



Growing
ideas
through
networks

UAV plant phenotyping under abiotic stress

ADRIAN GRACIA ROMERO, PhD

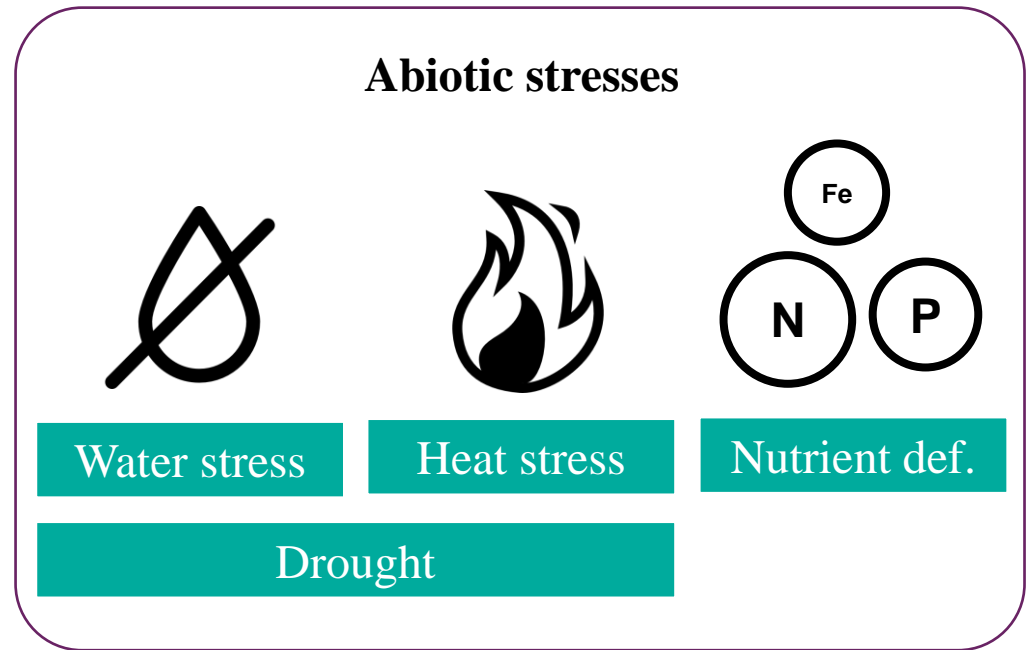
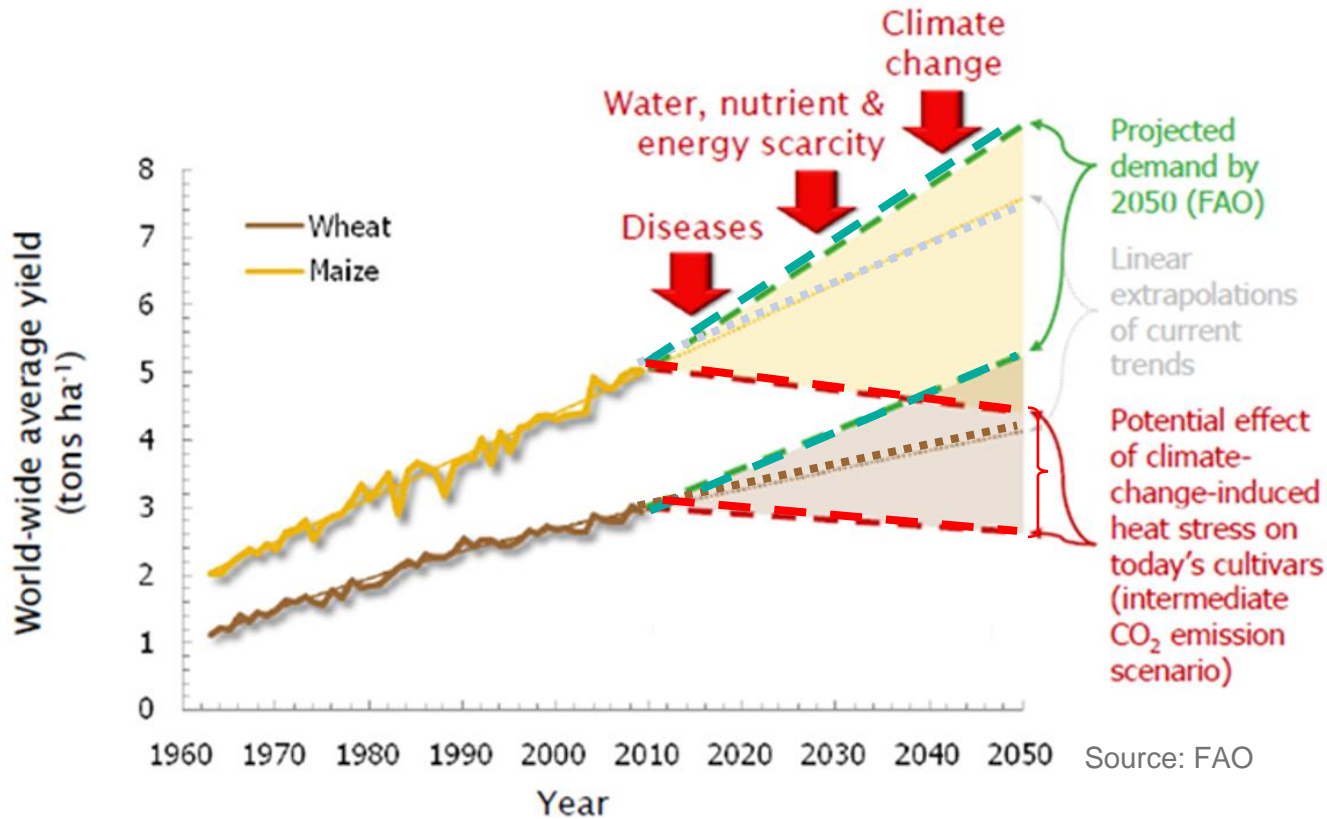
UNIVERSITAT DE BARCELONA



