

SISMaT

*Smart Irrigation Scheduling and Yield Forecasting for Maize
in Namibia's Maize Triangle Using Earth Observation*

Midterm Progress Report

EO AFRICA R&D FORUM 2026 · Achievement and Future Pathways

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What we will cover

1

The problem

Why soil moisture matters for Namibia's maize farmers

2

The project

SISMaT at a glance

3

Presentation emphasis

Sentinel-1 SAR calibration against gravimetric field data

4

Methods

Field campaign · lab analysis · SAR preprocessing · regression

5

Results

Fitted retrieval and seasonal application across the Maize Triangle

6

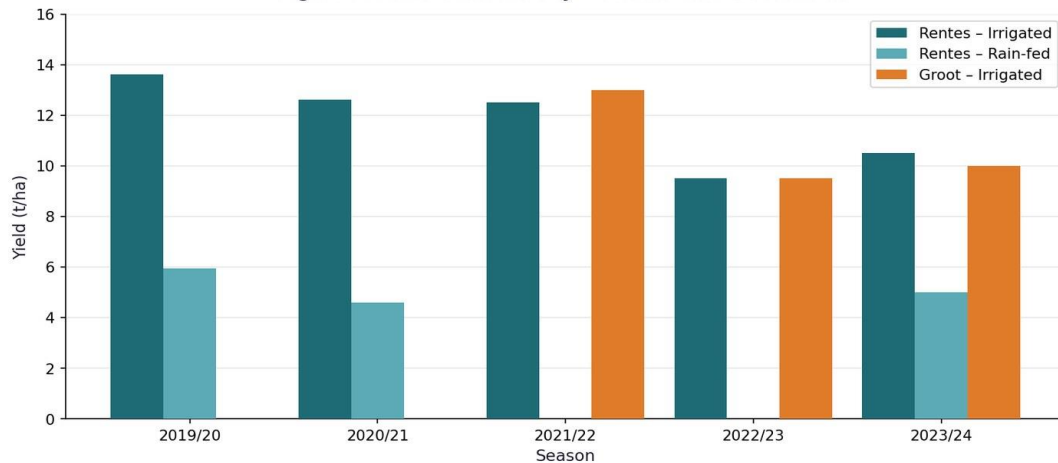
Path forward

What remains in the final five months of the project

Why soil moisture matters for Namibia's maize sector

There has been a multi-year yield decline in Maize production that aligns with regional water-storage stress

Figure 3: Maize Yield History — Rentes and Groot Farms



Maize yield history, SISMaT pilot farms

-30 %

Yield drop at Rentes Farm 2019–20 → 2022–23

13.6 → 9.5

t/ha — irrigated maize yield at Rentes Farm

2023

El Niño drought year confirmed by water-storage low from GRACE satellite

Without operational, field-level moisture information, irrigators cannot match scheduling to actual root-zone demand. SISMaT is closing that gap.

SISMaT at a glance

A 15-month NUST–NTU collaboration under the ESA EO AFRICA R&D Facility

Funder

ESA EO AFRICA R&D Facility

In collaboration with African Union Commission



Duration

Sep 2025 — Aug 2026

15 months · midterm reporting Apr 2026

Partnership

NUST & NTU

Tandem African–European research project



Pilot sites

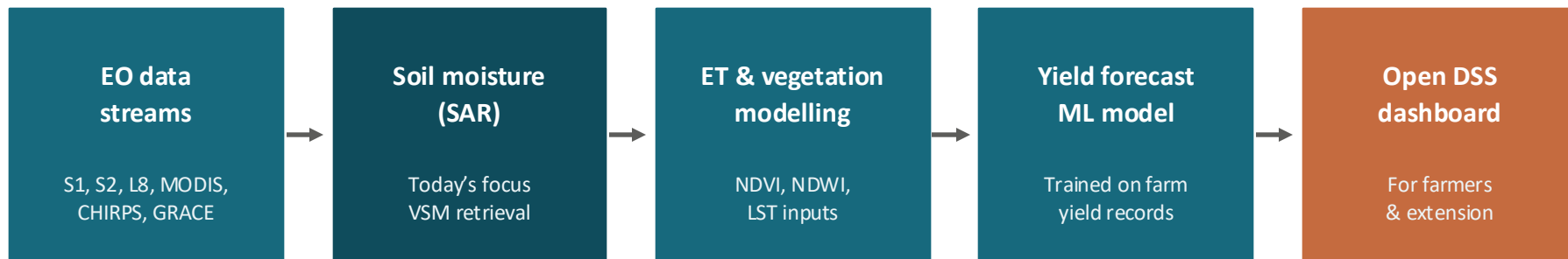
2 farms, ~150 ha

Rentes Farm (Otavi) · Groot Farm (Grootfontein)

