Field Guide to Measurements

Normalized Difference Vegetation Index (NDVI)

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NORMALIZED DIFFERENCE VEGETATION INDEX

TABLE OF CONTENTS

What is it?.. 4

Why do we measure it?.. 4

How do we measure it?.. 5

What does the data look like?.. 7

How can you use it?.. 7

Example use case 8

APPLICATIONS:

Canopy growth, crop phenology, plant stress monitoring, growth stage predictions, irrigation scheduling

OTHER RELATED MARK MEASUREMENTS:

Crop coefficient (Kc_{NDVI})
Canopy evapotranspiration (ET_c)
Chlorophyll index (CI)
Growing degree days (GDD)

What is it?

The **Normalized Difference Vegetation Index (NDVI)** is a common method used in precision agriculture to assess live green biomass; a higher NDVI is indicative of higher crop biomass. This measure is based on how the plant reflects and absorbs light at specific wavelengths. Healthy plants absorb more radiation in the red spectrum of light and reflect more near-infrared radiation.

Why do we measure it?

An experienced grower develops a keen eye for changes in their plants. Visiting your field and getting a good look at the health and vigor of the plants—whether or not their size, shape, and color match what they should be at that moment in the season—is an essential part of making sure your crop will produce when and as needed. By measuring NDVI, we gain the ability to differentiate soil from vegetation, identify stressed plants, and track crop growth over the season.

This vegetation index is both a crop status monitor and a decision-making tool. NDVI plots visually represent the growth of the crop and you can quickly compare NDVI values between fields and between seasons to make sure your crop is healthy and reaching the growth milestones you expect during the season.

NDVI IS A POPULAR VEGETATION INDEX TO DETERMINE CANOPY COVER. IT CAN BE A VISUAL PROXY OF PLANT PHENOLOGY THAT CAN BE USED TO COMPARE THE RELATIVE GROWTH BETWEEN FIELDS.

How do we measure it?

The Arable Mark 2 features an upward-facing and downward-facing spectrometer to measure the incoming and reflected radiation of specific ranges of light. These ranges of light (wavebands) will be absorbed or reflected based on the amount of green canopy present under the spectrometer.

An index is a **ratio** or coefficient that demonstrates a relationship between related quantities. In the case of NDVI, it is actually a ratio of ratios.

The first ratio we calculate is the **reflectance (ρ)**, which is the amount of light that is leaving the plant (upwelling, measured by the downward-facing lens) divided by the amount of light entering the plant (downwelling, measurement by the upward-facing lens). For NDVI, we calculate the reflectances of the **red** and **near infra-red (NIR) wavelengths (λ)**. This is how we know how much of the red and NIR light the plant pigments are "taking" and "rejecting."

$$\rho = \frac{{}^{\lambda}\text{upwelling}}{{}^{\lambda}\text{downwelling}}$$

NDVI is then calculated as the ratio between the difference of NIR and red bands reflectance and the sum of reflectance from the same bands:

$$\text{NDVI} = \frac{\rho\text{nir} - \rho\text{red}}{\rho\text{nir} + \rho\text{red}}$$

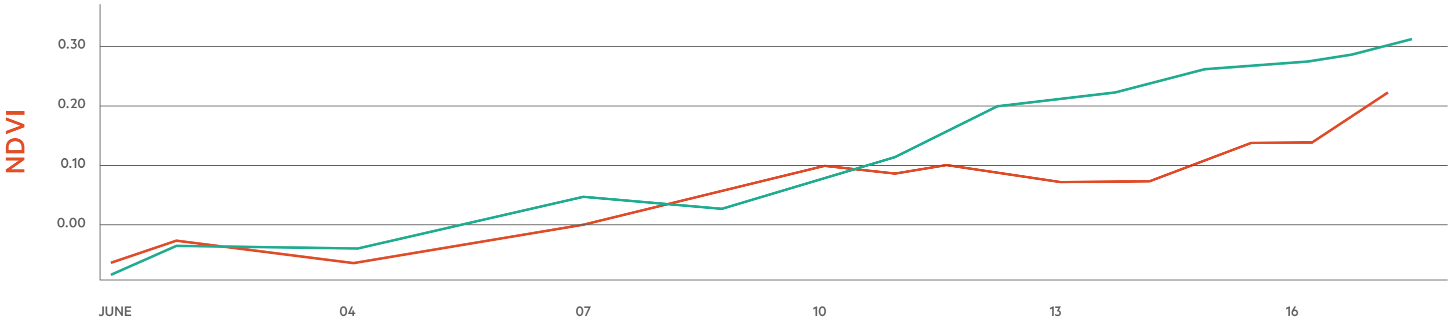
Arable also uses NDVI to provide localized, crop-specific **canopy evapotranspiration (ET_c)** rates based on the **crop coefficient (Kc_{NDVI})**. Kc_{NDVI} is a multiplier that accounts for the plant's leaf area and thus its evaporative demand—the more leaf area the more water inputs it will require. We use the Kc_{NDVI} to convert a **field evapotranspiration (ET_f)**, which is based on climate conditions, to the crop-specific ET_c.

