Assessing crop performance with time-lapse photography

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In recent years, high-tech imaging devices involving satellites, drones, and even lasers have entered the discussion about how to develop improved, cost-effective decision support for precision agriculture. Our group (the Geospatial Laboratory for Environmental Dynamics at the University of Idaho) is working hard to improve the performance and usability of these high-tech tools in ecosystems ranging from the arctic tundra of northern Alaska, the tropical rainforest of Central America, and the rolling hills of the Palouse. There is enormous potential in these systems to help land managers and growers better understand the variability of crop performance, nutrient use, water availability, and weed and pest outbreaks across agroecosystems.

However, in a recent REACCH survey of 37 growers in the Pacific Northwest, 43% of respondents reported that they don't use available precision agriculture technologies because the equipment is too expensive. Furthermore, 30% said the software is too expensive or requires too much technical support or training, and 27% reported that it is too time consuming to learn.

IMPACT

Time-lapse photography has the potential to enhance crop performance and could be an effective precision agriculture management tool. High-tech tools may help us understand both natural and human-managed ecosystems better in the not-too-distant future.

Thus, we asked the following question: What about one of the most basic tools in our toolbox—a simple, color digital camera with the capability of taking time-lapse photos—all for the cost of about a tank of gas in your pickup? The objective of this report is to describe: (1) the ability of time-lapse imagery to estimate chlorophyll and nitrogen concentrations in spring wheat, and (2) the potential of this simple technology to aid as a decision support tool for precision agriculture.

During the 2012 and 2013 growing seasons, we mounted time-lapse cameras atop a 75-foot-tall tower at the Washington State University Cook Agronomy Farm (Figure 1), as well as on 5-foot-tall posts at four other farms at the top of small watersheds around the Palouse (Figure 2). Throughout the growing season, ground measurements of plant biomass, plant density, crop height, chlorophyll content, leaf nitrogen concentration, and soil moisture were collected at a total of 150 GPS points across all farms. Our main objective was to see how well simple vegetation indices (VIs) computed from the changes in colors captured by digital cameras might correlate to our ground measurements and add insight to improved crop management.

To quantify the amount of light energy that is reaching the camera for a given pixel in the image, we used a user-friendly software package called "ImageJ," which can be downloaded from the Internet at no charge. Each pixel on an image taken from any digital camera has digital numbers (DNs) between 0 and 255 associated with the brightness (the amount of light energy) being reflected in each band (red, green, and blue). Using the DN values for a specific pixel, we can calculate the relative percent brightness to account for daily changes in solar illumination (i.e., whether the image is darker or lighter at a different time of day).

Figure 1. *Troy Magney, raising the pneumatic pressure tower to 75 feet at the Washington State University Cook Agronomy Farm. The tower was gifted to the lab by NASA more than a decade ago. Photo by Lee Vierling.*

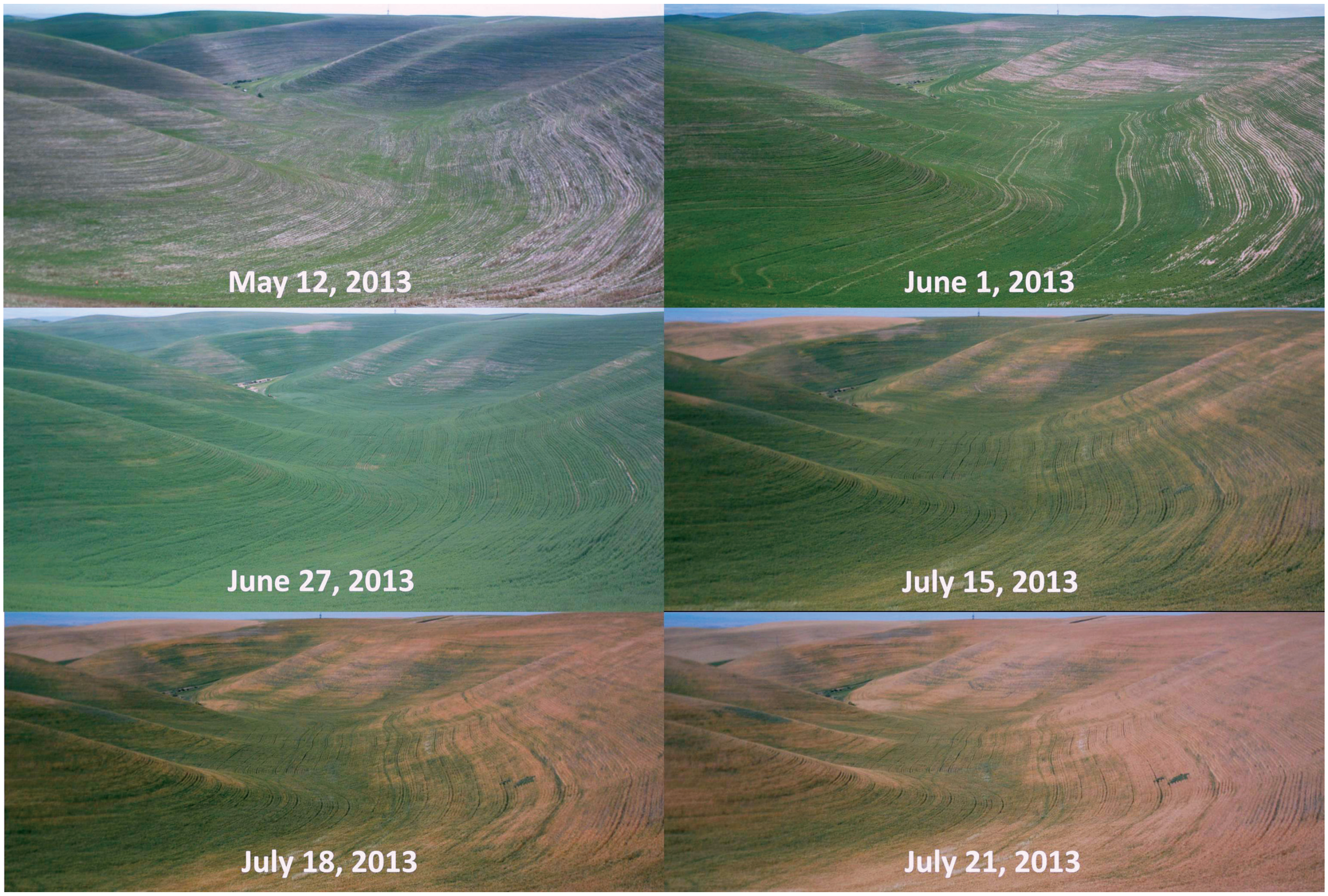
For example, in Figure 3, we calculate the "greenness index" (GI) for each experimental plot. Plots received one of four different nitrogen application rates at planting (0, 40, 80, or 120 kg/ha). In the closest plot to the camera in Figure 3, the DN values for the red, green, and blue pixels were 75.5, 87.8, and 64.2, respectively—averaged over the entire plot area. To calculate the GI, then, the green band is divided by the sum of all bands (as a means to normalize the data): $G/(R+G+B)$, or $87/(75+87+64) = 0.386$.

