

# ***Crop Circle ACS-430 User's Guide***

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## **SAFETY**

This product has been designed and tested to be a safe and “environmentally friendly” device. To ensure safe operation and to keep the product safe, the information, cautions, and warnings in this manual must be followed.

## **CERTIFICATION**

Holland Scientific certifies that this product met its published specifications at the time of manufacture. Accuracy of the data recorded by this data acquisition system depends on the user adhering to the procedures published in this manual.

## **WARRANTY**

Holland Scientific warrants this product against defects in material and workmanship for a period of one year from the date of shipment. During the warranty period, Holland Scientific will, at its option, either repair or replace products that prove to be defective.

For products returned to Holland Scientific for warranty service, Buyer shall prepay shipping charges to Holland Scientific and Holland Scientific shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to Holland Scientific from another country.

## **LIMITATION OF WARRANTY**

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

Information in this manual is subject to change without notice. No liability is assumed for damages resulting from the use of this information, device or software described.

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## 1. PRODUCT OVERVIEW

The Crop Circle ACS-430 is a unique light sensor that can measure plant canopy reflectance day or night. The sensor can be mounted to virtually any type of vehicle to remotely sense crop or plant canopy biomass on-the-go. The sensor incorporates its own polychromatic light source technology to illuminate a plant canopy. The light source technology simultaneously emits visible and near infrared light (NIR) from a single LED light source. The key benefit of this new light source technology is that the area of plant canopy illumination is identical for both visible and the infrared light bands, essentially mimicking the spatial composition of natural light. The Crop Circle ACS-430 measures reflectance in three bands simultaneously: 670 nm, 730 nm and NIR bands. Reflectance data measured by the Crop Circle ACS-430 allows the user to calculate classic vegetation indexes from plant canopies such as the NDVI and SRI indexes. The reflectance data produced by the Crop Circle data is height invariant. This allows the user to use dozens of vegetation indexes developed for aerial and satellite remote sensing applications. Serial data produced by the sensor can be easily captured using a laptop PC, PDA or other data acquisition devices.

### 1.1 Theory of Operation

Plant tissue readily absorbs light in the visible portion of the spectrum (and reflects a small amount typically 2% to 10%) and reflects NIR light (35% to 60%) due to a discontinuity in the refractive indexes between cell walls and intercellular air gaps. The interplay between canopy reflectances in the visible and NIR portions of the spectrum can be utilized to determine the approximate biomass (or comparative status) of a plant remotely. The ACS-430 has been designed precisely to take advantage of this phenomenon. When near infrared and visible light emitted from the sensor is directed toward a plant canopy, a portion of that light is reflected back to the sensor. The portion of emitted light reflected back to the sensor is detected by an array of spectrally sensitive photosensors. Additionally, by modulating the light source (rapidly pulsing the light source on and off many times a second), the ACS-430 can distinguish its own light signal from that of surrounding ambient light. This allows the sensor to make canopy measurements under all ambient lighting conditions: cloudy skies, full sun, complete darkness, or artificial lighting. The measured reflectance signals are then utilized by the sensor to make vegetative biomass calculations. The magnitude of this vegetation calculation is directly proportional to plant biomass (for red/NIR sensor measurements under partial canopy closure conditions; LAI<2) or plant biomass/stress (for Red-Edge/NIR sensor measurements under full canopy closure; LAI>2). Tables 1 and 2 list the output fields contained in the ACS-430 serial data stream and Table 3 lists some useful vegetative indices that can be calculated from reflectance data produced by the ACS-430.

Table 1. Sensor fields for multi-sensor mode.

SF1	SF2	SF3	SF4	SF5
NDRE	NDVI	Red-Edge	NIR	Red

Table 2. Sensor fields for auto send mode.

