FIELD SCOUT®

GreenIndex+

PRODUCT MANUAL

Item # 2910A, 2910B

Spectrum®
Technologies, Inc.

CONTENTS

This manual will familiarize you with the features and operation of your new FieldScout GreenIndex+ App and Target Board. Please read this manual thoroughly before using your instrument. For customer support, or to place an order, call Spectrum Technologies, Inc. at 800-248-8873 or 815-436-4440 between 7:30 am and 5:30 p.m. CST, FAX at 815-436-4460, or E-Mail at info@specmeters.com. www.specmeters.com

General Overview

This manual explains how to use the GreenIndex+ as a tool for managing the nitrogen needs of your crop and overall plant health.

The FieldScout GreenIndex+ App captures and processes images from an iPhone, iPod Touch, or iPad and instantly computes the DGCI (Dark Green Color Index) of your leaves. Our GreenIndex+ technology is sensitive to low nitrogen levels in the leaves. DGCI has been correlated to SPAD readings in corn at the V6 growth stage. This computed SPAD index is displayed by GreenIndex+. Nitrogen uptake increases dramatically at the beginning of the V6 development stage. Corrective measures, based on early diagnosis of severe nitrogen deficiencies, can prevent yield reduction.

Digital images taken in the field typically exhibit variation due to ambient lighting, shadows, and texture. Green and yellow reference standards on a pink background provide contrast and aid the imaging processing software. This allows for images to be captured under a broad range of lighting conditions.

FieldScout GreenIndex+ offers digital image analysis of leaves, providing growers with an accurate, low-cost method for managing in-season fertility and helps you deliver improved yield, lower nitrogen costs, and increased profits. All data is logged and geo-referenced, and can be emailed to your PC for further analysis.

Components

- 2010A - GreenIndex+ App - Must be purchased through the Apple App Store (see link at www.specmeters.com)
- 2910B - GreenIndex+ Pink Target Board with green and yellow disks and gray calibration background
- Rear-Camera Equipped iPhone, iPod Touch, iPad running iOS 6.0 or later - Not Included

Target Board

The Target Board (item 2910B) is shipped in a protective manila sleeve. The front side of the board is primarily pink with green and yellow disks set against a gray background at the top. These are used to compensate for different ambient light levels. The back side of the target board has four narrow loops that each have a piece of Velcro hook next to them.

The 9 1/2" strap made of Velcro loop should be woven through two of the loops and attached to the adjacent segments of Velcro hook. The board is designed so the strap can be attached to either side of the board. Choose the side you are most comfortable holding the board from when taking the picture.

Front
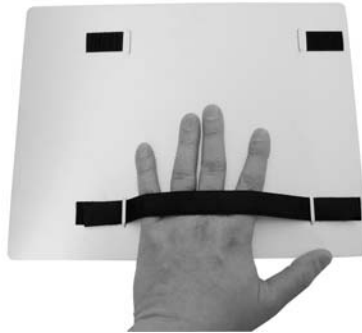
Back

Board Maintenance

Clean with a damp cloth. If necessary, some mild detergent can be added to the wash water.

Getting Started

Locate the GreenIndex+ icon on your smartphone. Tap the icon to bring up the application.

The GreenIndex+ App consists of **5** screens; **Take Picture**, **Process**, **Results**, **Settings** and **Calculation Settings**. When the App is brought up, the last active screen will be displayed. Details on the various screens are given on pages 6 to 9. If the device has just been powered up, the **Take Picture** screen will appear first.
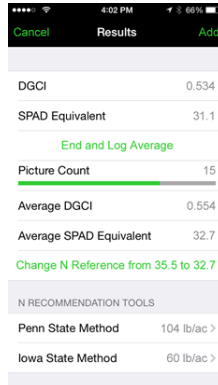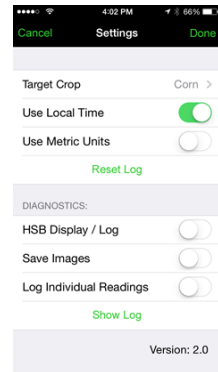

Take Picture screen

Process screen

Calculation Settings screen

Results screen

Settings screen

"Take Picture" screen

The **Take Picture** screen is used to capture the photographic images GreenIndex+ uses to compute the DGCI (see **About DGCI**, p. 21 and **Collecting Data**, p. 14). The numeral next to the title indicates how many readings are included in the running average.

