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Leds used as spectral selective light detectors in remote sensing techniques

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Abstract. Remote sensing has been commonly considered as an effective technique in developing precision agriculture tools. Ground based and satellite spectral sensors have wide uses to retrieve remotely quantitative biophysical and biochemical characteristics of vegetation canopies as well as vegetation ground cover. Usually in-field remote sensing technologies use either a combination of interferential filters and photodiodes or different compact spectrometers to separate the spectral regions of interest.
In this paper we present a new development of a sensor with LEDs used as spectrally selective photodetectors. Its performance was compared with a photodiode-filter sensor used in agronomic applications. Subsequent measurements of weed cover degree were performed and compared with other methodologies. Results show that the new LEDs based sensor has similar features that conventional ones to determining the weed soil cover degree; while LEDs based sensor has comparative advantages related its very low manufacturing cost and its robustness compatible with agricultural field applications.

Key words: Remote sensing, radiometry, photometers, weeds detection.

1. Introduction.

Weeds distribution within a field is often an aggregate distribution pattern [1 , 2]. The ability to separate weeds-soil-crop components, allows variable rate herbicides applications and acts on economics aspect while minimizing the resistant weeds occurrence [3]. Different methodologies to determine field weeds presence have been studied. Within of these should be mentioned: weed cover degree by visual estimations, weeds leaf area index measurements, visual and photographic models combinations [4]. To support weeds identification, different optical methods have been proved recently. These methods are an alternative that is still under development [5]. The basis of these lies in the possibility of spectrally separating landscape components (soil, vegetation) from particular bands of the electromagnetic spectrum that interact differently with these components [6, 7]. One way to perform an optical remote sensing is through of reflectance studies. This technique commonly uses interference filters and photodiodes as detector elements. Spectral reflectance portable equipment (hand held radiometers) allows high spatial resolution resources management [4, 8].

The advances in sensor technologies have enabled weeds detection and develop the potential for the current researches [9]. In the 1980's, researches on weeds detection were accomplished using analogue video equipment and color photographs [10, 11]. Today, remote sensors information offer a non-invasive method of acquiring information about weed's population for a given field area [9]. In this study sought to establish the sensitivity of a remote sensing technique, based on LEDs used as detector elements, to estimate weeds soil cover degree. This technique was compared with traditional remote sensing technologies. Also was compared with other proven methodologies such as image processing programs and grids in pictures determinations.

2. Methodology and materials.

The field measures were made in La Plata, Buenos Aires, Argentina (34 º 55 'S, 57 º 50'W), in 2009. Radiometric data collection and digital photographs were made in experimental plots of 0.5 m^2 with different weed cover levels.

To measure spectral reflectance in particular bands, we build a non-dispersive multichannel spectrorradiometer, able to detect total (direct plus diffuse) sunlight and the corresponding light reflected from the soil and vegetation (Figure 1). The sensor consists in eight pairs of detectors made with LEDs of different composition. Each pair has the same LED, one for total light (looking at the sky) and other for the reflected radiation (looking soil-weeds). Each one is followed by a transimpedance amplifier. Other references about the use LED's as detectors can be found in [12].

Previously each LED's family had to be characterized as detectors because exist a shift in the spectral response compared to when it behaves as an emitter (data no shown). LEDs used in this application are radiation detectors in the spectral range corresponding to red (640 nm, central wavelength; 50 nm, bandwidth) and near-infrared (830 nm, central wavelength; 50 nm, bandwidth).

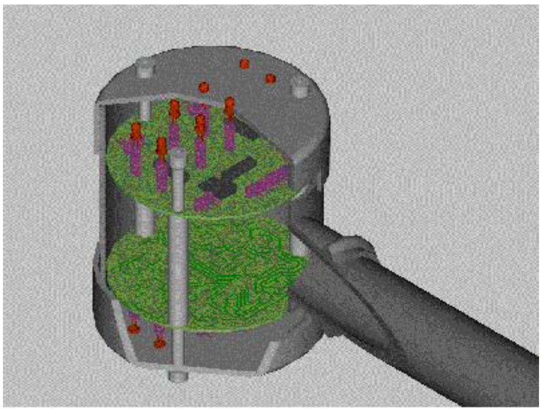

Figure 1. LED-based sensor, diagrammatic external and internal view.