SF1	SF2	SF3	SF4	SF5
Red-Edge	NIR	Red	NDRE	NDVI

Table 3. Summary of two-band and three-band vegetation indexes compatible with ACS-430 active sensor. This table was adapted, in part, from Gong et al. (2003)

Vegetation Index	Formula	Index Name
SRI	$\frac{\rho_{NIR}}{\rho_R}$	Simple Ratio Index- Red
Chl I	$\frac{\rho_{NIR} - 1}{\rho_{RE}}$	Chlorophyll Index- Red-Edge
PVI	$\frac{1}{(a^2 + 1)^{1/2}} (\rho_{NIR} - a\rho_R - b)$ <i>a = soil line slope</i> <i>b = soil line intercept</i>	Perpendicular Vegetation Index
NDVI	$\frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}$	Normalized Difference Vegetation Index
NDRE	$\frac{\rho_{NIR} - \rho_{RE}}{\rho_{NIR} + \rho_{RE}}$	Normalized Difference Red-Edge
WDRVI	$\frac{a\rho_{NIR} - \rho_R}{a\rho_{NIR} + \rho_R}$ <i>a = NIR scale factor (0 to 1)</i>	Wide Dynamic Range Vegetation Index
SAVI	$\frac{(\rho_{NIR} - \rho_R)(1 + L)}{\rho_{NIR} + \rho_R + L}$ <i>L = soil line correction factor</i>	Soil Adjusted Vegetative Index
TSAVI	$\frac{a(\rho_{NIR} - a\rho_R - b)(1 + L)}{a\rho_{NIR} + \rho_R - ab + X(1 + a^2)}$ <i>a = soil line slope</i> <i>b = soil line intercept</i> <i>X = factor to minimize soil background</i>	Transformed Soil Adjusted Vegetation Index
NLI	$\frac{\rho_{NIR}^2 - \rho_R}{\rho_{NIR}^2 + \rho_R}$	Non-Linear vegetation Index

Table 3. (Continued) Summary of two-band and three-band vegetation indexes compatible with ACS-430 active sensor. This table was adapted, in part, from Gong et al. (2003)

Vegetation Index	Formula	Index Name
NDVI*SRI	$\frac{\rho_{NIR}^2 - \rho_R}{\rho_{NIR} + \rho_R^2}$	
SAVI*SR	$\frac{(\rho_{NIR}^2 - \rho_R)}{(\rho_{NIR} + \rho_R + L)\rho_R}$ <i>L = soil line correction factor</i>	
RDVI	$\frac{\rho_{NIR} - \rho_R}{(\rho_{NIR} + \rho_R)^{1/2}}$	Re-normalized Difference Vegetation Index
MNLI	$\frac{(\rho_{NIR}^2 - \rho_R)(1 + L)}{\rho_{NIR}^2 + \rho_R + L}$ <i>L = soil line correction factor</i>	Modified Non-Linear vegetation Index
MSR	$\frac{(\rho_{NIR}/\rho_R) - 1}{(\rho_{NIR}/\rho_R)^{1/2} + 1}$	Modified Simple Ratio
WDVI	$\rho_{NIR} - a\rho_R$ <i>a = soil line slope</i>	Weighted Difference Vegetation Index
WICI 1	$\frac{\rho_{NIR} - \rho_{RE}}{\rho_{NIR} + \rho_R}$	Water Invariant Chlorophyll Index 1
WICI 2	$\frac{\rho_{NIR} - \rho_{RE}}{\rho_{RE} + \rho_R}$	Water Invariant Chlorophyll Index 2
NIR	$\rho_{NIR}$	Near InfraRed band reflectance
RE	$\rho_{RE}$	Red-Edge band reflectance
R	$\rho_R$	Red band reflectance

## 1.2 Sensor Specifications

### Optical Specifications

**Sensor-to-Canopy Range:** Typically 10 in (25 cm) to >96 in (244 cm)

**Field-of-View:** ~40-45 degrees by ~6-10 degrees

**Lateral Measurement Variation:** Typically +/- 10%

**Light Source:** Modulated polychromatic LED array

**Photodetection:** Silicon photodiode array

**Wavebands:** Detector 1: 730 nm; Detector 2: NIR; Detector 3: 670 nm

**Ambient Light Rejection:** up to 400 W·m<sup>-2</sup> (reflectance)

### Electrical Specifications

**Measurement Methodology:** Synchronous modulation and demodulation

**Sample Output Rate:** Programmable for 1 sample per second to 20 samples per second; default is 10 samples per second

**Operating Range:** 0 to 50 °C

**Temperature Drift:** < 0.1%/°C

**Communication Interface:** RS-485 multi-drop (bidirectional communication); RS-232 (autosend, output only)

**Serial Communication:** RS-232 (autosend): 38400, no parity, 8 data bits, 1 stop bit; RS-485 multi-drop: 76800, no parity, 8 data bits, 1 stop bit