Stakeholder partners: Agronomy Producers' Association of Namibia · MAFWLR · SASSCAL

Project objectives and analytical pipeline

From multi-satellite EO into actionable irrigation guidance



Four project objectives:

- Develop a SAR-based surface soil moisture product calibrated to local conditions
- Estimate field-level evapotranspiration from EO
- Train a machine learning yield forecasting model on farm historical records
- Deliver all objectives via an open-source, cloud-hosted dashboard

Study area — Namibia's Maize Triangle

Otjozondjupa and Oshikoto Regions



Maize Triangle

~5,000 km² · central-north Namibia

Climate: semi-arid, summer-rainfall (Nov–Apr)

Dominant agriculture: irrigated and rain-fed maize

Pilot farms

Rentes Farm

Otavi · 19.57°S, 17.36°E

100 ha (40 ha irrigated, 60 ha rain-fed)

Maize producer since 2019

Groot Farm

Grootfontein · 19.26°S, 17.97°E

48 ha (fully irrigated)

Maize producer since 2021

Objective 1: Sentinel-1 SAR soil moisture calibration

The team made attempts to connecting in-situ field data to satellite EO.

This is the foundation on which every other product in the SISMaT pipeline depends

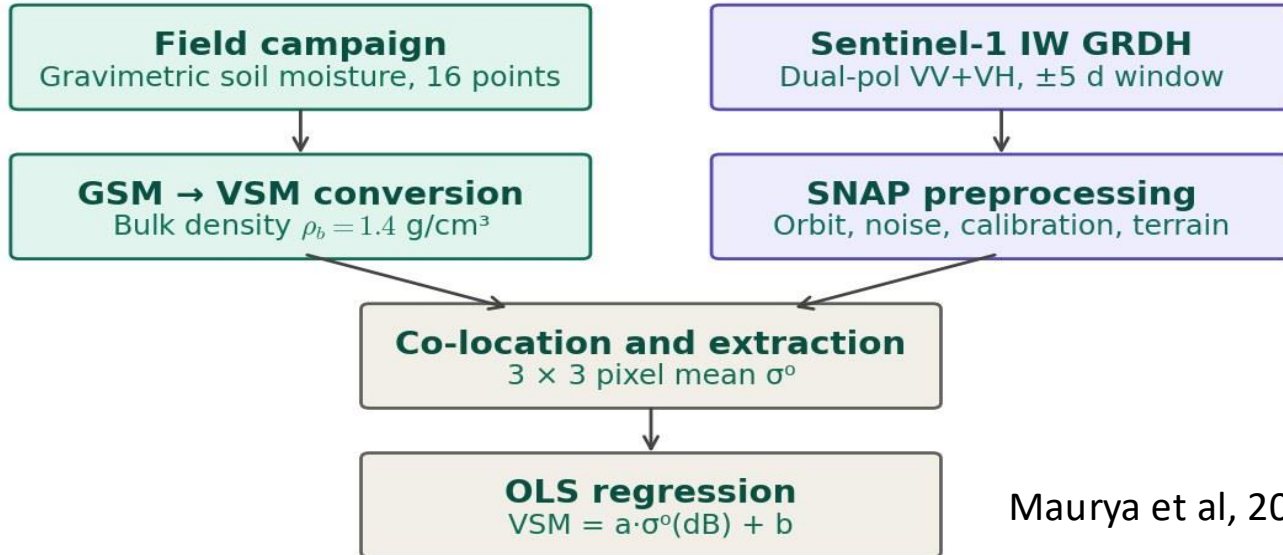
WHAT Empirical relationship between Sentinel-1 σ^0_{VW} backscatter and in-situ volumetric soil moisture

WHY No universal σ^0 → VSM formula, hence, site-specific calibration is essential before operational use

HOW In-situ field campaign → gravimetric lab → SAR preprocessing → OLS regression

Calibration workflow

Two parallel data streams converge to an OLS regression



Maurya et al, 2021

Field campaign — 25–26 November 2025

Two-day soil sampling at Rentes (Otavi) and Groot (Grootfontein) Farms



32

paired soil samples

16

GPS-referenced points

2

sampling sessions (AM/PM)

Soil auger extraction, in-field weighing, GPS coordinate logging, transport to NUST laboratory the same day.

