Field-Based High-Throughput Phenotyping Using Newly Developed Proximal Sensor Device

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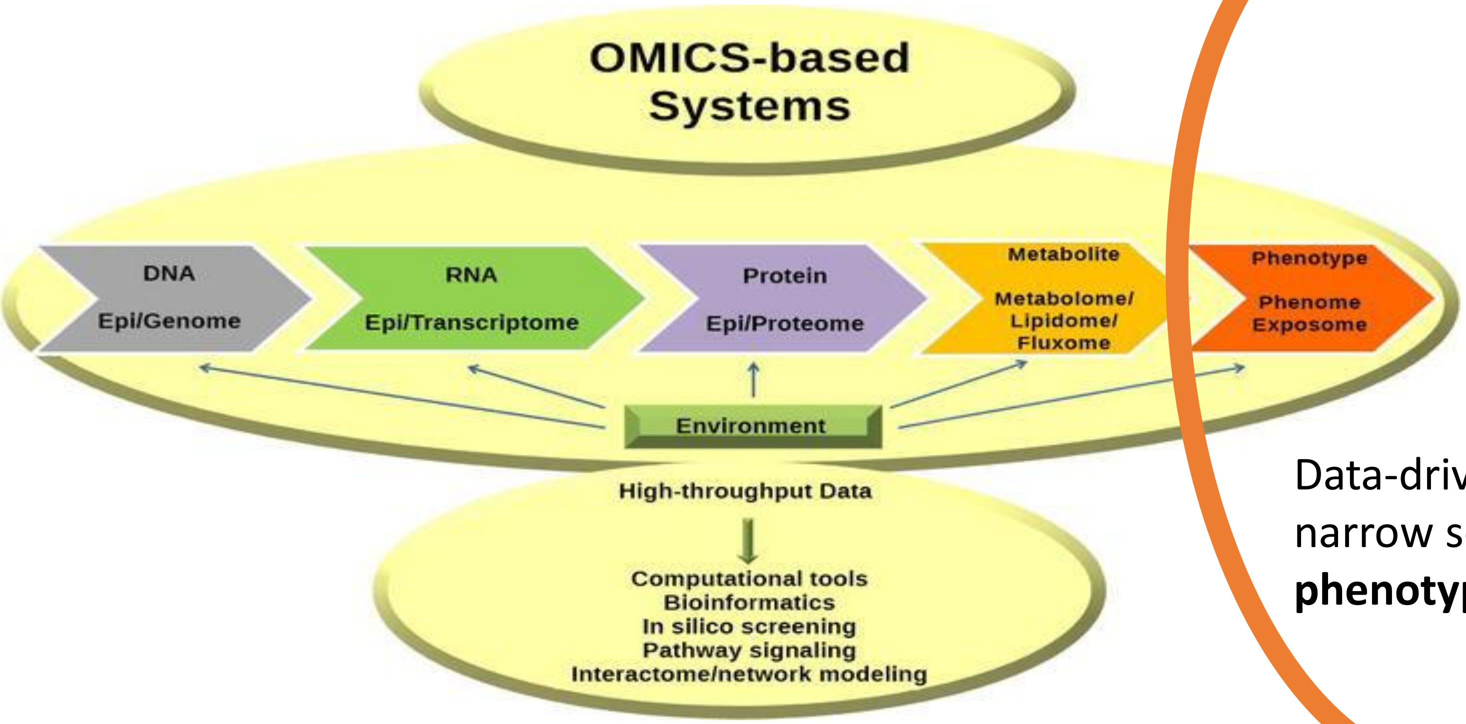
Data-driven agriculture

- Data-based decisions for better farming – only „visible” data
- Data-driven **research** in agriculture?

A totality of data (OMICS) is needed ➔ big data management and analysis

Universes of high-throughput OMICS data: from genomics to **phenomics**



Data-driven agriculture in narrow sense – **only phenotyping**

Plant breeding?