Funded by the Horizon 2020 Framework Programme
of the European Union



Food security in the face of climate change



Closing gaps through plant phenotyping

Selection of more favorable cultivars

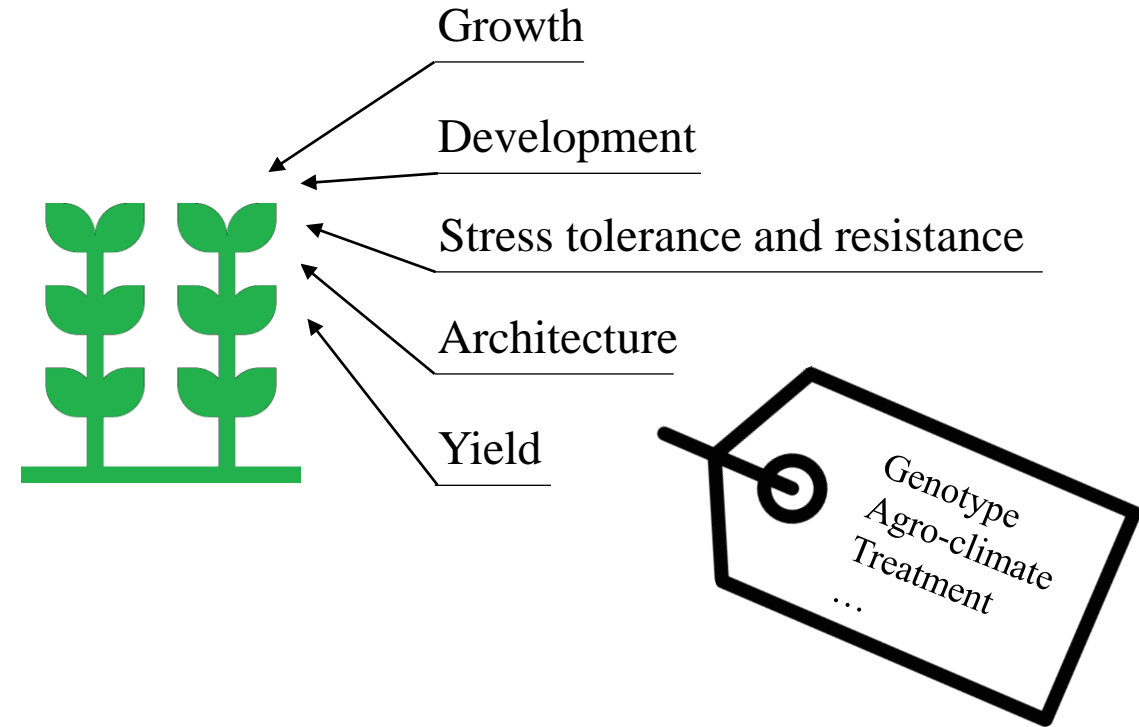


Virus resistant cultivar

High yielding cultivar

Virus resistant and high yielding cultivar




Adoption of better management practices



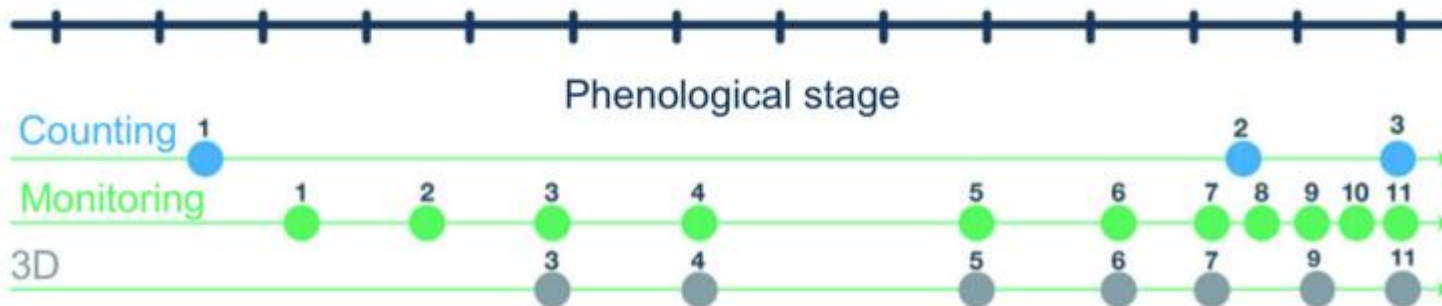
Phenotyping is the foundation of any breeding selection process

UAVs as high-throughput plant phenotyping tools



-  Precision
-  Efficiency
-  Throughput

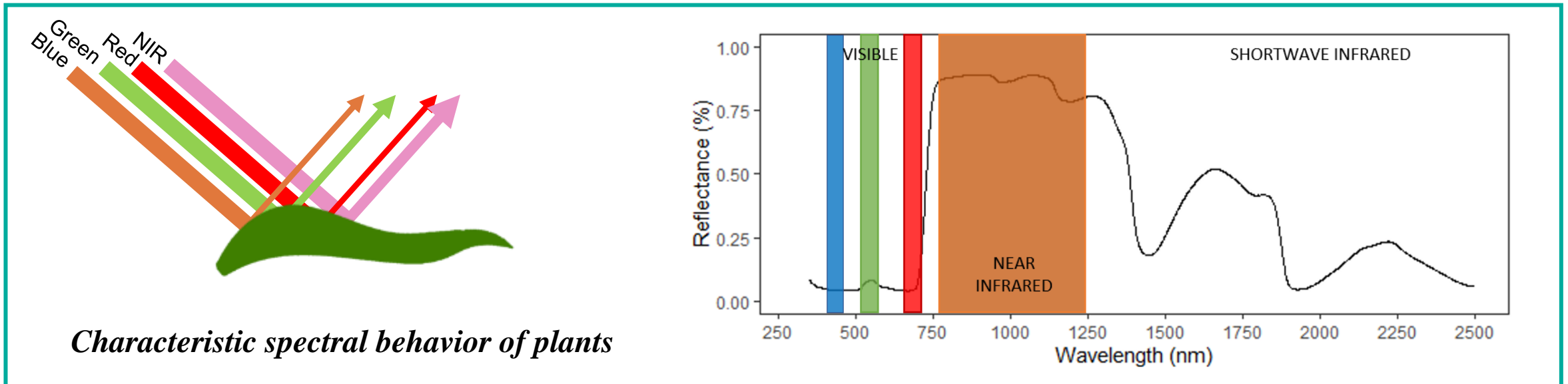
UAVs as high-throughput plant phenotyping tools



- Seedling, inflorescence, fruit counting
- Crop growth monitoring
- Crop height, biomass