Lab analysis — oven-dry gravimetric method

ASTM D2216 → GSM → conversion to volumetric VSM



1. Gravimetric (mass-based)

$$\text{GSM (\%)} = \frac{M_{\text{wet}} - M_{\text{dry}}}{M_{\text{dry}}} \times 100$$

2. Volumetric — assuming $\rho_b = 1.4 \text{ g/cm}^3$ (sandy loam)

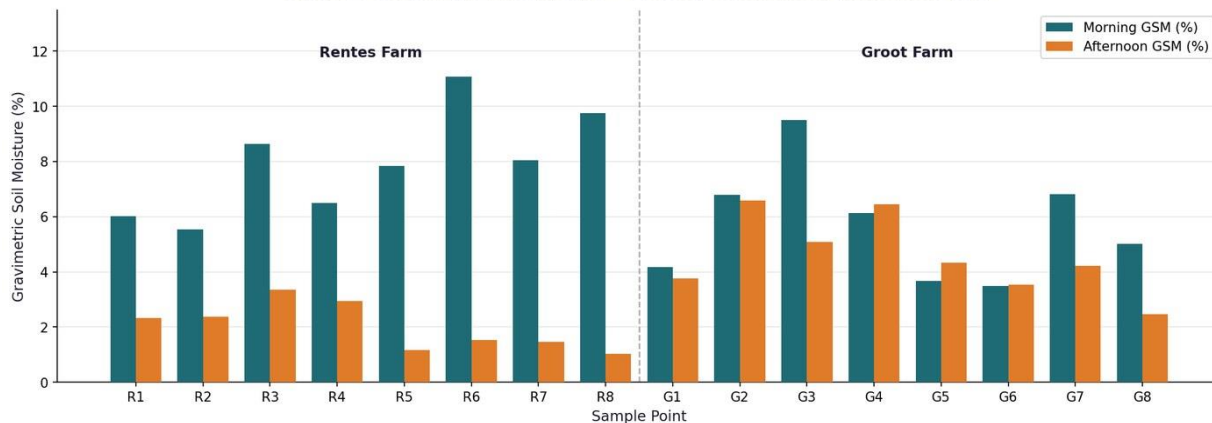
$$\text{VSM (\% VWC)} = \text{GSM} \cdot \frac{\rho_b}{\rho_w}$$

All 32 samples processed at the NUST soil lab — weighed wet, oven-dried to constant mass at 105 °C, re-weighed.

Field soil-moisture results

Diurnal evapotranspiration drops Rentes from ~8–11 % to ~1–3 % GSM in hours

Figure 1: Gravimetric Soil Moisture — Morning vs. Afternoon (November 2025)



Key observations

Rentes

Strong diurnal signal
7.93 → 2.05 % GSM

Groot

Modest diurnal signal
5.70 → 4.56 % GSM

Range

Morning VSM 4.9–15.5 % VWC

Why this matters for calibration:

The wide morning VSM range (4.9–15.5 % VWC) provides the dynamic range needed to fit a regression slope, but the afternoon range was too compressed at Rentes.

Sentinel-1 acquisition and preprocessing

IW GRDH Dual-Pol (VV+VH) · 7-step SNAP chain (Filipponi 2019)

- 1 Apply Precise Orbit File
- 2 Thermal Noise Removal
- 3 Border Noise Removal
- 4 Radiometric Calibration → σ^0
- 5 Refined Lee speckle filter (5×5)
- 6 Range-Doppler Terrain Correction
- 7 Linear → dB conversion

Choices specific to this calibration

Acquisition window:

±5 days around field campaign

Pass direction:

Ascending only (descending unavailable)

Local overpass:

~18:00 Namibia time (UTC+2)

Extraction kernel:

3×3 pixels (≈30×30 m mean) per sample

Processing environment:

Google Earth Engine COPERNICUS/S1_GRD

Bands retained:

