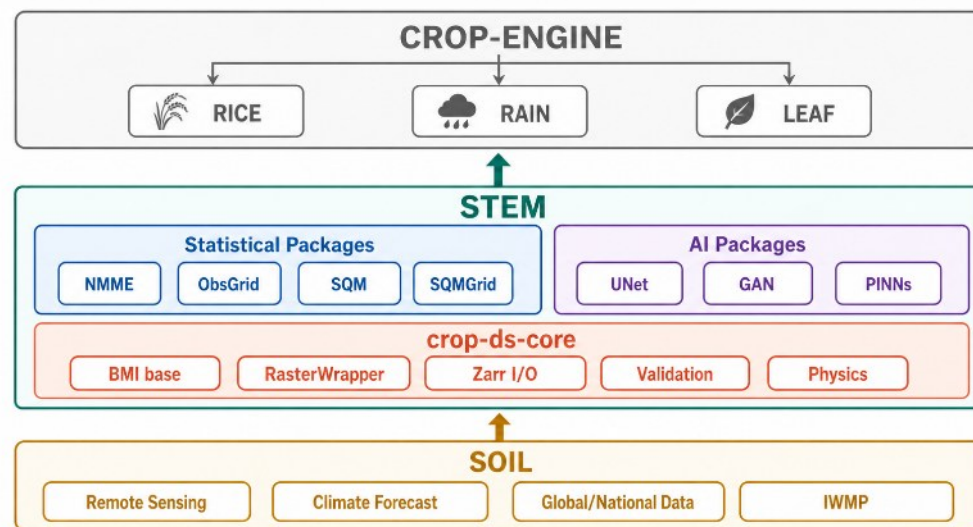
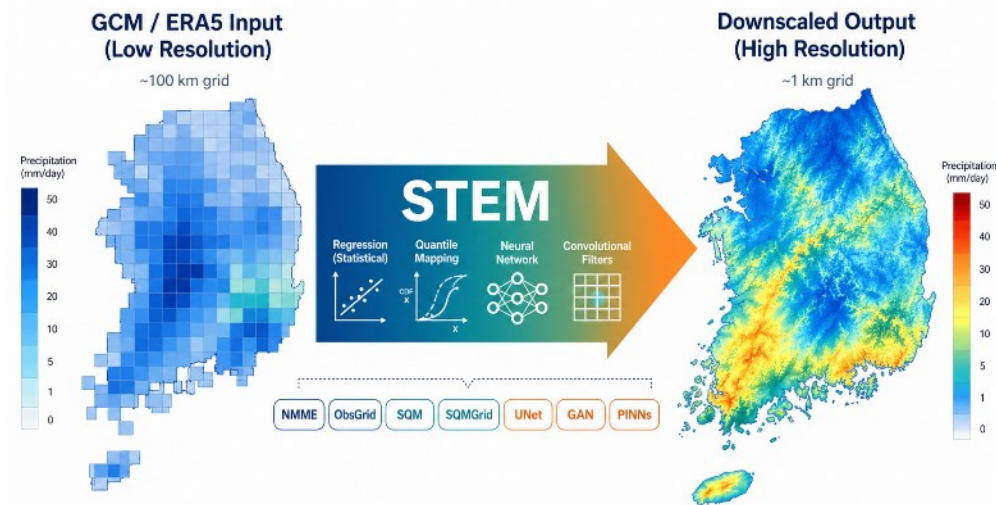
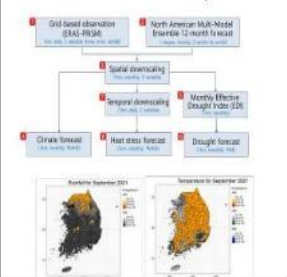
SQM-Grid

- Same downscaling method as SQM is used.
- Same GCMs, SSP scenarios, and variables as SQM
- Bias-corrected data is created based on the same resolution of ObsGrid output.
- ETCCDI and Bioclim indices are calculated based on downscaled data.



