Using time-lapse imagery for applied agricultural monitoring

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IMPACT

Time-lapse imagery, captured using affordable time-lapse digital cameras, may prove useful in tracking the rate of crop senescence, both temporally and spatially, potentially providing insight into the drivers of crop productivity—and ultimately advancing our ability to monitor agroecosystems for improved agricultural decision making.

Remote sensing technology is advancing our ability to understand and monitor agroecosystems, particularly interactions among factors such as water availability, stress, nutrient availability, and crop production. However, these technologies are expensive and require technical know-how and interpretation skills. Yet the information gained from monitoring systems based on remote sensing is invaluable for determining long-term trends in agricultural landscapes.

In recent years, there has been a growing movement to make remote sensing technology more accessible to people outside of the discipline. Our group, the Geospatial Laboratory for Environmental Dynamics at the University of Idaho, has been experimenting with the use of low-cost (~$150), weatherproof time-lapse digital cameras as an affordable, easy-to-use tool for monitoring spring wheat (*Triticum aestivum* L.) in the Palouse. With this in mind, the goal of this study was to investigate a method to monitor spring wheat throughout the growing season, using simple, affordable time-lapse digital camera technology.

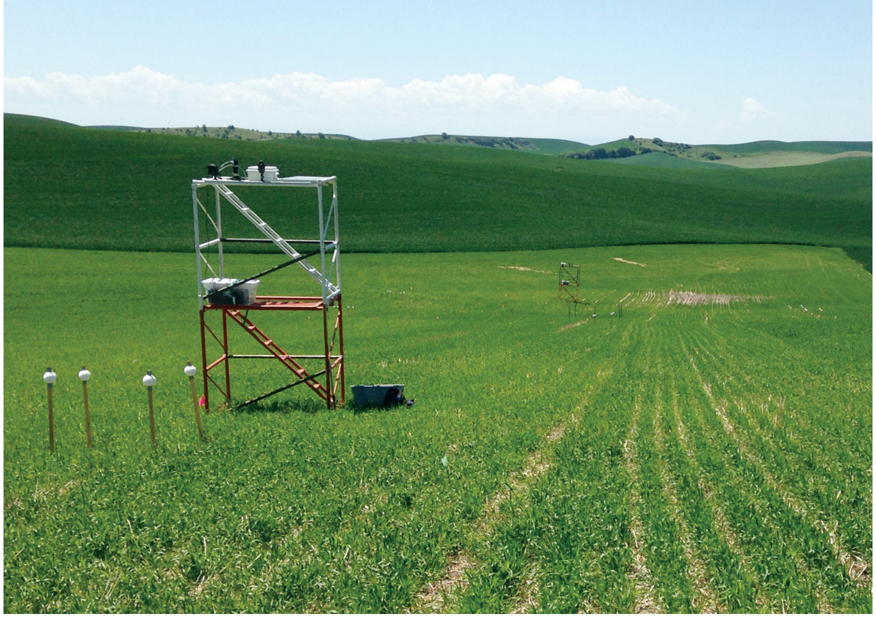

Figure 1. *Tower setup at the Washington State University Cook Agronomy Farm. Photo by Jyoti Jennewein.*

For the past two summers (2013 and 2014), four to six time-lapse digital cameras were mounted on three 15-foot-tall towers at the Washington State University Cook Agronomy Farm near Pullman, WA (Figure 1). Each camera was programmed to take between five and seven photos per day to monitor experimental plots under different nitrogen treatments (Figure 2). In the early summer of 2014, three different experimental areas were set up, each with sixteen 32-foot by 32-foot plots. Each plot received one of four nitrogen fertilizer treatments at planting: zero (0 pounds per acre), low (35 pounds per acre), medium (70 pounds per acre), and high (110 pounds per acre). Throughout the growing season, ground measurements of plant biomass, crop height, chlorophyll content (measured with a chlorophyll meter), and soil moisture were collected. These measures served as ground validation of crop development throughout the growing season, which were then compared to the values recorded in the red, green, and blue (RGB) band by the time-lapse digital cameras.

