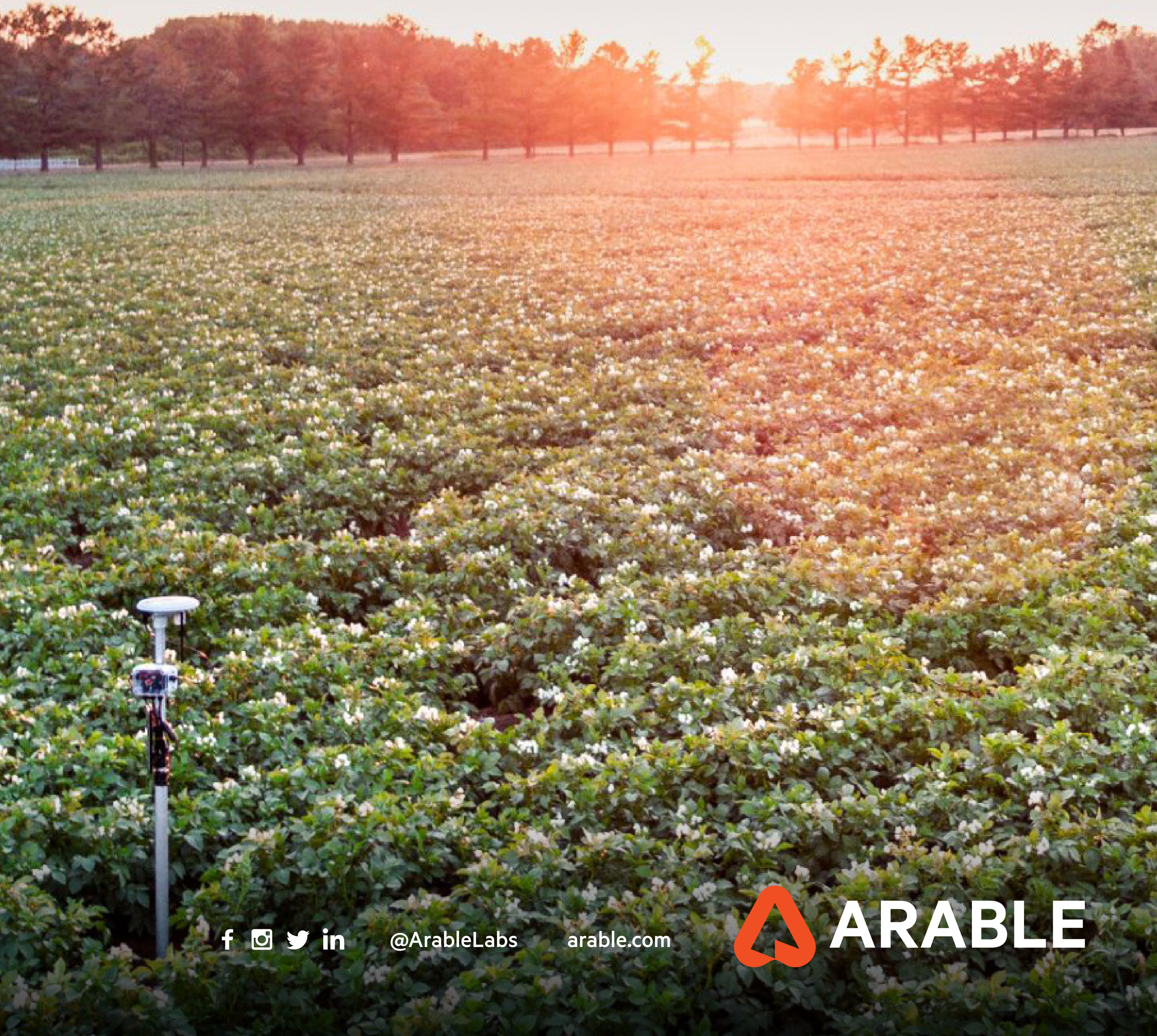
Field Guide to Measurements

Shortwave Solar Radiation And Its Derivatives

Photosynthetically Active Radiation (PAR), Daily Light Integral (DLI), Sunshine Duration (SD)



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SOLAR RADIATION
LIGHT MEASUREMENTS

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APPLICATIONS:

Light use efficiency (LUE), crop growth, variety comparisons and breeding, field site evaluations and comparisons, plant stress monitoring

OTHER RELATED MARK MEASUREMENTS:

Air temperature (T)
Normalized difference vegetation index (NDVI)
Chlorophyll index (CI)
Canopy Evapotranspiration (ET_c)

What is it?