NMME (grid-based)

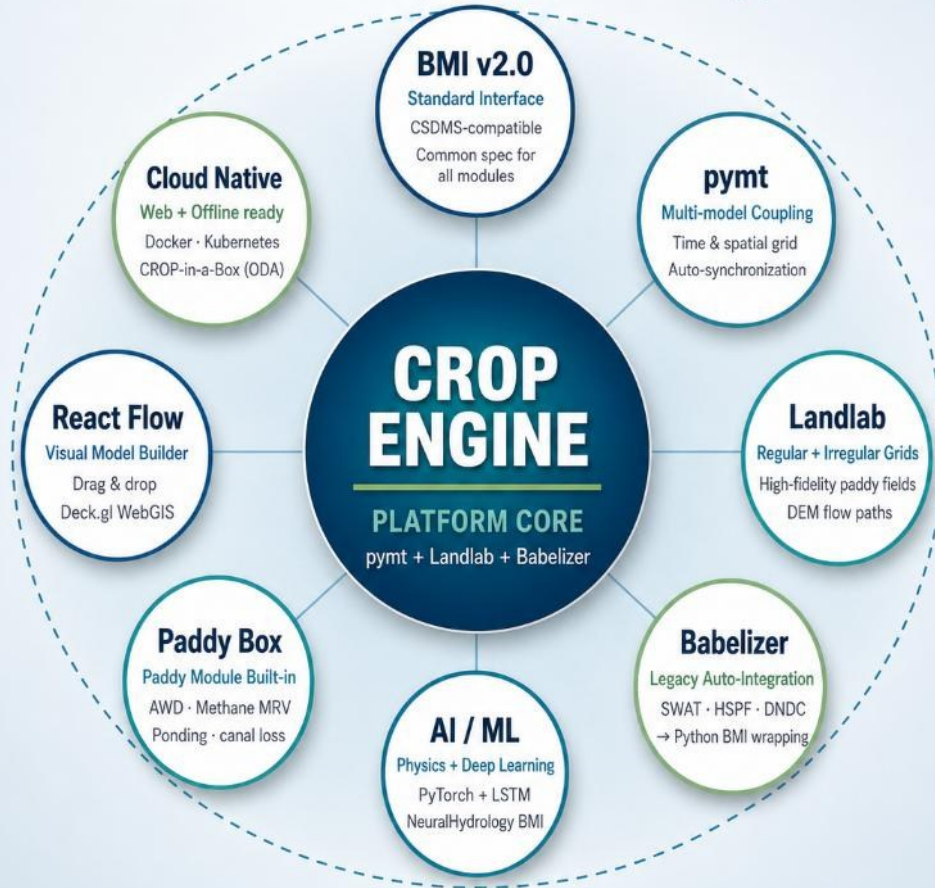
- North American MME is used as input
- Creating downscaled seasonal forecast data based on same resolution of ObsGrid output.
- Probabilistic drought (EDI) and heat wave forecast information is provided.



CROP-Engine : A New Standard for Platform-Based Watershed Modeling

PLATFORM-BASED WATERSHED MODELING

From monolithic models to a modular assembly platform



10-Layer Architecture · CSDMS Standard · Open Source · BMI v2.0 Compliant

PostGIS + TimescaleDB · Zarr/NetCDF · FastAPI · EPSG:5186 (Korea) / EPSG:4326 (Global)

