



Field weather record

Soil, Season and Disease

for one **field**, from open data

Published models run on open data for a single corn field, with the soil-moisture downscaling test reported as it came out and the season brief that could not compute its drought indices left visible.



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Introduction



This paper describes how Axine Laboratories reads weather, soil moisture and disease exposure for a single field from open data and published models. It follows one worked example, a 61 ha corn pivot in Kansas, through three questions a grower asks in a normal week, and it reports the one test that came out negative.

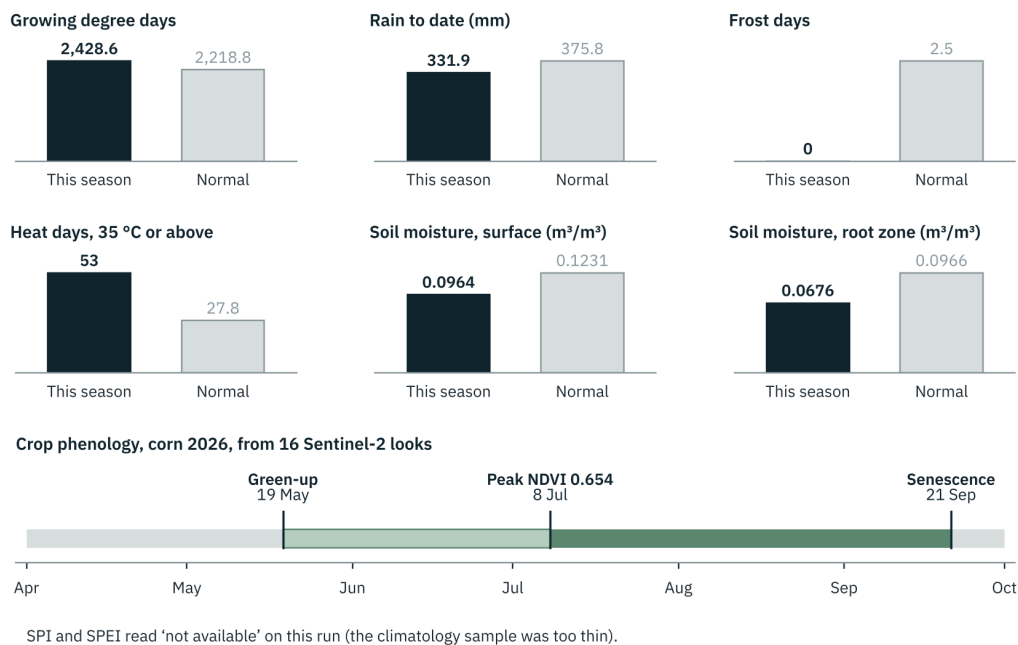


Figure 1. Season brief for the worked example field, run on 6 October 2026, 184 days into the 2026 season. Six panels set this season (dark) beside a normal year (grey); the strip below gives the phenology dates read from Sentinel-2.

Motivation: three questions about one field

A grower and an agronomist looking at a field ask a short, recurring set of questions. Is the soil wetter or drier than normal, at the surface and at root depth, and is it drying or wetting this week? How has the season run so far against a normal year for heat, cold, rain and drought? Given the forecast, does any disease this crop is exposed to cross its published action threshold in the next two weeks, and on which day?

The stakes in the last question are large and they move from year to year. The Crop Protection Network estimated that disease reduced United States and Ontario corn yield by 6.0 percent in 2024 and by 7.0 percent in 2025, about 1.3 billion bushels in the second year, with tar spot alone accounting for 188.8 million bushels¹. For soybean in 2025 the estimate was 4.8 percent of potential

production, 216.5 million bushels, of which white mould took 17.7 million bushels and frogeye leaf spot 5.5 million². Growers planted 95.3 million acres of corn and 85.4 million acres of soybean in 2026³, and none of them could know in April which kind of year it would be.

- + **Soil moisture.** Measurements are needed for applications that range from agricultural monitoring to weather prediction and drought and flood forecasting⁴. Ground probes are sparse, so a reading for a given field usually comes from a model.
- + **Season context.** Growing degree days, rain, frost days and heat days only mean something against a normal for the same day of the season.
- + **Disease exposure.** Each published disease model reads its own weather window and carries its own threshold, so the answer differs by crop and by day.



A dark ploughed field in the foreground with pale straw-coloured crop or stubble on the slope behind it.

Three Axine products answer these in turn: a soil-moisture reading with a field-scale pattern, a one-page season brief, and a 14-day disease forecast built from seven published models, five of which ran live for this field. We give the soil-moisture product most of the space because its validation produced a genuine negative result, and Axine publishes a failed gate as failed.