In addition a conventional radiometer technology was used. The radiometer, described elsewhere [8] is built in modules, each one comprising an interferential optical filter and a silicon photodiode. The soil-looking channels have an aperture to limit their field of view (FOV) to 30º, which determines a sensing area of 1 m^2 at a sensor altitude of 2 m. All photodiodes were used in current mode, rendering linearity and high signal-to-noise ratio. In both cases output voltage was recorded in a Hewlett-Packard 34970A data logger at a rate of 1 signal /channel / 30 seconds. All instruments were powered by a DC-AC converter and a small 12 V battery.

Reflectance values were calculated as ratio between soil-looking signal and that obtained by the corresponding channels looking towards the sky (Equation 1). In this way, synchronous signal detection between object and illumination source was obtained. This normalization way is practically independent of changes in incident light [8]. If dark current in each channel is subtracted, we obtain,

$$R_{\lambda} = \frac{R_{S\lambda} - Z_{\lambda}}{R_{i\lambda} - Z_{\lambda}}, \quad (1)$$

Where $R_{s\lambda}$ is the signal from weeds and soil in the band λ, $R_{i\lambda}$ is the incident light signal (sky) for the same λ, and finally Z_{λ} is dark current in each band.

To establish a bi-univocal relationship between the reflectance measurements and studied phenomena, it is necessary to derive a parameter that normalizes the influence of other disturbing factors, so that the main magnitude have same value for a given level of vegetation, independently if it grows on soils with different optical properties, or under different environmental conditions during measurement. This aspect can be solved by means of vegetation indices (VI) use [9]. In this work, the red and the NIR individual bands were combined in the form of the Normalized Differential Vegetation Index, NDVI [13] (Equation 2),

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}}, \tag{2}$$

Where R_{NIR} is the reflectance of the NIR band and R_{RED} corresponds to RED band.

Simultaneously, areas under study were photographed with a LZ5 Panasonic Digital Camera with full resolution of 6MP. Two proven methodologies were used to determine ratio between weeds and ground cover: visually by grids [14] and by image processing software with a supervised classification [15]. In this case the maximum likelihood algorithm was used. The program returns the result as a percentage of pixels of the selected Regions of Interest or "ROI's" (weeds in this case). The ROI's was selected manually (Figure 2).

A b

Figure 2. Original image and processed image by software, weed classified (In red).

3. Results and discussion.

One example of the behavior of both reflectance measurements, LEDs and photodiodes corresponding to four scenes is shown in Figure 3. Close fit was found when the two optical sensors tested were compared (R^2 = 0.98). The slope of curves is a responds at the weeds cover degree increments (pictures 1-4).

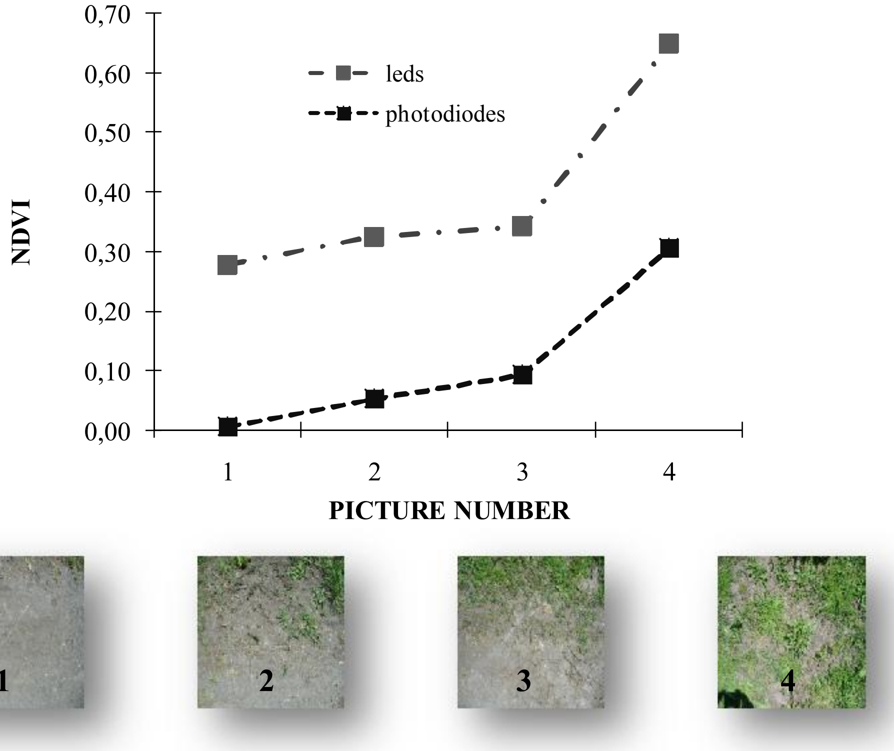

Figure 3. NDVI variations with the increase in weed cover degree:
LED's based sensor (upper curve) and photodiodes based sensor (lower curve)

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NDVI obtained by using LEDs sensors and weed cover results corresponding with results from grids and software image processing also show very good fit (Figure 4).