MODEL COMPARISON | SWAT · DANSAT · CROP-Engine

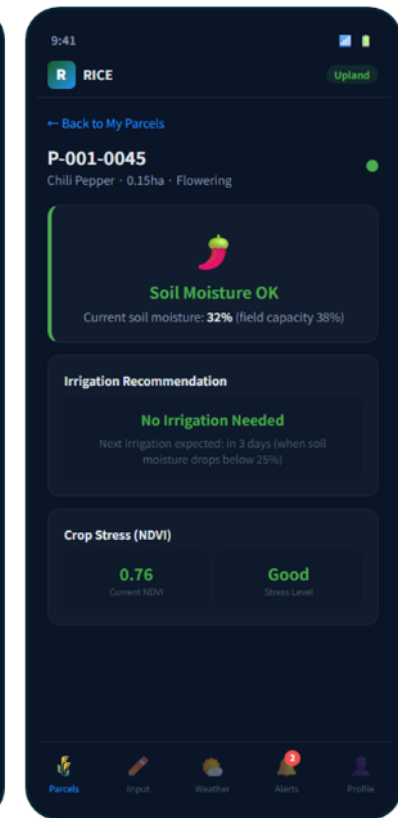
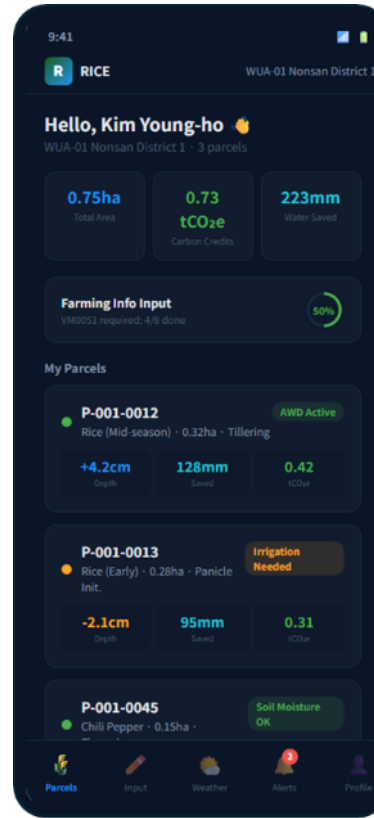
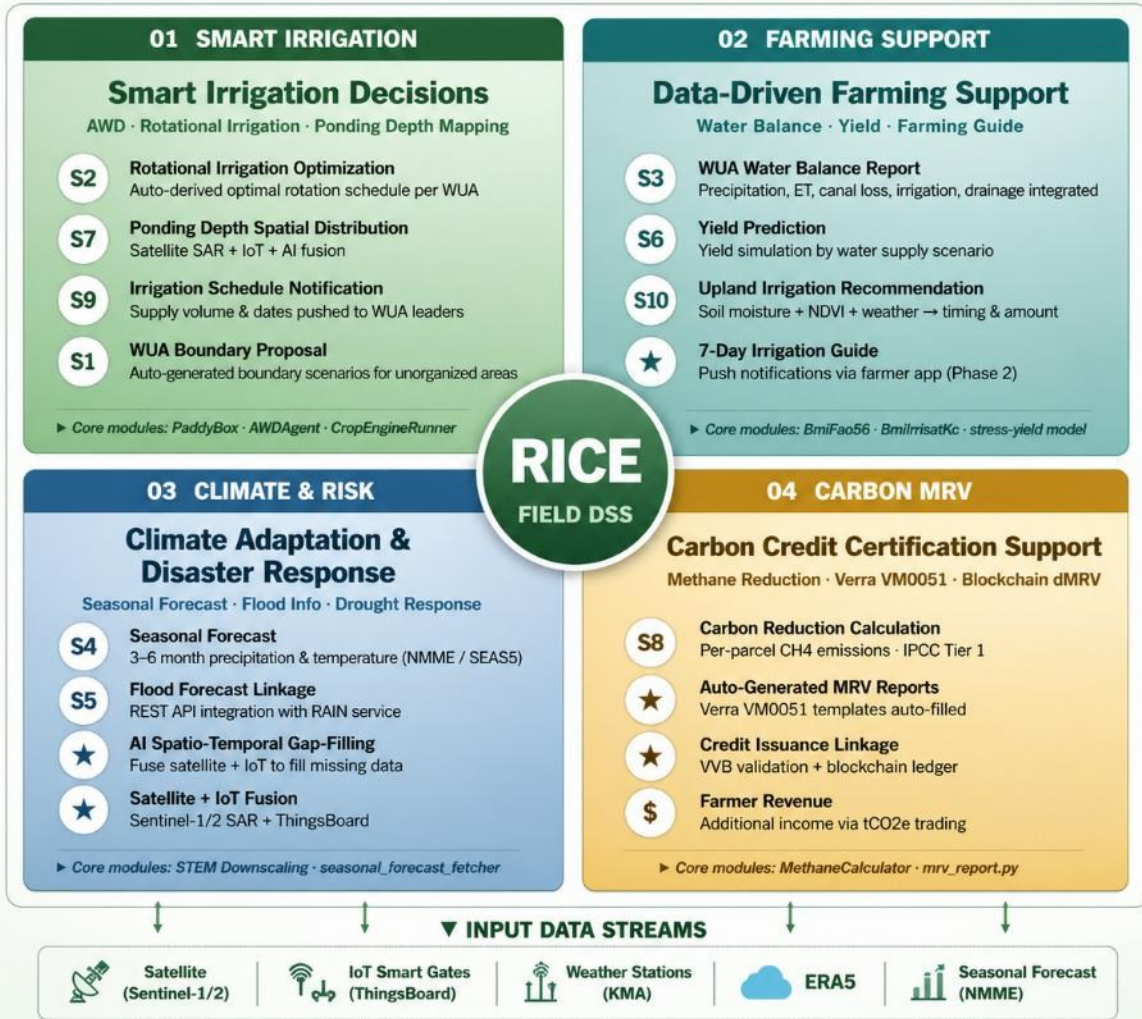
Comparison	SWAT	DANSAT	CROP-Engine
Model Architecture	Monolithic (Fortran)	Monolithic (Fortran)	Platform · Modular Assembly
Spatial Resolution	Semi-distributed (HRU lumped)	Fully distributed (grid)	Regular + Irregular (Landlab)
Standard Interface	None	None	BMI v2.0 (CSDMS)
Multi-Model Coupling	Limited (external tools)	MODFLOW-MT3D coupling	Free coupling via pymt
Paddy & Irrigation	Add-on (SWAT+ Rice)	Not supported (upland · BMP)	Paddy Box + AWD built-in
Time Resolution	Daily	Daily	Daily ~ sub-daily
AI / ML Integration	Not supported	Not supported	PyTorch BMI wrapping
User Interface	ArcSWAT (GIS plug-in)	No dedicated UI	Web-based visual builder
Legacy Integration	Standalone	Standalone	Direct integration via Babelizer
Deployment / Scaling	Desktop monolithic	Desktop monolithic	Cloud + CROP-in-a-Box