This screen consists of 5 buttons.

CAMERA

Tap this button to take a photo of the leaf. GreenIndex+ will then proceed to the Process screen (See **Process**, p. 7).

SETTINGS

Tap this button to go to the **Settings** screen (See p. 9). The **Take Picture** screen is the only screen with access to the **Settings** screen.

SHARE

Tapping the SHARE button will bring up a screen which gives you the option of Emailing a copy of your logged data file (see **Log File**, p. 20). Select **Email Log** to proceed to the address entry screen. Select the CANCEL button to return to the **Take Picture** screen.

INFORMATION

Tap the INFORMATION button to go to the **Info** screen that describes the App. The Info screen also contains a tour that explains how the app works.

WHITE BALANCE

Used to lock the camera's white balance function (see **White Balance Locking**, p. 12)

"Process" screen

The **Process** screen is where you mark the locations of the disks and leaf on the images captured in the **Take Picture** screen so GreenIndex+ can calculate DGCI (see **About DGCI**, p. 21 and **Collecting Data**, p. 14).

This screen consists of 3 buttons.

Done DONE

When you are happy with the placement of the 3 white circles on the image, tap this button to proceed to the **Results** screen where the GreenIndex+ computations will be displayed. This button will be inactive until all 3 circles have been placed.

↺ UNDO

Tap this button to remove the last circle placed. This button will be inactive until the first white circle (locating the green disk) has been placed.

Cancel CANCEL

Tapping the CANCEL button will return you to the **Take Picture** screen. No computations will be made and no data will be saved.

"Results" screen

The **Results** screen is where the computed GreenIndex+ data is displayed. The format of the screen is determined by what options are selected in the **Settings** screen (see also **Output** p. 16).

This screen consists of 4 buttons.

Add ADD

Tapping this button will add the current reading to the running average, increment the picture count, and return you to the **Take Picture** screen.

Cancel CANCEL

Tapping the CANCEL button will return you to the **Take Picture** screen. The data is not sent to the log file or included in the average.

| END AND LOG AVERAGE | END AVERAGE |

Tapping this button will end the current averaging, reset the picture count to 0, and return you to the **Take Picture** screen. The appearance of this button depends on whether **Log Individual Readings** is set to ON or OFF (see p. 11).

| Change N Reference from 35.5 to 32.7 |

Tapping this button will change the N reference value used for fertilizer recommendations to the current average SPAD equivalent value. This button is only available when Target Crop is set to "Corn".

"Settings" screen

The **Settings** screen is where GreenIndex+ is configured. This screen is accessed by tapping the SETTINGS button on the **Take Picture** screen (p. 6). The options in the lower half of the screen are diagnostic in nature and, in general, will be disabled. The different options are described in detail in the **Configuring GreenIndex+** section (p. 10).

This screen consists of 4 buttons.

Done DONE
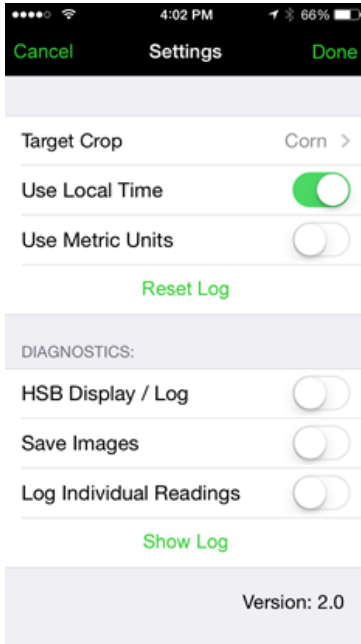
Tapping the DONE button saves the selected options and returns you to the **Take Picture** screen.