σ^0_{VV} , σ^0_{VH} , cross-pol ratio

Calibration model — empirical linear regression

Standard approach for C-band SAR over sparsely-vegetated agricultural soils (Muarya et al, 2021)

$$\text{VSM} = a \cdot \sigma_{\text{VV}}^0 (\text{dB}) + b$$

Calibration target selection

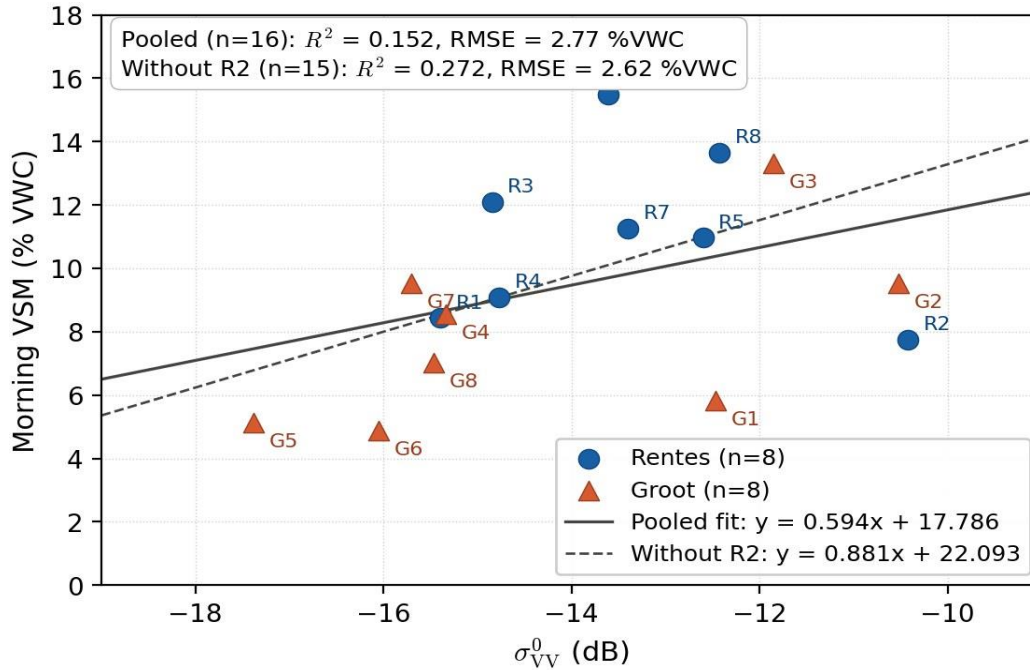
Sentinel-1 ascending overpass (~18:00 local) is closer in time-of-day to the afternoon field samples — initially adopted as the primary target. However, the narrow afternoon VSM range produced a regression slope of incorrect sign ($R^2 = 0.002$). The morning VSM, despite the larger time offset, preserved the moisture dynamic range needed to fit a physically meaningful slope, and was retained as the operational calibration target.

Variants assessed:

Sample points (n=16) · outlier-removed (n=15, R2 excluded) · per-farm stratified (Groot, Rentes) · two-variable (VV+VH)

Calibration result

Pooled OLS regression — physically consistent positive slope



FITTED RETRIEVAL

VSM = 0.594 · σ^0_{VV} (dB) + 17.79

Slope sign physically expected ✓

R²	0.152	<i>Pooled (n=16)</i>
RMSE	2.77 % VWC	<i>Pooled (n=16)</i>
R²	0.272	<i>Outlier removed (n=15)</i>
R² (Groot only)	0.327	<i>Per-farm stratified (n=8)</i>
R² (Rentes only)	0.004	<i>Per-farm stratified (n=8)</i>

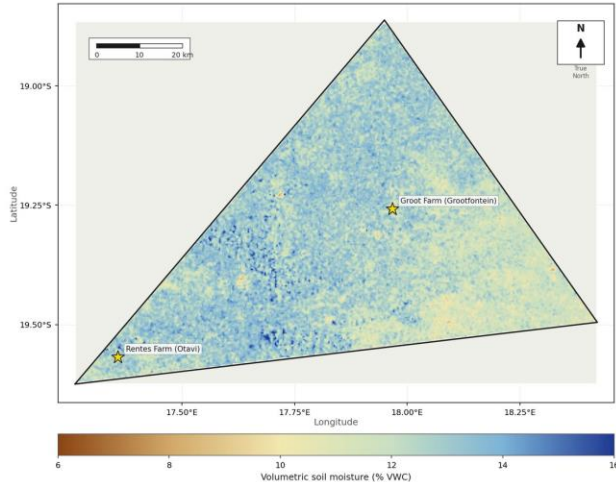
R2 outlier:
 Anomalously bright VV (-10.4 dB). This is likely a tillage or geolocation effect.

