Measurement system for parameters used in determining and monitoring the crops vegetation status

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Measurement system for parameters used in determining and monitoring the crops vegetation status

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Abstract. The paper presents a data acquisition system designed for measuring parameters involved in determining and monitoring the crops vegetation status, such as: plant height, temperature on plant leaves, environment temperature and humidity and spectral response at the incident sunlight. The system is mounted on a tractor and the measurements are made “on the go”. Using the spectral response for different wavelengths, vegetation indices can be computed. They can offer important information about the health status of the crop, moisture stress, pest and diseases, necessary nutrients and so on. All data are correlated with the GPS coordinates in order to generate favourability and risk maps using a special designed software that imports data, processes them in order to be proper stored in the database, computes different vegetation indices and display corresponding maps.

1. Introduction
Vegetation status depends on different type of factors: climate characterized by solar radiation, precipitation, wind etc.; chemical nutrients as N-K-P Nitrogen-Phosphorous-Potassium complexes; soil chemistry; growing cycles; pests; diseases and so on. If we are referring at crops status, then health directly influences the productivity that is why we are interested in measuring and monitoring the entire development cycle.

The health vegetation status can be visually observed, but many times it is too late to intervene if something goes wrong. It is very important to early find out if the health status is threatened. We need for this a “special eye” that sees more than the biological one. Smart sensors are the solution for doing this.

Information that can be used for determining the health status can be measured using two categories of sensors: with contact and without contact [1].

Remote sensing is now one of the top subjects in investigating large areas vegetation status [2]. Satellites, aircrafts, Unmanned Aerial Vehicles (UAV) are used for taking photos with different resolutions, in different wavelength domains (VIS – visible, NIR – Near InfraRed, SWIR – Short Wave InfraRed and so on) [3-5].

When the solar radiation meets a surface, it can be absorbed, reflected or transmitted at a certain level. Each surface will be affected differently by sunlight, regarding the three actions mentioned before. In this way, each material will have its own footprint associated with the reflectance spectrum. This principle allows to identify vegetation areas and to determine the health or development of the

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vegetation. The leaf reflectance depends on the inside pigments, structure of the cells, content of water and so on and all these factors can be identified in different areas of the spectrum [6].

Depending on the number of wavelengths the reflectance is measured at, we discuss about multispectral or hyperspectral sensors. These values are used to compute the so called vegetation indices, very useful data for precision agriculture, that offer information about the health status of a crop, moisture stress, pest and diseases, necessary nutrients etc. [7].

2. Hardware structure
For measuring parameters involved in determining and monitoring the crop vegetation status a data acquisition system was designed and developed. It contains sensors for measuring plant height, temperature on plant leaves, environment temperature and humidity and spectral response at the incident sunlight – figure 1.

![Diagram of data acquisition system](image)

**Figure 1.** Hardware structure of the data acquisition system.

For plant height sensor an Ultrasound sensor MaxSonar® from MaxBotix™ was used, the temperature of plants is measured using an infrared sensor. Multispectral sensor is a Cropscan with it specific DLC – Data Logger Controller. Data from DLC and GPS are received by the microcontroller board through serial interfaces, while the wireless one is an Xbee module that communicates with a server. Data can also be stored on a SD Card.

3. Software aspects
The software consists in two programs: one stored in the microcontroller memory that manages the data acquisition process from sensors, stores data on the SD card or transmit them to the server; the other one stored on server receives data or import them from the SD card, processes data in order to store them in a database with a specific structure, computes vegetation indices, and displays georeferenced data on different type of maps.

