Sensor-Based Platform for Evaluation of Atmospheric Carbon Sequestration's Potential by Maize Crops

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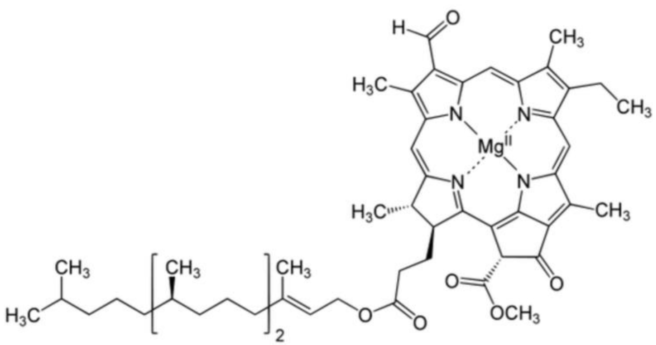
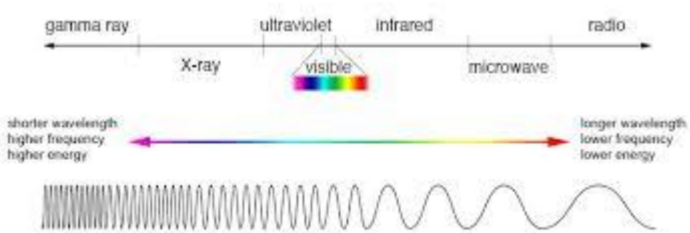
Abstract

This study has led to new insights into the management of crop fields for food and biomass production for energy. It also brings together information related to the carbon sequestration potential, which can allow opportunities not only for the use of sensors and related techniques in soil science but also for value aggregation for the agricultural process and environmental care.