ALL LIGHT ENERGY IS NOT CREATED EQUAL

Plants absorb wavelengths of light in the red spectrum but not in the near-infrared spectrum. Why? Well, the frequency of the wavelengths corresponds to the amount of energy contained in the light particles (photons). It would not be efficient for the plants to try and absorb all of these different intensities of energy (imagine trying to catch a curveball, fastball, and slider at the same time), so they have specialized into only absorbing the blue and red parts of the visible spectrum. The soil, however, is pretty good at absorbing NIR energy. So the more the plants grow and block out the soil, the more NIR gets reflected and the higher NDVI gets.

What does the data look like?

NDVI is a measurement in the range of -1 to 1. You can see how the values increase as the canopy develops. Below is an example of two rice fields in California with two different fertilizer treatments. Both fields were planted at the same time, but the crops with higher nitrogen input show higher NDVI values versus the crops receiving less fertilizer.



Two rice fields plotted in one graph show how NDVI increases with canopy development as the season progresses.

How can you use it?

You should expect to see a reduction in the NDVI values when the fields start looking less uniformly green or there is any indication of chlorosis[1]. If your plants are in the early growth stages, NDVI should increase continuously until they reach crop maturity, after which the values will begin to decrease indicating other phenological stages and canopy senescence[2]. An unexpected decrease in NDVI during canopy development could be an indicator of plant stress, plant disease, nutrient deficiency, or canopy mismanagement.

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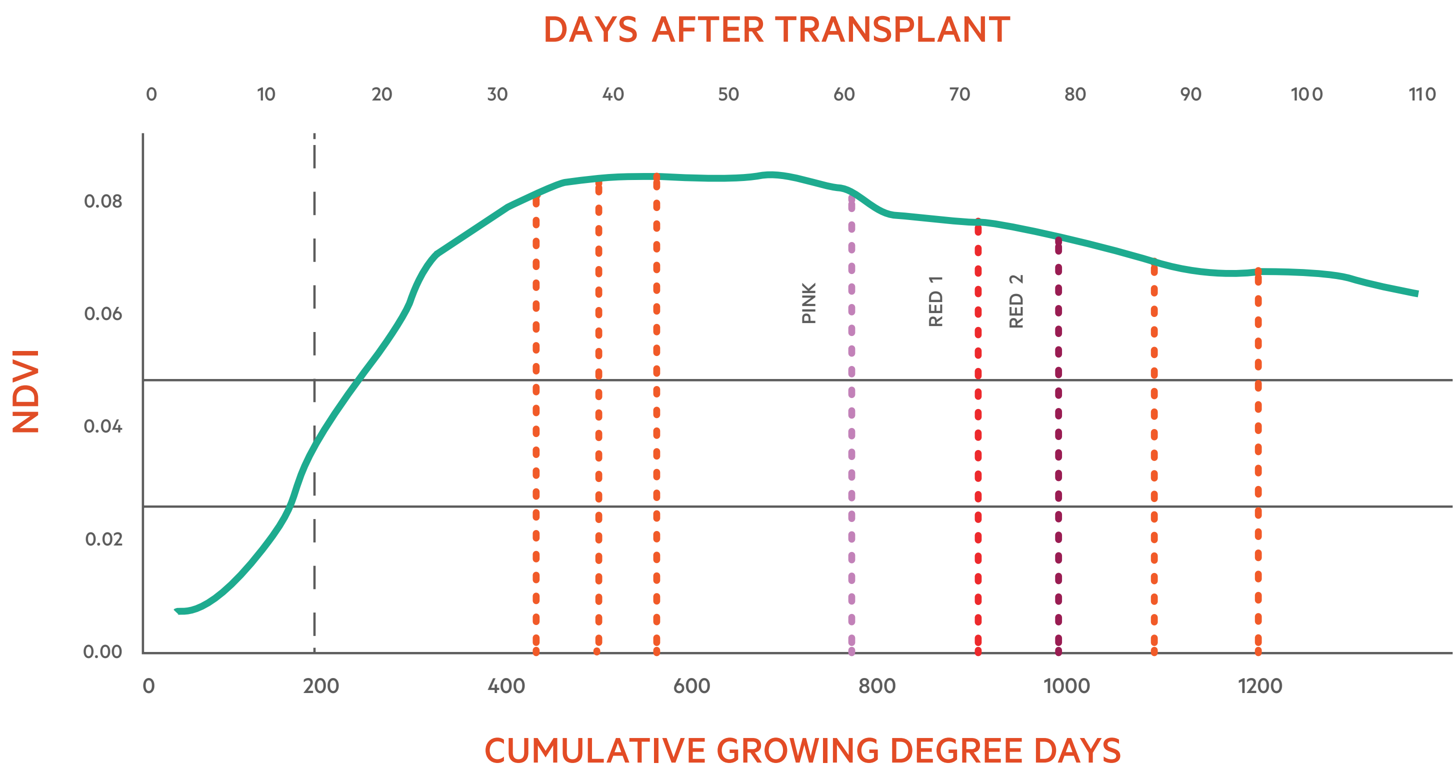
[1] Chlorosis is the loss of chlorophyll in the plant which presents as a lightening of the green or yellowing of the leaf tissues. Since the nitrogen and chlorophyll content are tightly linked it is also synonymous with nitrogen deficits.