3.1. Messages structure
In the data acquisition process, values are written as messages to a file on the SD card or are transmitted to the server. The message structure for each sensor respects the following format:

```
<Sensor_ID>;<Header>;<Data>;<Footer>
```

where
- `<Sensor_ID>` is the ID defined for the infrared plant temperature sensor (IRT), plant height ultrasonic sensor (SNR), Cropscan multispectral sensor (CRP) and GPS sensor (GPS);
<Header> includes date and time using YYYYMMDDhhmmsgkxx format, where we denoted YYYY - year, MM - month, DD - day, hh – hour, mm - minute, ss - second, xx - hundredth of second;

<Data> represent the acquired values, specific to the sensor type. Multiple values are comma separated [val1], [val2], ..., [valn];

<Footer> contains a similar structure as the header.

Headers contain the exact moments of the acquisition start, while footer contain the moments when the acquisition stops. Information are obtained from a Real Time Clock module (RTC) included in the system. Headers and footers are automatically added by software and are used later in the synchronization and interpolation process by the server routines. They are needed because sensors have different sampling rates, while we need the shortest total acquisition time.

3.2. Acquired and processed data
A part of a sample input file containing acquired data is presented in figure 2.

![Figure 2. Acquired data structured by messages.](image)

It can be observed the structure discussed in previous section.

The program on the server processes the input data taking into account the headers information so that to be stored in a database. Each record will contain the following fields:

- Time – obtained from headers processing;
- Latitude, Longitude – obtained from GPS sensor;
- Snr - plant height obtained from the ultrasound sensor;
- Irt – plant temperature from the infrared sensor;
- Reflectance values computed from data obtained from the sixteen channels of the Cropscan sensor;
- Some computed vegetation indices

A part of some records from the database is presented in figure 3.

![Figure 3. Processed data are stored in a database.](image)

Based on these information, the software can display georeferenced data on maps. Each field with data from sensors can be selected to be displayed on a map and also computed vegetation indices can be displayed.
4. Results

Data acquisition system was tested on a potato experimental field divided in areas that contains two variety of potato (S1 and S2), irrigated or not (B2 and B1), and having different amounts of fertilizer (D1, D2 and D3), presented in figure 4.

|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|
| R4| S1| S1| S1| S1| S1| S1| B1| B1| B1| D1| D2| D3| S1| S1| S1| S1| S1|
|   | B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1|
| R3| S1| S1| S1| S1| S1| S1| B1| B1| B1| D1| D2| D3| S1| S1| S1| S1| S1|
|   | B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1|
| R2| S1| S1| S1| S1| S1| S1| B1| B1| B1| D1| D2| D3| S1| S1| S1| S1| S1|
|   | B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1|
| R1| S1| S1| S1| S1| S1| S1| B1| B1| B1| D1| D2| D3| S1| S1| S1| S1| S1|
|   | B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1| B1|

![Figure 4. Experimental potato field structure.](image)

The field was prepared by the researchers from the National Institute of Research and Development for Potato and Sugar Beet Brasov Romania so that to create different conditions for the vegetation status and to identify and monitor it using vegetation indices.

Using different quantities of fertilizer, it will be emphasized the need of nutrients. Irrigating only some areas, the plant water stress can be observed.

With red colour are represented technological paths (columns 3, 6, 9, 12, 15) followed by the tractor in the data acquisition process. With R1 to R4 are denoted the parameters combination rows. The same group of combinations were arranged in the lower and upper parts of the experimental field. Columns 1, 11 and 17 (in green colour) are used for potato varieties separation. In the lower part of the experimental field some areas are irrigated (blue colour – columns 7, 8, 10, 13, 14, 16).

In the beginning the data acquisition system was tested in a preliminary version without environment temperature and humidity sensors and also without the wireless interface. Two persons made static measurements, meaning they went to the experimental field with the equipment and they acquired data step by step from different points, situated at different distances in different areas. Data were stored on the SD card and after the entire acquisition process was finished, they were imported in the server.

Images in figure 5 present the experimental potato field (a), different areas marking (b), preliminary measurement tests (c) and an aerial view of the field obtained by a drone from 30 m altitude representing the NDVI - Normalized Difference Vegetation Index distribution (d). The acquired data were processed (synchronized, linear interpolated, computed reflectance and some vegetation indices) and stored in the database.
Figure 5. Experimental potato field and preliminary measurement tests.