These results are indicative of the potential use of LEDs as light spectral detector elements.

The spectral reflectance measurements made with a LEDs based sensor, combined in a vegetation index, show a slightly better sensitivity, in relation to the photodiode detector when increasing signal intensity behavior with weed soil cover increments. This behavior was verified by comparing the NDVI measures with two detection techniques on the coverage degree and very good fits were found (Figure 4).

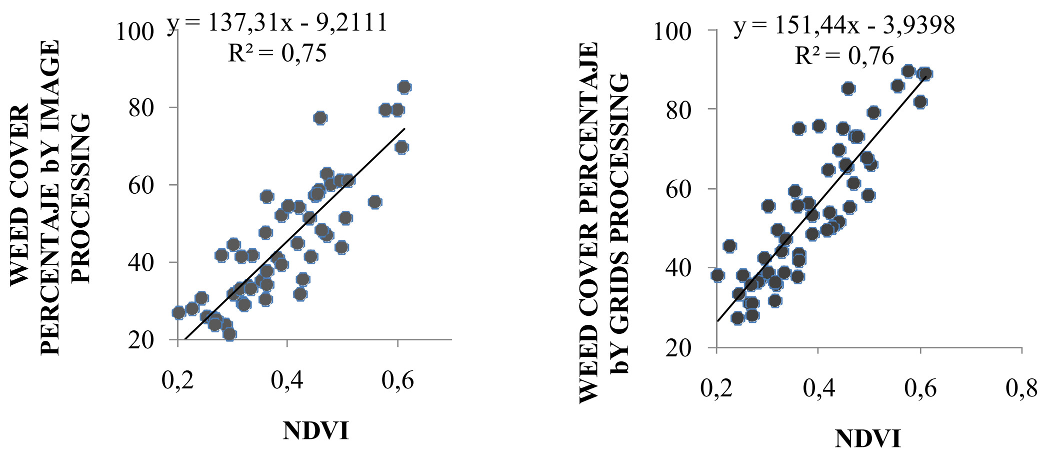

Figure 4. NDVI response (calculated by LEDs based sensor) when weed cover increases (measure by software, left figure, and by grids in pictures, right figure).

This weeds detection method is best implemented before or on newly implanted crops (over stubble or on bare soil in conventional tillage). After that, emerged weeds can be confused with crops, or the different signals can be difficult to classify (weed / crop / soil) based only on reflectance. It is also important to know the weed emergence condition and growth habits of both weeds and crop. It should be clarified further that remote sensing instruments take a weed cover proportion, not necessarily its density.

A small individual weed plant has a low influence on the reflectance may be undetected. However, from the herbicides application point of view is questionable whether the spatial resolution should and / or has to be small enough to detect individual plants, since previous studies have found that this minimal screening is not economically justifiable.

The current generations of satellite systems do not provide a spatial and temporal resolution when are used for identifying and mapping weeds at field scale. Airborne hyperspectral scanner systems instead have high resolution and can provide a spatial resolution and flexibility for use required for weed mapping. However, these systems can be economically feasible only on a large scale [16].

In recent years there have been numerous articles detailing herbicides savings by variable rate application [17]. Savings in the amount of herbicides ranging from 60% in corn to 77% in wheat, in relation to total field applications [18]. The field-scale remote sensing can help it.

4. Conclusions.

Radiometric techniques performed with a sensor based on LEDs shows adequate sensitivity to be used with reliability in weed infestation determining. The LEDs were shown to be correct light detectors in particular bands used to determine NDVI, so that the sensor tested is presented as a promising tool for managing site-specific of one of the most important inputs used in modern agriculture.

In addition, the build sensor has very low cost and is adequately strong for field applications by eliminating such fragile components as interferential filters.

Optical remote sensing can be extended to large fields, while other methodologies are difficult to extrapolate to large surfaces because resolution losses in pictures capture, or inapplicable because of the time and labor required as in grids use.

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