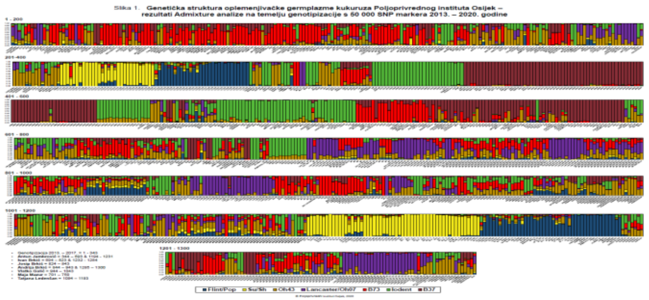
High-Throughput Data in Plant Breeding

Genomics & Phenomics

• The first true high-throughput data from **genotyping** 🡐 genomics (since 2000s)

DNA arrays = DNA chips in maize: 50.000 or 600.000 DNA datapoints in more than 2000 maize samples (inbred lines):

<u>More than **450 million DNA datapoints**</u>



• Recently, advances in high-throughput data from **phenotyping** 🡐 phenomics

<u>It was impossible to generate big data framework = low-throughput data</u>

Newly developed proximal sensor

➔ First high-throughput phenotyping data

High-Throughput Pheotyping in Plant Breeding

- Data-based decisions in plant breeding – completely new paradigm

Classical approach: Assumption(s)➔Data➔Analysis➔Conclusions

Data-driven approach: ~~Assumption(s)~~➔Big data➔Advanced analysis➔Conclusions

- Phenotyping of leaf rolling in maize
- **Newly developed proximal sensor**
- Machine learning

remote sensing

MDPI

Article

Machine Learning in the Analysis of Multispectral Reads in Maize Canopies Responding to Increased Temperatures and Water Deficit

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IoT-polje

Newly developed proximal sensor

- low-cost AMS (ams-OSRAM AG, Austria) AS7263 sensor unit with six spectral bands (3×2 photo diode array)
- responsive to wavelengths in red and near-infrared spectra (**610, 680, 730, 760, 810 and 860 nm**) with 20 nm full width at half maximum.
- plastic housing, a lens and photodiode array with aperture of 0.75 mm and 20.5° viewing angle.
- connected to Arduino Uno prototyping board
- data logged based on a programmed button-interrupt to an SD card

Objectives

- To evaluate functionality of the newly developed multispectral sensor for prediction of physiological status
- To compare data with reads of other sensor devices in large scale field trials in Osijek

Methods

- Measurements in barley, wheat and maize using several devices concurrently
- **Trimble GreenSeeker -** measuring reflectance at undisclosed wavelengths („**commercial sensor**”), retrieving normalized difference vegetation index (NDVI). Used in total of 191 plots of barley, wheat and maize at the same phenological stages.
- a handheld **fluorimeter** Hansatech Handy **PEA**. Ten measurements on each of 72 plots (10 m^2) in barley, and on 55 plots (10 m^2) in wheat, both at the booting stage. Maize at the V9 stage in 64 plots. ten measurements was considered as a single data point (total of 191 measurements) . Chlorophyll fluorescence applying JIP test = a reference method for evaluating plant physiological status.

Newly developed sensor vs. Commercial sensor (NDVI)