KEY TAKEAWAY SWAT and DANSAT are single-purpose models for specific domains; CROP-Engine is a standard platform that freely couples them.

RICE — Realtime Irrigation & Climate-responsive Engine

RICE SERVICE MAP

Field-level Decision Support · Smart Irrigation + Farming + Climate + Carbon



10 core services · 117 medium basins · 850 standard sub-basins · 3,659 field surveys · 3 years (2025–2027)

RAIN — Realtime Analysis of Integrated Nexus-forecasting

RAIN SERVICE MAP

Watershed-level Decision Support · Drought + Flood + Water Quality / Ecology

▼ FORCING & DATA

Rainfall (KMA · radar · satellite) · ERA5 / NMME forecasts · RAWRIS reservoir levels · IWMP IoT · Stream gauges (water level / discharge)

RAIN

DOMAIN 01

DROUGHT

Drought Forecast · Water Supply



- 01 Dam Inflow Forecasting** CFE / Noah-OWP + LSTM correction
- 02 Reservoir Level Analysis (KRC)** Rapid screening of 17,000 reservoirs
- 03 Drought Stage Classification** SPI · SPEI · SMI · ARDI indices
- 04 Water Supply Scenarios** Release operations · rotational irrigation decisions
- 05 Seasonal Outlook (3–6 months)** NMME / SEAS5 downscaling

Users: K-water · KRC

CFE · Noah-OWP · LSTM
PaddyBox · DistrictReservoir

FLOOD

Flood Early Warning · Safety



- 01 Ensemble Water-Level Forecasting** 10–50 parallel scenario simulations
- 02 Auto-Issued Flood Alerts** River Act standards · 4-tier severity
- 03 Flood Inundation Mapping (FIM)** Real-time inundation maps + WebSocket push
- 04 Reservoir Safety Alerts** Overtopping · breach · EAP stage classification
- 05 Urban Flood (LID Effect)** Sewer network + stormwater storage + infiltration sim

Users: K-water · MOIS · Local Governments

CROP-Engine · HEC-RAS · FIM
RainGauge · EWS · WebSocket

DOMAIN 03

WQ·ECO

Water Quality · Ecology · TMDL



- 01 Water Quality Monitoring** T-N · T-P · BOD · EC real-time monitoring
- 02 WQ Modeling & Forecasting** QUAL2K / WASP / CE-QUAL-W2
- 03 TMDL Load Allocation** Watershed unit load allocation
- 04 Ecology Assessment** Habitat · Biodiversity · Flow regime
- 05 Algal Bloom & Risk Alerts** Cyanobacteria predictive alerts

Users: MOE · Local Governments · Researchers

QUAL2K · WASP · EcoLab
WaterQualityGauge · AlgaeAlert



**INTEGRATED
OUTPUTS**



DASHBOARDS
Basin / Watershed
real-time dashboards



ALERTS & NOTIFICATIONS
Multi-channel alerts
(SMS · App · Email)



MAP SERVICES
Forecast maps · Inundation maps
WQ maps · Risk maps



REPORTS
Automatic reports
& Open API



OPEN PLATFORM
REST API · Data sharing
Interoperability (BMI v2.0)

12 core services · 117 medium basins · 850 standard sub-basins · 3,659 field surveys · 3 years (2025–2027)

LEAF — Legal Evaluation & Availability Framework

LEAF SERVICE MAP

Legal & Policy Decision Support · 5-Step Filter for Practical Available Water

PHYSICAL TOTAL PRACTICAL AVAILABLE

1 **PHYSICAL AVAILABILITY**
Physical water availability · flow analysis (CROP-Engine hydrologic model) streamflow · storage **100%**

▼ subtract instream flow requirements and environmental flow

2 **LEGAL RESERVATIONS**
Legally reserved water · instream flow · environmental flow · protected zones env. flow · MOE gazette **~80%**

▼ subtract permitted and registered water rights (WAMIS / GIMS)

3 **ALLOCATION RIGHTS**
Allocable water · permitted withdrawals vs remaining allocable volume permits · registrations **~55%**

▼ adjust using actual withdrawals vs permitted volume and dispute history

4 **ENFORCEMENT RISK**
Enforcement risk adjustment · disputes · complaints · violation history disputes · violations **~40%**

▼ apply remaining TMDL allowable load (water quality assimilative capacity)

5 **WATER ASSIMILATIVE CAPACITY**
Water quality assimilative capacity · remaining TMDL allowable load (linked with RAIN) load_remaining **★ NEW**

