Using Light-Band Sensors for Stress Evaluation in Rainfed Maize Agricultural Crop

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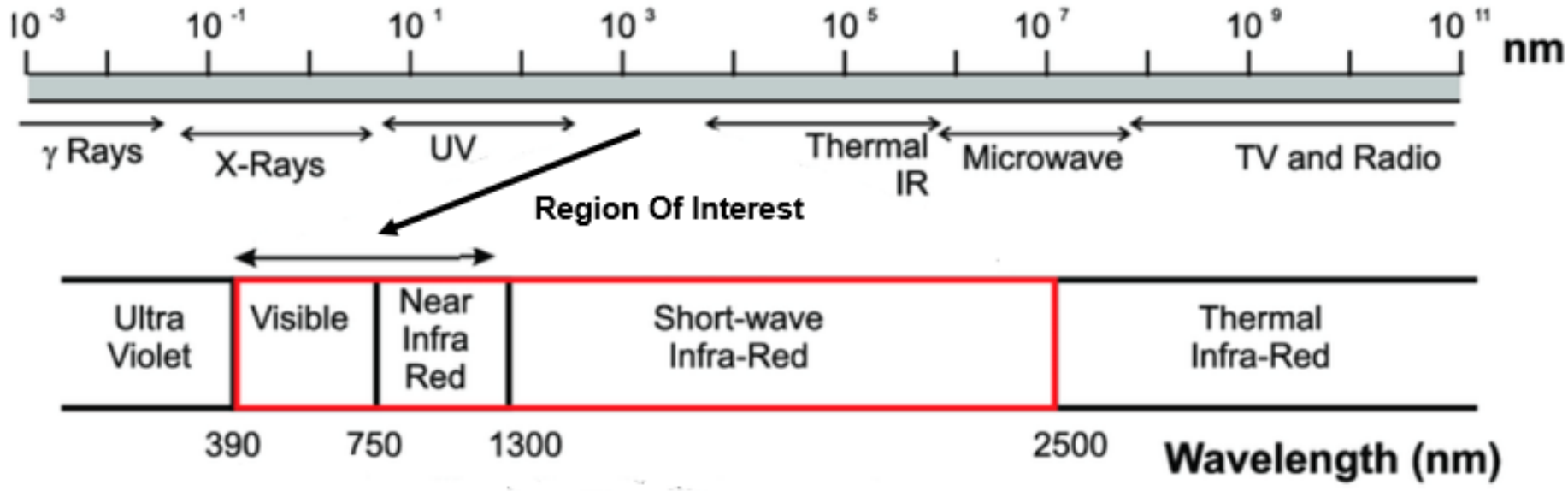
Outline

1. Introduction
2. Materials and Methods
3. Results and discussion
4. Conclusions
5. Future Works

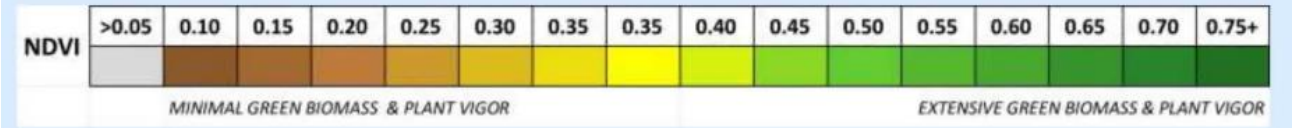


In this study, based on the use of sensors for red and the near-infrared lights spectra, the stress of rainfed maize crop was evaluated as a function of both Nitrogen dose and water availability.

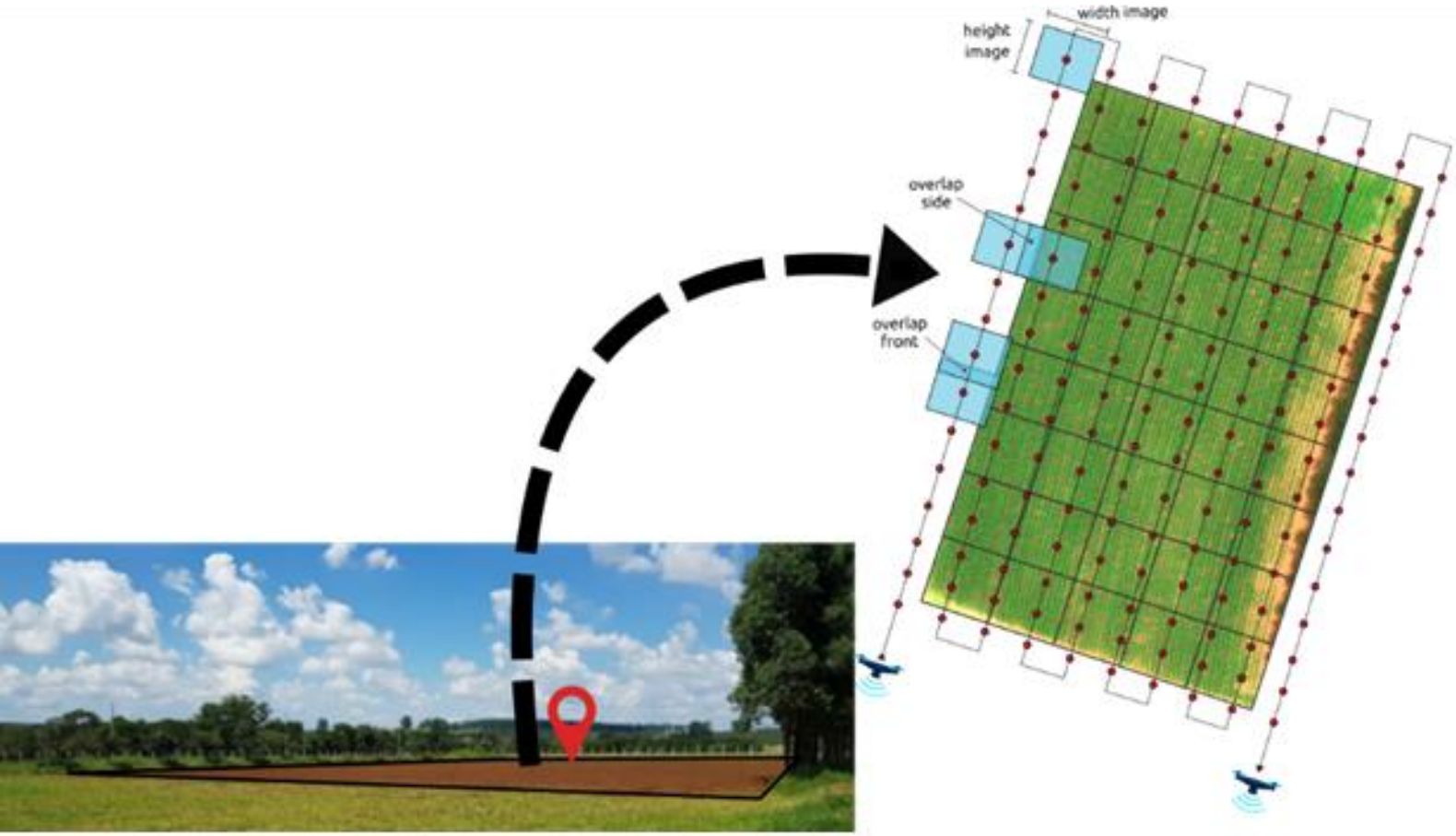
The Normalized Difference Vegetation Index (NDVI) was established in 1974 (Rouse et al.) and later validated (Tucker, 1979) through linear combinations of the RED and NIR bands to monitor biomass density.

