

# Chapter 8. Normalized difference vegetation index

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The normalized difference vegetation index (NDVI) is widely used at ground level, and from low, high and satellite altitudes to measure vegetative greenness and canopy photosynthetic size. The field-portable NDVI sensor (Figure 8.1) provides rapid ground level measurement of crops at a resolution to characterize the canopy for: leaf area index (LAI) and green area index (GAI), biomass and nutrient content (e.g., nitrogen). Data can be used to estimate yield prediction, biomass accumulation and growth rate, ground cover and early vigor, senescence pattern estimations, and for biotic and abiotic stress detection. NDVI technology is also used for making decisions in precision agriculture: weed detection and herbicide spraying, and rate and timing of nitrogenous fertilizer applications.

NDVI is calculated from measurements of light reflectance in the red and near infrared (NIR) regions of the spectrum. A healthy green canopy will absorb most of the red light and reflect most of the NIR light as chlorophyll absorbs mainly blue and red light and the mesophyll reflects NIR light:

$$NDVI = (R_{NIR} - R_{Red}) / (R_{NIR} + R_{Red}) \quad \text{Equation 8.1}$$

The majority of field-portable NDVI sensors are 'active' (i.e., they produce their own source of light) which allows measurements to be made under any light condition, and for data to be comparable across date and time of day.

## Site and environmental conditions

For 'active' sensors, measurements can be taken under any light conditions (for NDVI sensors without a light source take measurements on a clear, sunny day). Take measurements when there is negligible wind as even a light wind can modify canopy structure. It is important that the plant surfaces are dry and not wet from dew, irrigation or rain.

## Time of day

For active sensors, measurements can be taken at any time of day. For NDVI sensors without a light source, take the majority of measurements as close to solar noon as possible; typically from 11:00h to 14:00h.

## Plant developmental stage

Measurements can be taken at any developmental stage and/or at regular intervals from the emergence to physiological maturity, depending on the experimental objectives/timing of peak stress. To compare between genotypes, do not take measurements during heading and anthesis where differences in phenology may confound results:

- Early vigor: take three measurements, at 5, 10 and 15 days after emergence (DAE), to rank genotypes. It is recommended to use the same seed source for all genotypes, as seed from different environments may present variation in establishment which may confound analysis.



Figure 8.1. (A) Greenseeker NDVI portable sensor; (B) in-field use at GS31; and, (C) in-field use during grain-filling.

- Biotic and abiotic stress detection: take measurements before, during and after the stress event/period. Effects on NDVI (e.g., for estimation of green biomass) will allow discrimination of sensitive and stress tolerant/resistant genotypes.
- Biomass accumulation and crop growth rate: take measurements periodically from emergence to the end of anthesis to estimate biomass accumulation over time for the calculation of crop growth rate.
- Senescence, stay-green and grain-filling duration: take measurements weekly from anthesis to physiological maturity. Genotypes which maintain canopy green area, greenness and duration are associated with higher yield.

### Number of samples per plot

Take one measurement per plot of a fixed duration (depending on plot size); e.g., approximately 5 seconds for a 5 m plot.

### Procedure

The following procedure describes taking in-field measurements using a hand-held Ntech 'Greenseeker' NDVI meter (an active sensor).

Take the following equipment to the field:

- Field portable NDVI sensor

### Advice on taking measurements

Whilst taking measurements, ensure to hold the sensor head:

- Levelled horizontally so that the field of view is directly over the crop.
- Consistently aligned over the plot, typically centered over the middle row. Ideally the field of view should cover two or more rows (Figures 8.1C and 8.2B).
- At a distance of 60-120 cm above the crop - within the optimal distance range the readings are not affected by height variance (check manufacturer recommendations). Differences in plant canopy height between genotypes from emergence to the initiation of stem elongation are inconsequential, however, after heading, plant canopy height may differ between genotypes and it may be necessary to adjust the height of the sensor head between plots in order to maintain a constant distance between the sensor head and the crop canopy. A weighted string attached behind the sensor head helps the operator to maintain a constant distance between the sensor head and crop canopy (see Figure 8.1C).

Walk at a steady speed (typically  $1 \text{ m s}^{-1}$ ). Most field-portable NDVI sensors take a constant number of measurements per second while the trigger is held, and then provide an average these data. Walk up and down