Every pixel from a digital image has an associated digital number (DN), which ranges from 0 to 255. The RGB visual data were analyzed using ImageJ, which allows the RGB DN values to be extracted from the digital images. DNs are related to the brightness, the amount of light energy, being reflected in each wavelength (red, green, and blue). Using the DN values in each image, we computed the relative percentage of brightness to account for day-to-day variations in weather, which alters the DNs associated with each pixel.

Three different vegetation indices (VI) were calculated from the DNs (Figure 3) and compared to our ground measurements through simple, bivariate correlations. These VIs include the green index, the green/red ratio, and the blue index, where the green and blue indices are simply ratios of brightness in one part of the spectrum normalized by cumulative reflectance in all three wavebands. For example, when calculating the green index, we took the DN for the green band and divided it by the sum of all three bands to normalize data from each plot for each sampling day. This allowed us to correct for changing illumination conditions (cloudy, sunny, etc.) as well as any differences that might be present between digital camera images.

Our results indicate that chlorophyll content correlates strongly with the green VI ($R^2 = 0.65$) on fields with higher soil moisture, and moderately well ($R^2 = 0.38$) on fields with lower soil moisture. However, none of the calculated VIs showed statistically significant relationships with the leaf area index, which is a measure of

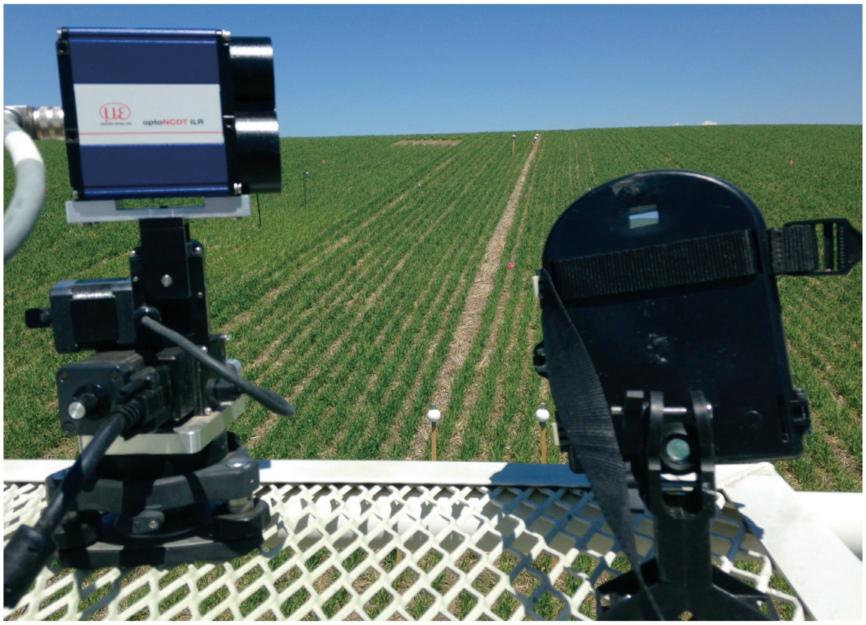

Figure 2. *Time-lapse digital camera (on the right) mounted to monitor spring wheat throughout the growing season. Photo by Jyoti Jennewein.*

plant structure and is often related to plant biomass. This result suggests that digital imagery is more successful at remotely monitoring plant function (such as chlorophyll content) than plant structure. It also indicates that a visual examination of the chlorophyll content over different fertilizer concentrations is possible. Figures 4 and 5 display this detectable differentiation over time between fertilizer treatments in both chlorophyll measures (SPAD) and the green VI.

These results suggest that we can successfully monitor the distribution of soil water content using time-lapse digital cameras, since crops that have less water available start to senesce and lose chlorophyll earlier in the growing season. The summary of the results in Figure 3 demonstrates that there is a detectable, statistically significant ($p < 0.05$) relationship between soil water content and the three VIs calculated from the digital images. These trends are especially visible once peak greenness in spring wheat is reached and dry-down begins.