Why This Is Hard



Each of the three questions sits on a different kind of record, and each record has a weakness that decides how far its answer can be pushed.

Soil moisture has few ground truths

The USDA NRCS Soil Climate Analysis Network (SCAN) runs more than 200 automated sites that record soil moisture and temperature at depths from 5 to 100 cm⁵. Two hundred sites cover a continent thinly, and the field of interest almost never has a probe in it. The widely used reanalysis product, ERA5-Land, describes land water and energy cycles hourly at 9 km⁶, so a single cell spans many fields with different soils. A reanalysis cell assumes one soil texture across that area, and a probe reads one point with its own texture. The difference between the two shows up as a persistent bias that no downscaling step is able to remove.

A season only means something against a normal

Heat and rain totals have no meaning without a reference period. A standardised drought index adds a second requirement: enough years of record to fit a distribution. The WMO guide to the Standardized Precipitation Index says it can be calculated on as little as 20 years of data, and that the series should ideally hold at least 30 years⁷. The record used for the worked example here is ten years, below that floor, and that is the reason one result in this paper reads "not available".

Disease models were built on their own data

Each disease model is a published equation, fitted to a particular set of field observations, and its accuracy belongs to that study. The tar spot ensemble reached 87.4 percent on 588 observations from Midwest field trials in 2018 to 2022⁸. The soybean white mould models were fitted to about 3,900 field observations from Iowa, Michigan and Wisconsin in 2014 to 2016⁹. A model is an input to a decision. Running it on a new field with a new forecast does not repeat the accuracy of the paper.

Forecasts get worse with lead time

The disease models read a 16-day forecast. Forecast skill falls toward the far end of that horizon, and the forecast minimum temperature carries a known cold bias against the ERA5 reanalysis used for the season record. Every temperature-keyed model can therefore cross its threshold earlier, later or not at all for that reason, with the largest effect on the furthest-out days.

The Axine Method



Every input is open and read without a credential, with one exception, NASA SMAP L4, which was not available to this run.

Data sources

Source	What it supplies	Read through
ERA5-Land ⁶	Volumetric soil water at 0 to 7, 7 to 28 and 28 to 100 cm; the coarse soil-moisture reading and its climatology	Open-Meteo archive API
ERA5 ¹⁰	Daily temperature and precipitation, the basis of the season totals (GDD, frost, heat, SPI, SPEI)	Open-Meteo archive API
Sentinel-1 RTC	The change-detection radar pattern that the field-scale soil-moisture downscaling reads	Microsoft Planetary Computer, anonymous access
Sentinel-2 L2A	NDVI for the vegetation guard and for phenology (green-up, peak, senescence)	Microsoft Planetary Computer
Open-Meteo Forecast	The field's own 16-day forecast plus trailing hourly weather, the input every disease model reads	Daily and hourly, one call
USDA NRCS SCAN ¹¹	Public-domain 5 cm soil-moisture probes at ten stations, the independent ground truth	NRCS AWDB data service, element SMS:-2:1

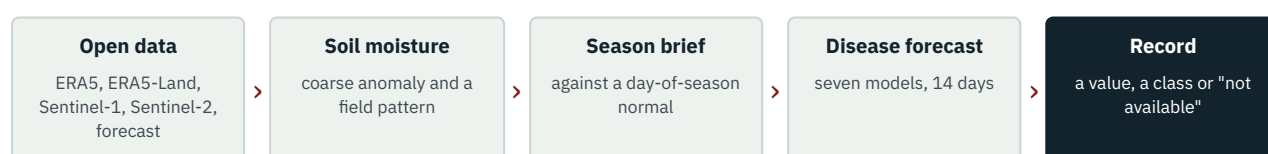


Figure 2. From open data to a record for one field.

The worked example field

All three live outputs in this paper ran on one field on 6 October 2026: a Kansas centre-pivot field of 0.61 km² (61 ha) in corn, spanning 37.900 to 37.907 N and 100.900 to 100.891 W. The soil-moisture validation uses ten SCAN stations across six states. The field has no ground probe, so the stations stand in for one question: if this field had a probe, would the downscaled map or the coarse cell read closer to it?

Soil Moisture: A Negative Result



The coarse ERA5-Land cell ships as the primary reading. A field-scale radar pattern ships beside it, labelled as a non-primary layer, because the validation did not show it to be closer to the truth.

The two numbers we compute

The product reports a coarse ERA5-Land reading at about 9 km and, when enough Sentinel-1 scenes are available, builds a field-scale pattern by change detection^{12,13}, then anchors that pattern so its spatial mean matches the coarse cell, the DISPATCH constraint¹⁴. The validation asks whether a Sentinel-1 read earns a map closer to the truth than the coarse cell's single number.