Application across the Maize Triangle

internal-consistency stress test of the calibration implemented directly as a Band Maths expression in SNAP across 3 *Sentinel-1* dates

Surface Soil Moisture — Rainy Season

Composite of Sentinel-1 acquisitions 13-20 February 2025, Maize Triangle, Namibia



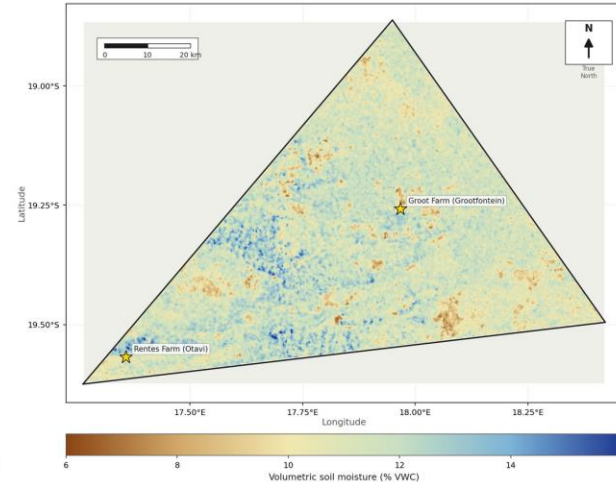
Source: Sentinel-1: 1 IW GRD, ASC pass - Model: VSR = 0.394 * 0°_VV(BB) + 17.79 - SISMaT 2026 Projection: Geographic (WGS84) CRS: EPSG:4326

Rainy season

13–20 Feb 2025

Surface Soil Moisture — Calibration Date

Sentinel-1 acquisition 22 November 2025, Maize Triangle, Namibia



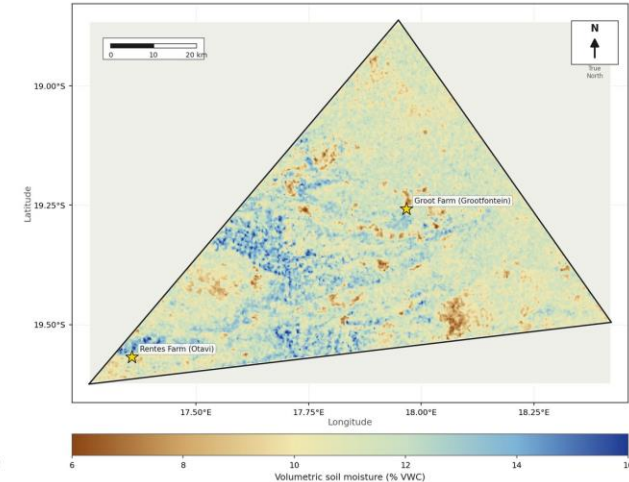
Source: Sentinel-1: 1 IW GRD, ASC pass - Model: VSR = 0.594 * 0°_VV(BB) + 17.79 - SISMaT 2026 Projection: Geographic (WGS84) CRS: EPSG:4326

Calibration date

22 Nov 2025

Surface Soil Moisture — Dry Season

Composite of Sentinel-1 acquisitions 25-30 August 2025, Maize Triangle, Namibia



Source: Sentinel-1: 1 IW GRD, ASC pass - Model: VSR = 0.594 * 0°_VV(BB) + 17.79 - SISMaT 2026 Projection: Geographic (WGS84) CRS: EPSG:4326