Figures 4 and 5 demonstrate the time-series similarities in chlorophyll content (SPAD) and the green VI, starting at peak greenness and continuing through the dry-down period. This correlation is important because field locations that exhibit early-season crop senescence may be candidate areas for adjusting seeding density, fallow, or crop types so that limited soil water is used efficiently. Furthermore, preliminary analyses of these data reveal that it may be possible to detect a relationship between the VIs and crop yield at the end of a season. However, additional analyses are needed to determine the reliability and feasibility of such methodology.

The results from this study help advance the case for using time-lapse digital imagery in future scenarios involving the timing and spatial distribution of senescence (dry-down) in crops throughout the growing season. They suggest that we can track the rate of crop senescence both temporally and spatially, potentially providing insight into the drivers of crop productivity—and ultimately advancing our ability to monitor agroecosystems for improved agricultural decision making.

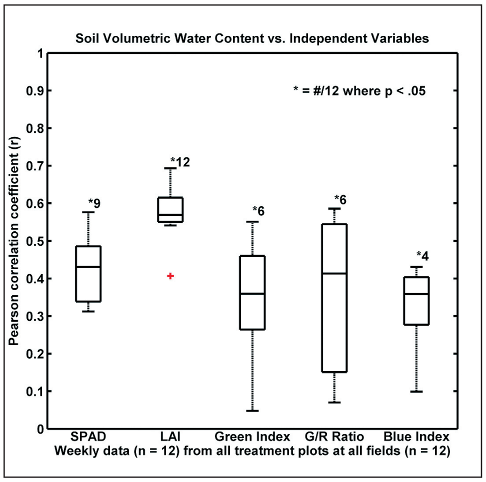

Figure 3. *Correlation of three vegetation indices (green index, green/red ratio, and blue index), chlorophyll content (SPAD readings), and leaf area index (LAI) with soil volumetric water concentrations.*

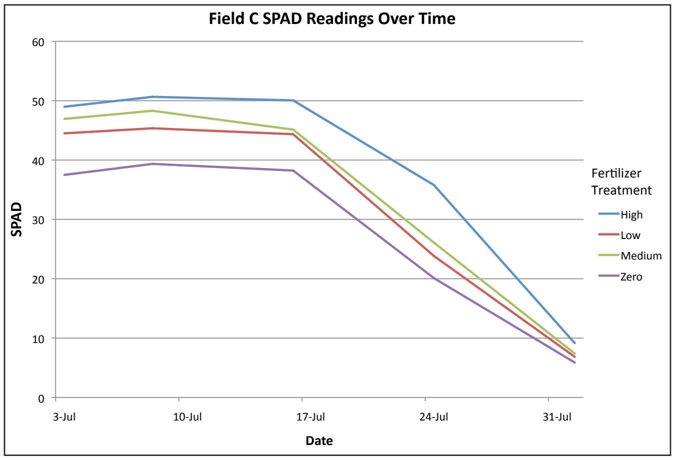

Figure 4. *Chlorophyll content (as measured by SPAD readings) starting at peak greenness and continuing through the dry-down period.*

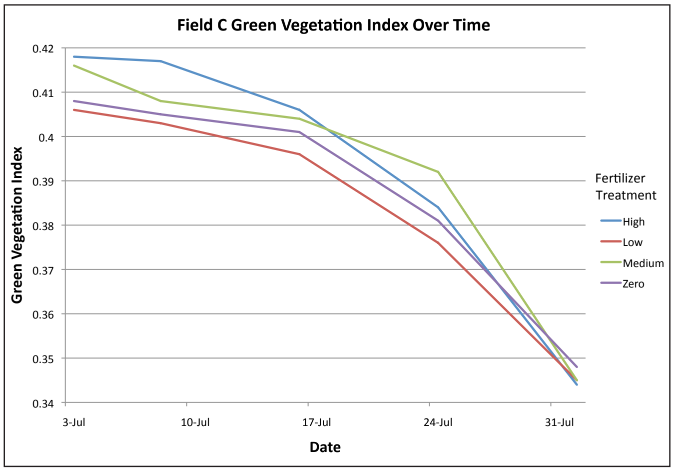

Figure 5. *The calculated green index starting at peak greenness and continuing through the dry-down period.*