Araus, J.L., Kefauver, S.C., Vergara-Díaz, O., Gracia-Romero, A., Rezzouk, F.Z., Segarra, J., Buchailot, M.L., Chang-Espino, M., Vatter, T., Sanchez-Bragado, R., Fernandez-Gallego, J.A., Serret, M.D., and Bort, J. (2022). Crop phenotyping in a context of global change: What to measure and how to do it. *J. Integr. Plant Biol.* 64: 592–618

Basis of remote sensing for plant phenotyping: Multispectral/hyperspectral information

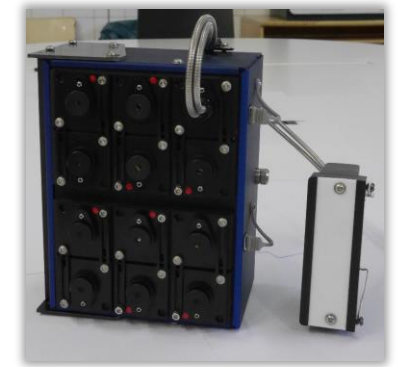


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Table 1. Summary of the most common vegetation indices, their spectral nature and possible traits targeted

Target trait	Spectral information	Vegetation indices	Applications
Vegetation cover and plot greenness	HIS color model,		Stress detection
	CIElab color model Red-Green-Blue (RGB, visible)		Canopy cover, LAI Shoot green biomass Growth dynamics Senescence Canopy greenness Agronomic and yield traits
	Red, near infrared	NDVI (Rouse et al., 1973) SAVI (Huete, 1988) OSAVI (Rondeaux et al., 1996)	Plant emergence Phenology Stress detection Chlorophyll content Leaf nitrogen content
Chlorophyll content	Green, red, near infrared	MCARI (Daughtry et al., 2000) TCARI (Haboudane et al., 2002) TCARI/OSAVI (Haboudane et al., 2002)	Shoot green biomass Senescence Canopy greenness Stress detection Chlorophyll content Leaf nitrogen content
Anthodyanin and carotenoids content	Blue, red, near infrared	ARI2 (Gitelson et al., 2001) CRI2 (Gitelson et al., 2002)	Photosynthetic status Chlorophyll content Anthocyanin and carotenoids content Leaf nitrogen content Stress detection
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Water content	Water content	WBI (Peñuelas et al., 1993) NDWI (Gao, 1996)	Plant water status monitoring

**Multispectral camera –
Tetracam micro-MCA12**
12 independent imaging
sensors + incident light
sensor



Araus, J.L., Kefauver, S.C., Vergara-Díaz, O., Gracia-Romero, A., Rezzouk, F.Z., Segarra, J., Buchailot, M.L., Chang-Espino, M., Vatter, T., Sanchez-Bragado, R., Fernandez-Gallego, J.A., Serret, M.D., and Bort, J. (2022). Crop phenotyping in a context of global change: What to measure and how to do it. *J. Integr. Plant Biol.* 64: 592–618

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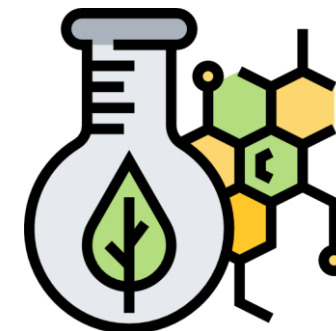


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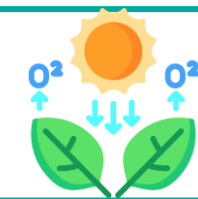


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Basis of remote sensing for plant phenotyping: Multispectral/hyperspectral information



Article

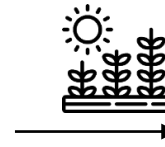
Phenotyping Conservation Agriculture Management Effects on Ground and Aerial Remote Sensing Assessments of Maize Hybrids Performance in Zimbabwe

Adrian Gracia-Romero¹, Omar Vergara-Díaz¹, Christian Thierfelder², Jill E. Cairns², Shawn C. Kefauver^{1,*} and José L. Araus¹

Gracia-Romero, A.; Vergara-Díaz, O.; Thierfelder, C.; Cairns, J.E.; Kefauver, S.C.; Araus, J.L. Phenotyping Conservation Agriculture Management Effects on Ground and Aerial Remote Sensing Assessments of Maize Hybrids Performance in Zimbabwe. *Remote Sens.* 2018, 10, 349. <https://doi.org/10.3390/rs10020349>