Dry season

25–30 Aug 2025

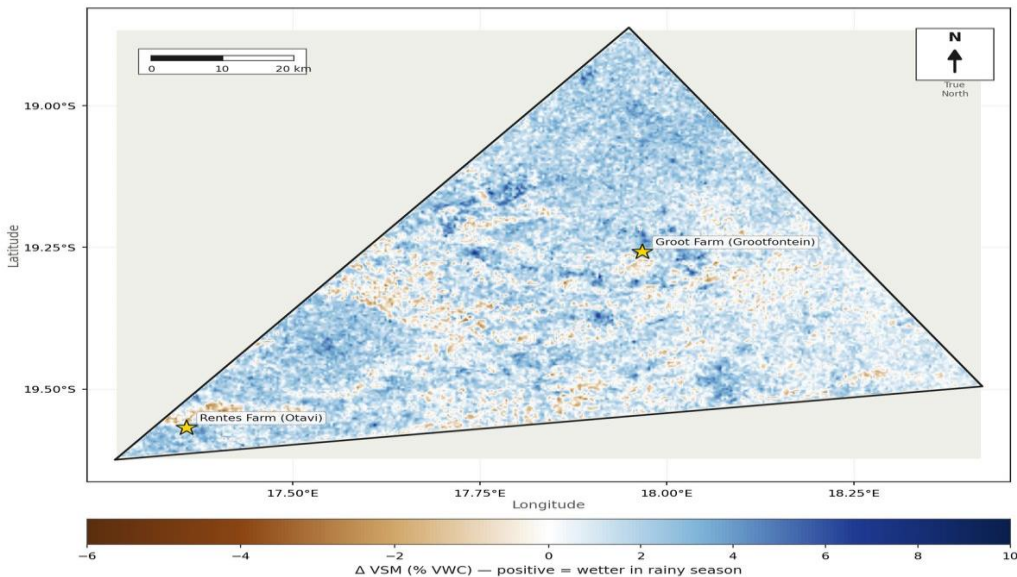
Triangle-mean VSM: rainy 12.6 % > shoulder 11.4 % > dry 11.3 % . The expected climatological ordering is preserved

Internal consistency check — rainy minus dry difference

Predominantly positive difference field with isolated noise — confirms physical sign

Soil Moisture Difference — Rainy – Dry Season

Per-pixel difference between February 2025 and August 2025 composites



Three findings

1

CORRECT SIGN

Rainy – Dry is positive across the overwhelming majority of the Maize Triangle at 30 m resolution.

2

INCOHERENT NOISE

Few negative cells are isolated and spatially incoherent. This is characteristic of residual SAR speckle, not systematic bias.

3

PERSISTENT FEATURES

Centre-pivot irrigation circles around Otavi remain detectable as wet anomalies against the dry-season background.

Limitations of the preliminary calibration

Delimitation of the operational envelope

Quantitative bound

1.3 %

Seasonal contrast
(rainy – dry mean)

2.77 %

Calibration RMSE
(uncertainty floor)

The seasonal signal is below the uncertainty value. This shows that although the qualitative patterns are preserved, the quantitative seasonal-balance is not absolutely reliable.

Four compounding factors

- 1 Narrow σ° _VV dynamic range at Rentes (only 5 dB across a wide VSM range)
- 2 Assumption of a uniform ρ_b despite heterogeneous Groot soil profile biases the VSM
- 3 Temporal mismatch between SAR image and data set. The ascending pass happens around 18:00 against the morning sampling done around 08:00–11:00.
- 4 Small sample size (n = 16)

Three priority developments

From preliminary calibration to operational soil-moisture product

1

DATA

Wet-season field campaign

Second campaign was done in Oshikoto Region during the wet season to extend the VSM calibration range above 15 % VWC and break the dry-end bias of the current dataset.

2

DIAGNOSTICS

R2 outlier investigation

Targeted return visit to the R2 sampling point to determine whether the anomalously bright VV signature reflects a tillage feature, a geolocation artefact, or genuine soil-surface condition.

