Science Societies

Why early crop stress is invisible and how UAV reveal it

Part 1 of the series ‘Seeing the Stress from Above’

By Harmeet Singh-Bakala, Francia Ravelombola, Maiara Oliveira, Grover Shannon, and Feng Lin

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Photo courtesy of Adobe Stock/Monopoly919.

Farmers in the Mid-South are losing yield because water and heat stress often go unnoticed until it's too late for effective intervention. In this three-part series, we'll show how modern UAV imaging uncovers early, invisible crop stress—and how farmers can use the right tools and maps to make smarter irrigation decisions that boost efficiency, reduce risk, and increase profitability.

In this first article in the series, we'll explain how drone-based thermal and multispectral imaging can reveal early, invisible stress signals—long before crops show visible symptoms—allowing growers to act sooner and allocate water more efficiently. By shifting from reactive scouting to proactive, field-wide monitoring, UAV tools help farmers protect yield potential and make smarter irrigation and management decisions.

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In recent years, particularly in 2022–2023, farmers across the Mid-South—from Missouri and Arkansas Delta down through Tennessee, Mississippi, Louisiana, and eastern Texas faced a harsh combination of drought, heat waves, and erratic rainfall. These conditions led to significant yield and insurance losses (Rowsey & Heckel, 2022). Nationally, the 2022 drop in corn production reflected the same pattern with yields reduced by about 8% compared with 2021 as high temperature and limited moisture stressed the crops (USDA, 2022).

Though this scenario spans the entire Corn Belt—from delta clays and alluvial plains to sandy ridges and heavy-textured soils—fields with marginal or poorly managed irrigation were hit hardest. In this environment, irrigation is no longer just "recommended," it often becomes the dividing line between profit and loss. Dryland corn, cotton, soybean, and rice on those soils suffered the greatest damage while fields with dependable wells, pivots, or well-managed flood systems generally fared better.

"By the time leaves droop, stalks curl, or wilting become visible, the crop has already been under stress for several days."

But even in the irrigated fields, the key challenge is knowing when and where to apply water. Conventional scouting and visual checks only tell part of the story. By the time leaves droop, stalks curl, or wilting become visible, the crop has already been under stress for several days. That lost time often translates into lost yield.

Rainfall patterns in the Mid-South have become increasingly unpredictable with heavy downpours that runoff quickly followed by dry heat spells. Under these conditions, a “wet” soil surface can be misleading, and even well-placed soil moisture sensors represent only a few points across large, variable fields. Together, these factors create a difficult operating environment for farmers and agronomists, especially in the Mid-South. They also raise a critical question—if water stress is only recognized when visible symptoms appear, how much yield potential has already slipped away?

Drone-based imagery—from thermal maps that detect canopy temperature to multispectral maps that track canopy vigor—can detect stress before symptoms appear and reveal which parts of a field are most vulnerable (Dong et al., 2024). Instead of reacting to visible decline, farmers can act earlier, prioritize irrigation zones, and confirm that systems are working as intended.

In this series, we will explore how unmanned aerial vehicle (UAV) sensing can help shift water management from a reactive task to a proactive, data-driven strategy. In modern crop production, stress rarely begins with visible wilt—it starts with a plant that can no longer cool itself effectively.

What water stress actually does in the plant—“the plant fever effect”

Plants regulate temperature through transpiration. When soil moisture is available, stomata stay open and water evaporates from the leaves, cooling the canopy much like sweat cools human skin (Figure 1). A healthy crop typically maintains leaf temperature a few degrees below the surrounding air.