**Vegetative Calculations:** Normalized Difference Vegetative Index (NDVI), Normalized Difference Red-Edge (NDRE), Red-edge band reflectance  $R_{RE}$ , NIR band reflectance  $R_{NIR}$ , Red band reflectance  $R_R$

**Power:** 11.5 to 17V DC @ ~300mA

### Mechanical Specifications

**Enclosure:** Injection-molded polycarbonate housing, o-ring sealed for dust and water resistance

**Environmental:** IP68 for dust and water resistance

**Weight:** 0.85 lb. (385 gm)

**Sensor Mount:** (2) 6MX1 threaded holes in base of sensor spaced 1.25 in (3.18 cm)

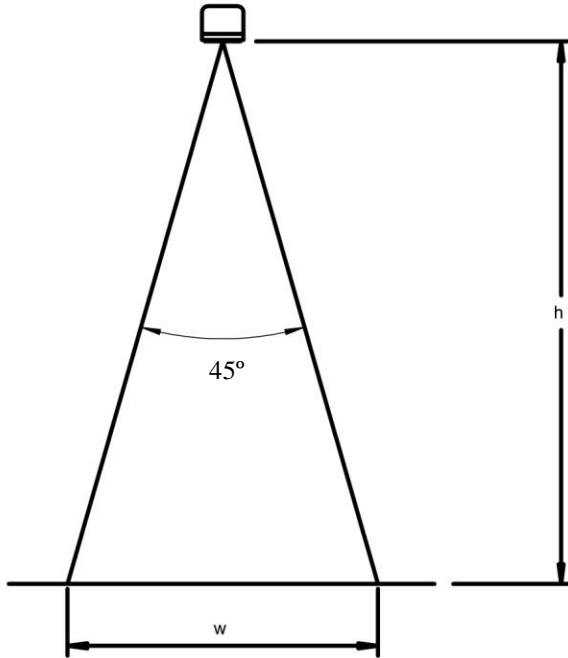
**Dimensions:** Width 1.75 in (3.8 cm), Length 7.0 in (17.8 cm), Height 3.0 in (7.6 cm)

## 2. Mounting the Sensor

**Figure 1** diagrammatically shows an ACS-430 sensor mounted at height  $h$  above a plane target. The width of the projected beam when mounted height  $h$  above a target is defined by the following equation,

$$w=2 \cdot h \cdot \tan\left(\frac{\theta}{2}\right)=0.82 \cdot h$$

where  $\theta$  is the angular FOV in degrees (~45 degrees for the ACS-430),  
 $w$  is the projected beam width and  
 $h$  is the height of the sensor above the target.



**Figure 1. Sensor Field-of-View (FOV).**

The sensors are typically positioned over the canopy of interest by fastening the sensor to mast or boom. While the sensor can make biomass measurements over distances ranging from ~10 to 96 inches, optimal sensor-to-canopy distances range from 30 to 36 inches. There is no need to control this height mechanically.

### 3. MAINTENANCE

Maintaining the Crop Circle sensor is relatively easy and straight forward. Proper care and storage of the system will help ensure reliable and repeatable operation. Follow the recommendations below to properly care for your Crop Circle ACS-210B sensor.

**Before use:** Inspect optical surfaces prior to use. Clean to remove any dust or soil from interfering with the optical signal. Use a moist, soft cotton cloth to clean surfaces and enclosure. **Never** use an abrasive cleaner or rough cloth. **Never** use a solvent-based cleaner to clean optics or enclosure.

**Storage:** Between field surveys and after the seasonal usage, the sensor should be stored at room temperature and in low humidity environment. Although the sensor enclosure was designed to be water resistant, water vapor may (over time) diffuse into the housing if left in extreme humidity. This may result in damage to the optical elements in the sensor which will affect the optical stability of the spectral bands.

## 4. NOTES