Part A: the coarse cell against ten stations

We compared the coarse cell with ten SCAN stations over 2023 and 2024¹¹. Pooled over 6,653 station-days the RMSE was 0.137 m³/m³, r was 0.44 and the bias was +0.047 m³/m³. Bias runs from -0.14 to +0.26 m³/m³ from station to station. Most of that spread is a representativeness effect: the soil texture a reanalysis cell assumes rarely matches the soil at one point. This is the reasoning the literature gives for not bias-correcting SMAP against sparse networks¹⁵. This is why the product reports an anomaly against the field's own multi-year normal. Part A is a pipeline check and makes no accuracy claim.

Part C: does the downscaled pixel read closer to station truth

Round two scores the downscaled pixel at each station's own coordinate. The dry and wet radar reference each pixel needs follows the cited papers: each point's full 2017 to 2022 Sentinel-1 RTC history, taken at the 5th and 95th percentiles, with none of the 2023 to 2024 scoring window used to build it. We tested four variants on the same 110 station-dates (ten stations, bi-monthly, 2023 to 2024). The count is 106 to 108 for the variants where a vegetation guard or a reference could not be built for every date. One variant adds an NDVI vegetation correction, the point-scale analogue of what ships in production, and another adds a VH/VV cross-ratio correction.

Variant	RMSE (m ³ /m ³)	r	Bias (m ³ /m ³)	n
Coarse ERA5-Land cell	0.1428	0.436	+0.054	110
Downscaled, orbit-normalised	0.1480	0.432	+0.062	108
Downscaled, no orbit correction	0.1477	0.433	+0.061	108
Downscaled, orbit-normalised + NDVI	0.1419	0.462	+0.057	106
Downscaled, orbit-normalised + cross-ratio	0.1461	0.440	+0.063	108

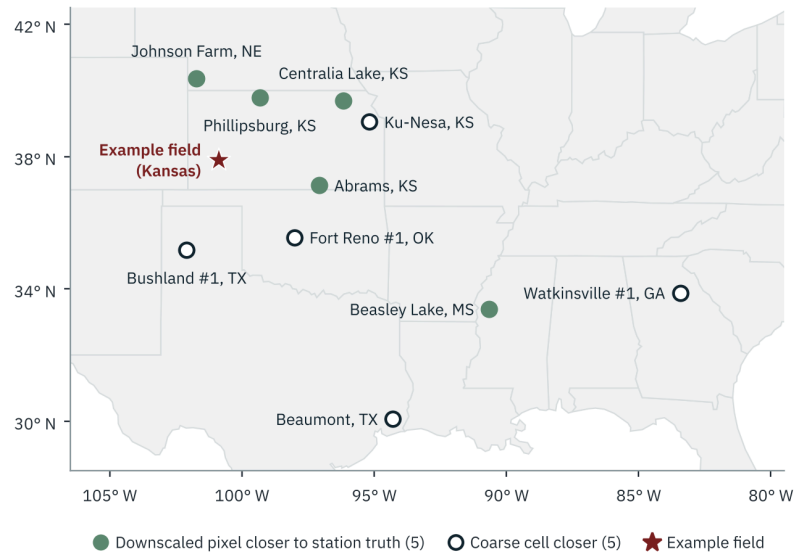


Figure 3. The ten SCAN validation stations. A filled circle marks the five stations where the downscaled pixel read closer to station truth (Abrams, Phillipsburg, Centralia Lake, Johnson Farm, Beasley Lake); a hollow circle marks the five where the coarse cell read closer (Ku-Nesa, Fort Reno #1, Beaumont, Bushland #1, Watkinsville #1). The star is the worked example field in Kansas.

The NDVI-corrected variant has the best point estimate of the four and is the vegetation guard already used in production. Its edge is small, and a station-clustered bootstrap says it cannot be told apart from zero. The bootstrap resamples stations and leaves rows whole, with 5,000 resamples, because twelve dates at one station share one wet and dry season and are not independent draws.