Introduction

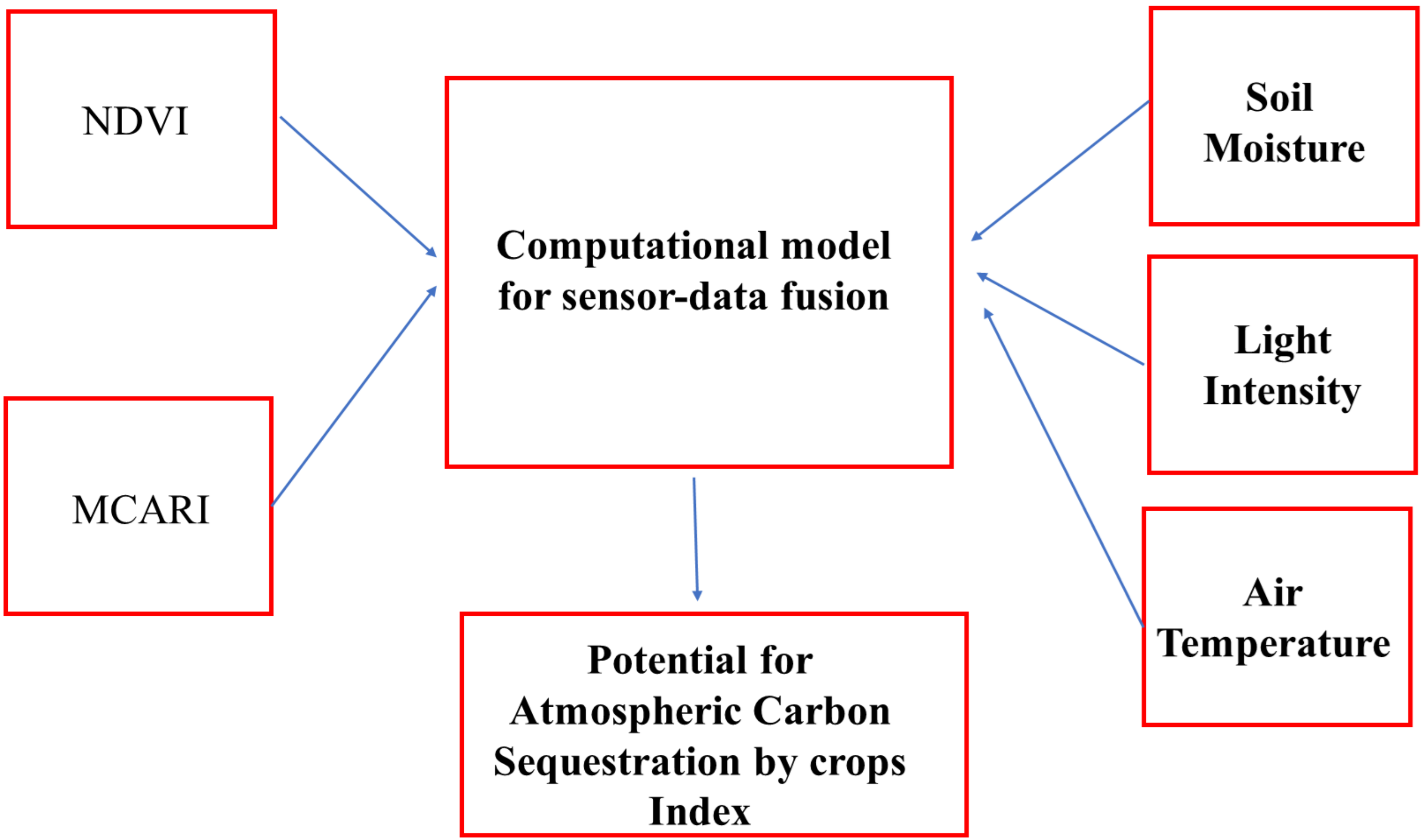




The estimation of leaf chlorophyll content is important in monitoring the growth status of plants, and is quite involved in the photosynthesis process.

For the evaluation of chlorophyll content in plants, one may use different vegetation indexes, which can be obtained based on the use of multispectral data collected with adequate sensors.

Material & Methods

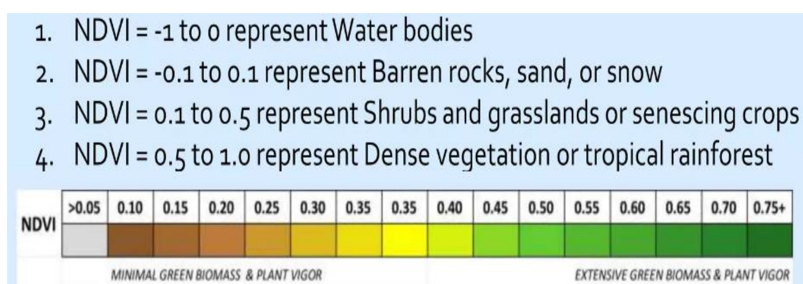


Normalized Difference Vegetation Index (NDVI) and the **Modified Chlorophyll Absorption in Reflective Index** (MCARI), both calculated based on data acquired with a multispectral camera, as well as taking into account three other sensors for **solar light intensity, soil water content**, and **air temperature** measurements.