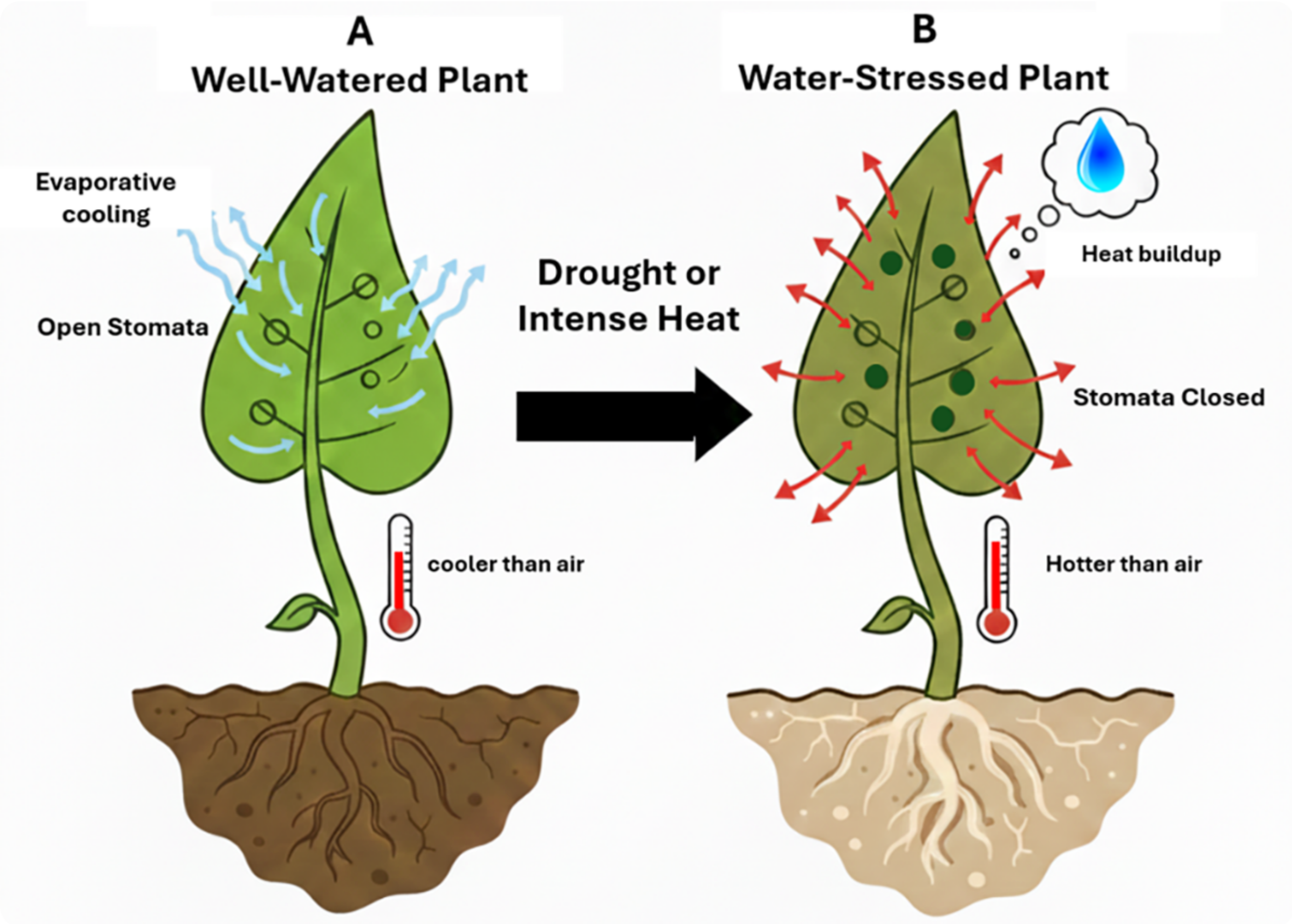

Figure1. *A well-watered plant (A) stays cooler than surrounding air through active transpiration. Under drought or intense heat (B), stomata close, transpiration declines, and the canopy becomes hotter—long before visual symptoms appear.*

Under drought or intense heat, this balance breaks. As soils dry and atmospheric demand rises, stomata begin to close to conserve water. With limited transpiration, the canopy warms quickly. Inside the plant, photosynthesis declines, energy is diverted from growth, and stress responses activate—often long before any visible wilting or leaf color changes.