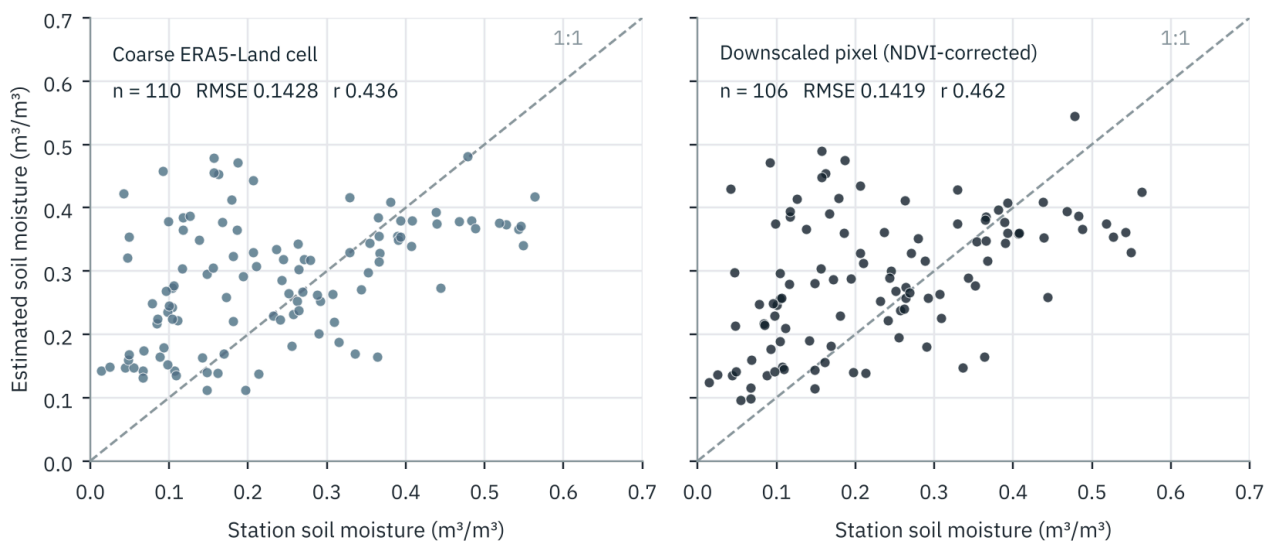


Figure 4. Estimate against SCAN station soil moisture (m^3/m^3) with the 1:1 line. Left, the coarse ERA5-Land cell ($n=110$, RMSE 0.1428, r 0.436). Right, the downscaled NDVI-corrected pixel ($n=106$, RMSE 0.1419, r 0.462). Neither cloud sits visibly closer to the line.

Variant	RMSE improvement, 95% CI (coarse minus variant)	Significant?
Orbit-normalised	[-0.0085, -0.0007]	Yes, worse than coarse
No orbit correction	[-0.0087, +0.0006]	No
Orbit-normalised + NDVI	[-0.0034, +0.0072]	No, includes zero
Orbit-normalised + cross-ratio	[-0.0062, -0.0000]	Yes, worse than coarse

0.1428

coarse ERA5-Land RMSE, m³/m³ (110 station-dates)

0.1419

downscaled, NDVI-corrected RMSE, m³/m³ (106 station-dates)

5 of 10

stations where the downscaled pixel reads closer

At 110 station-dates across ten stations, the published downscaling method, built the way the cited papers specify it, does not read closer to station truth than the coarse ERA5-Land cell's single number. Two variants are confidently worse, since their intervals sit entirely on the losing side. The best variant's apparent edge cannot be distinguished from no effect at this sample size.

Station by station

The picture is closer to even than the pooled number suggests. Five of ten stations beat the coarse cell on RMSE and five lose.

Station	State	n (dates)	RMSE, coarse	RMSE, downscaled (NDVI)	Result
Abrams	KS	12	0.1831	0.1711	Downscaled
Phillipsburg	KS	12	0.1193	0.1150	Downscaled
Ku-Nesa	KS	12	0.0440	0.0479	Coarse
Centralia Lake	KS	12	0.0903	0.0874	Downscaled
Fort Reno #1	OK	11	0.0393	0.0474	Coarse
Johnson Farm	NE	12	0.0862	0.0780	Downscaled
Beaumont	TX	3	0.0528	0.0700	Coarse
Bushland #1	TX	12	0.1203	0.1243	Coarse
Watkinsville #1	GA	12	0.2947	0.2979	Coarse
Beasley Lake	MS	12	0.1345	0.1343	Downscaled