Cancel CANCEL

Tapping the CANCEL button will return you to the **Take Picture** screen without saving any newly selected options.

Show Log / Reset Log   SHOW LOG/RESET LOG
These buttons are used to manage the on-App display of the Log file (see **Log File**, p. 20).
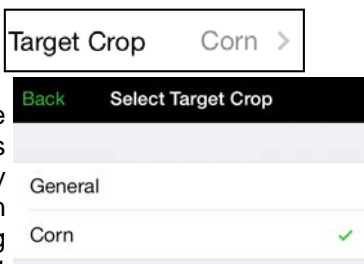
Configuring GreenIndex+

GreenIndex+ is configured in the **Settings** screen (see p. 9). The different options are described below. When the configuration is complete, tap the DONE button in the upper right corner. Tapping the CANCEL button will exit the configuration process without making any changes.

The options in the upper half of the **Settings** screen are used to customize the data format and identify the type of plant being measured. The options in the lower half are diagnostic in nature and, in general, will be disabled during general use.

Target Crop
In addition to DGCI and raw data values, GreenIndex+ can compute and display nitrogen recommendations for corn (see **Output**, p. 16). This feature is activated and deactivated by tapping on the current selection in the **Target Crop** option. Doing so will bring up the **Select Target Crop** screen. From this screen select the desired mode and then hit the BACK button in the upper right corner. If Target Crop is set to "General", only DGCI data will be displayed.

Use Local Time
If ON is selected, logged data will record current time as the user would see it on their device. If set to OFF, UTC (GMT) is logged.
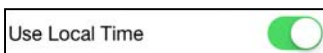
Use Metric Units
Sets display for corn expected yield and nitrogen recommendation to appropriate unit system.

Diagnostic Modes

HSB Display/Log
If the **HSB Display/Log** option is
enabled, GreenIndex+ will

HSB Display / Log

display and store the raw Hue, Saturation, and Brightness
values in addition to the DGCI and SPAD equivalent values
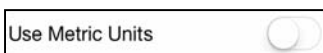(see **Output**, p. 16).

Save Images
If **Save Images** is enabled, the
device will save the photographs

Save Images

to the camera roll. This feature is intended for diagnostic
purposes. During normal operation, this option should be set to
OFF.

Log Individual Readings
It is recommended that the
average of several leaves be used

Log Individual Readings

when making measurements with GreenIndex+. Therefore, the
default mode is for the **Log Individual Readings** option to be
set to OFF. In this configuration, only averaged values will be
stored in the log file when the END AND LOG AVERAGE
button is tapped. However, for each measurement,
GreenIndex+ will display both the individual reading and the
running average on the **Results** screen. To continue adding
readings to the running average, you must tap the ADD button
before taking further readings.
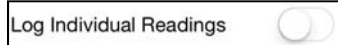
If you are planning to do statistical analysis, it may be desirable
to have every reading stored in the data log. In this case, set
the **Log Individual Readings** option to ON. In this
configuration, individual readings will be sent to the log file
whenever the ADD or END AVERAGE button is tapped. In this
configuration, averaged values will <u>not</u> be logged.

White Balance Locking

Before taking readings, the device camera's white balance feature should be locked. This is done with the button in the lower left of the **Take Picture** screen (see figures 1 and 2). The button has two states: "balance scale" and "lock". The "balance scale" button indicates the meter is in dynamic white balance (DWB) mode, which is the default setting. In this mode, the camera's white balance will constantly adjust to differing light levels. This is ideal for taking standard photographs but causes problems when using the camera to collect data. The "lock" button indicates the meter is in static white balance mode (SWB). When this option is selected, the camera's white balance settings are locked in. This will only apply to the camera while the app is being used. It will not affect the camera's normal operation.