Similar heat buildup can result from other abiotic stresses common in the Mid-South fields:

- **Waterlogging or poor drainage:** oxygen-starved roots limit water uptake.

- **Compaction or shallow rooting:** plants cannot access deeper moisture.

- **Extreme night temperatures:** crops fail to cool and respiratory losses increase.

Regardless of the cause, the early physiological signal is the same—a stressed plant becomes hotter. This rise in canopy temperature is a consistent indicator of water stress and forms the basis of the long-established crop water stress index (CWSI). Thermal sensing including UAV-based imaging is designed to detect this signal before stress becomes visible.

Visual scouting often comes too late

Traditional field scouting remains essential, but for water stress, it is mostly reactive. Visual symptoms, such as leaf rolling, a dull canopy, or wilting usually show up after several days of reduced transpiration and heat buildup via impaired photosynthesis. By that point, some crop yield potential is already gone.

Traditional field scouting remains essential, but for water stress, it is mostly reactive. Photo courtesy of Adobe Stock/Serhii.

In the Mid-South, heat and drought stress escalate quickly. High nighttime temperatures limit the plant recovery, and even a brief delay in irrigation during a hot, dry spell can push parts of the field into stress before it becomes visible from ground level. A field that looks uniformly green from the pivot road can still contain “hot zones” that are already struggling and losing yield potential quietly.

Scouting also has a spatial limitation. Even highly experienced agronomists can only check a fraction of a large field while water availability and infiltration vary dramatically across sandy ridges, clay depressions, compacted headlands, or uneven residue strips (Figure 2). Two plants just a few rows apart may face entirely different stress levels. Relying solely on what eyes can see often means acting after much of the damage has occurred. Earlier detection allows irrigation and management decisions to be corrective rather than preventive.