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

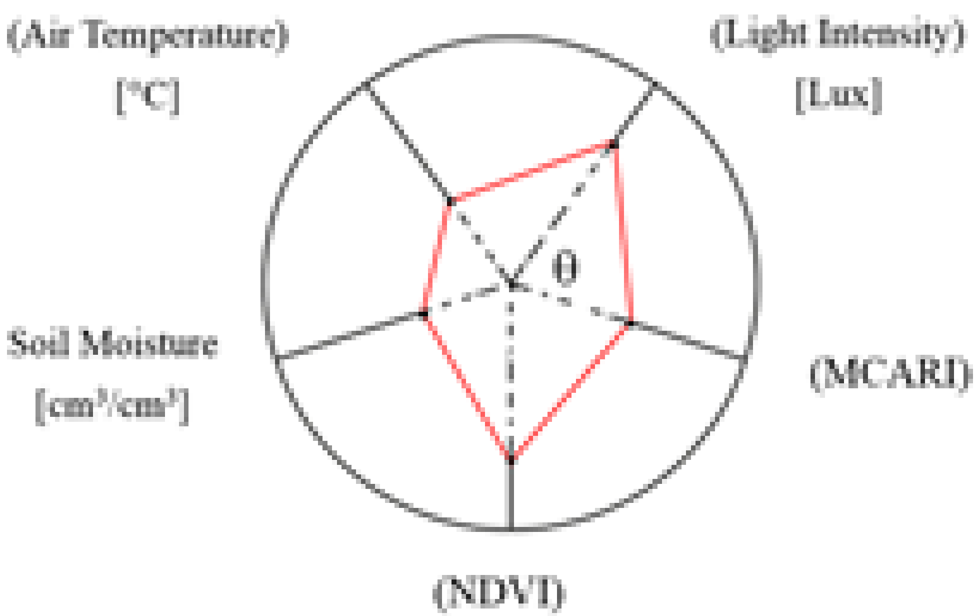
$$MCARI = \left((NIR - RED) - 0.2(NIR - GREEN)\right)\left(\frac{NIR}{RED}\right)$$

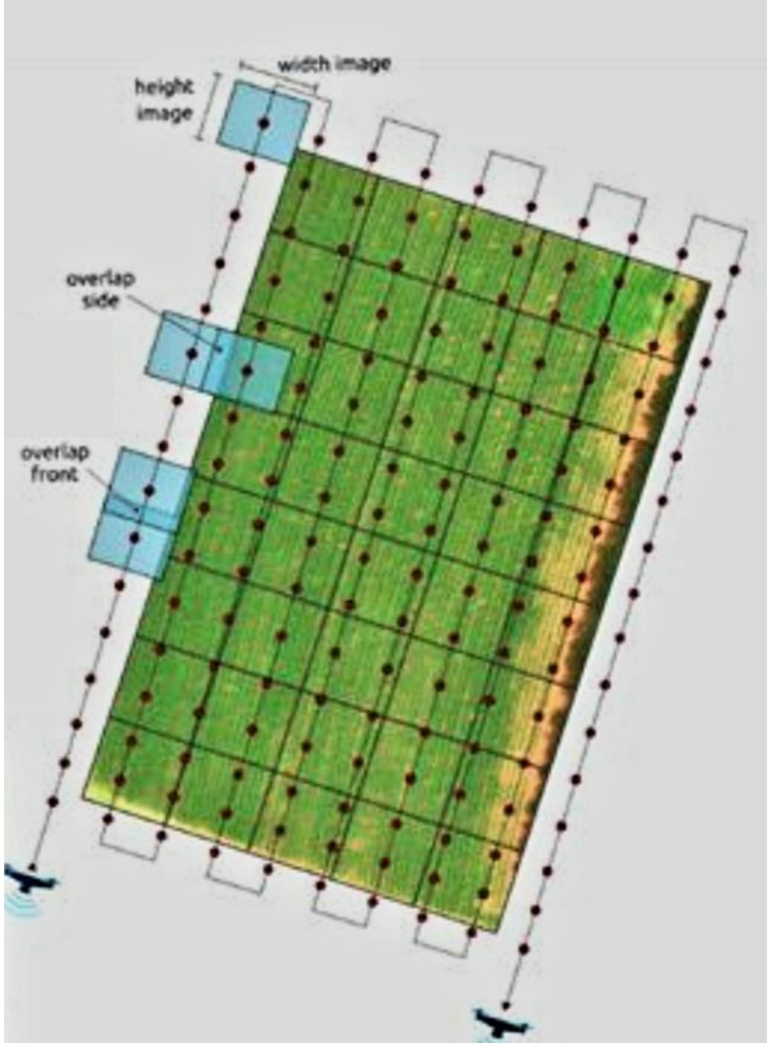
The Normalized Difference Vegetation Index (NDVI) was established in 1974 (Rouse et al.) and later validated (Tucker, 1979) through linear combinations of the RED and NIR bands to monitor biomass density.