Fig. 1: Dynamic White Balance (DWB)

Fig. 2: Static White Balance (SWB)

To optimize the GreenIndex+ App for data collection, white balance should be calibrated to a gray standard. This only needs to be done at the beginning of a sampling session. If the device goes into power-saving mode, the white balance calibration should be retained. However, the locking procedure will have to be repeated whenever the camera returns to DWB mode. This will be the case, for example, whenever the device is powered up or if the device's camera is opened in a different App.

<u>Locking Procedure</u>

1. While in the **Take Picture** screen, check that the "Balance Scale" icon is visible. This indicates the camera is in dynamic white balance (DWB) mode. A warning message will also appear on the screen if the white balance is not locked. If the "lock" button is visible, tap it to shift to DWB mode ("Balance Scale" icon).

2. Hold the device such that only the gray portion of the GreenIndex Board is visible in the viewing area.

3. Tap the "balance scale" button to lock the white balance and put it in static white balance (SWB) mode. The icon should change to the "lock" icon to indicate that it is in SWB mode.

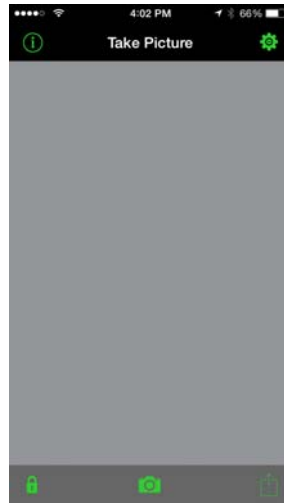Fig. 3: Device in dynamic
(DWB) mode

Fig. 4: Device in locked
(SWB) mode

Collecting Data

Open up GreenIndex+ and go to the **Take Picture** screen. Using the newest fully developed leaf on the plant, gently lay it over the middle of the target board so that the green and yellow disks and the plant leaf are all visible on the screen of the device you are using. Take great care to avoid any shadows and glare. In the field, it may be necessary to remove the leaf before laying it on the board.

Standard Procedure

1. Open up GreenIndex+ and go to the **Take Picture** screen. If the device is in dynamic white balance mode, follow the white balance locking procedure (p. 14).

2. Capture the image by tapping the camera icon located at the bottom center of the screen. This will advance GreenIndex+ to the **Process** screen.

3. GreenIndex+ will prompt you to tap the green color disk. This will create a white circle where the screen is tapped. Once placed, this circle cannot be moved. The circle should be completely within the green color disk. If it is not, tap the UNDO button to re-locate the circle.

4. Repeat step 2 for the yellow color disk

5. GreenIndex+ will then prompt you to tap the screen near the portion of the leaf you want to measure. This circle <u>can</u> be moved and resized. The circle is moved by sliding your finger along the screen. It is resized by pinching the image with your finger and thumb. Manipulate the circle until it surrounds the desired portion of the leaf. It does not matter if any of the pink background is included in this circle. However, take care that neither the green nor yellow disk is included in the leaf selection.

6. When the 3 circles are satisfactorily placed, tap the **Done** button. GreenIndex+ will then proceed to the **Results** screen to display the results of the measurement (see **Output**, p. 16).
Note: At any point, you can tap the CANCEL button to re-do the photo.

Field Sampling

There are two aspects to taking readings with GreenIndex+: proper leaf sampling and the creation of a nitrogen-rich reference strip.

Leaf Sampling
You will need to take readings from 10 to 30 plants to capture a representative sample. Select healthy leaves that are fully emerged. Avoid readings from plants that vary from the average plant spacing for the field.

For corn, it is recommended that GreenIndex+ readings be taken about 1/2 to 3/4 of the leaf length from the leaf base. Leaving some room between the gray portion and the leaf will allow you to capture a large leaf sample. The best results will be attained after the corn has reached the V6 stage.