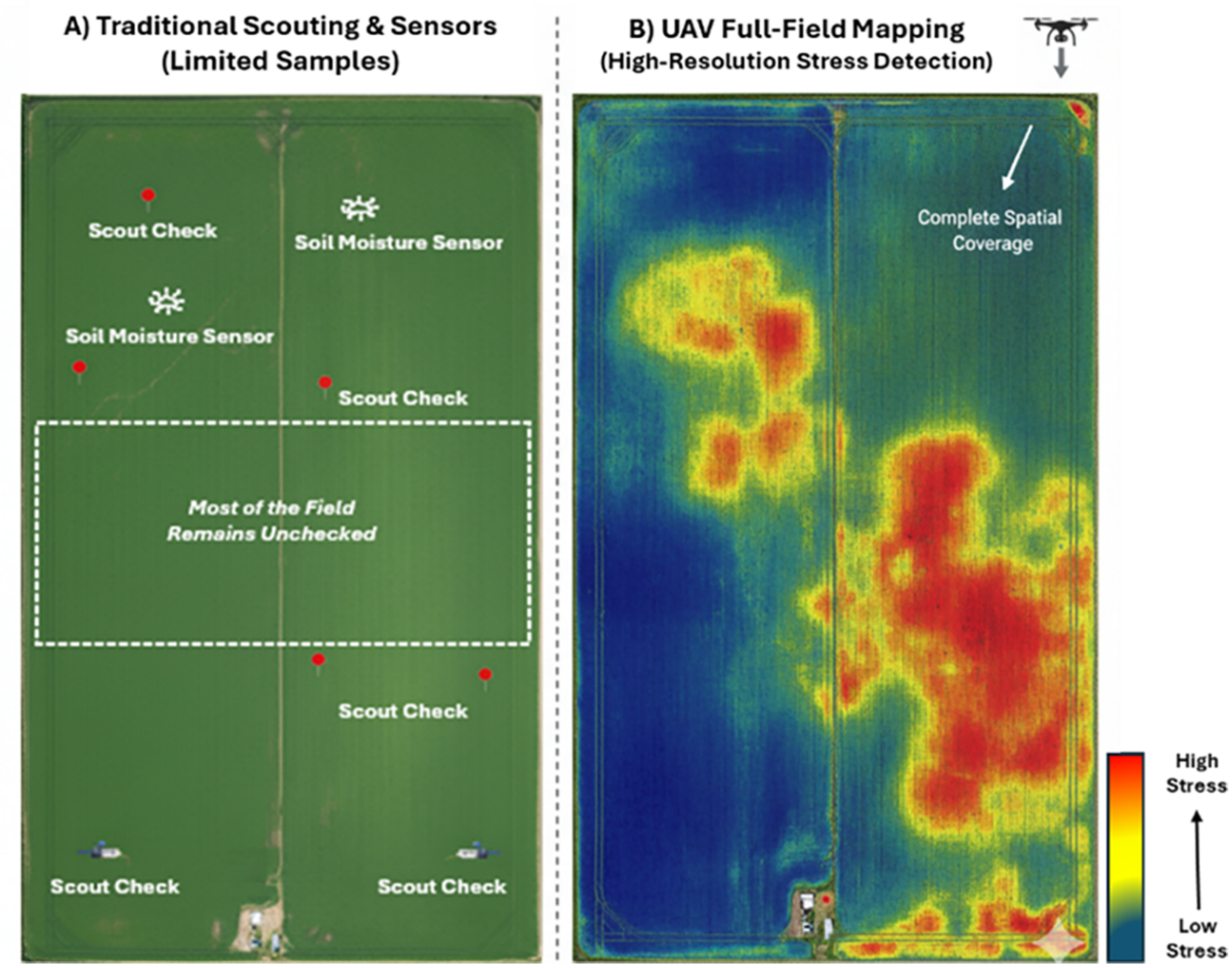

Figure 2. *Traditional scouting samples only a few points in the field (A), leaving most variability unseen. Mapping with UAV (B) provides complete spatial coverage, revealing hidden stress patterns that develop long before visual symptoms.*

How UAV sensing detects stress before we see it

When a crop begins to experience water shortage, stress first shows up in canopy temperature and behavior, not in leaf color or wilt. UAV-based sensing captures that early change across the entire field. Thermal imaging shows how well plants are keeping themselves cool. As stomata close to conserve water, transpiration slows, and the canopy heats up. A rise in leaf temperature relative to air temperature and well-watered reference areas signals the onset of water stress even if the crop still looks healthy at ground level. Drone-based thermal sensors have been shown to correlate strongly with plant water status and can reliably identify stressed zones using indices such as CWSI (Crusiol et al., 2020).

Thermal data, however, are only part of the picture. Multispectral imaging (such as NDVI, chlorophyll indices) helps track canopy vigor and early growth decline that may follow or coincide with water stress. Field studies combining thermal and multispectral data reduce false positives and improve detection accuracy compared with either source alone (Wang et al., 2024).

> *"A rise in leaf temperature relative to air temperature and well-watered reference areas signals the onset of water stress even if the crop still looks healthy at ground level."*

This approach is made practical at the field scale with UAVs. A single flight can monitor hundreds of acres with high-resolution maps of canopy temperature and vigor. Spectral patterns reveal the zones of concern linked to variable soils, compaction, infiltration, or irrigation performance. The spatial and temporal coverage is difficult, often impossible, to achieve with handheld tools or isolated sensors. Sensing with UAVs shifts stress detection from reaction ("the field looks bad") into prevention ("this zone is heating up—check water there first"). That shift from reaction to prevention provides the greatest benefit to farmers.

Mid-South field snapshots: What early stress may look like

Real fields in the Mid-South often appear uniform from ground level. Drone imagery reveals a different picture—subtle stress patterns forming earlier than visual scouting can detect.