3

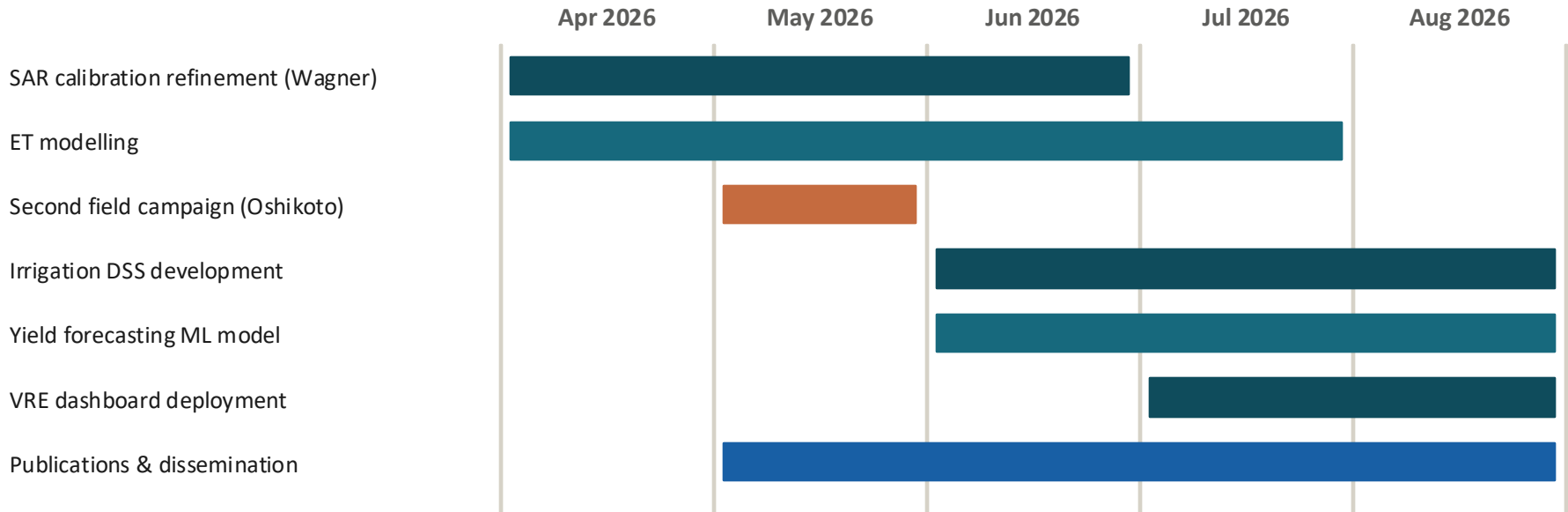
METHOD

Wagner change-detection retrieval

Parallel implementation of a multi-temporal per-pixel rescaling against σ^0 extrema, expected to be more robust to surface-roughness, vegetation, and bulk-density heterogeneity than the present linear model.

Project completion timeline

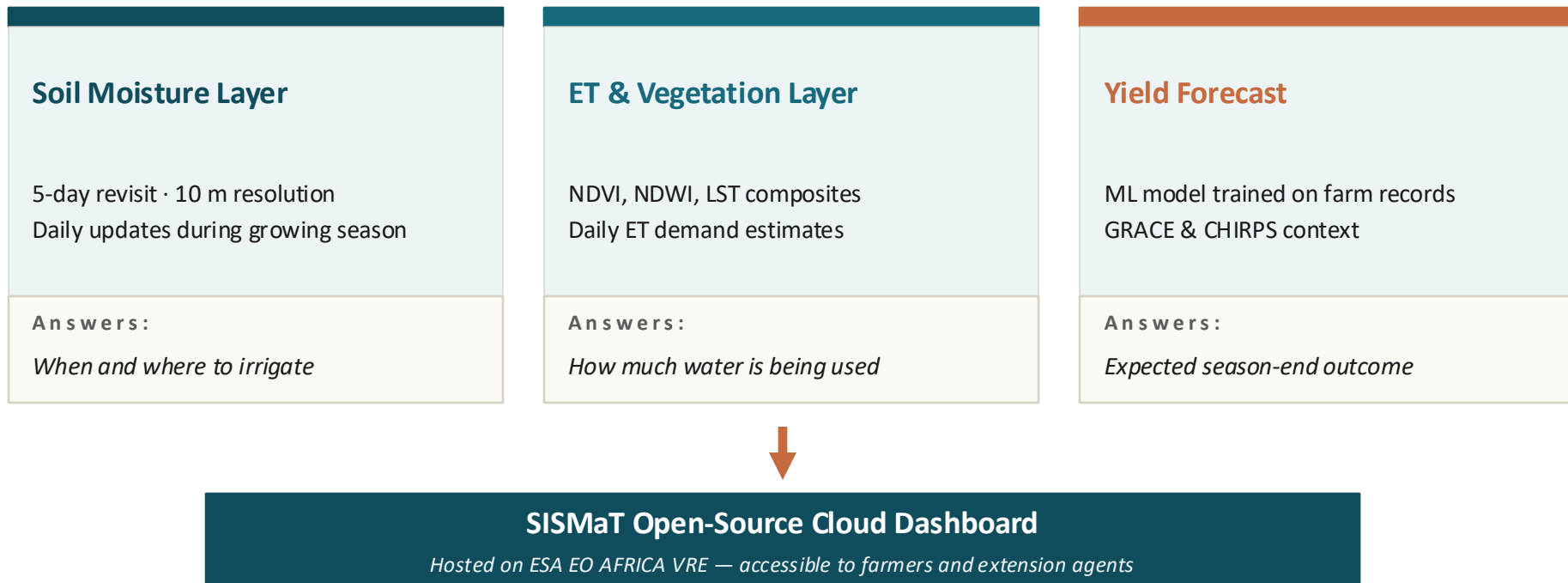
Five remaining months — April to August 2026