Solar radiation is the energy emitted by the sun to the entire solar system. This energy travels on average 150 million kilometers to Earth, determining climate and allowing life on our planet in general. Within the full spectrum of wavelengths emitted by the sun, a portion (between 100nm to 300nm) is captured by Earth's atmosphere before hitting the ground. The other part of the spectrum—shortwave radiation (300nm to 3000nm)—is relevant to meteorological phenomena and reaches the surface in diffuse and direct irradiances.

Growers can use solar radiation measurements to estimate photosynthesis efficiency and crop growth in the field (G. Szeicz, 1974). Arable uses the shortwave measurements (300-2500 nm) to calculate the number of **light molecules** in this range that the plant receives in a second, the amount of **energy** that a plant gets in a day (Daily Light Integral), and the **time** the plant is exposed to this level of light (Sunshine Duration).

Other essential factors to know are the location and movement of the sun relative to the crop. These considerations, which indicate where the sun appears directly overhead at solar noon (the point when the sun reaches its highest altitude), require knowledge of the latitude and day of the year (Connor, D. J., et al., 2011.)

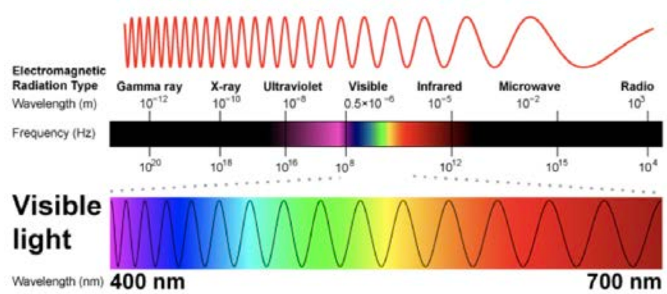


Figure 1 illustrates the correlation between electromagnetic energy, wavelength, and frequency. Credit: https://learn-biology.com/ap-biology/module-30-menu-photosynthesis/photosynthesis-3-light-and-pigments/.

Why do we measure it?

Nearly all life on earth starts with sunlight hitting a plant's leaf, transforming that energy into carbohydrates that move up through the food chain. The cost of receiving all that energy is transpiration, or the exhalation of water through the plants' stomata to keep from overheating. Thus, Arable's solar radiation measurements estimate the crop's vital rates: photosynthesis and transpiration. Growers are well aware of their specific crop's need for light, and most crops are grown in field layouts that maximize their access to it. Beyond that, management considerations such as water, nutrients, and crop protection are controllable and generally take precedence over light.

However, while we can't control how much sunlight the earth receives, we can make decisions to maximize its use. How well a crop uses its accessible light tells us a lot about its health. Moreover, since different species and varieties use different amounts and qualities of light, knowing the dynamic light variables can help a grower with many field-level questions, including:

- Which species or variety to put in which field?
- What variety has the highest light use efficiency in a trial?
- Why is one year's crop performing better or worse when all other variables are the same?
- How do natural disasters like wildfires affect yield and quality?

Light measurements provide insight into an essential thing a crop does: converting atmospheric CO_2 into organic carbons. Carbon fixation is incredibly energy-intensive, and thus plants evolved to use the energy that was in great abundance all around them: light. The plant pigments hijack the electrons from the light molecules and transfer them onto energy molecules that fuel the carbon fixation cycle.