$$NDVI = \left(\frac{NIR - RED}{NIR + RED}\right)$$

1. NDVI = -1 to 0 represent Water bodies
2. NDVI = -0.1 to 0.1 represent Barren rocks, sand, or snow
3. NDVI = 0.1 to 0.5 represent Shrubs and grasslands or senescing crops
4. NDVI = 0.5 to 1.0 represent Dense vegetation or tropical rainforest

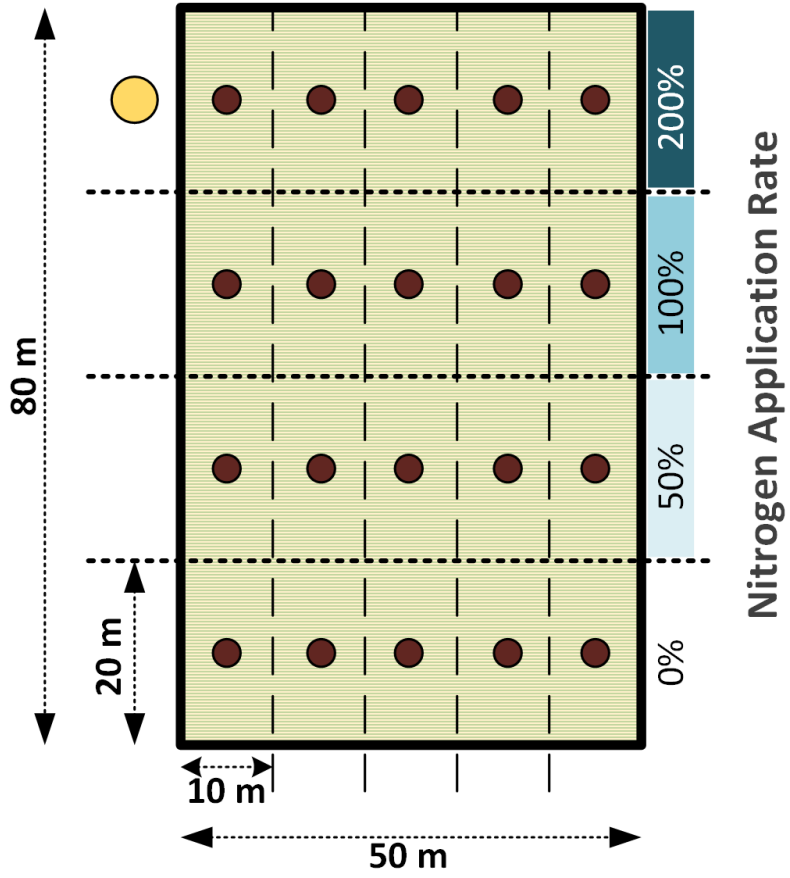


This work presents a study to minimize the limitations when using the NDVI to evaluate stress regions in tropical agricultural crops due to lack of water and nutrients based on image sensors that respond to RED (668 nm ± 10 nm) and NIR (840 nm ± 40 nm) wavelengths to aid the agricultural management process.



21◦57’3.9” S and 47◦51’10.9” W, National Reference Laboratory for Precision Agriculture (LANAPRE) in Brazil.

The evaluation of the crop stress was organized in an agricultural area with maize (Zea mays), having 4000 m^2, and sampling grid equal to 10 m × 10 m.