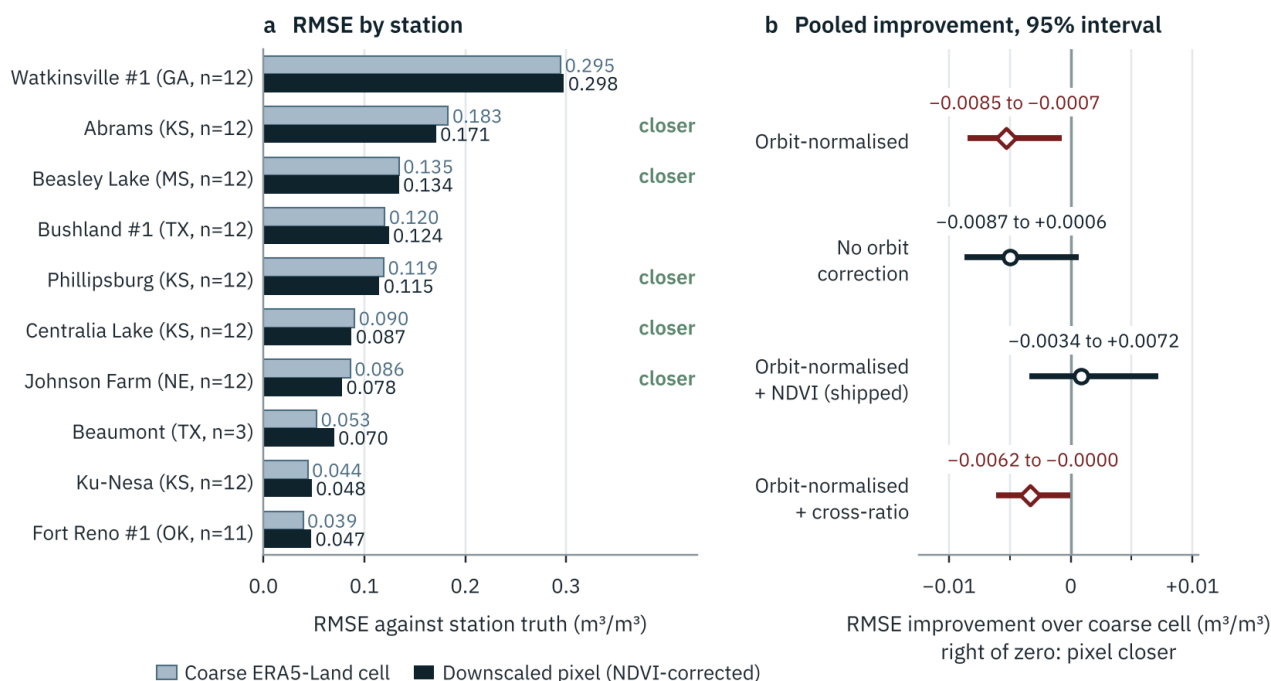


Figure 5. (a) RMSE per station for the coarse cell and the downscaled NDVI-corrected pixel, sorted by coarse RMSE from Watkinsville (0.295) to Fort Reno (0.039); "closer" marks the five stations where the pixel wins. (b) Pooled RMSE improvement with its 95 percent station-clustered bootstrap interval for the four variants; red diamonds mark intervals wholly below zero, and the NDVI-corrected interval includes zero.

Watkinsville #1 has an RMSE of about $0.29 \text{ m}^3/\text{m}^3$ for both the coarse and the downscaled estimate. It is the same representativeness effect that Part A named for this station, a $+0.26 \text{ m}^3/\text{m}^3$ bias on a clay-rich Georgia Piedmont soil. A downscaling step anchored to the coarse product inherits that mismatch, which is what the DISPATCH constraint predicts it cannot repair.

What ships from this

The coarse ERA5-Land anomaly ships as the field's primary soil-moisture reading. The NDVI-corrected Sentinel-1 pattern ships as well, as a separately labelled non-primary layer. We keep it because it is the best-performing variant, because it uses the vegetation guard already in production, and because a spatial pattern inside a field can be useful even when its absolute level is not shown to be more accurate than the coarse number it is anchored to. The coarse number is the one a field should be read from, and that is a finding of this validation.

The Season Brief



A one-page answer to how the season has run, with every index read against a day-of-season normal and a guard that refuses to print a number it cannot support.

What the brief contains

The brief reports growing degree days, rain, and counts of frost and heat days against a day-of-season normal. It adds two drought indices (SPI on precipitation, SPEI on precipitation minus evapotranspiration), a soil-moisture summary for the season, and phenology dates read from NDVI. For phenology it uses two fixed thresholds: 0.3 for green-up and 50 percent of the season's peak for senescence¹⁶.

Growing degree days follow method 2 of McMaster and Wilhelm¹⁷. Frost days and heat days follow the ETCCDI FD and SU35 definitions¹⁸¹⁹. SPI follows McKee, Doesken and Kleist and the WMO user guide²⁰⁷: a gamma distribution fitted by maximum likelihood for each calendar month, with Thom's mixed distribution for months with zero precipitation²¹. SPEI follows Vicente-Serrano, Begueria and Lopez-Moreno²². Potential evapotranspiration comes from Thornthwaite's method with the FAO-56 day-length correction²³²⁴, and the distribution is a log-logistic fitted by probability-weighted moments (L-moments)²⁵²⁶.

The SPEI fit changed on 5 October 2026. The earlier maximum-likelihood fit had shipped with a sign error in its beta term, which we found by testing the fit against a known synthetic log-logistic sample, and we replaced it with the L-moment fit that the source paper's own equations specify.