Critical path: SAR calibration → ET modelling → irrigation DSS → yield model → VRE deployment → dissemination

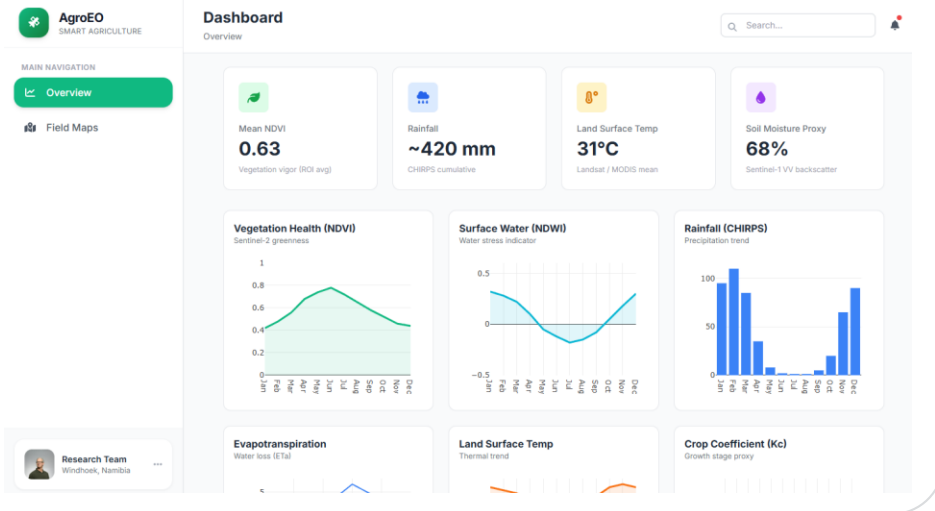
Operational deployment — beyond calibration

Three streams converge into a single decision support dashboard for farmers



Prototype dashboard interface

Overview dashboard



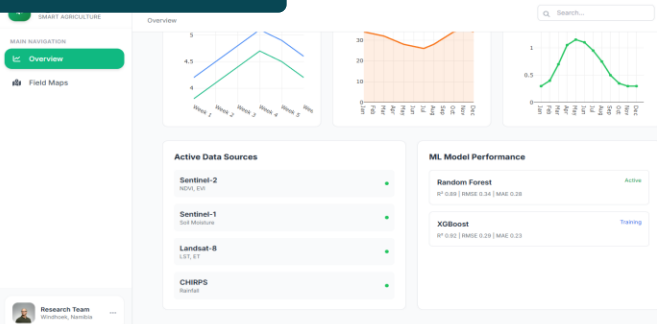
Model status

Active data streams and machine-learning performance are visible in the same dashboard.

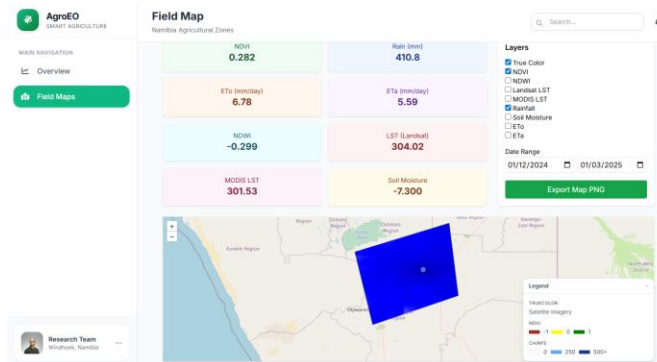
EO indicators

NDVI, rainfall, land surface temperature and soil-moisture proxy are summarised

Data sources & ML status



Field map interface



Acknowledgements

Funding & coordination

- ESA EO AFRICA R&D Facility
- African Union Commission (AUC)
- European Space Agency (ESA)

Stakeholder partners

- Agronomy Producers' Association of Namibia
- Ministry of Agriculture, Fisheries, Water and Land Reform
- SASSCAL (Southern African Science Service Centre)

Host institutions

- Namibia University of Science and Technology
- Nottingham Trent University

Field partners

- Rentes Farm (Otavi) — owners and farm staff
- Groot Farm (Grootfontein) — owners and farm staff



Special thanks to the farmers who allowed us onto their land and shared multi-year yield records.

Thank you

SISMaT Project

Namibia University of Science and Technology, Windhoek & Nottingham Trent University, UK

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