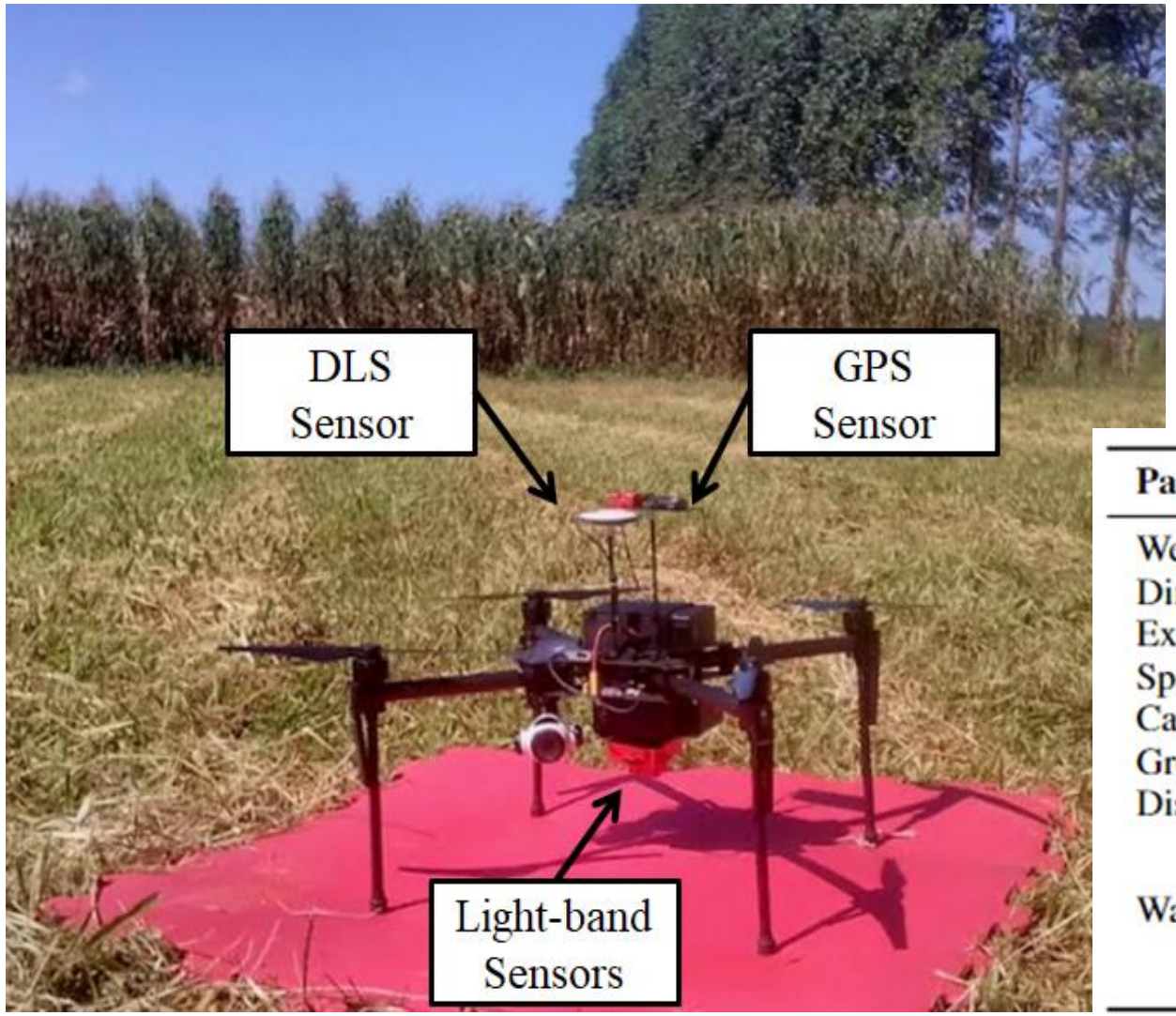


Agrometeorological Data Logger using LoRa

Soil Sampling Points

Cornfield under Different Nitrogen Conditions

Soil fertilization occurred once and scaled applications of Nitrogen (top-dressing fertilization) were also considered, i.e., using the 0, 18, 36 and 72 kg/ha, respectively 0%, 50%, 100%, and 200% in relation to agronomic recommended dose



Micasense RedEdge-M multispectral camera was embedded, and provided onboard; Eight flight missions were considered; multirotor Unmanned Aircraft System (UAS), DJI Matrice 100

Parameters	Specifications
Weigth	170 g (Including DLS)
Dimensions	9.4 cm × 6.3 cm × 4.6 cm (3.7" × 2.5" × 1.8")
External Power	4.2V−15.8V, 4W nominal, 8W peak
Spectral Bands	Narrowband: Blue, Green, Red, Near-IR
Capture Rate	1 capture per second (per band), 12−bit RAW
Ground Sample Distance (GSD)	5.95 cm/pixel (per band)
Wavelength	Blue (475 nm center ± 20 nm) Green (560 nm ± 20 nm) Red (668 nm center ± 10 nm) Near-IR (840 nm ± 40 nm)

The collected images have been filtering by means of a Gaussian filter. Likewise, for each ROI the rotation angle has been found by calculation.

$$G_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

$$Rotation = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -t_x \\ 0 & 1 & -t_y \\ 0 & 0 & 1 \end{bmatrix}$$

The NDVI correction was based on the reuse of the NIR light-band, in order to allow information beyond the biomass evaluation and plant growth only, i.e., emphasizing plant`s stress due external abiotic factors like water and nutrients availability in the crop area.

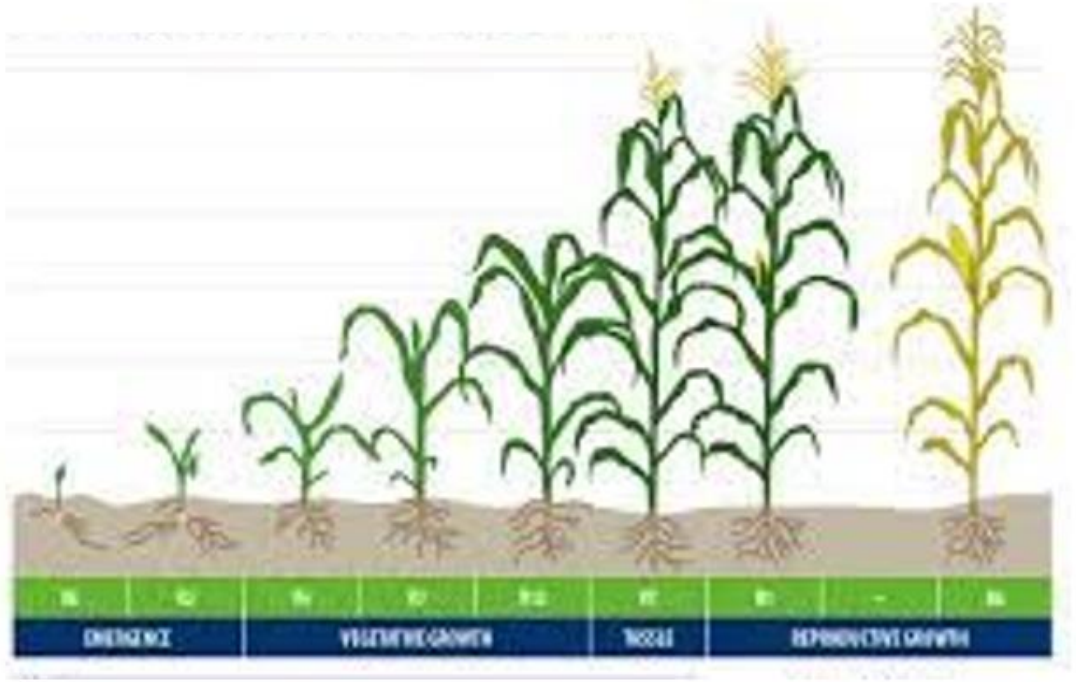
$$\widehat{NDVI} = \left(\frac{NIR-RED}{NIR+RED}\right)\overline{NIR}$$

