Agricultural Aircraft and Thermal Imaging

From detecting sand boils at the levee to irrigation management

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During the Mississippi River flood event of 2011, a thermal imaging system mounted on an agricultural aircraft was used to detect potential problem areas at the levee. The imaging system is operated by researchers within the USDA-ARS Crop Production Systems Research Unit (CPSRU), Stoneville, Miss., who have also used it for research in detection of crop water stress.

The CPSRU in Stoneville conducts field research in spray drift management, efficacy of spray application, evaluation of variable rate aerial systems and plant damage assessment using spray sampling, biological measurements and remote sensing. Three full-time scientists and engineers work on the spray application project, with collaboration from plant physiologists within the research unit for direct plant health assessment, many external collaborators and funding from commodity groups. In addition to the spray application research, we use camera-based remote sensing systems in agricultural aircraft to detect weeds, assess herbicide-induced plant injury, and to detect field areas most favorable for production. These applications utilize multispectral imaging (that use as few as three or four spectral bands, many of which the human eye is sensitive to such as green, red, and blue) and hyperspectral imaging (that divides the spectrum into many more bands).

Agricultural aircraft have the advantage of being easy to schedule for frequent remote sensing runs because they are already used in the field for crop protection and application of harvesting aids. This relatively new and exciting application for agricultural aircraft (thermal imaging) has shown potential to assess the levee and detect spatial differences in crop water stress to assist in crop management.

An Eye on the Levee

Using remote sensing to monitor the levee came about as a truly collaborative effort between many federal and state government agencies. The Yazoo Mississippi Delta Levee (YMDL) Board owns and maintains the mainline Mississippi River Levee from Memphis to the Bolivar/Coahoma County line. The agency also owns and maintains the Yazoo River backwater levees from Vicksburg all the way up the Cold Water and Tallahatchie Rivers. The mainline Mississippi River Levee was designed to withstand a 500-year flood event plus seven vertical feet of "freeboard," and a sizeable stand of trees are grown on the river-side of the levee to prevent scour, or erosion, of the levee due to wave and water friction. Rising water against the levees creates an increase in hydraulic pressure on the soil. The resulting increase in hydraulic pressure can cause "boils"—the eruptions of geysers—as far as 500 meters inland from the levee. Sandy soils are particularly susceptible to the formation of boils. The erosive capacity

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***Fig. 1.** Thermal imaging camera on board the Air Tractor AT-402B agricultural aircraft.*

of water flowing through subterranean channels may rapidly increase in size and, if left unchecked, create a blowout and failure of the protective levee. Locating boils in an effort to prevent levee failure thus becomes the principal challenge in managing a flood event. Primary and traditional means of locating boils involve sending manned patrols composed of YMDL Board and National Guard personnel scouting around historic trouble spots. In heavy vegetation and cropland, this process is quite arduous.

Given the widespread nature of the flood event during April and May 2011 and limited personnel, YMDL Board was immediately in need of a more effective method for detecting boils, and they wanted to know if spatial imaging technologies could help. We suspected that remote sensing techniques could be used in a timely fashion to help with the detection of boils. Engineers from the cooperating agencies told us that water from a boil would be at least a few degrees colder than any surrounding surface water because it would be coming from a greater depth in the river and would pass through cooler layers of soil before emerging on the surface. While the river level was near its peak, we decided to evaluate the potential of using thermal imaging to detect sand boils and observe possible temperature anomalies along each side of the levee. A Sofradir Electrophysics PV-320T thermal imaging camera flown in an Air Tractor 402B agricultural aircraft (Fig. 1) was chosen for its high spectral resolution of temperature, which can be represented visually in very narrow ranges.

Sand boils were easily detectable in a thermal image as a cool (blue) area indicative of a sand boil near Deeson, Miss. (Fig. 2). Temperatures were set within a relatively narrow range using the Electrophysics Velocity 2.0 software and adjusted until differences could be easily discerned. These boils were not easily distinguishable from surrounding features by simple photograph or video.