The ideal stage to sample wheat is at the Feekes 5 stage. Acceptable readings can also be made at the Feekes 6 stage. Sample the first fully expanded, collared leaf from the top of the plant. Take readings midway between the base and tip of the leaf and halfway between the leaf edge and the mid-rib.

Reference Area
In addition to N status, factors such as hybrid, water stress and temperature can affect the greenness of the leaf. Therefore, the DGCI of any site must be interpreted in conjunction with simultaneous readings in a specially prepared high N reference area. See **Corn Nitrogen Recommendations** (p. 18) for more details.

Output

After an image is captured and processed (see **Collecting Data,** p. 14), the GreenIndex+ results are displayed on the **Results** screen. The appearance of this screen depends on what options are selected in the **Settings** screen (see **Configuring GreenIndex+**, p. 10).

Standard Screens

The **Results** screen will always display the DGCI value (see **About DGCI**, p. 21), Picture Count, and current average. The color of the Picture Count bar will change from red, to yellow, to green based on the number of readings taken. The more readings taken, the more representative the average value. Tap the ADD button to include the result in the average and add

DGCI	0.534
SPAD Equivalent	31.1
End and Log Average	
Picture Count	15
Average DGCI	0.554
Average SPAD Equivalent	32.7

Results Screen:
Target Crop=Corn

additional readings to it. Tap END AND LOG AVERAGE (or END AVERAGE) to include this reading and end the averaged group.

If the Target Crop is set to Corn, SPAD Equivalent and Average SPAD Equivalent values will also be displayed. Additionally, two

N RECOMMENDATION TOOLS	
Penn State Method	104 lb/ac >
Iowa State Method	60 lb/ac >

nitrogen recommendations will be displayed at the bottom of the screen along with the current N reference value. When you have finished taking readings in the reference area, you can set the N reference value by tapping the CHANGE N REFERENCE button (see p. 8). The N reference can also be keyed in on one of the **Calculation Settings** screens. See **Corn Nitrogen Recommendations** p. 18 for more details.

If the **HSB Display/Log** option is enabled, GreenIndex+ will display the raw Hue, Saturation and Brightness values for the green and yellow color disks as well as

Green area HSB	82 / 62% / 85%
Yellow area HSB	60 / 31% / 100%
Turf HSB	2/ / 3/% / 31%

for the selected leaf segment. The color values are displayed in groups of 3. The first value is Hue, the second is Saturation, and the third is Brightness. These values will also be stored in the log file. If the app is set to log averages only, the hue, saturation, and brightness values saved to the log file will be the last values measured, not the average. Therefore, if you are logging HSB, it is recommended that the app be set to **Log Individual Readings** .

Corn Nitrogen Recommendations

Nitrogen-Rich Reference Strip

When the Target Crop is set to Corn (see **Settings**, p. 9), GreenIndex+ will compute fertilizer recommendations based on two university models. Both models require the SPAD equivalent value of a nitrogen-rich reference area. This is because, in addition to N status, factors such as hybrid, water stress and temperature can affect the greenness of the leaf. Therefore, the greenness of any site must be interpreted in conjunction with simultaneous readings in a specially prepared high N reference area. The reference area can be a strip through the field or rectangular area made up of portions of several rows. Do not select a reference area that is in an area of extreme (high or low) yield potential. The reference area should receive a more than adequate amount of nitrogen to assure the plants achieve optimum chlorophyll levels.

Iowa State Method

The Iowa State method[1] bases the N recommendation of the management zone on the ratio of the SPAD value in the management zone to the reference SPAD value. The recommendations are listed in table 1. The N reference value can be set in the **Results** screen (see p. 8). It can also be typed in manually by tapping on the current value in the **Calculation Settings** screen and then using the keypad. Tap the RESULTS or DONE button to return to the **Results** screen where you can see the updated recommendations.