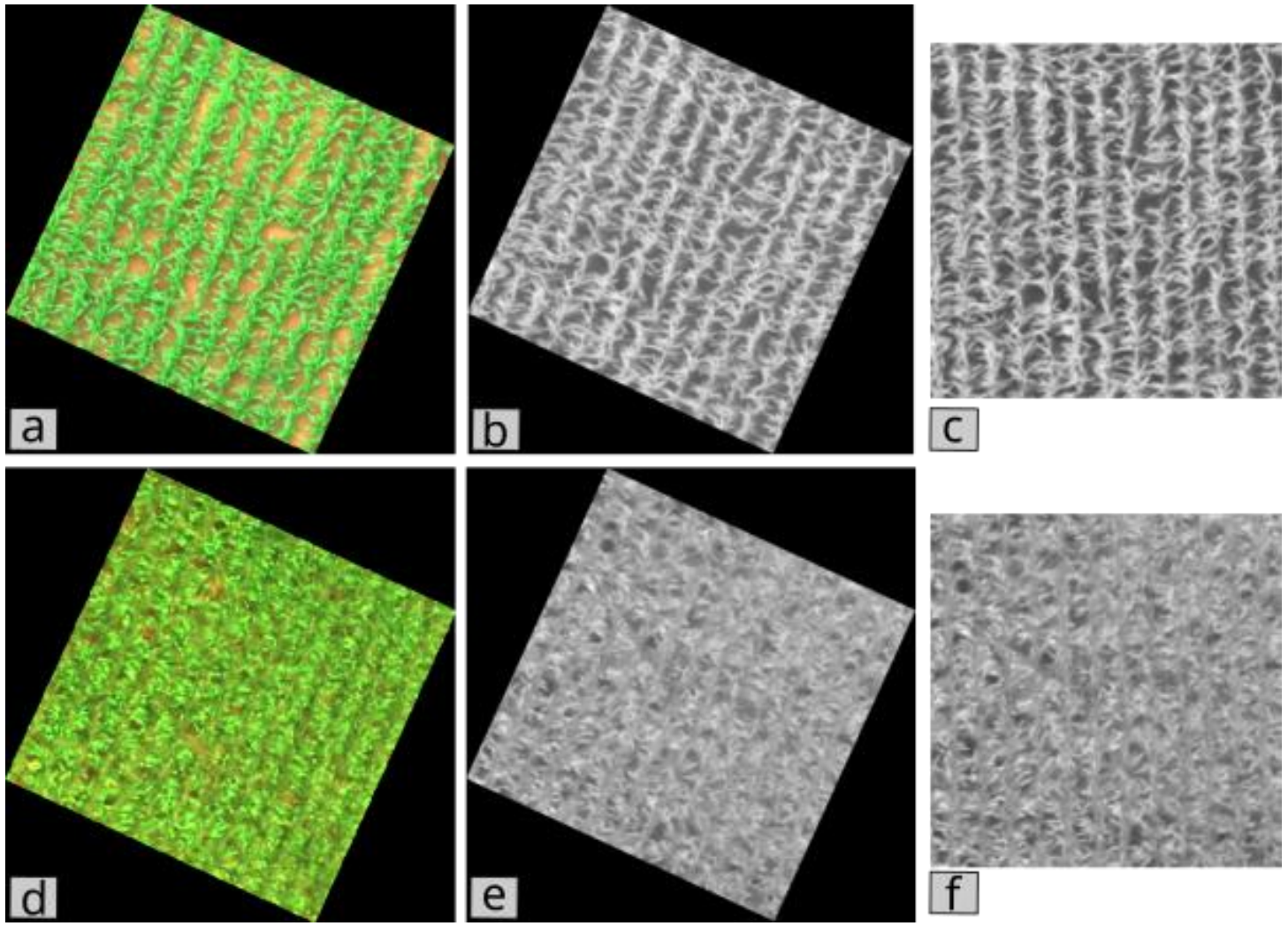
$\overline{NIR}$ correspond to the mean value of the NIR pixels values