Southern Africa regional station of CIMMYT, Domoboshawa, Zimbabwe

8 maize hybrids



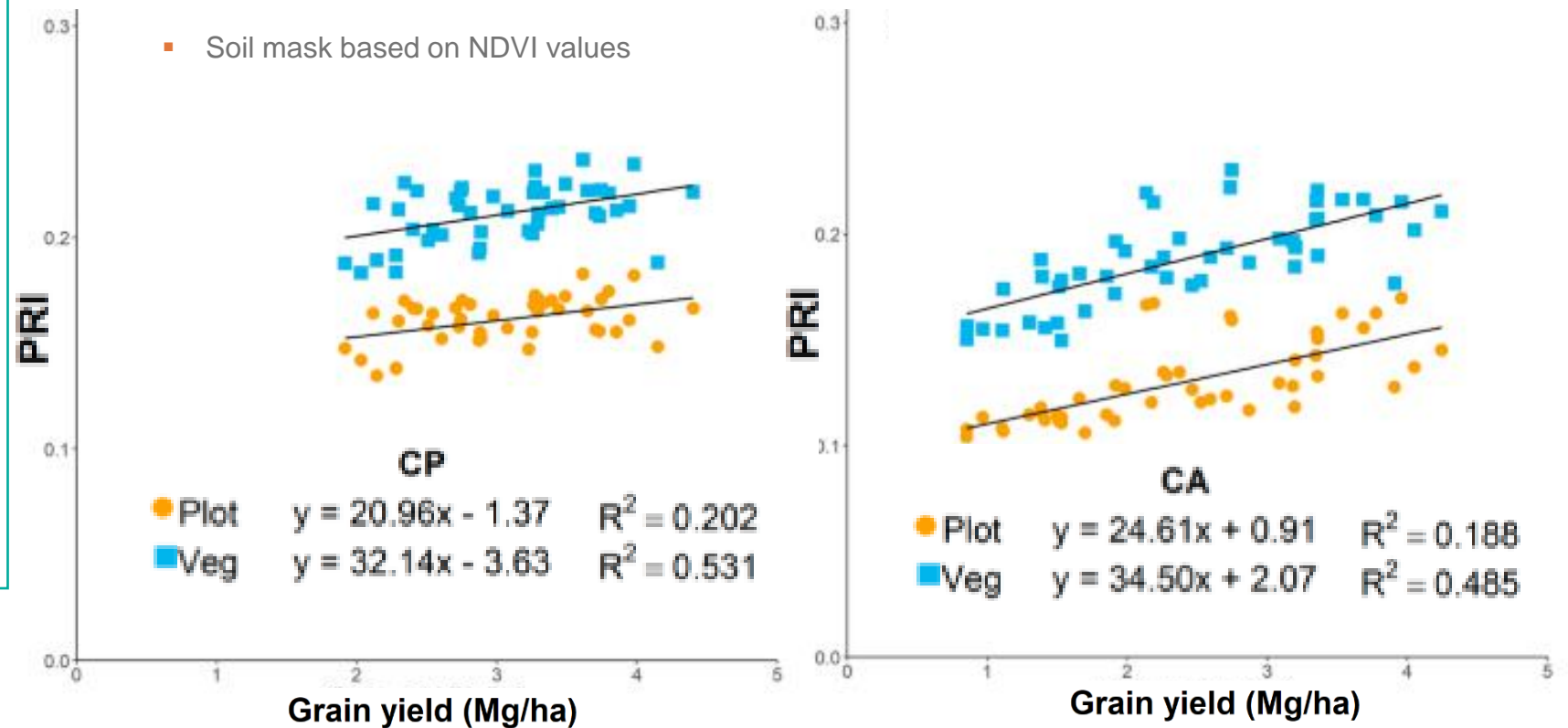
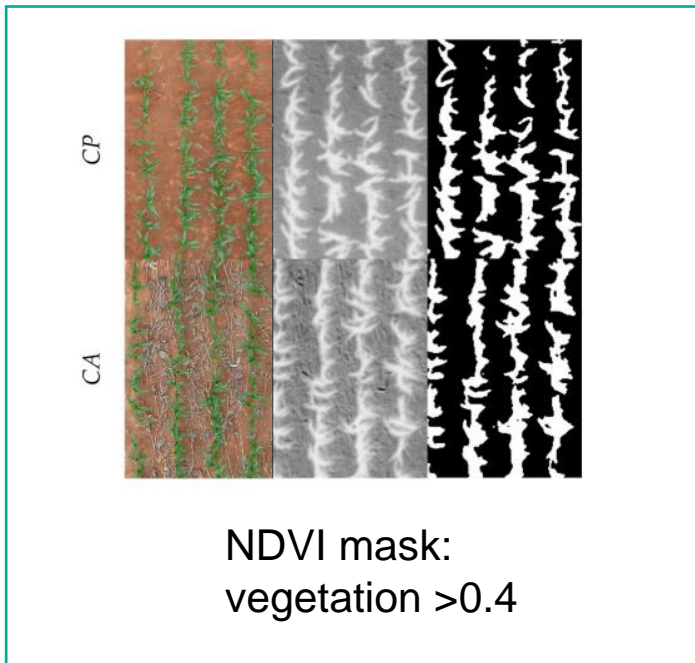
Conservation Agriculture (CA)
Conventional Ploughed (CP)



According to the FAO definition, the soil surface has to be covered at least by 30% to qualify as CA



Basis of remote sensing for plant phenotyping: Multispectral/hyperspectral information

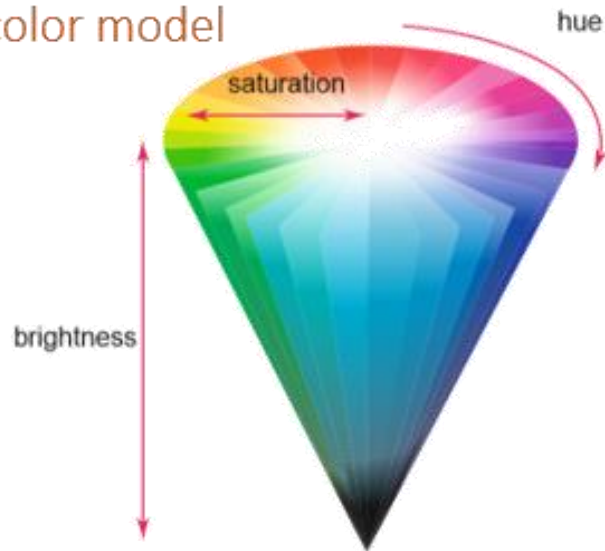


Basis of remote sensing for plant phenotyping: Conventional RGB images

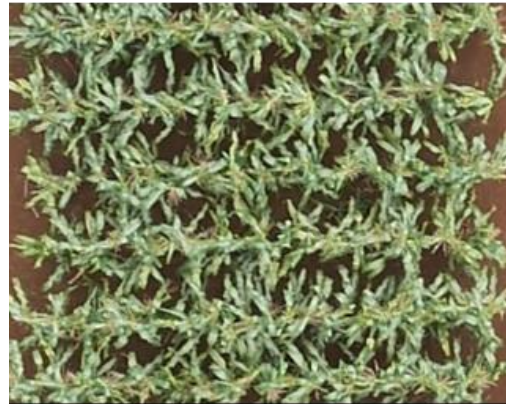


Indexes based on
greenness of the image

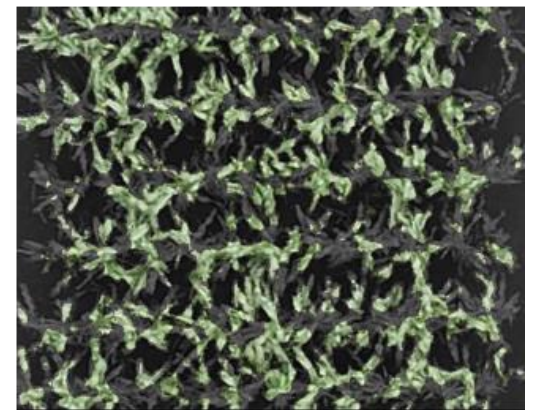
HIS color model



Green Area (GA)
(% pixels con $60^\circ < \text{Hue} < 180^\circ$)