‹ Results	Calculation Settings	Done
	IOWA STATE METHOD	
	High-N Reference (SPAD)	28.0

| SPAD Ratio	N rate (lb/a)
< 0.88	100
0.88 - 0.92	80
0.92 - 0.95	60
0.95 - 0.97	30
> 0.97	0

Table 1. Iowa State Method N Recommendations

Penn State Method

The Penn State method[2] requires 4 user inputs; N Reference Value, Expected Yield, Manure Application, and Corn Leaf Stage. The N reference value can be set in the **Results** screen (see p. 8). It can also be typed in manually by tapping on the current value in the **Calculation Settings** screen and then using the keypad. The Expected Yield value must be entered via the keypad. If manure was applied to the field since the last harvest, that option should be set to ON. Leaf Stage is selected using the slider bar. The slider will increment the leaf stage in 0.25 units. A description of the fractional leaf stages is given below the slider bar. The DONE button will save changes made with the keypad and allow further changes to be made to this screen. The RESULTS button will return you to the **Results** screen where you can see the updated recommendations.
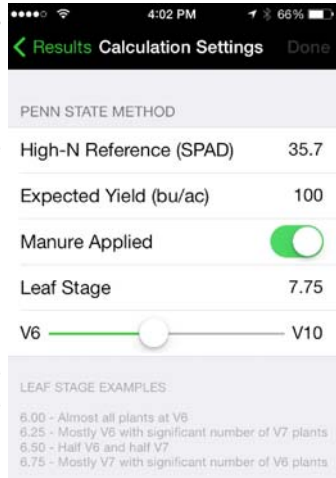
References

[1]Sawyer, J., J. Lundval, J. Hawkins, D. Barker, J. McGuire, M. Nelson. 2006. PM 2026: Sensing Nitrogen Stress in Corn. Iowa State University/University Extension.

[2]Piekielek, W., D. Lingenfelter, D. Beegle, R. Fox. 2008. Agronomy Facts 53: The Early Season Chlorophyll Meter Test for Corn. Pennsylvania State University.

Log File

Transferring Data

All readings taken by GreenIndex+ are stored in internal memory on your device. The data is transferred as a tab-delimited file to an external computer via an Email attachment. The Email screen is accessed by tapping the SHARE button on the **Take Picture** screen. Select the EMAIL LOG option to continue (Tap CANCEL to return to the **Take Picture** screen). Once in the Email screen, type the address(es) to which you would like the data sent. A default Subject line is provided but can be edited to better identify what data is being sent by this transmission. It is also possible to type a message in the text field to convey any additional information to the recipient(s). Tap the SEND button to send the Email. You must have internet access to successfully complete the transmission. If you do not want to complete the transmission, tap the CANCEL button. This will bring up a question box that will ask if you wish to delete or save this draft. Hitting the CANCEL button in the question box will return you to the Email screen.

Settings Screen Options

Show Log

In addition to sending the data file to a computer, GreenIndex+ also allows you to view the log on the device. The **Log** screen can be accessed by tapping the SHOW LOG button on the **Settings** screen. This screen is intended to confirm that the readings are being stored as expected. It is not designed for on-device analysis.

Reset Log

Data will be written to the log file every time a new reading is made. After data has been successfully transferred, or if it is otherwise not needed, it can be deleted from the device's memory with the RESET LOG button. You will be asked to confirm this request.

About DGCI

One way to assess the health of a crop is by evaluating the greenness of the leaves. This is an indicator of the chlorophyll levels which are impacted by stresses caused by inadequate nutrition and moisture, pest pressure, or excessive compaction levels. Over the years, several objective greenness indexes have been developed and incorporated into portable devices used to evaluate plant health. Among these are the SPAD value or the Normalized Difference Vegetative Index (NDVI). These indexes are calculated from data collected by devices which measure spectral reflectance or transmittance of pre-selected wavelengths of light. These devices require specialized light emitters and/or filters to make these measurements.