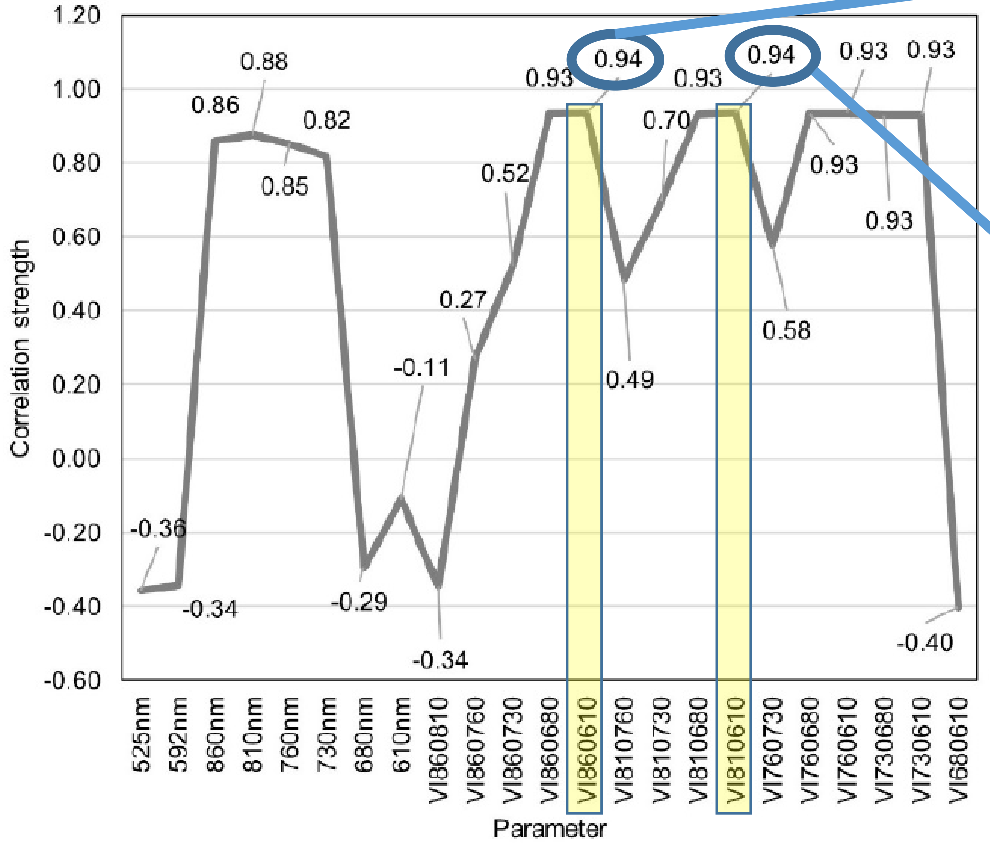


Fig. 1. Correlation coefficients between reads of newly developed multispectral sensor and commercial multispectral sensor. The first eight parameters were raw sensor outputs at eight wavelengths, and others were values of different normalized difference vegetation index (NDVI).