Greener Area (GGA)
(% pixels con $80^\circ < \text{Hue} < 180^\circ$)

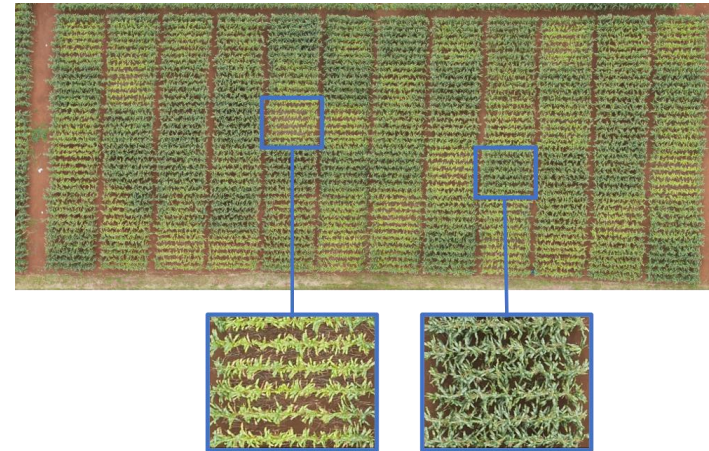


Basis of remote sensing for plant phenotyping: Conventional RGB images

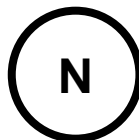
OPEN Leaf versus whole-canopy remote sensing methodologies for crop monitoring under conservation agriculture: a case of study with maize in Zimbabwe

Adrian Gracia-Romero^{1,2}, Shawn C. Kefauver^{1,2}, Omar Vergara-Díaz^{1,2}, Esnath Hamadziripi³, Mainassara A. Zaman-Allah³, Christian Thierfelder³, Boddupalli M. Prassana³, Jill E. Cairns³ & José L. Araus^{1,2,3*}

Gracia-Romero, A.; Vergara-Díaz, O.; Thierfelder, C.; Cairns, J.E.; Kefauver, S.C.; Araus, J.L. Phenotyping Conservation Agriculture Management Effects on Ground and Aerial Remote Sensing Assessments of Maize Hybrids Performance in Zimbabwe. Remote Sens. 2018, 10, 349. <https://doi.org/10.3390/rs10020349>