$\widehat{NDVI}$ represents the modified NDVI value

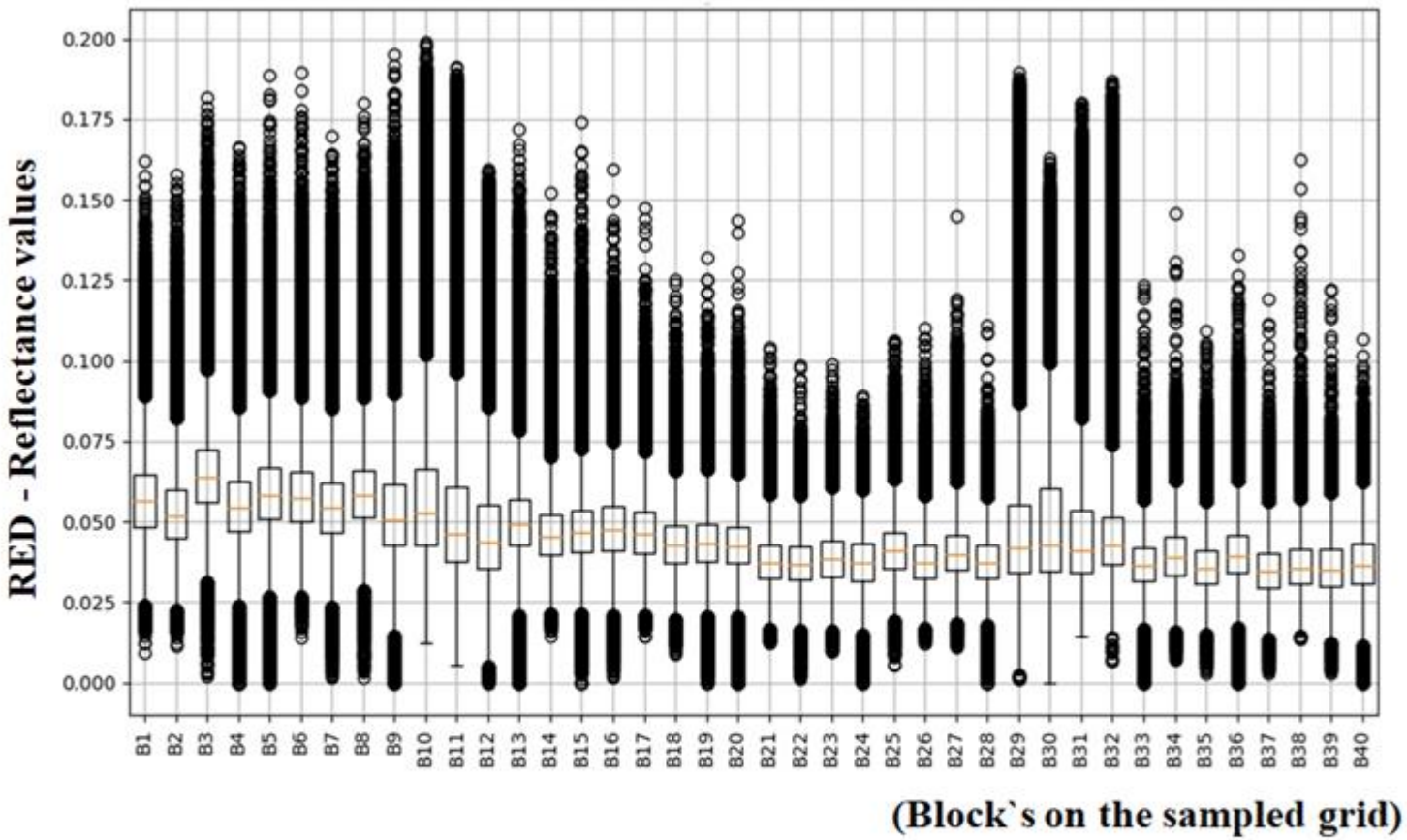
The number of registered images for all the realized flight was equal to 300 for each spectral band, i.e., leading to a total amount of 9600 images (29.52 GB).

Description	Values	Units
Flying altitude	138	m
Mission flying time	12	min
Max. speed of flying	11	m/s
Front and side overlap	80	%
Ground sample distance	5.95	cm/pixel