▼ **FINAL OUTPUT INDICES**

LAI

Legal Availability Index
legal availability (quantity)
Steps 1-4 result

×

WAI

Water Assimilative Index
water quality assimilative capacity
Step 5 result

=

COMPOSITE

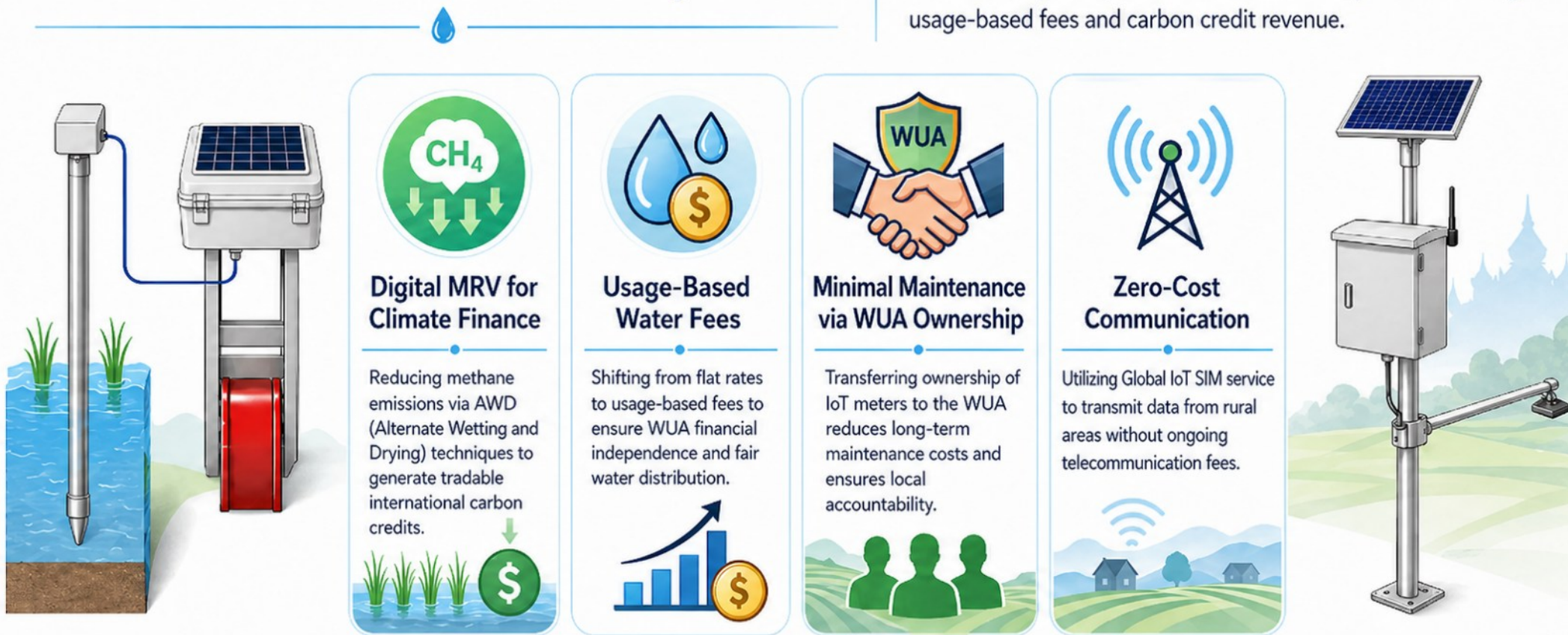
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Composite Water Availability
Quantity + Water Quality

Possible Application in LAOS (KOICA IBS)

Smart Irrigation & Carbon Finance: A New Era for Water Sustainability in Laos

This initiative implements an innovative “Inclusive Business Model” in the Nam Hom district of Laos. By combining Smart Irrigation Gates with IoT-based water metering, the project enables Water User Associations (WUAs) to achieve financial independence through usage-based fees and carbon credit revenue.



Sustainable Water Management.

Financial Independence.

Climate Resilience.

Stronger Rural Communities.



Баярлалаа

ขอบคุณ

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ຂອບໃຈ

Спасибо

Gracias

Dziękujemy

Terima kasih

Teşekkür ederim

감사합니다

Thank you

شكراً

Благодаря

Asante sana

Merci

धन्यवाद



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