Southern Africa regional station of CIMMYT, Harare, Zimbabwe

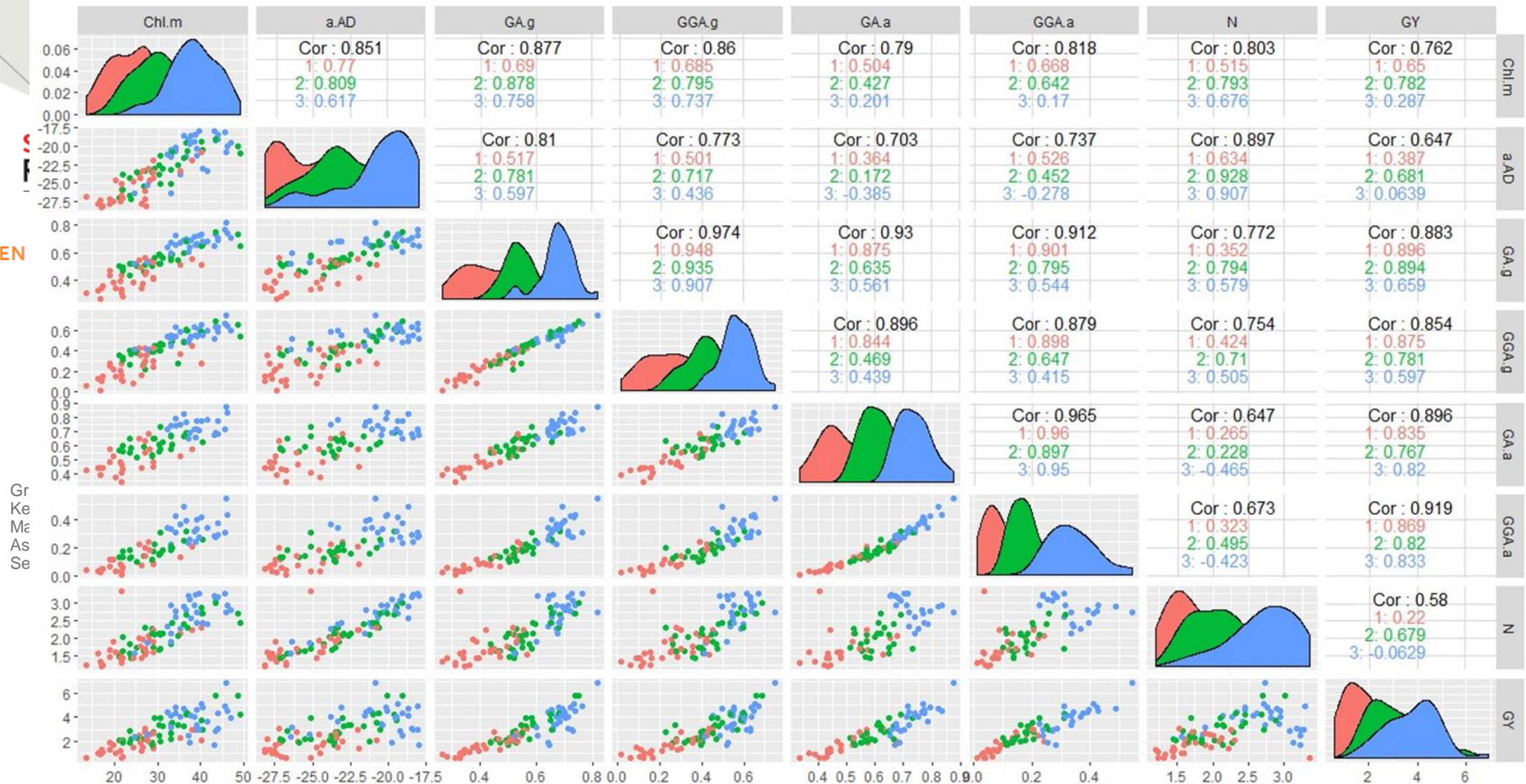


- 6 residue levels
- 3 top-dressing fertilizer levels
- Conventional tillage

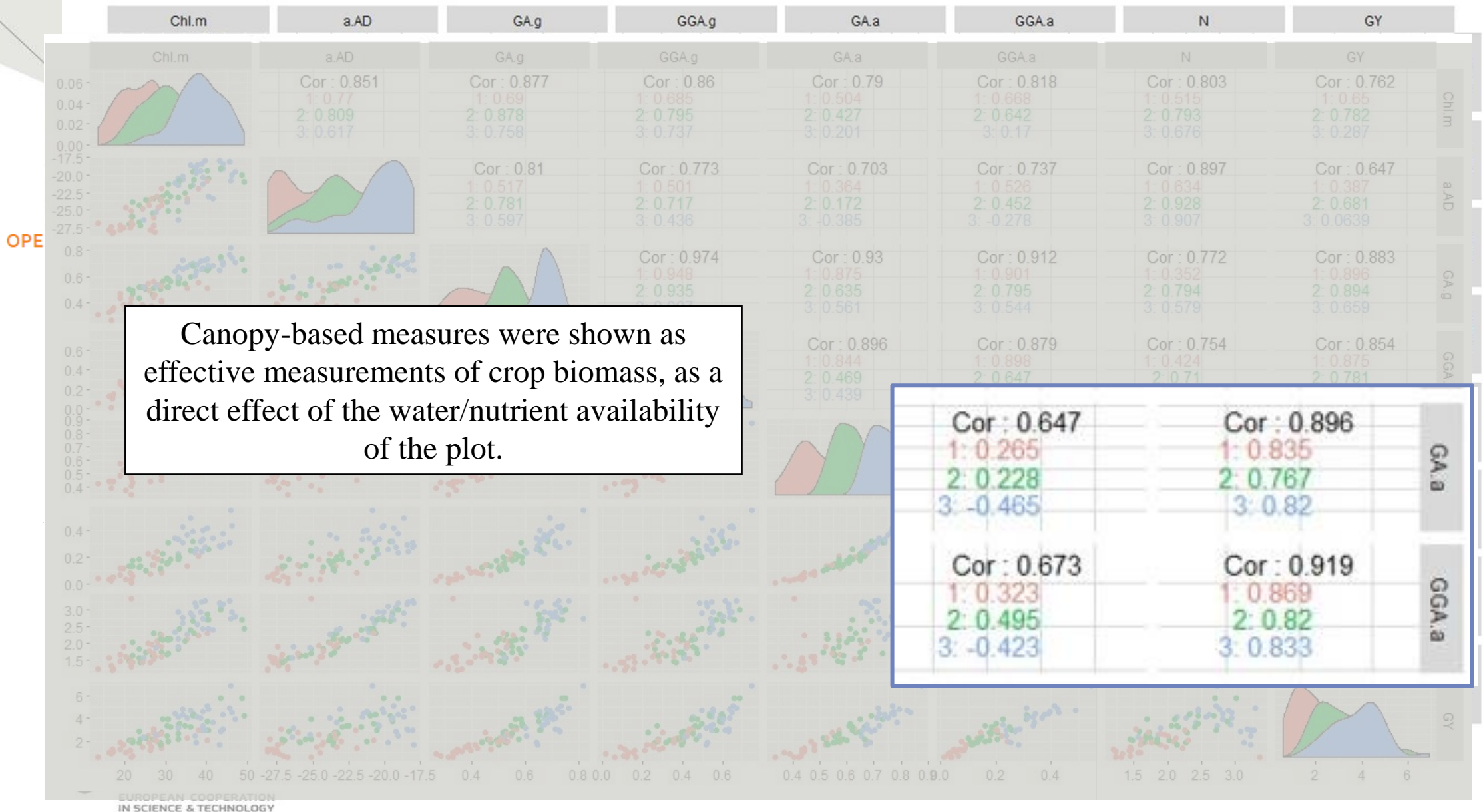


- Level of N fertilizer application

OPEN



■ Level of N fertilizer application



Canopy-based measures were shown as effective measurements of crop biomass, as a direct effect of the water/nutrient availability of the plot.

Cor: 0.647
1: 0.265
2: 0.228
3: -0.465

Cor: 0.896
1: 0.835
2: 0.767
3: 0.82

Cor: 0.673
1: 0.323
2: 0.495
3: -0.423

Cor: 0.919
1: 0.869
2: 0.82
3: 0.833



Comparative Performance of Ground vs. Aerially Assessed RGB and Multispectral Indices for Early-Growth Evaluation of Maize Performance under Phosphorus Fertilization

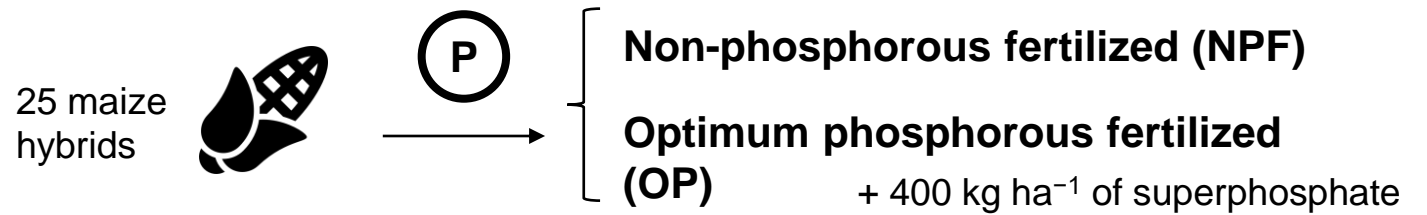
Adrian Gracia-Romero¹, Shawn C. Kefauver¹, Omar Vergara-Díaz¹, Mainassara A. Zaman-Allah², Boddupalli M. Prasanna², Jill E. Cairns² and José L. Araus^{1*}

Gracia-Romero A, Kefauver SC, Vergara-Díaz O, Zaman-Allah MA, Prasanna BM, Cairns JE and Araus JL (2017) Comparative Performance of Ground vs. Aerially Assessed RGB and Multispectral Indices for Early-Growth Evaluation of Maize Performance under Phosphorus Fertilization. *Front. Plant Sci.* 8:2004. doi: 10.3389/fpls.2017.02004