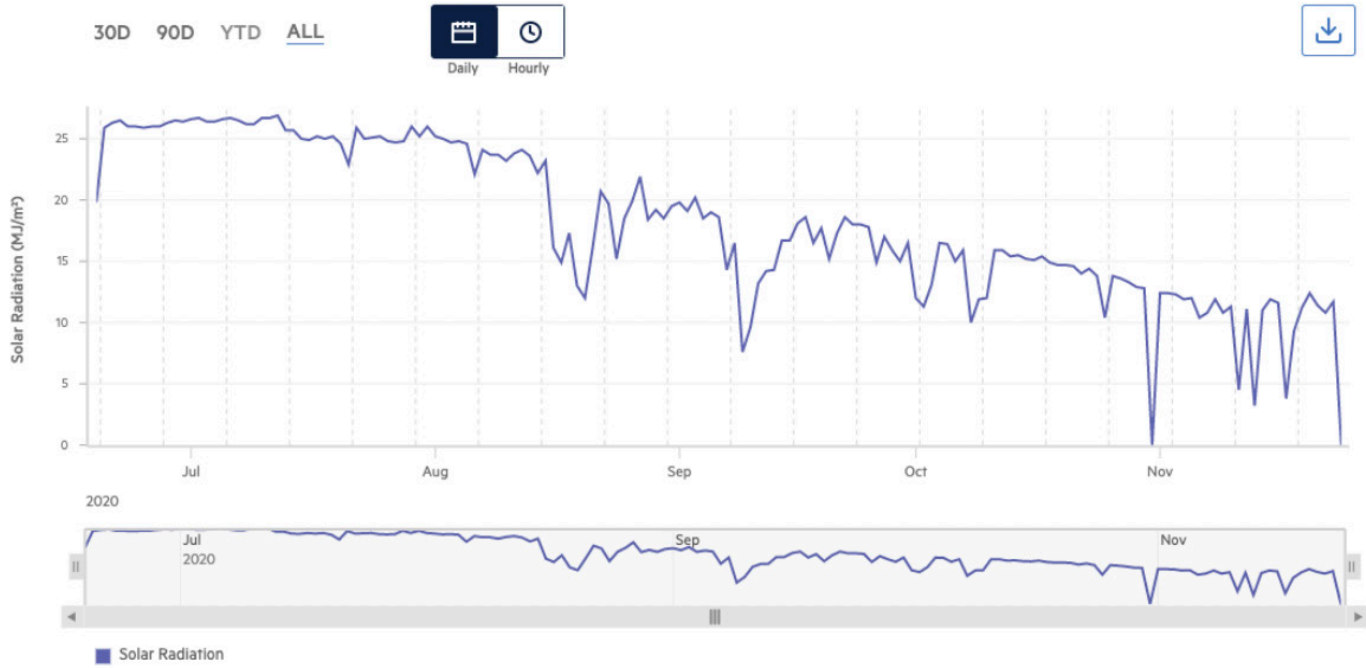
With the increasing efficiency of management and resource availability in agriculture, many researchers and growers find that, under controlled environments, their crop productivity is limited only by light (Bugbee, B., & Monje, O. 1992). Another group of researchers found that alfalfa and corn productivity increased under the smoky conditions of high photosynthetically active radiation caused by wildfires in California (Hemes, K. S et al., 2020).

How do we measure it?

The Arable Mark has a unique set of sensors measuring shortwave—solar—radiation in the 300-2500nm range. We measure the incoming energy with the upwelling spectrometer and the amount of outgoing—reflected—energy with the downwelling spectrometer.

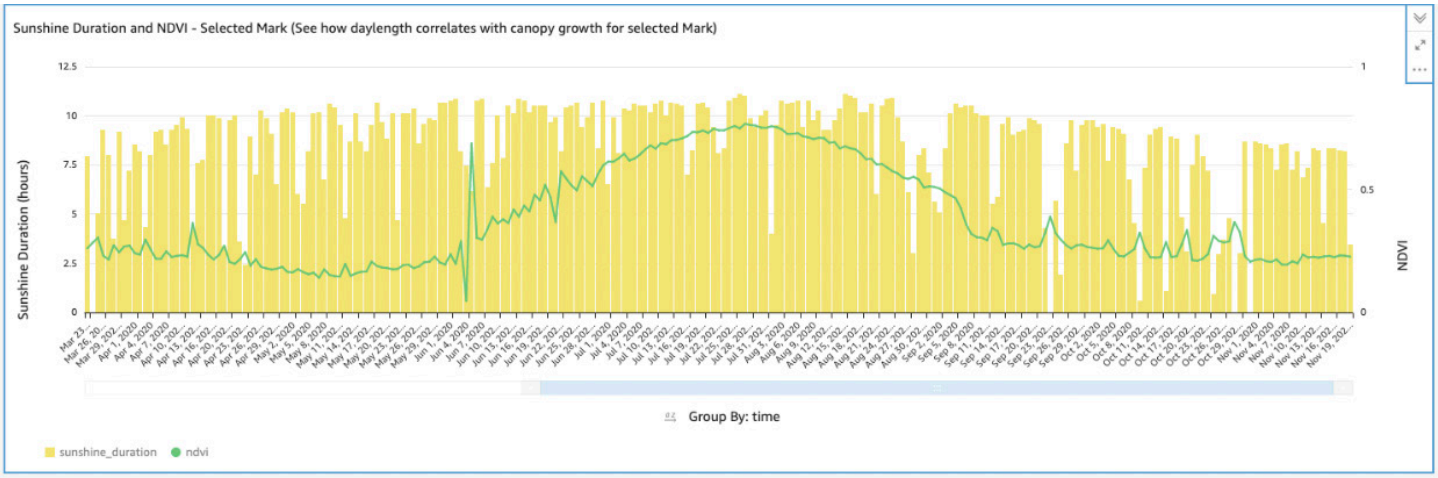
What does the data look like?