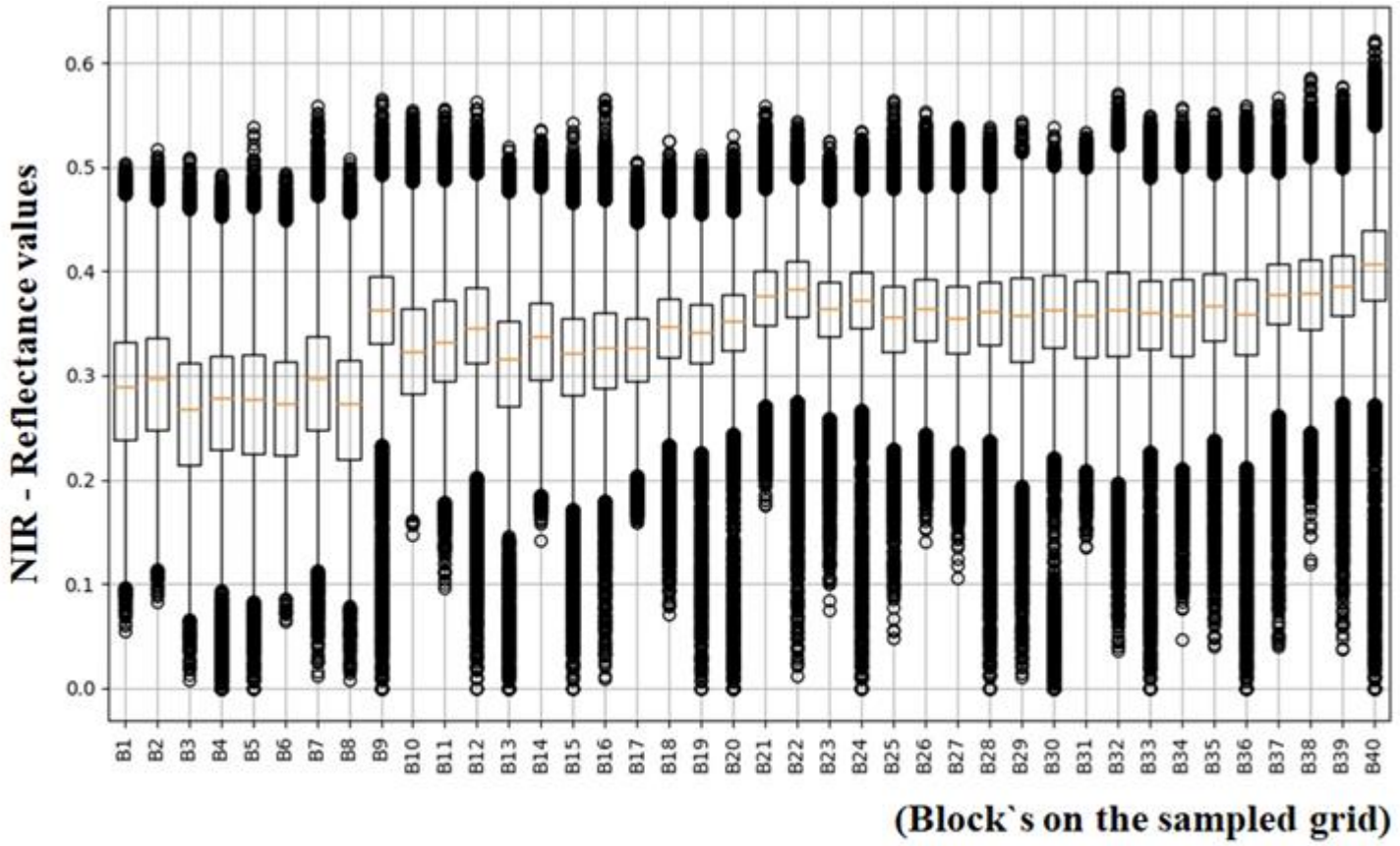




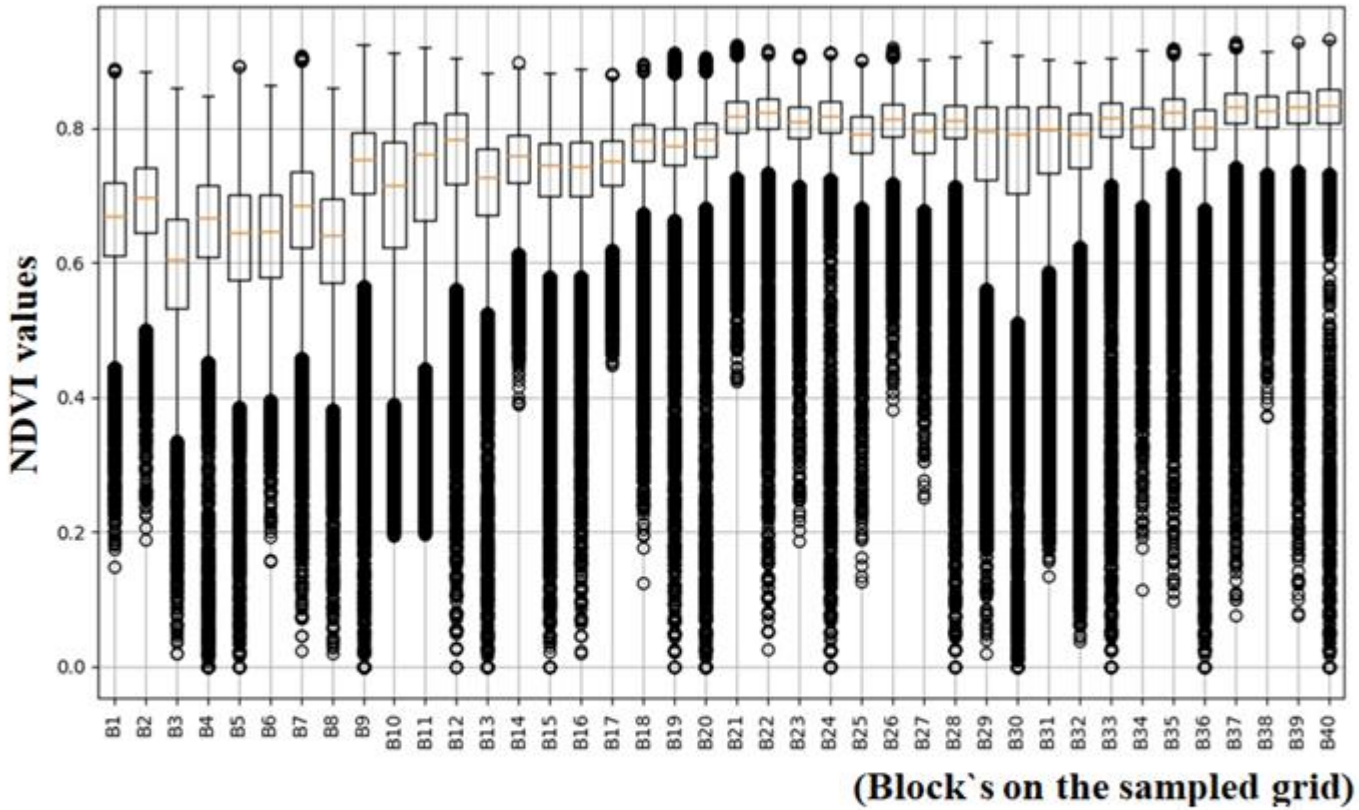
Sample of analysis for the block 25: from the second flight - (a) RGB, (b) NIR, and (c) ROI NIR; from the eighth flight - (d) RGB, (e) NIR and (f) ROI NIR.