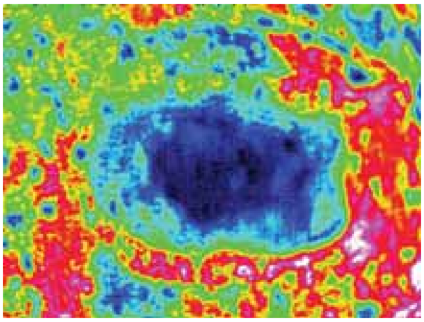

Fig. 2. *Sand boil near Deeson, Miss.*

Temperature differences were observed on both the leading edge (the river side) and trailing edge of the levee (Fig. 3). The dark blue areas represent the river, and cool areas along the leading edge of the levee show blue areas of water presence. This most likely indicated a certain amount of internal seepage, and green areas of cooler temperatures on the trailing edge of the bank are most likely vegetation, although green to blue color would also indicate weakness in the levee (not indicated here). Temperatures were set to a wide range so cool water to warmer vegetation and soil could be indicated in the same image (Fig. 3). Much narrower temperature ranges can be set over specific portions of the image in software, revealing differences in greater detail.

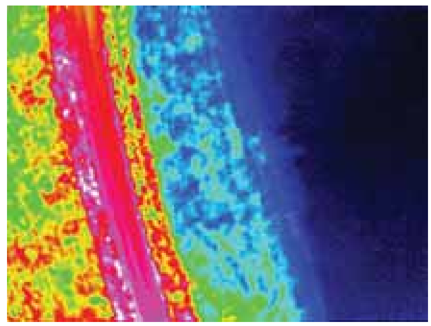

Fig. 3. *Overhead thermal image showing temperature differences on both trailing (left) and leading (right) edges of the levee.*

Thermal Imagery and Crop Water Stress

Proper irrigation system management is a challenge no matter what type of irrigation scheduling methods or systems are used. Irrigation scheduling can be facilitated with soil water sensors, methods that estimate crop water use (evapotranspiration or ET), or evaporation devices modified for ease of use. However, there has been limited success in widely promoting irrigation scheduling aids because some farmers perceive a need for intensive management and difficulty in interpreting trends in crop water stress from sensors. Many commercial systems are now available for cellular and web-based monitoring of irrigation systems and soil water sensors to improve operational convenience for the farmer, but farmer-oriented procedures for "smart scheduling" are still in great need.

Center pivot irrigation systems can take up to several days to complete a circle (Fig. 4), and a thermal "snapshot" of a field can show "hot spots" or field areas that consistently stress before others or areas indicating poor drainage (cooler areas towards dark blue). A stressed crop outside the center pivot will exhibit a warmer canopy (in green), and fine differences in canopy temperature within the irrigated field can also be seen.

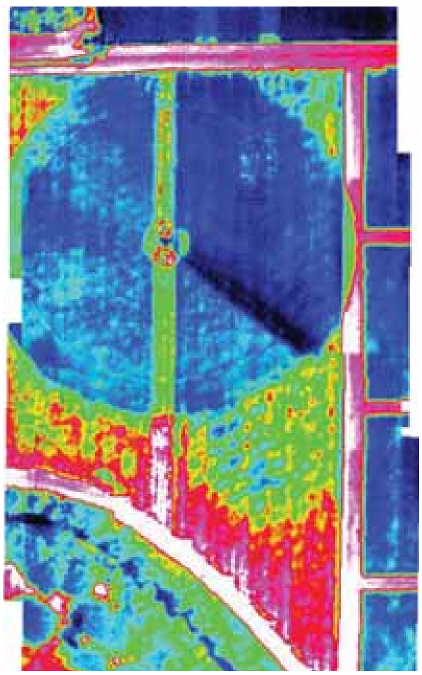

Fig. 4. *Thermal image of a center pivot irrigated field near the USDA-ARS research facility at Stoneville, Miss., and obtained from an AT-402B agricultural aircraft.*

It is easy to see "hot spots" in a single image but much more of a challenge to use thermal imaging for irrigation scheduling. This is because so many factors influence what the camera "sees" as canopy temperature. Differences in solar radiation, wind and altitude all need to be considered. Fig. 5 illustrates how a series of images should look if weather conditions and altitude of image acquisition are consistent between days. The progression of drying in certain field sections is apparent by blue areas in the first image turning green in the second image.