Basis of remote sensing for plant phenotyping: Conventional RGB images

Southern Africa regional station of CIMMYT, Harare, Zimbabwe



RGB mosaic





Comparative Performance of Ground vs. Aerially Assessed RGB and Multispectral Indices for Early-Growth Evaluation of Maize Performance under Phosphorus Fertilization

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Ground vs. aerial

	<i>r</i>	<i>p</i> -value
GA	0.970***	0.000***

Basis of remote sensing for plant phenotyping: Conventional RGB images

Ground level (<1 m)



Aerial level (50 m)

Basis of remote sensing for plant phenotyping: Conventional RGB images



Article

UAV and Ground Image-Based Phenotyping: A Proof of Concept with Durum Wheat

Adrian Gracia-Romero^{1,2}, Shawn C. Kefauver^{1,2}, Jose A. Fernandez-Gallego^{1,2}, Omar Vergara-Díaz^{1,2}, María Teresa Nieto-Taladriz³ and José L. Araus^{1,2,*}

¹ Integrative Crop Ecophysiology Group, Plant Physiology Section, Faculty of Biology, University of Barcelona, 08028 Barcelona, Spain; adriangraciaromero@hotmail.com (A.G.-R.); sckefauver@ub.edu (S.C.K.); fernandezgallego@gmail.com (J.A.F.-G.); omarvergaradiatz@gmail.com (O.V.-D.)

² AGROTECNIO (Center for Research in Agrotechnology), Av. Rovira Roure 191, 25198 Lleida, Spain

³ Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), Ctra. de la Coruña Km. 7.5, 28040 Madrid, Spain; mtnieto@inia.es


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Experimental field of INIA in Colmenar de Oreja, Spain

▪ 24 wheat genotypes 

▪ Well-irrigated 

▪ Rainfed 

▪ Late planting 

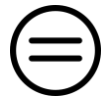
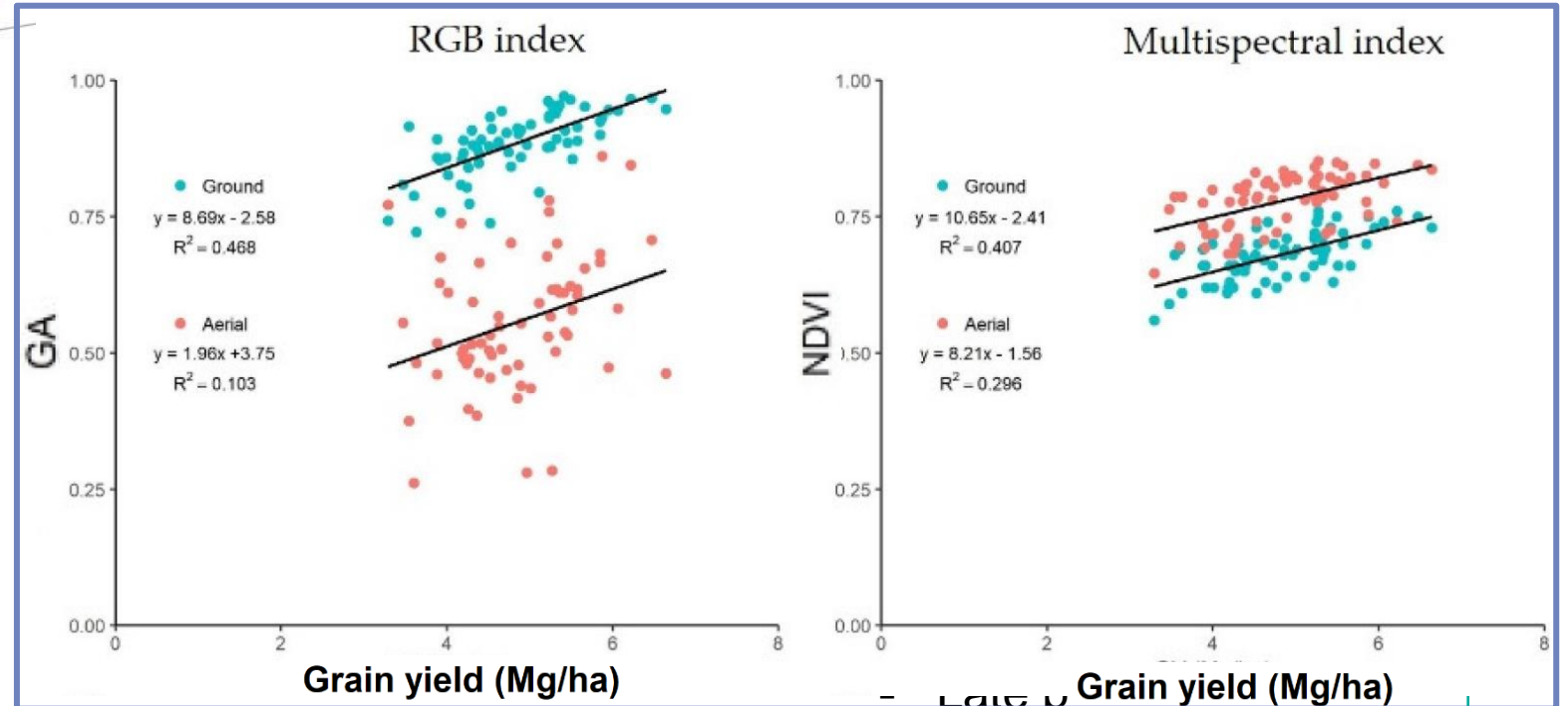




Ground level
(<1 m)



Aerial level
(50 m)



Similar performance



Whole plot assessment





Ground level
(<1 m)