The MCARI was published in the year 2000 (Daughtry et al.), it is used considering the RED (668 nm ± 10 nm), NIR (840 nm ± 40 nm)), and GREEN) (560 nm ± 20 nm) light bands to estimate the amount of chlorophyll in crops.

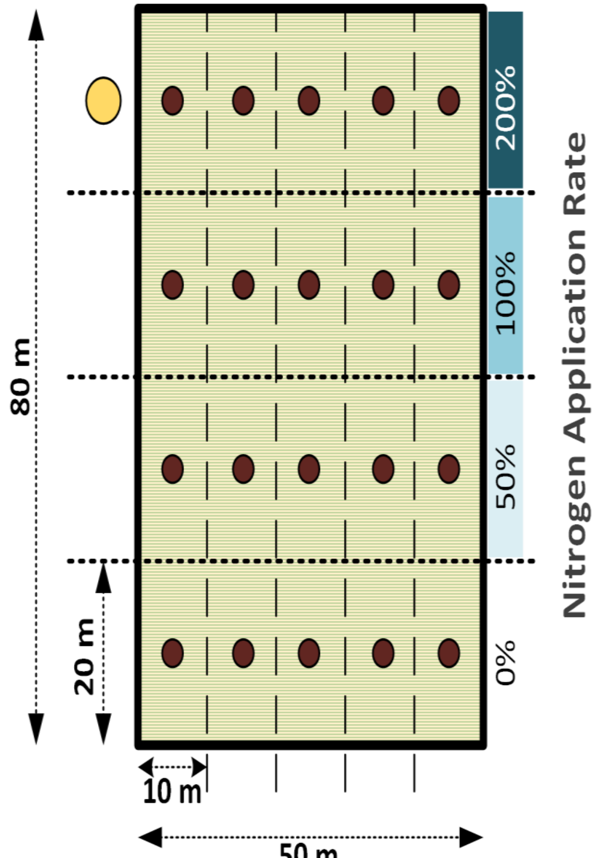
$$PACSI \triangleq g\begin{pmatrix} Light\ Intensity, Air\ Temperature, \\ Soil\ Moisture, NDVI, MCARI \end{pmatrix}$$