Furrow Irrigation System Maintenance

Thermal imaging has shown value for detection of water leakage from a furrow irrigation system (Fig. 6). The location of a water leak is quite obvious in the image, with an extensive dark blue area, indicating a leaking irrigation riser valve. Small light green-to-bright red areas or "hot spots" can also be seen in the left side of the field, which indicate restricted water flow to these areas most likely due to trash or high spots in the furrows. Field maintenance, such as cleaning out the furrows or re-grading the field might be in order to assure proper irrigation.

An interesting anecdote relates to the field to the far right. A student employee inadvertently began irrigating this field and then, realizing his error, promptly switched to irrigate the correct field on the left. His supervisor was away when this occurred and did not notice the error when he returned, as drying had already occurred over a few days. His supervisor could not see evidence of the missed irrigation on a trip to the field, but the thermal image indicating light irrigation (in green) on the dry field (in red) "gave it away."

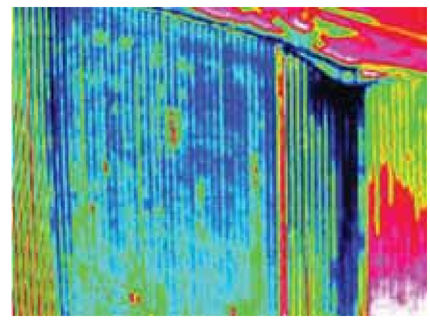

Fig. 6. *Thermal image of a furrow irrigated field.*

Summary

Thermal imaging has shown great potential for use in levee surveillance and crop health assessment. The ability to use the system on agricultural aircraft allows frequent imaging concurrent with other remote sensing systems that monitor crop health. Our imaging system can be brought into service when future water seepage concerns are present at the Mississippi River Levee, in consultation with appropriate state and federal agencies. Although standard digital video can be obtained (and position-referenced with GPS) simultaneously, one additional goal on the technical side is to integrate GPS position referencing with the digitally stored thermal imagery to save time in locating troublesome areas. ■

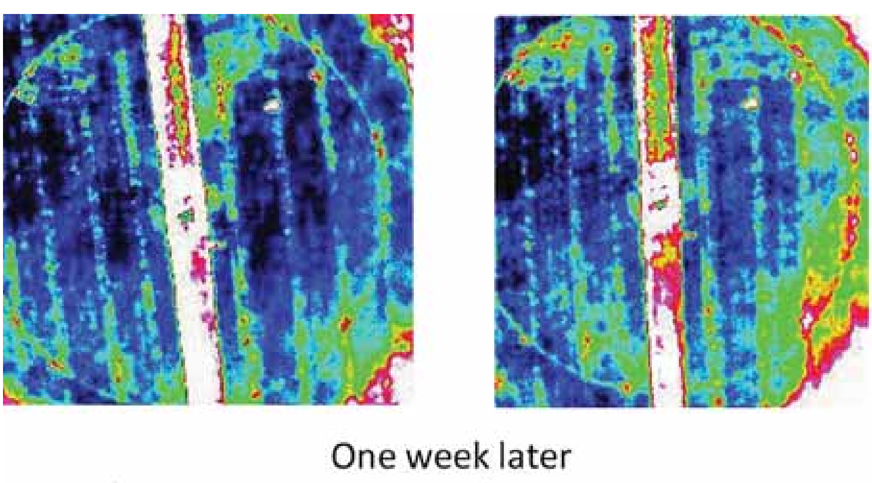

Fig. 5. *Progression of drying as illustrated by increasing soybean canopy temperatures at the USDA-ARS research fields in Stoneville, Miss.*