In 2003, researchers at the University of Arkansas developed a method for measuring greenness using images captured with a digital camera. This method was later adapted for use in corn. GreenIndex+ uses this same technique to quantify plant greenness using the camera contained in a smartphone.

A digital camera captures an image as a series of pixels that have different levels of Red, Green, and Blue (RGB) color. However, for the purposes of quantifying plant greenness, it is not accurate to just use the Green parameter from this color scheme. This is because the amount of Red and Blue also affect how green a plant looks. Therefore, the RGB color scheme must first be converted into Hue, Saturation, and Brightness (HSB).

Hue has a value between 0 and 359, Saturation and Brightness have values between 0.0 and 1.0. DGCI is then calculated from the HSB values as follows:

$$DGCI = \frac{1}{3}[(\frac{Hue-60}{60}) + (1-Saturation) + (1-Brightness)]$$

It is recommended that the DGCI be used with a specially prepared reference strip that has adequate fertilizer and water. Management or experimental treatment areas can then be compared to the reference strip.

Frequently Asked Questions

1. Does the number of pixels affect the GreenIndex+ reading?
No. The number of pixels required to perform the DGCI computations is much smaller than are found in a standard smartphone camera image.

2. What is the effect of light?
The green and yellow color disks are of known color and are designed to compensate the GreenIndex+ readings for differences in light levels. However, it is important to ensure that the board is uniformly illuminated with no glare and uniform or no shadow.

3. How does the position of the board impact the readings?
To maintain consistency, the board should be held in a similar manner for all readings. Hold the board at a comfortable angle and distance such that the disks and leaf are all visible.

4. Why is the board colored pink?
This allows the GreenIndex+ app to distinguish between the leaf material and the background.

7. How does DGCI compare to SPAD readings or NDVI?
In University studies, DGCI has shown good correlation to SPAD, NDVI, and leaf nitrogen concentration.

8. What is the impact of different hybrids?
Because different hybrids will have different color characteristics, the optimum DGCI value will vary from one to another. This is why it is advised to use a high-N test strip for each hybrid you are measuring.

9. Can I enter a yield goal for my field?
This is part of the Penn State Nitrogen Recommendation feature.

10. Should readings be taken inside or outside?
As GreenIndex+ is a field tool, readings should be taken outside. If possible, the leaf should remain on the plant.

11. Can GreenIndex+ be used with crops other than corn?
Yes, the DGCI value is relevant to any plant and can be used for diagnostic or comparative purposes.

12. Does a change from dynamic white balance to static white balance change other camera functions on the phone (i.e. camera roll)?
The white balance lock is only active for the GreenIndex+ app. If another camera app is run, the white balance will be lost and have to be re-established when GreenIndex+ is re-opened.

13. Will the GreenIndex+ app work with an older iPhone or iPod?
Older iPhones and the cameras they possess are more than adequate for GreenIndex+ purposes. However, version 2.0 of GreenIndex+ requires iOS version 6.0 or later. Note that the IDevice must have a rear-facing camera.

14. GreenIndex+ is not recording the GPS coordinates?
When GreenIndex+ is first installed, you should be prompted to allow the app to use your current application. You must allow this to bring GPS information into the data file. If you are not getting GPS coordinates, you must go to the iDevice settings and enable them for use in GreenIndex+.

Warranty

The GreenIndex+ Board is warranted to be free from defects in material or workmanship for one year from the date of purchase. During the warranty period Spectrum will, at its option, either repair or replace products that prove to be defective. This warranty does not cover damage due to improper installation or use, lightning, negligence, accident, or unauthorized modifications, or to incidental or consequential damages beyond the Spectrum product. Before returning a failed unit, you must obtain a Returned Materials Authorization (RMA) from Spectrum. Spectrum is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company.

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