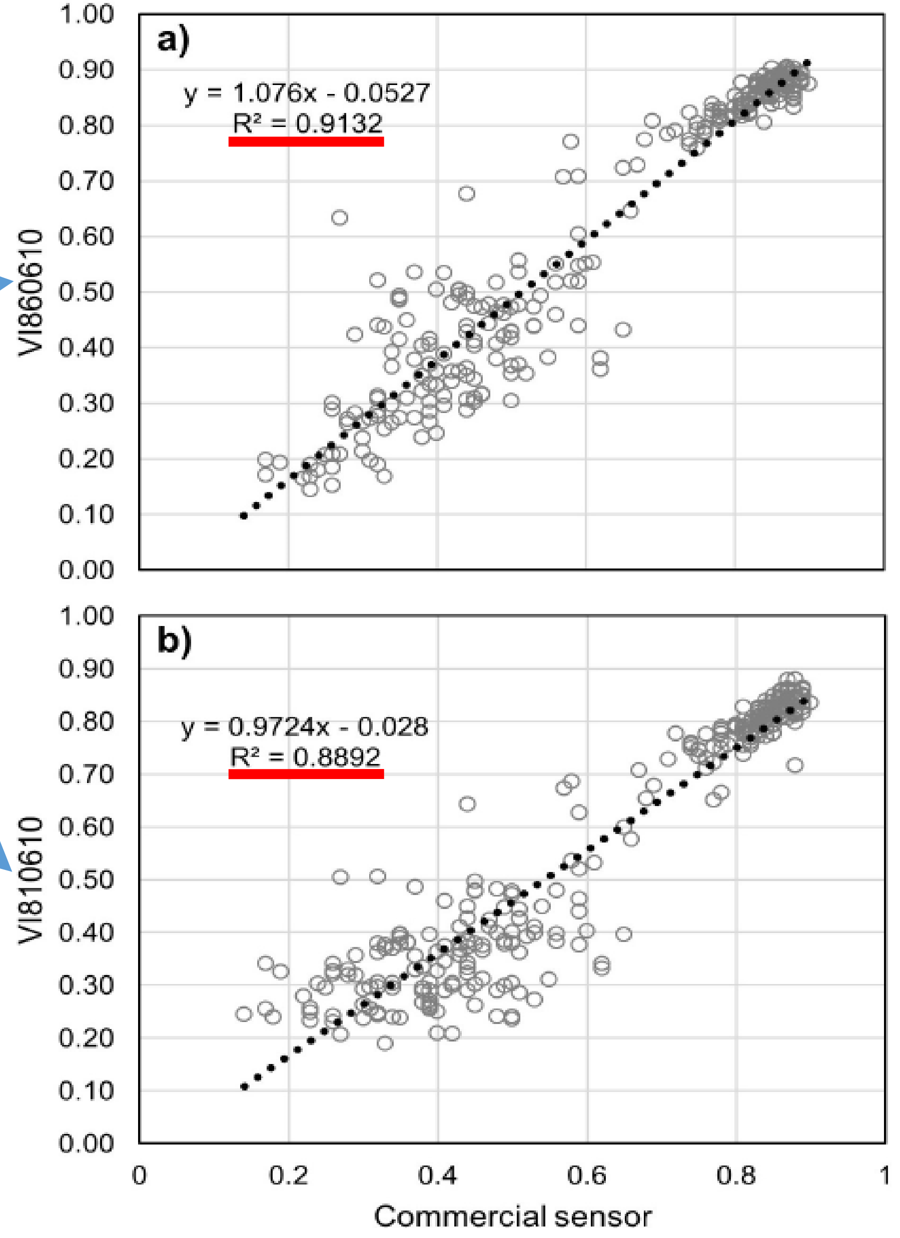


Fig. 2. Linear regression of NDVI reads obtained by commercial multispectral sensor and a) VI 860 610 nm and b) VI 810 610 nm reads obtained by newly developed multispectral sensor

Newly developed sensor vs. Fluorimeter (Chl fluorescence)

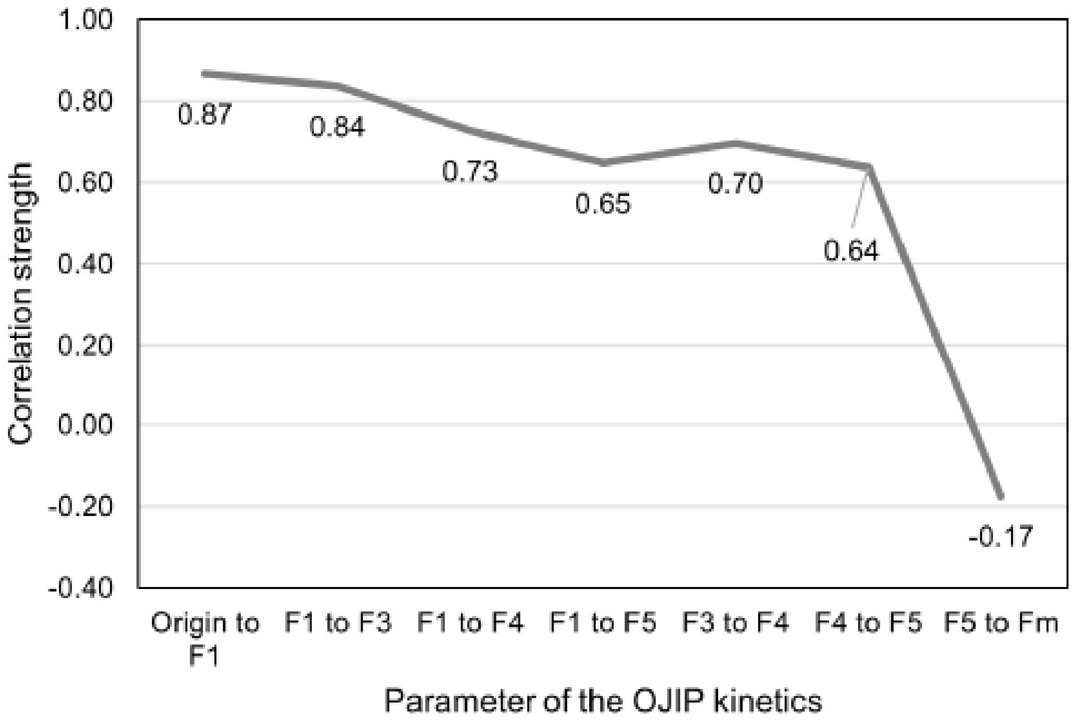


Fig. 3. Correlation coefficients between fluorescence rise kinetics ("Kautsky effect") and VI reads (VI 810 610 nm) obtained from newly developed multispectral sensor