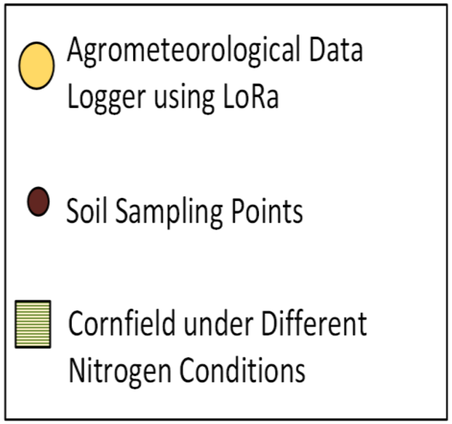




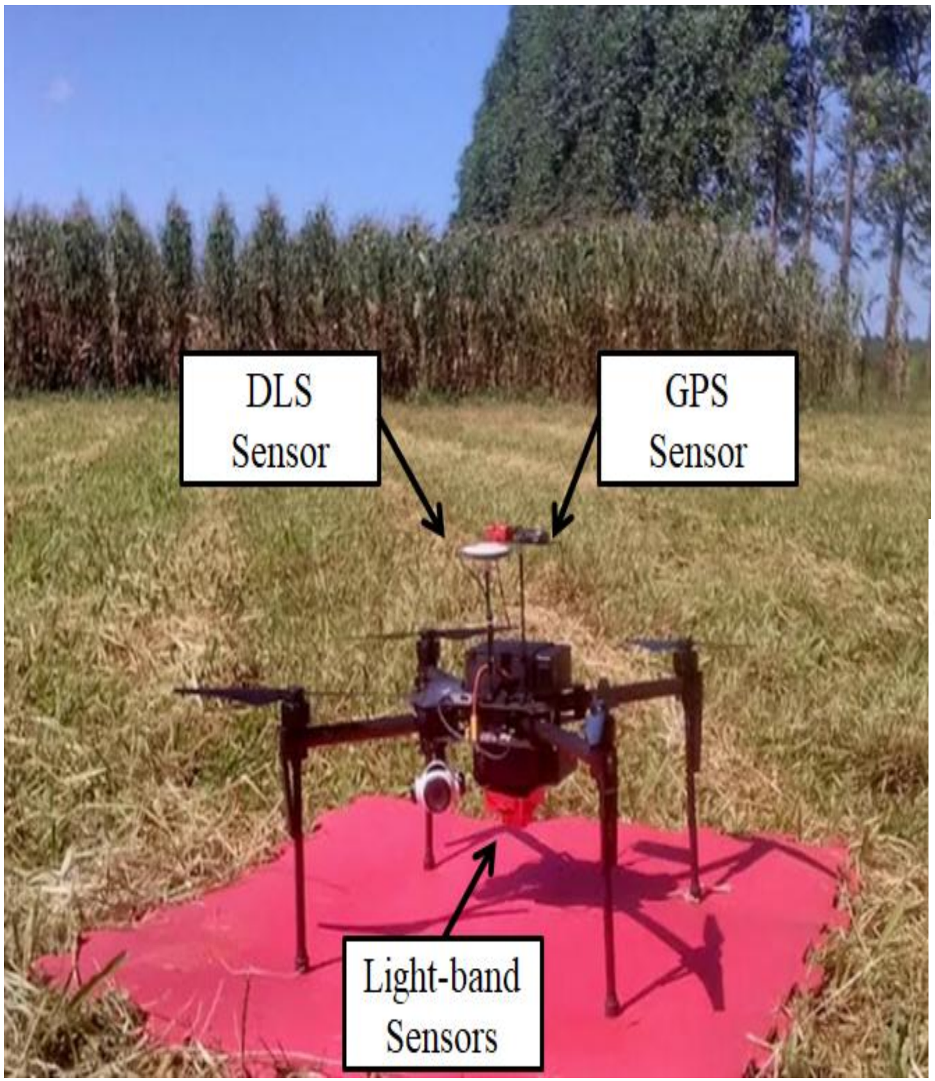
21◦57’3.9”S and 47◦51’10.9” W, National Reference Laboratory for Precision Agriculture (LANAPRE) in Brazil.

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.





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



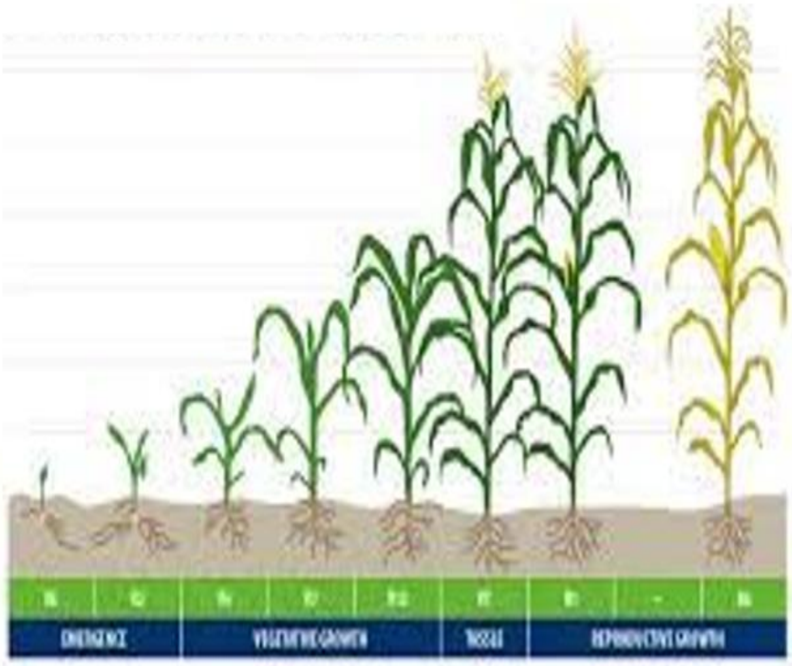
Micasense RedEdge-M multispectral camera was embedded, and provided onboard; Eight flight missions were considered; multirotor Unmanned Aircraft System