The multispectral sensor can detect the reflectance for sixteen wavelengths. O part of them are presented in table 1. Due to the paper space limit, reflectance values for the other 9 wavelengths and vegetation indices are not presented in another table.

Table 1. Georeferenced data obtained in the measurement process.

| Time  | Latitude | Longitude | Plant height (cm) | Plant temp (°C) | Reflectance (%) |
|-------|----------|-----------|-------------------|----------------|-----------------|
|       |          |           |                   |                | 860nm | 900nm | 970nm | 1050nm | 1100nm | 1200nm | 1300nm |
| 2016061712583017 | 45.6730442 | 25.5440271 | 46.00 | 23.4651 | 40.4044 | 38.0281 | 37.2654 | 38.7700 | 40.8212 | 34.0318 | 37.4393 |
| 2016061712583117 | 45.6730399 | 25.5440334 | 42.24 | 23.1708 | 51.5724 | 48.3095 | 47.0795 | 48.2698 | 50.7474 | 39.9054 | 44.1948 |
| 2016061712583217 | 45.6730345 | 25.5440389 | 50.28 | 23.4383 | 57.8486 | 54.6086 | 51.8646 | 53.7519 | 56.2666 | 42.7050 | 47.5778 |
| 2016061712583316 | 45.6730305 | 25.5440450 | 45.37 | 23.7791 | 57.8174 | 55.1065 | 50.6479 | 53.7455 | 56.3452 | 41.8552 | 46.7587 |
| 2016061712583517 | 45.6730240 | 25.5440553 | 44.76 | 23.2186 | 54.8101 | 51.3251 | 47.3942 | 50.9378 | 52.5533 | 40.1102 | 43.0353 |
| 2016061712583717 | 45.6730168 | 25.5440638 | 47.86 | 24.6922 | 40.5008 | 39.8610 | 37.3583 | 40.8112 | 40.3825 | 32.9648 | 36.6603 |
| 2016061712583817 | 45.6730130 | 25.5440678 | 49.60 | 22.6867 | 45.7191 | 44.3938 | 42.6143 | 45.1241 | 45.4190 | 37.0123 | 40.8111 |
| 2016061712583917 | 45.6730099 | 25.5440729 | 47.28 | 22.7116 | 53.3697 | 50.6017 | 48.8237 | 50.7524 | 52.4826 | 41.6550 | 45.8864 |
| 2016061712584017 | 45.6730063 | 25.5440779 | 74.90 | 22.9726 | 55.3507 | 52.2715 | 49.8117 | 51.8137 | 54.6981 | 42.0745 | 46.7753 |

The software on the server can compute the most used vegetation indices (NDVI - Normalized Difference Vegetation Index that measure the plant “greenness” or photosynthetic activity; LAI - Leaf Area Index; MCARI - Modified Chlorophyll Absorption Ratio Index; WBI - Water Band Index, WMI -Water Moisture Index etc.) and generates maps for spatial distribution of them.
Data were also analysed using ArcGIS software. Figure 6 presents the NDVI in the points corresponding to the acquired data (a) and the interpolated image of NDVI on the interest area (b).

![Figure 6. Acquired data analysed with ArcGIS software.](image)

### 5. Conclusions
A data acquisition system was designed and developed for measuring parameters involved in determining and monitoring the crops vegetation status. Data regarding plant height, temperature on plant leaves, environment temperature and humidity and spectral response at the incident sunlight are acquired and processed. Different vegetation indices are computed by a special designed software, offering information about the health status of the crop, moisture stress, pest and diseases, necessary nutrients and so on. Data are correlated with the GPS coordinates so that favourability and risk maps to be displayed. Tests were made on an experimental field with potato crop. Data were analysed also with ArcGIS software and the results confirmed the correlation between vegetation indices and crop vegetation status.

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