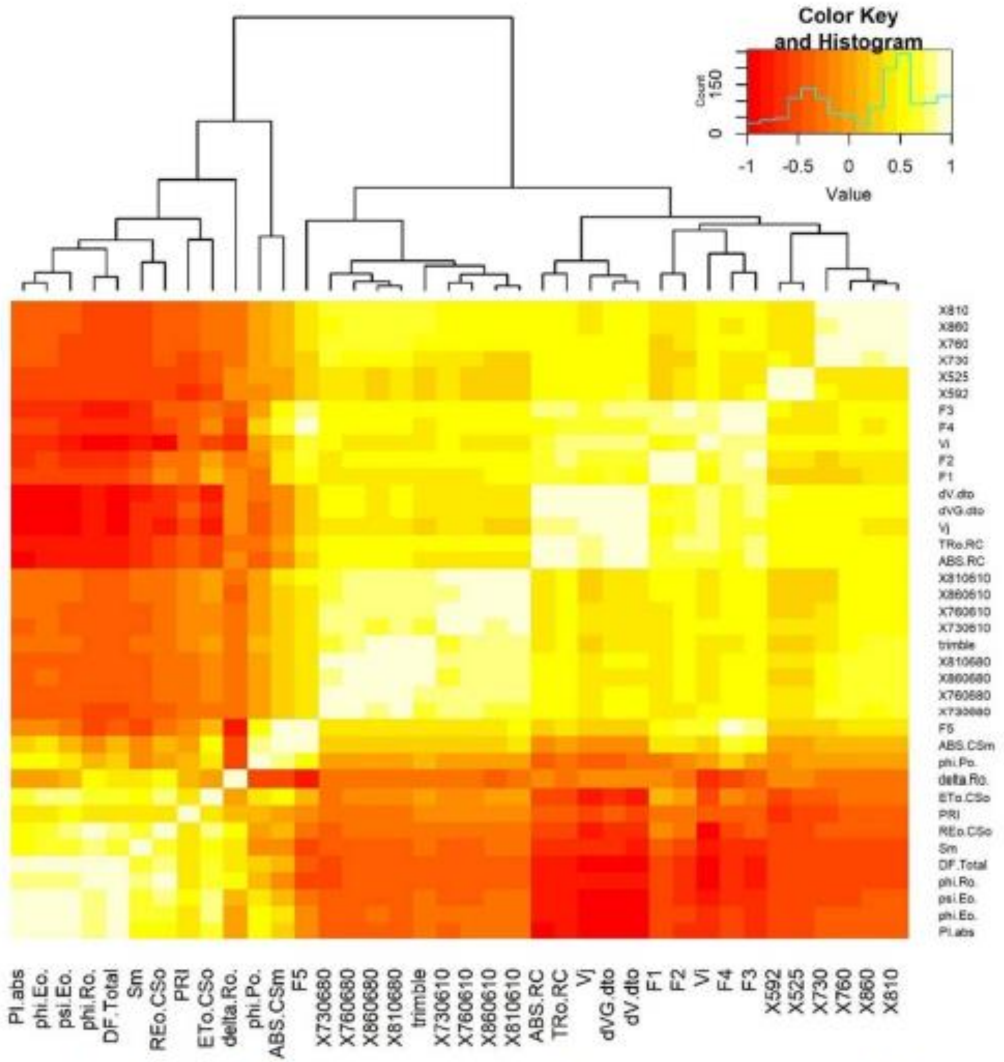


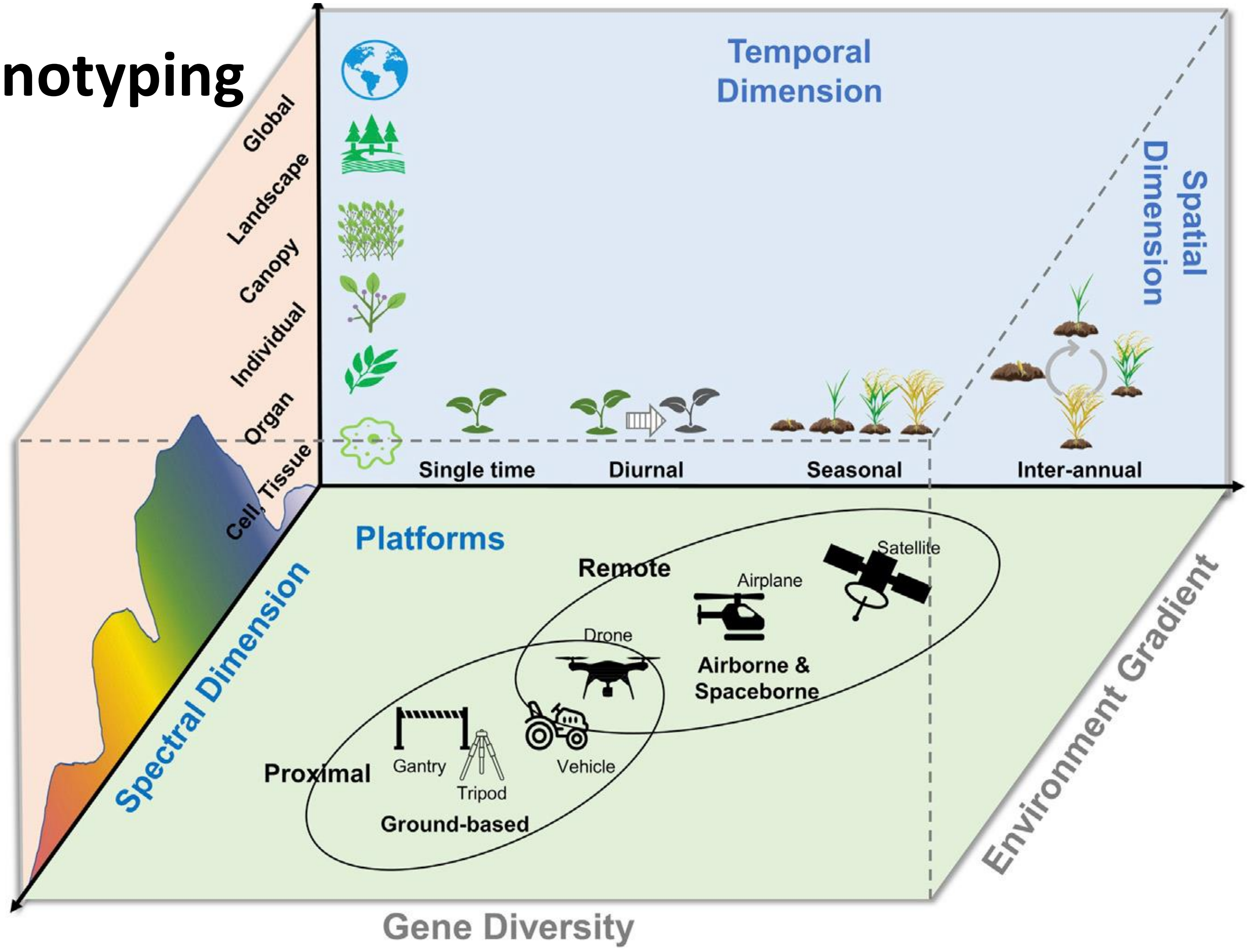
Fig. 4. Clustered heatmap of the correlation matrix between the most important parameters of photosynthetic efficiency and reads of newly developed multispectral sensor. Raw reads are denoted as X525 (...) X860 referring to the respective wavelength, while the calculated values of VI were denoted as "X wavelength1 wavelength2". Only parameters with significant correlations are shown.

Conclusions

- First high-throughput phenotyping for maize breeding in Croatia
- New proximal sensor **performed well** in comparison with a commercial multispectral sensor as well as with a handheld chlorophyll fluorimeter.
- The appropriate selection of **reflectance/fluorescence wavelengths** - critical step in design of novel proximal and remote sensing nodes.
- **VIs** to extract additional information from sensor reads and provide standardization of the results.

The next steps - multidimensionality

- High-throughput **genotyping + phenotyping**
- Plant physiology
- Proximal and remote sensing
- Spectral, temporal, spatial dimensions
- Multidiciplinary approach



Plant Communications
Review article

CellPress
Partner Journal

Proximal and remote sensing in plant phenomics: 20 years of progress, challenges, and perspectives

Haiyu Tao[1], Shan Xu[1], Yongchao Tian[1], Zhaofeng Li[2], Yan Ge[1], Jiaoping Zhang[4], Yu Wang[1], Guodong Zhou[5], Xiong Deng[6], Ze Zhang[2], Yanfeng Ding[1,3,5], Dong Jiang[1,3,5], Qinghua Guo[7] and Shichao Jin[1,3,5,8,*]

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