The live run on 6 October 2026

We ran the report on the worked example field, corn, with the L-moment SPEI fit. Growing degree days read 2,428.6 against a 10-year normal of 2,218.8 ($z=+3.30$). Rain was 331.9 mm against a normal of 375.8 mm ($z=-0.45$). The field had 0 frost days against a normal of 2.5, and 53 heat days (35 °C or above) against a normal of 27.8. Soil moisture averaged 0.0964 m³/m³ at the surface this season against a normal of 0.1231, and 0.0676 m³/m³ at root depth against 0.0966. Both read drier than normal, which is consistent with the heat and the rain deficit. Phenology came from 16 Sentinel-2 looks: green-up on 19 May 2026, peak NDVI of 0.654 on 8 July 2026 and senescence on 21 September 2026.

SPI and SPEI read "not available"

Both drought indices returned "not available" on this run. The completeness and variance guard reports a thin or degenerate climatology sample and prints no number. One case it covers is a zero-variance sample, where the gamma fit raises an error. We would rather publish that reading than smooth it over.

One day earlier, on 5 October 2026, a run on the same field with the earlier maximum-likelihood SPEI printed SPI -1.47 (moderate drought) and SPEI -3.72 (extreme drought). The L-moment change cannot explain why SPI also moved from a number to "not available", because SPI does not use the L-moment fit at all. We did not investigate why the current month's climatology sample tripped the guard when the 5 October sample did not, and we list it as unresolved. The run does confirm one open item from the previous day: the Kansas field has now been run end to end with the L-moment code path live. The earlier check of that path had been run on a different field. The guard that should refuse a thin sample did so on a real field, and its unit tests had until then covered only a synthetic one.

The 331.9 mm rain figure also differs from the 262.9 mm printed on 5 October 2026 for what should be nearly the same accumulation window (183 against 184 days into the same season). We did not investigate this either. ERA5-Land is a reanalysis whose recent days are provisional and can be revised as observations are assimilated, which is a plausible mechanism, but we did not check it against the revision history of the Open-Meteo service.

Disease Models and the 14-Day Forecast



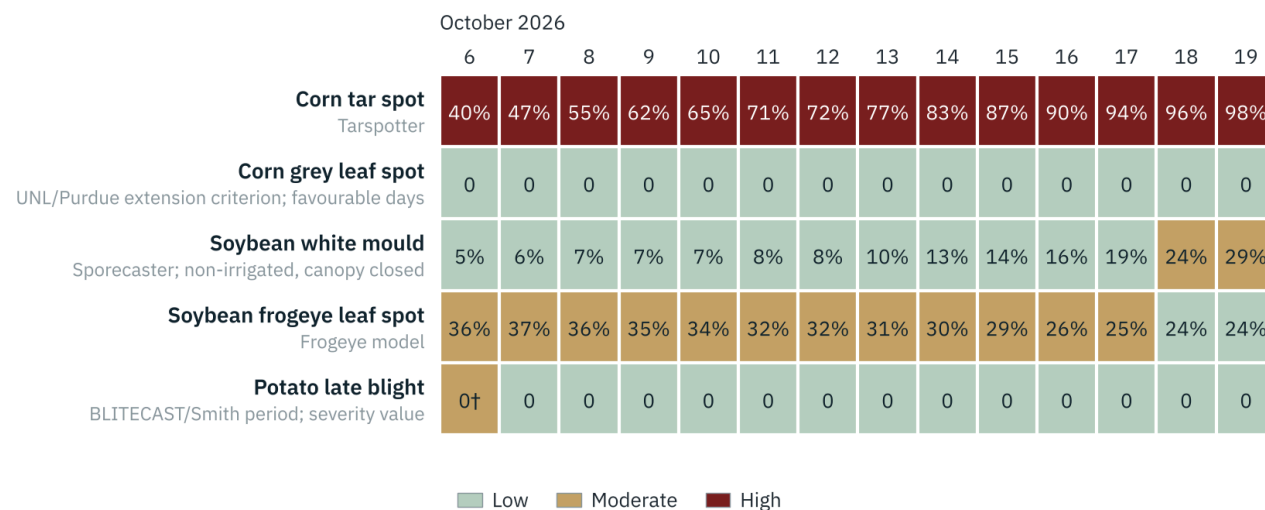
Seven published models give one risk class a day for the next 14 days, each on its own window and threshold.

The models read the field's own 16-day forecast plus the trailing weather each window needs. Several need hourly humidity and a horizon that the ERA5 season record does not carry.