[2] Senescence is the process of aging due to stressors or the appropriate passage of time. Symptoms are caused by a reduction in cell vigor and healthy replication, and typically appear as severe darkening (in the case of cell death), yellowing of tissues (in the case of loss of chlorophyll), or loss of structural integrity.

Example use case

Since NDVI values provide granular insights into your crop phenology and canopy vigor, they can also be used to time the implementation of complex management practices. You can picture the increase of the NDVI curve as the canopy development, and when the plant starts producing fruits the curve will reach the maximum values before the start of a slow decrease driven by fruit ripening.



NDVI through the growing season of processing tomatoes. When the fruits start maturing in mid-July, the NDVI declines gradually until the fruits fully ripen.

NDVI can help determine the optimal time to begin deficit irrigation in tomatoes. Several studies (see Johnstone, P. R., et al., 2005) indicate that beginning deficit irrigation at the pink fruit stage can maintain or even increase **Brix** yield[3]. Since NDVI is a key factor in determining the start date for **regulated deficit irrigation (RDI)**[4], it is vital to keep track of it as the pink fruit growth stage approaches. A small negative percentage change within the NDVI range for subsequent days means you are most likely seeing the change in color of your crops as the fruit ripens. Aligned with **growing degree days (GDD)**, which is a direct indicator of the crop development, an NDVI change like this is an indicator that it's time to implement RDI.

NDVI is a great tool for visualizing the health and vigor of your crop and detecting subtle changes in canopy cover. Unexpected percent changes in NDVI can be indicative of problems in your crop and expected changes can inform the implementation of important management practices.

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[3] Brix is a metric that represents the amount of sugar by weight present in fruit juices. One degree Brix is equivalent to 1 gram of sucrose in 100 grams of solution.

[4] Regulated deficit irrigation is a commonly used practice in which irrigation volumes are reduced to trigger a desired outcome (usually an increase in fruit soluble solids content) in crop plants.

Johnstone, P. R., Hartz, T. K., LeStrange, M., Nunez, J. J., & Miyao, E. M. (2005). Managing fruit soluble solids with late-season deficit irrigation in drip-irrigated processing tomato production. HortScience , 40(6) (pp. 1857-1861).

https://science.nasa.gov/ems/08_nearinfraredwaves

WHY WOULD A PLANT INCREASE THE STORAGE OF SUGARS DURING DEFICIT IRRIGATION?

The mechanics of deficit irrigation are a bit counterintuitive as we are depriving the plant of an essential biological need in order to make it produce other compounds. Limit the plant of water and it changes its physiology so that it can take up more water from the soil. This works because water always moves from a location with a low concentration of solutes to a high concentration of solutes (molecules dissolved in water). If the fruit increases its solute concentration by building more sugars, it has more "tension" on the soil water i.e., more strength to pull on the soil water. This tension is necessary because the water must move against gravity to travel through the plant. Therefore, increasing the sugar content increases the plants' ability to take up water in response to deficit irrigation, and thus the amount of water that moves from the soil into the plant.


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