- **Cotton—Mississippi Delta:** A thermal map shows a warm band near outer spans of the pivot. A pressure drop is limiting water delivery. A quick check and small hardware fix keep the affected rows on track.

- **Soybean—Missouri Bootheel:** Thermal and multispectral maps expose hot, low-vigor streaks on sandier soils, where roots cannot reach deeper moisture. Subtle soil moisture differences prompt zone-specific irrigation that protects yield potential.

- **Rice—Arkansas and Louisiana:** Cool thermal pockets mark waterlogged areas lacking oxygen early. These zones are corrected with drainage and levee adjustments before maturity and seed quality are affected.

Practical cautions

While UAV imagery is a powerful decision support tool, it does not replace agronomy. It must be interpreted within the field and weather context. Thermal maps are sensitive to time of day, humidity, cloud cover, and wind. Flights in early morning, rapidly changing light, or gusts can distort canopy temperature readings. Midday flights under stable sunlight are more reliable.

Hot areas on a map do **not always** mean drought. Compaction, shallow rooting, sandy soil, herbicide injury, pests, and residue gaps can all drive canopy heating.

Multispectral indices may saturate in dense canopies or be skewed by bare soil, standing water, or flowering. Stress indicated by imagery should be confirmed with simple ground checks before making major decisions (irrigation/input change). Drones require skilled operation. Poor flight planning, incorrect altitude, or a miscalibrated sensor can create noisy or unusable data. Finally, UAV sensing does not prevent stress—it reveals it sooner. The value comes when earlier detection is linked to timely irrigation, field/soil and drainage management, and system maintenance. Used thoughtfully, drones help ensure water and inputs go exactly where they are needed. Used without correct interpretation, they can create false alarms or missed opportunities.

From l to r: Compaction, shallow rooting, herbicide injury, pests, and residue gaps can all drive canopy heating. Photos courtesy of Adobe Stock.

Early crop stress detection is no longer optional in a region where heat and water limitations can scoop out yield in a matter of days. With UAV imagery, farmers and advisers can see risk forming before symptoms appear and direct irrigation where it will have the greatest impact. It turns variability from a source of surprise into a source of insight. Similar tools are already being used in other water-limited regains such as Colorado's irrigated Corn Belt where farmers and researchers combine drones, thermal cameras, soil sensors, and weather data to make the most of every available drop

(Press, 2019).

In the next article, we will shift from **why** early detection matters to **how** to select the right drones, sensors, and workflow that fit Mid-South conditions, so UAV stress detection becomes a practical tool for everyday decisions in the fields.

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1. What is the main reason early crop stress often goes unnoticed?

a. Farmers do not check their fields often enough.

b. Stress symptoms only appear after yield loss has already begun.

c. Soil moisture sensors are usually inaccurate.

d. Crops immediately wilt when stressed.

2. What does the "plant fever effect" refer to?

a. A rise in canopy temperature caused by reduced transpiration when stomata close.

b. An increase in plant respiration triggered by excess fertilizer.

c. Heat damage to leaf tissue caused by direct sunlight exposure.

d. A fungal infection that spreads rapidly under high humidity.

3. Why can a “wet” soil surface in the Mid-South be misleading?

a. Surface moisture does not always reflect deeper root-zone water availability.

b. Wet soil prevents roots from absorbing nutrients efficiently.

c. Rainwater temporarily increases leaf temperature.

d. Irrigation systems automatically adjust after rainfall.

4. What is one major limitation of traditional field scouting for water stress?

a. It requires expensive laboratory tests.

b. It cannot identify pest damage.

c. It replaces the need for irrigation.

d. It only evaluates a small portion of the field.

5. When is the most reliable time to conduct UAV thermal flights?

a. During strong winds.

b. Early morning before sunrise.

c. Midday under stable sunlight.

d. Immediately after rainfall.

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