Model	Crop	Source	What it reads	Published threshold
Tarspotter (tar spot)	Corn	Webster et al. 2023 ⁸	Mean of two logistic models (LR4, LR6): 30-day averages of mean temperature and maximum RH, and 14-day night-time hours of RH of 90% or more	35% risk probability
Grey leaf spot	Corn	Jackson and Rees ²⁷ ; Wise ²⁸	A single favourable day: 12 or more hours of RH at or above 90%, or leaf wetness, at 21.1 to 32.2 °C	Binary, as published
White mould (Sporecaster)	Soybean	Willbur et al. 2018 ⁹ , via the Crop Protection Network tool	Non-irrigated: mean of three logistic models on 30-day averages of maximum temperature, wind and RH. Irrigated: one model plus a row-spacing term	35% (non-irrigated), 10% (irrigated)
Frogeye leaf spot	Soybean	Gonzalez-Acuna et al. 2026 ²⁹	Fitted logistic model (LR7): 30-day moving averages of maximum temperature and hours of RH at or above 80%	50% and 25% bands (Axine's choice; the paper gives no fixed threshold)
Fusarium head blight	Wheat	De Wolf et al. 2003 ³⁰	Weather around the flowering date	As published
Late blight (BLITECAST, Smith Period)	Potato	Krause et al. 1975 ³¹ ; Wallin 1962 ³² ; Smith 1956 ³³ ; Bourke 1957 ³⁴	Daily severity 0 to 4 from hours of RH of 90% or more and their mean temperature, accumulated from emergence	18 accumulated, or a Smith Period (two days, minimum 10 °C or above, 11 or more hours of RH of 90% or more)
Apple scab (Mills table)	Apple	Grove and Xiao 2005 ³⁵	Wet-leaf hours at the period's mean temperature, read from the published table	Light, moderate, heavy cells, mapped to Low, Moderate, High

Five of the seven ran live against the worked example field on 6 October 2026: three crops, each with the forecast its own paper or tool specifies. Fusarium head blight and apple scab did not run, since the field grows neither wheat nor apples.

Live forecast, 6 to 19 October 2026



† Trailing 7-day total of 8 carried in from before the forecast window

Figure 6. Heat strip of daily risk class for 14 days, 6 to 19 October 2026, five models in five rows (Low light green, Moderate sand, High red). Tar spot reads High throughout, 40% rising to 98%; grey leaf spot reads Low (0) throughout. The dagger on the first late blight cell marks a Moderate class carried in from the weather before the forecast window.

The tar spot probability starts at 40% on day 1, already over the paper's 35% threshold, and rises across the 14 days to 98% on day 14 (19 October 2026). It tracks a trailing temperature and humidity trend that the forecast itself carries. The coefficients in the published equations are negative on both temperature and humidity, a finding of Webster et al.⁸, so the rising line follows the direction of the published model and does not reflect a general prior that warm, humid weather means more risk. Grey leaf spot shows zero consecutive favourable nights across all 14 days. The single-night criterion (12 or more hours of RH at or above 90% at 21.1 to 32.2 °C) never fires in this window, and the run reads Low throughout.

For soybean (non-irrigated, canopy closed), the white mould probability starts at 5% and climbs to 29% by day 14. It crosses from Low to Moderate on day 13 (18 October 2026, 24%) and does not reach the model's own 35% action threshold inside the forecast. Frogeye leaf spot starts at 36%, Moderate on Axine's band, and eases to 24% by day 14, Low, as the 30-day moving average of hours above 80% RH falls across the forecast window.

For potato, late blight shows a severity value of 0 on every day, since no day in the forecast accumulates hours of RH at or above 90% at a qualifying temperature. Day 1 reads Moderate on a trailing 7-day total of 8 carried in from the weather before the forecast window. Every later day reads Low as that trailing total empties out.

Limits and What Is Not Evaluated



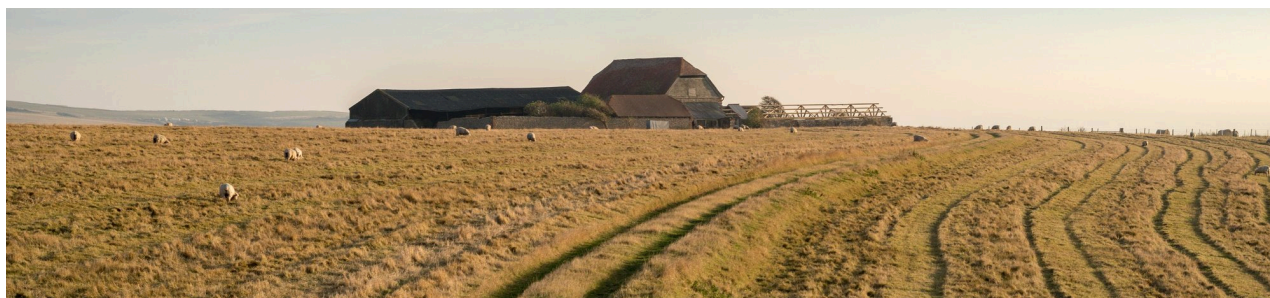
We list what was not measured next to what was.