This number is important because it provides a relative concentration of greenness (or chlorophyll); the lower the GI, the more chlorophyll, because more energy is being absorbed and used for photosynthesis. The result is likely to be higher biomass and, ultimately, higher yields. In Figure 3, the differences in chlorophyll content are indeed visible to the naked eye, but can now be quantified with the use of these tools.

For the particular plots shown in Figure 3, the GI was highly correlated to both relative chlorophyll concentration ($r^2 = 0.62$, $p < 0.01$) and total above-ground nitrogen ($r^2 = 0.73$, $p < 0.01$) during grain fill in spring wheat (July 26, 2013). These findings are consistent with previous studies using digital cameras to assess chlorophyll content. The utility of an entire growing season worth of daily imagery is likely to improve overall evaluations of crop performance, highlighting the high spatial variability inherent in most cropping systems. Additionally, our preliminary results from time-lapse imagery appear closely related to results from satellite imagery and in some cases outperform satellite imagery.

While the intent of this report was to focus on the ability of digital cameras to quantify the relative abundances of chlorophyll and above-ground nitrogen across the landscape, future work will seek to investigate the spatial dynamics of “wetting” and “drying” patterns on the field scale. This work could help to illuminate the spatial variability of water and nutrient availability across complex Palouse landscapes. Furthermore, it would provide high temporal resolution that might otherwise be missed by satellites that fly over only every 5 to 15 days.

Future work will use high-resolution digital camera data for evaluating soil water and nutrient availability as it relates to spatial crop dying dynamics, as well as toward predicted nitrogen use efficiency, yield, and protein concentration. Data available from time-lapse imagery is by no means an end-all decision support tool for assessing crop performance, but could continue to be a cost-effective, reliable, and user-friendly asset in the precision agriculture toolbox.



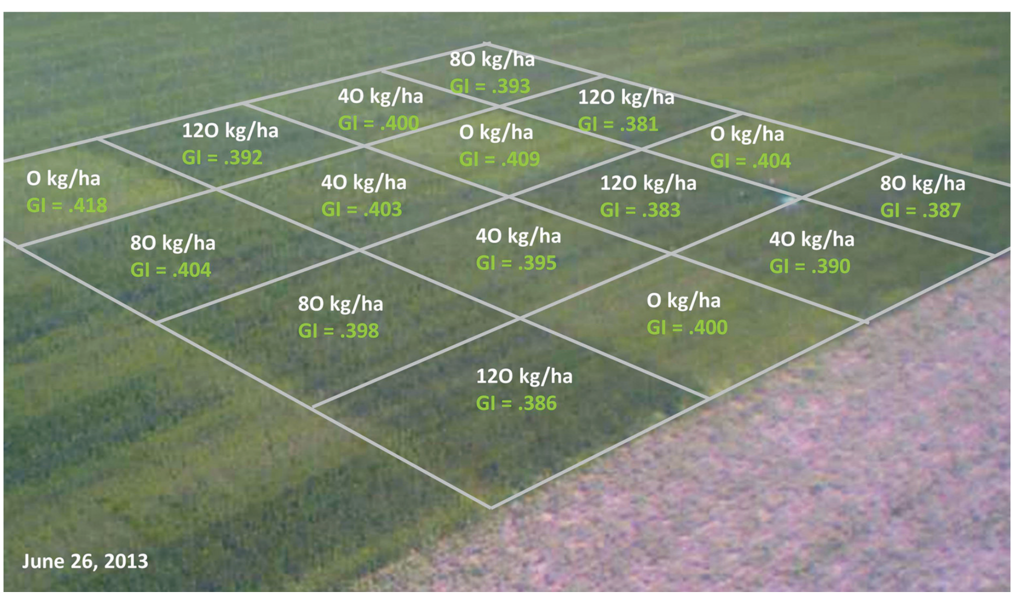


Figure 2 (above). *Selected time-lapse images from the 2013 growing season at a farm near Colfax, Washington.*

Figure 3 (left). *Experimental plots at the Washington State University Cook Agronomy farm. Each plot had a different nitrogen application rate at planting (shown in white). The associated greenness index (GI) value is shown in green. The GI is inversely proportional to the nitrogen application rate.*