Parameters	Specifications
Weigth	170 g (Including DLS)
Dimensions	9.4 cm $\times$ 6.3 cm $\times$ 4.6 cm (3.7" $\times$ 2.5" $\times$ 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 $\pm$ 20 nm) Green (560 nm $\pm$ 20 nm) Red (668 nm center $\pm$ 10 nm) Near-IR (840 nm $\pm$ 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.

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

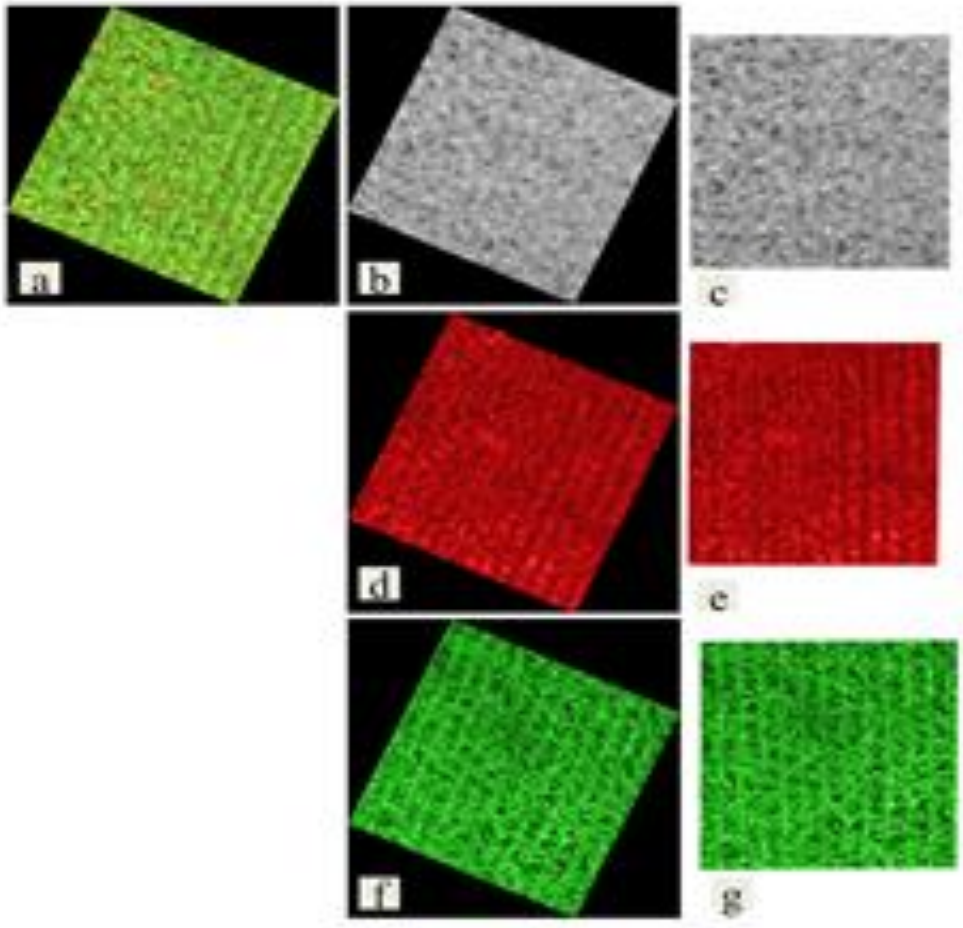
$$Rotation = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -t_x \\ 0 & 1 & -t_y \\ 0 & 0 & 1 \end{bmatrix}$$