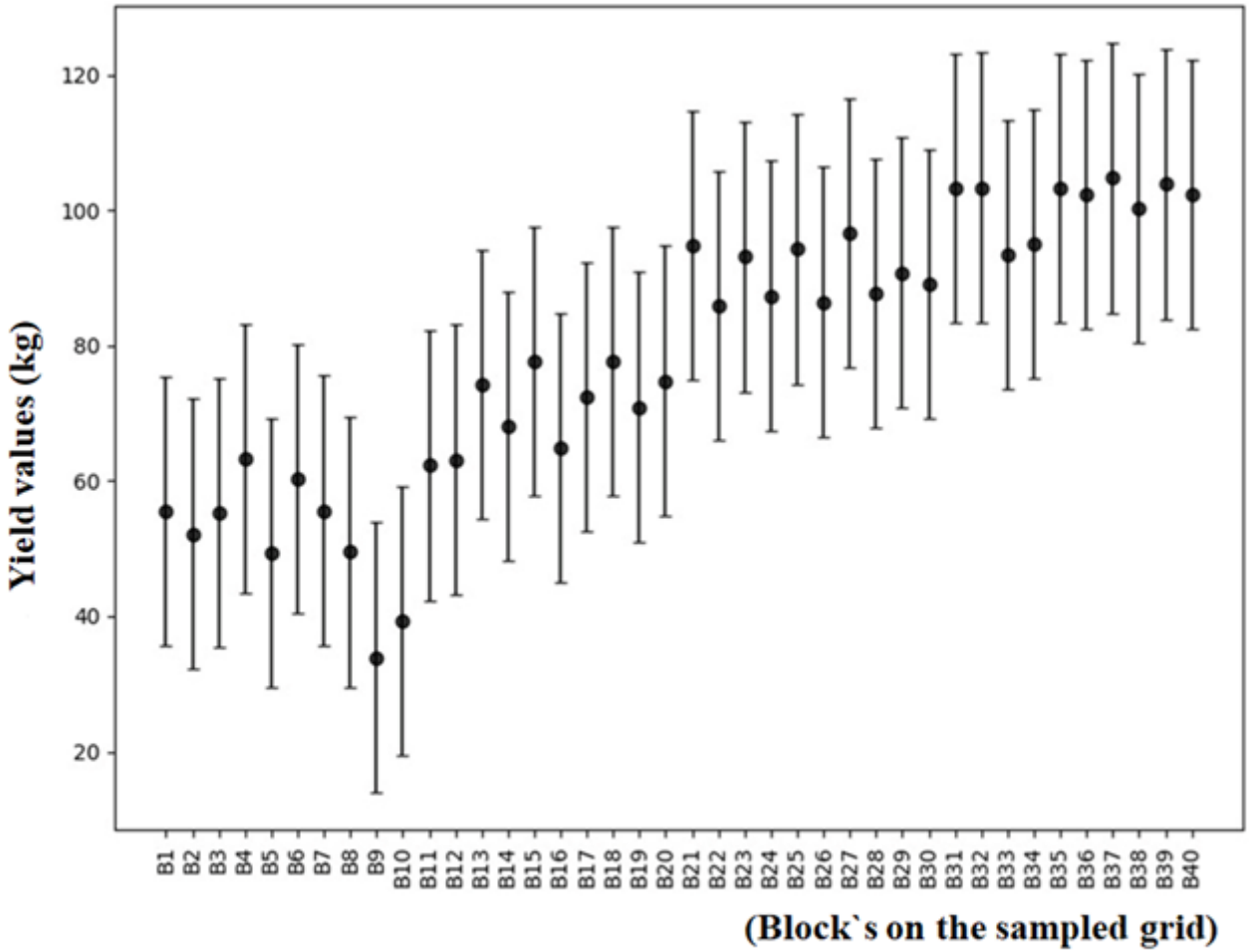
Statistical evaluation for the RED light-band reflectance in the specific-sites of the maize crop area, that means, considering all the experimental regions (from B1 to B40).



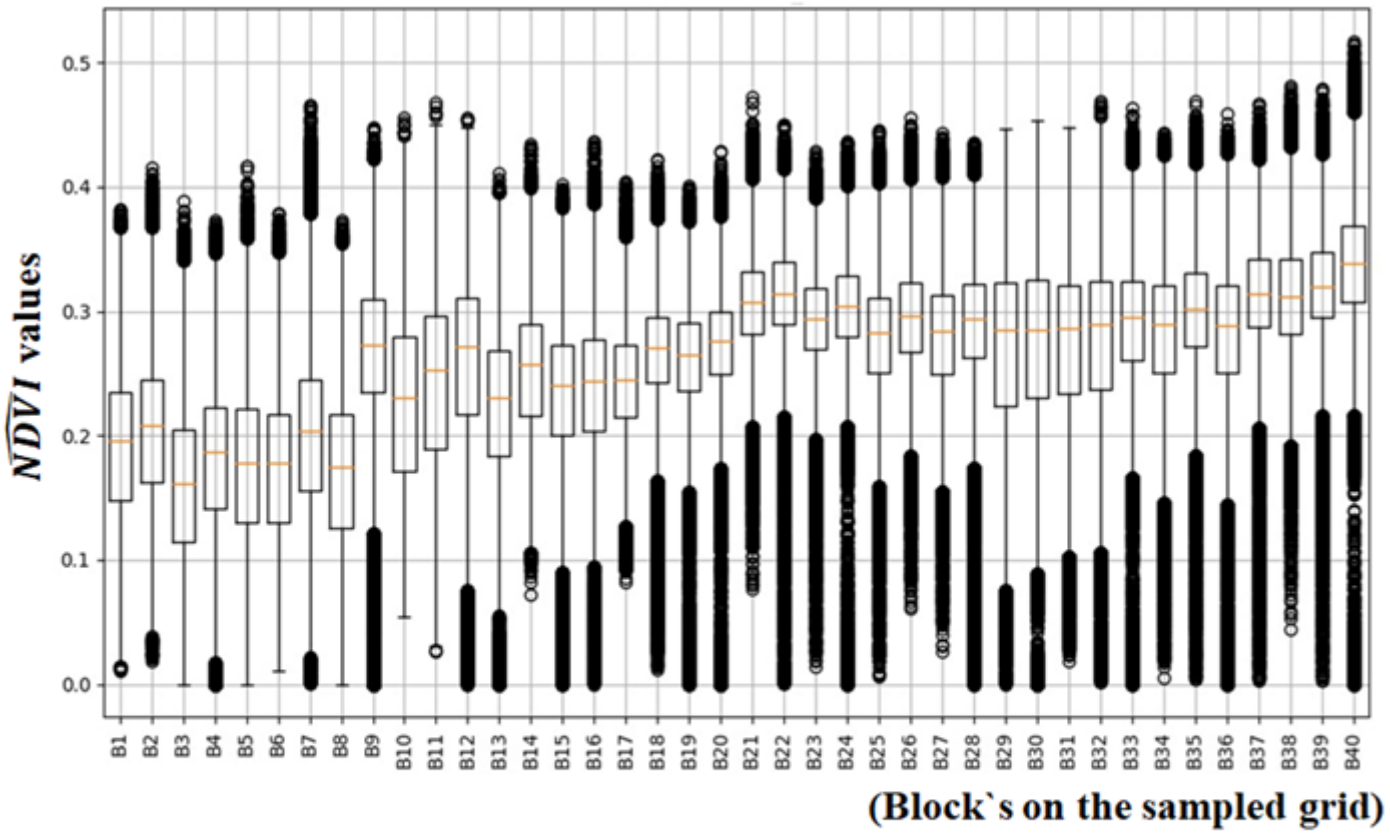
Statistical evaluation for the NIR light-band reflectance in the specific-sites of the maize crop area, that means, considering all the experimental regions (from B1 to B40).