- + **NASA SMAP L4 is unconfirmed.** The SMAP reader exists and is tested against a recorded catalogue reply and a synthetic HDF5 file built to our understanding of the SPL4SMGP layout. It has never run against a real granule, because that needs a free NASA Earthdata account and token that we did not have. Every number in this paper ran on ERA5-Land, the fallback path.
- + **Disease model accuracy is the papers' accuracy.** The published figures come from each paper's own training and testing split. The tar spot ensemble reached 87.4 percent⁸, and the two best logistic models scored 86.8 and 86.3 percent. The frogeye LR7 accuracy is not printed as one number in the main text of its paper. We have run no field trial and no county-level back-test against any model's output. We checked the implementation against each paper's own equation on known inputs, with the sigmoid of the published coefficients computed by hand and matched to one decimal place. That confirms the arithmetic and says nothing about real infection events in this field.
- + **The downscaling test is screening-sized.** It rests on 110 station-dates at ten stations. A firm claim needs a pre-registered, stratified campaign across SCAN, USCRN and TxSON stations, which we have not run. The result shows what this sample supports and does not show that downscaling never helps.
- + **Forecast skill falls off with lead time.** The forecast minimum temperature has a known cold bias against ERA5, so any temperature-keyed model can cross its threshold early, late or not at all. The effect is largest for days 10 to 14.
- + **SPI and SPEI need a long record.** The WMO guide gives 20 years as the floor and 30 as the ideal⁷. This run uses ten, below both, so the guard returns "not available" more often than a 30-year record would.
- + **The field map is anchored to the coarse cell.** Its absolute value carries the caution that Part A applies to that cell. The map redistributes that number across the field and is no more accurate than it.
- + **Some bands are Axine's choices.** The Moderate and High bands for frogeye leaf spot and apple scab, and the cold-season override in the white mould tool, are our choices layered on a published equation or table.
- + **Sentinel-1 coverage has changed.** The constellation is now Sentinel-1C and 1D, with the six-day repeat re-established on 24 June 2026 and Sentinel-1A ended at the end of June 2026³⁶. The scored station-dates fall in 2023 and 2024, before that, so the test says nothing about the present revisit.

How the Record Is Used



One record per field, read each week against a normal, with every value labelled by what it is and what it is not shown to be.



Dry golden pasture with two tracks leading to a group of low farm buildings on the horizon, and a few sheep on the grass.

Reading the three answers together

The soil-moisture reading answers the Monday question. It is reported as an anomaly against the field's own multi-year normal, at the surface and at root depth, with the coarse ERA5-Land value as the primary number. The field-scale pattern sits beside it with its non-primary label, and it shows where within a field the soil is relatively drier or wetter.

The season brief answers the question that can come on any day. It places growing degree days, rain, frost and heat days, and the season's soil moisture against a day-of-season normal, and it states the phenology dates read from Sentinel-2. When SPI or SPEI cannot be computed from the record, it says so.

The disease forecast answers the daily question for the next two weeks. Each model returns one class a day (Low, Moderate or High) read against its own published threshold, so a reader can see which crop is exposed, on which day, and how the class is changing.

What a reader can rely on

Each statement carries the strength of its evidence. The tar spot and white mould thresholds are published ones, and the frog-eye and apple scab bands are Axine's. The coarse soil-moisture number is the one to read a field from, and the downscaled pattern has no demonstrated accuracy advantage. SPI and SPEI return a number only when the climatology supports one. A forecast class far from today carries more uncertainty than a near one. We publish the failed or unavailable outcome with the same prominence as the passed one, and the record will be rerun as longer climatologies, SMAP access and a larger station campaign become available.

About Axine Laboratories

Axine Laboratories builds satellite spectral analytics for forestry, agriculture, water monitoring, energy and mining. The company is registered in the United States and run by a technical team of geologists and engineers.

Our approach rests on three commitments. Detection is physics-based and reproducible, derived from measured spectra and published formulations. Every published figure is backed by a pre-registered test against an independent reference, with the validation regime stated alongside it, and a result that fails its gate is published as failed. A plot or field the method cannot assess is reported as not evaluated, because a silent clear is the most expensive output a record can give.

Every record ships with the scenes, dates and parameters behind it, so a client can check any figure against the public archive it came from.

Axine Laboratories

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