Results & Discussions

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



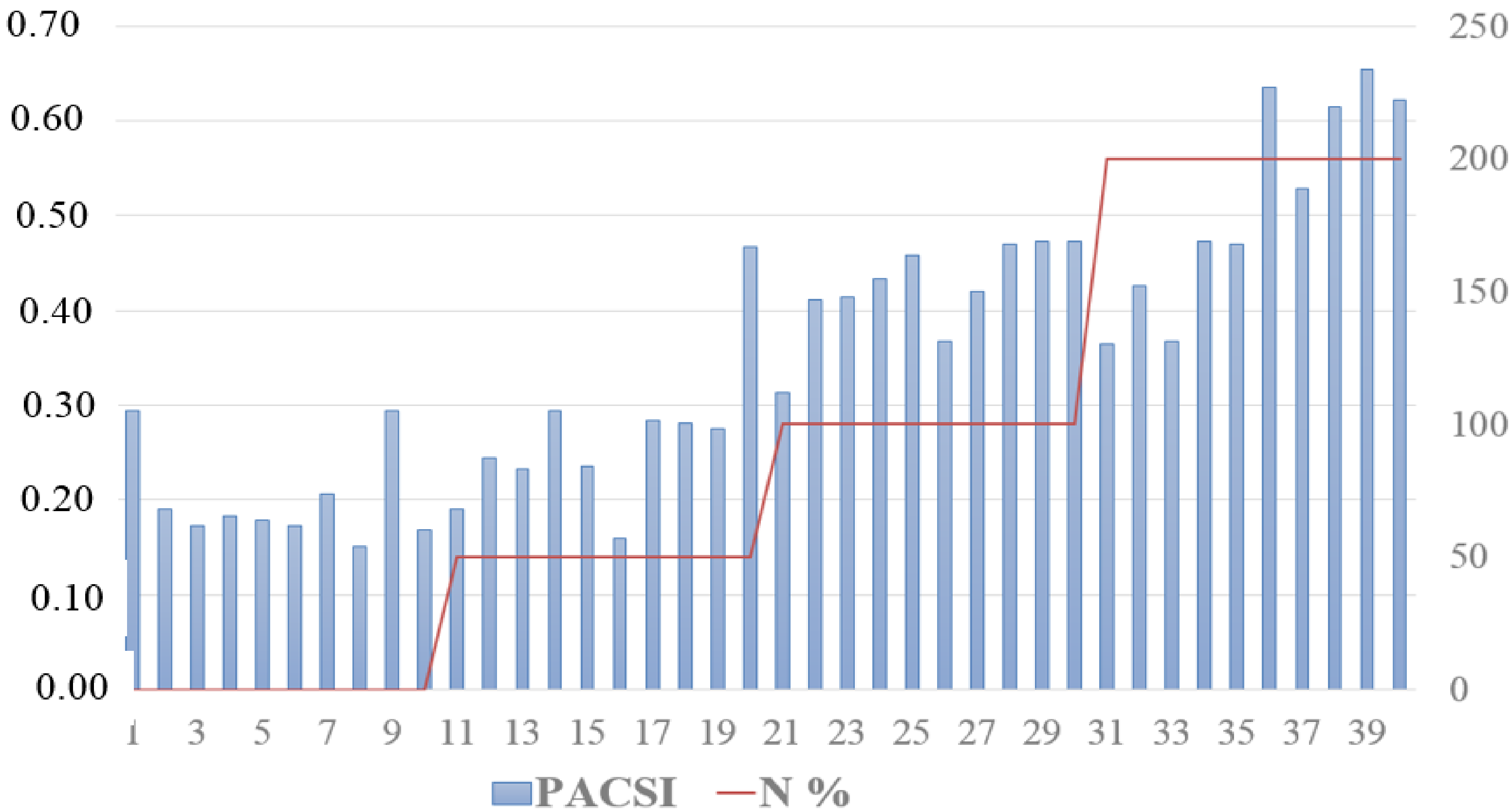
Sample of analysis for the block 25: from the second flight - RGB, NIR, RED, and GREEN with the ROIs