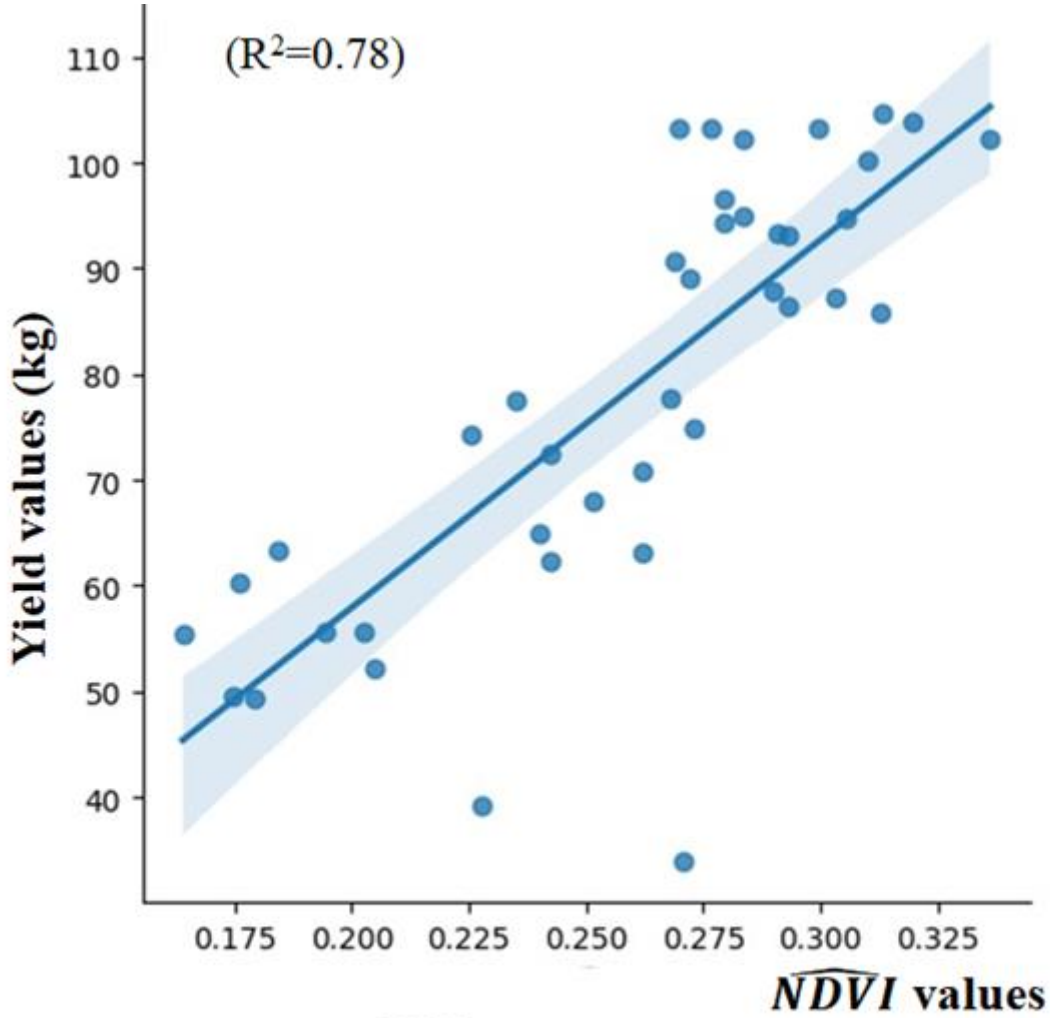
Statistical evaluation for the NDVI for all sites-specific of the maize crop area, that means, considering the experimental regions (from B1 to B40).



Productivity for each specific site from the maize crop area that means, considering the experimental regions (from B1 to B40).



Statistical evaluation for the $\widehat{NDVI}$, i.e., considering all specific sites of the experimental maize crop area.



Correlation analysis ($\widehat{NDVI}$ and Yield), considering all sites-specific of the experimental rainfed maize crop area.

Carbon and Hydrogen (C-H), Oxygen and Hydrogen (O-H), and Nitrogen and Hydrogen (N-H) absorption wavelengths fall in the NIR spectrum. NIR is suitable for use in agriculture mainly because in the living plants the organic compounds are the major components.

The signature related to plants led to a new sensor-based index to support decision making related to crop stress and its relation to productivity improvement, which is an original contribution. If an analysis shows a deficiency of Nitrogen, a manager can provide timely nutritional supplements, i.e., by aggregating values in sustainability of the crop area, avoiding over-use of fertilizers, decreasing the resulting toxicity in plants, as well as decreasing the costs.

Future research works will consider the development of customized agricultural sensors for smart and real-time crop stress evaluation.

Thank you for your attention!!