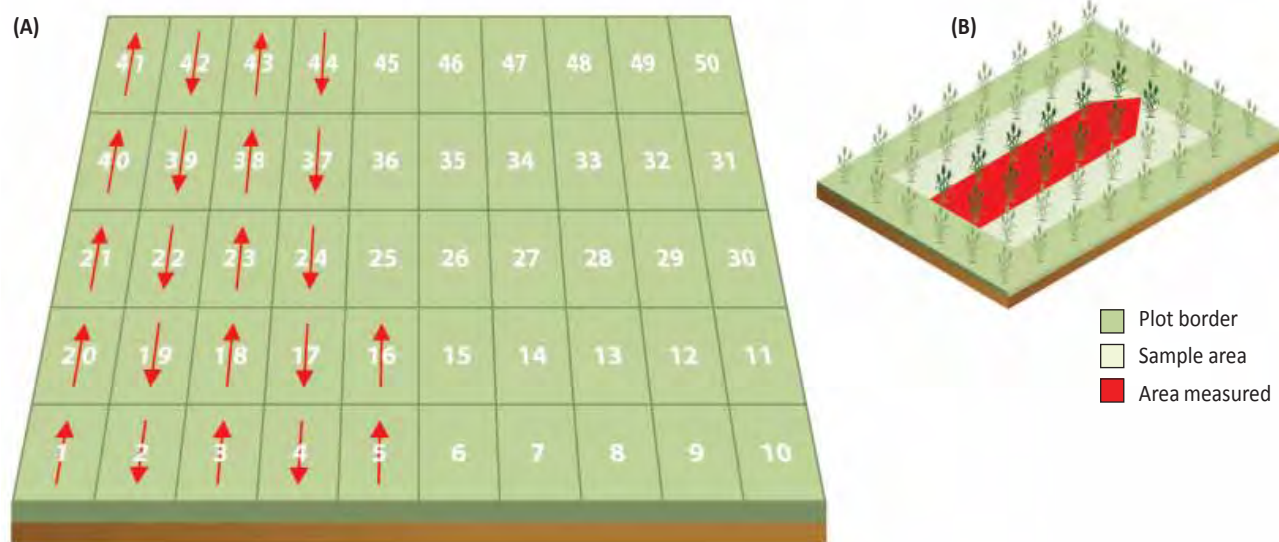


Figure 8.2. (A) field map and direction of measurement (the order of sampled plot is: 1, 20, 21, 40, 41, 42, 39, 22...); and, (B) area sampled within each plot by passing the sensor above central crop rows and excluding plot borders.

the rows, regardless of the experimental design as it is generally easier to rearrange the data in the office than to follow the plot number in the field (see Figure 8.2).

It is necessary to control for phenology in populations with diverse anthesis dates as plants under different stages of development have different architectures and present differences in the source-sink relationships, and these may confound the analysis. This can be corrected by splitting the population into early and late lines, and therefore making different populations to be screened. A range of up to 10 days in anthesis date is quite reasonable.

### Preparations

Ensure that the sensor unit and palmtop computer (PDA) batteries are fully charged (this typically requires >6 hours).

Check connections between the Greenseeker sensor head, battery unit, telescoping tube and PDA.

Check the sensor head angle in relation to the ground (this should be horizontal), and check the distance from sensor head to the canopy by adjusting the sensor head angle mount and the telescoping pole.

Adjust the shoulder straps to give a good balanced weight distribution of the instrument for comfortable working.

1. After turning on the Greenseeker unit and PDA, allow the instruments to equilibrate with the ambient temperature for around 10 minutes. Go to 'START' > 'PROGRAMS' and run 'NTECH CAPTURE' software. Then go to 'SENSOR' > 'START GREENSEEKER'. Select 'LOGGING PLOTS' mode, the display will show three cells:

- (i) SAMPLE NO.: shows the number of measured plots.
- (ii) NDVI: shows NDVI value of the last plot.
- (iii) AVG NDVI: shows the average NDVI value of all previously recorded plots.

The sensor is now ready.

### Trial measurements

2. Position the sensor at the start of the plot (see advice on taking measurements). Press and hold the trigger whilst moving across the plot, release the trigger at the end of the sample area. A continuous beep sound is produced while the trigger is held.
3. Walk up and down the rows, regardless of the experimental design (see Figure 8.2). In case of an error during the sampling, take note of the 'SAMPLE NO.' and correct during data processing.

### Final measurements and completion

4. After measuring the whole trial. Go to 'FILE' > 'SAVE' - assign a file name (e.g., trial name and date).
5. Saved data can be downloaded with the software supplied with the instrument. Data is typically downloaded as a 'comma delimited' text file and imported into MS Excel.

### Data and calculations

First, it is necessary to re-order the downloaded data where the sample number and plot ID are in a different order. Three individual text files are created for each trial: (i) a general file with NDVI and vegetation index (VI) (Red/NIR) values for each measured point (approximately 10 values per second); (ii) a file of the 'AVG NDVI' and VI data for each plot; and (iii) a file with diagnostic information (indicated with the suffix 'DIAG').

Typically the AVG data file is used. NDVI values from a crop canopy range from 0 to 1 (where: 0 represents no green area, and 1 represents maximum greenness) (Table 8.1).

**Table 8.1. Sample of the AVG normalized difference vegetation index (NDVI) and vegetation index (VI) data.**

Time (ms)	Plot	Count	NDVI	VI_2
173610	1	29	0.54283	0.30748
178610	2	25	0.45732	0.38388
184410	3	35	0.60763	0.25526

## Troubleshooting

Problem	Solution
Large error variance in data.	NDVI meter is not held centrally over plot, and/or small plots with a large border effect.
Variable reflectance values and/or with high error variance.	Low battery causes a reduction in the light source intensity affecting the reflectance value (i.e., the active sensor becomes a passive sensor).
An unintentional value was recorded.	Take a note of the plot number and mistake, and delete the unintentional value during data processing.
No association between biomass and NDVI score.	Confounding effects of plant height within the trial. This can be corrected by grouping phenotypically similar lines within the population.

## Useful references

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