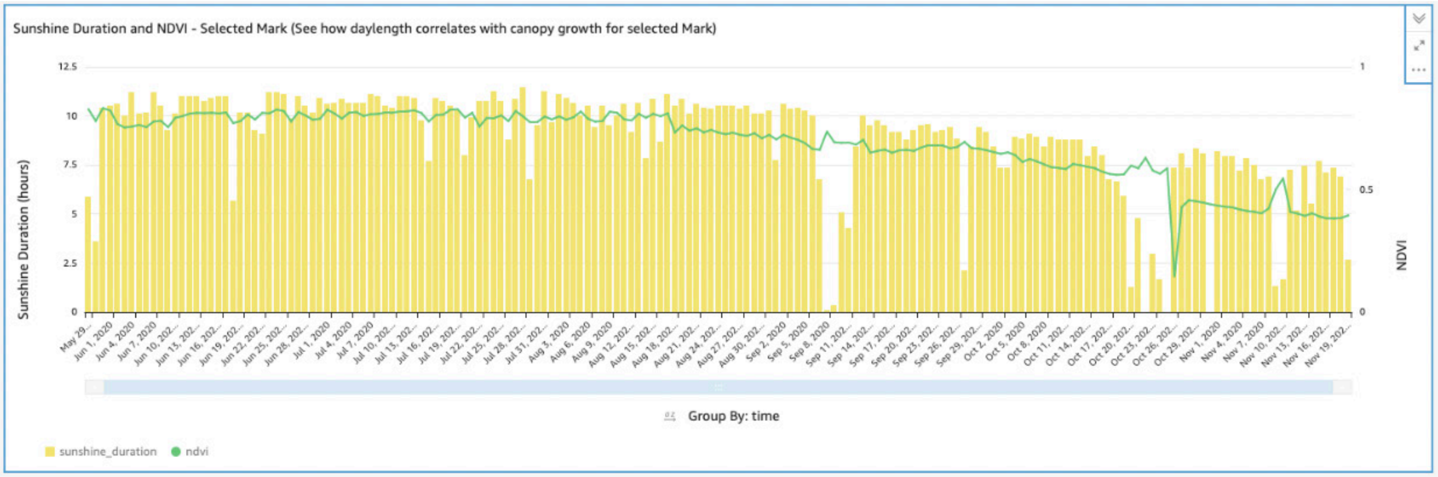
Below is an example of daily solar radiation (MJ/m2) in California. Between August and September, the Arable Mark captured a drop in solar radiation due to smoke caused by the wildfires of 2020.



How can you use it?

You can keep track of the crop growth (NDVI) through the season and see how the hours of sunlight influence your field's development. Below are two examples. The first plot shows a rice field in Arkansas, where growth peaks as the days become longer throughout the year. The second plot shows a close relationship between the duration of the day and the maturity and senescence of hops in Nebraska.





CITATIONS

Bugbee, B., & Monje, O. (1992). The Limits of Crop Productivity. BioScience, 42(7), 494-502. doi:10.2307/1311879

Connor, D. J., Loomis, R. S., & Cassman, K. G. (2011). Crop ecology: productivity and management in agricultural systems. Cambridge University Press.

Hemes, K. S., Verfaillie, J., & Baldocchi, D. D. (2020). Wildfire- Smoke Aerosols Lead to Increased Light Use Efficiency Among Agricultural and Restored Wetland Land Uses in California's Central Valley. Journal of Geophysical Research: Biogeosciences, 125(2), e2019JG005380.

Szeicz, G. (1974). Solar Radiation for Plant Growth. Journal of Applied Ecology, 11(2), 617-636. doi:10.2307/2402214

How Big Is the Solar System? – NASA Solar System Exploration. (2020, February 01). https://solarsystem.nasa.gov/news/1164/how-big-is-the-solar-system/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