EXAMPLES -
BLOCKS RESULTS
FOR FLIGHT EIGHT

Specific Site (Block #)	X - UTM [m]	Y - UTM [m]	MCARI	NDVI	Light Intensity [Lux]	Air Temperature [°C]	Soil Moisture [cm^3/cm^3]
1	205,320.60	7,569,399.92	0.0295	0.6627	84,500	31.3	0.61
2	205,324.77	7,569,409.01	0.0283	0.6884	84,432	31.2	0.60
3	205,311.51	7,569,404.09	0.0309	0.5991	84,495	31.5	0.60
4	205,315.68	7,569,413.18	0.0289	0.6583	84,502	31.4	0.62
5	205,302.42	7,569,408.26	0.0295	0.6358	84,505	31.6	0.61
6	205,306.59	7,569,417.35	0.0291	0.6360	84,504	31.4	0.62
7	205,293.33	7,569,412.43	0.0295	0.6760	84,506	31.3	0.40
8	205,297.50	7,569,421.52	0.0292	0.6307	84,504	31.7	0.42
9	205,284.24	7,569,416.60	0.0326	0.7398	84,508	31.8	0.35
10	205,288.41	7,569,425.69	0.0292	0.6889	84,506	32.0	0.33
11	205,292.58	7,569,434.78	0.0261	0.7166	84,508	32.1	0.40
12	205,296.75	7,569,443.87	0.0256	0.7459	84,507	31.9	0.34
13	205,301.67	7,569,430.61	0.0270	0.7135	84,508	32.0	0.44
14	205,305.84	7,569,439.70	0.0260	0.7508	84,505	31.7	0.43
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

EXAMPLES - NORMALIZED RESULTS AND THE PACSI VALUE

Specific Site (Block #)	Normalized value for MCARI	Normalized value for NDVI	Normalized value for Light Intensity	Normalized value for Air Temperature	Normalized value for Soil Moisture	PACSI
1	0.735	0.274	0.895	0.273	0.600	0.294
2	0.633	0.383	0.000	0.182	0.733	0.191
3	0.857	0.000	0.000	0.182	0.733	0.173
4	0.679	0.255	0.000	0.182	0.733	0.183
5	0.732	0.158	0.000	0.182	0.733	0.178
6	0.701	0.159	0.000	0.182	0.733	0.172
7	0.730	0.331	0.000	0.182	0.733	0.207
8	0.710	0.136	0.947	0.182	0.300	0.151
9	1.000	0.606	0.882	0.091	0.067	0.294
10	0.706	0.387	0.974	0.091	0.000	0.168
11	0.443	0.507	0.947	0.000	0.300	0.190
12	0.403	0.633	0.987	0.182	0.033	0.245
13	0.518	0.493	0.934	0.091	0.367	0.233
14	0.435	0.654	0.961	0.182	0.333	0.293



Histogram of the calculated PACSI considering the flight eighth and the N doses applied

Conclusions and Future Works

This work presented a new sensor-based index for evaluation of agricultural crop potential for carbon sequestration (PACSI). It has proved to be useful not only to help in managing impacts due to climate change but also to be used as an indicator for needs in nitrogen fertilization by the farmers, i.e., allowing not only loss minimization but also gain in sustainability.

Future research works will consider the development of an integrated and customized agricultural smart sensor platform coupled to a Convolutional Neural Network (CNN) for real-time evaluation of the potential for atmospheric carbon sequestration by crops.

ACKNOWLEDGMENT

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Thank you all for the audience!