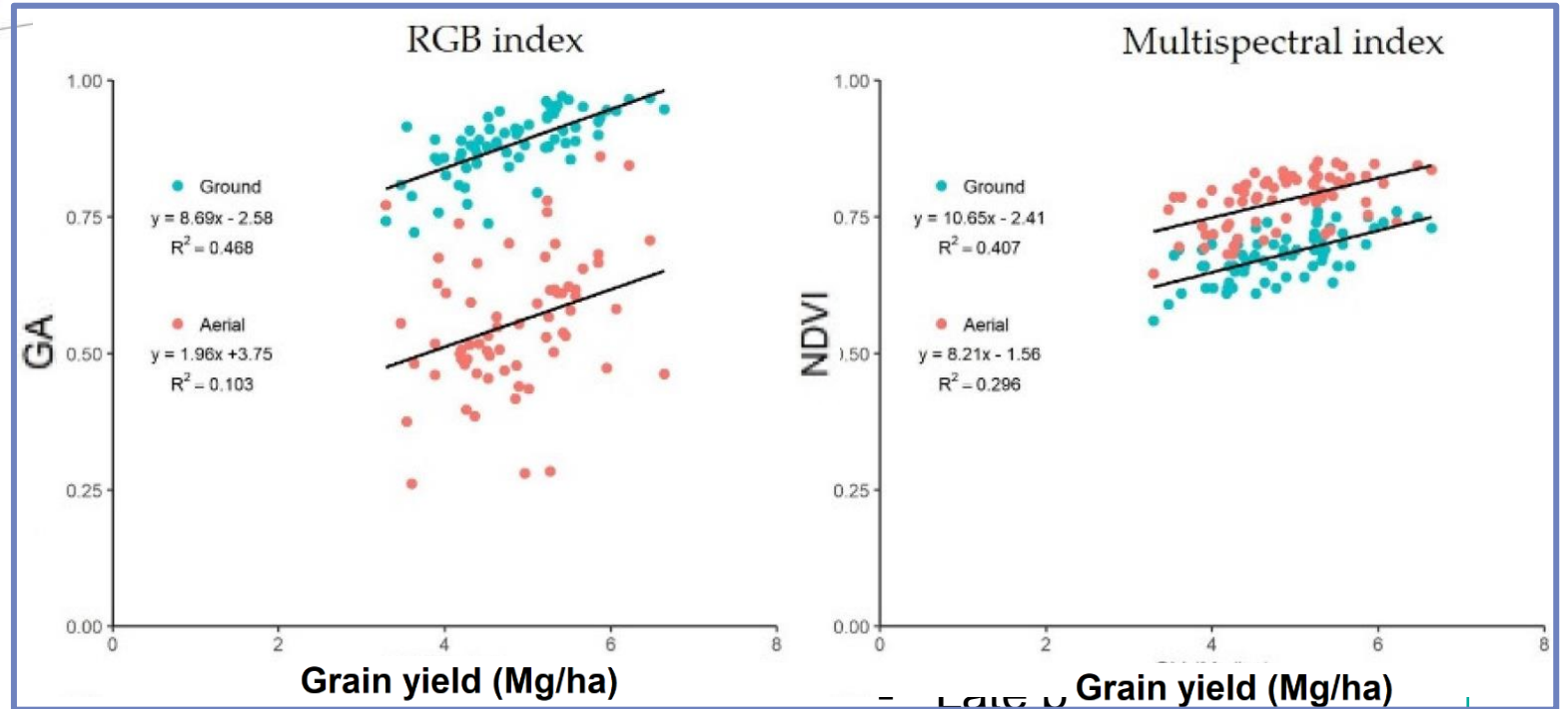
Aerial level
(50 m)



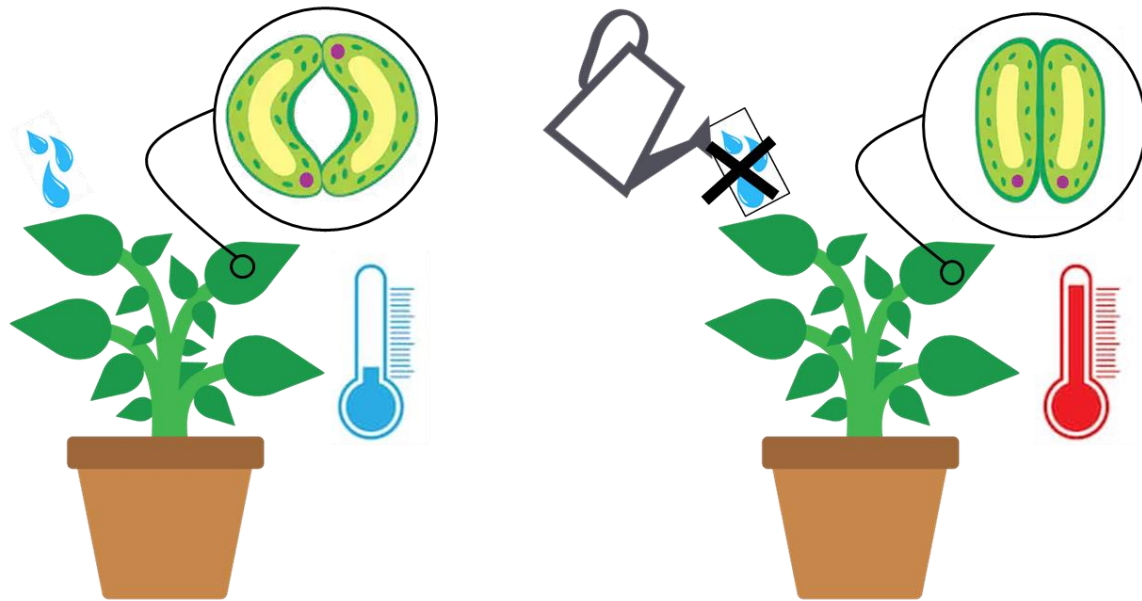
Similar performance



Whole plot assessment



Basis of remote sensing for plant phenotyping: Canopy temperature



Transpiration is one of the main factors reducing plant's temperature

Basis of remote sensing for plant phenotyping: Canopy temperature



Article

UAV and Ground Image-Based Phenotyping: A Proof of Concept with Durum Wheat

Adrian Gracia-Romero ^{1,2}, Shawn C. Kefauver ^{1,2}, Jose A. Fernandez-Gallego ^{1,2}, Omar Vergara-Díaz ^{1,2}, María Teresa Nieto-Taladriz ³ and José L. Araus ^{1,2,*}

¹ Integrative Crop Ecophysiology Group, Plant Physiology Section, Faculty of Biology, University of Barcelona, 08028 Barcelona, Spain; adriangraciaromero@hotmail.com (A.G.-R.); sckefauver@ub.edu (S.C.K.); fernandezgallego@gmail.com (J.A.F.-G.); omarvergaradiaz@gmail.com (O.V.-D.)

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Experimental field of INIA in Colmenar de Oreja, Spain

- Well-irrigated 
- 24 wheat genotypes 
- Rainfed 
- Late planting 





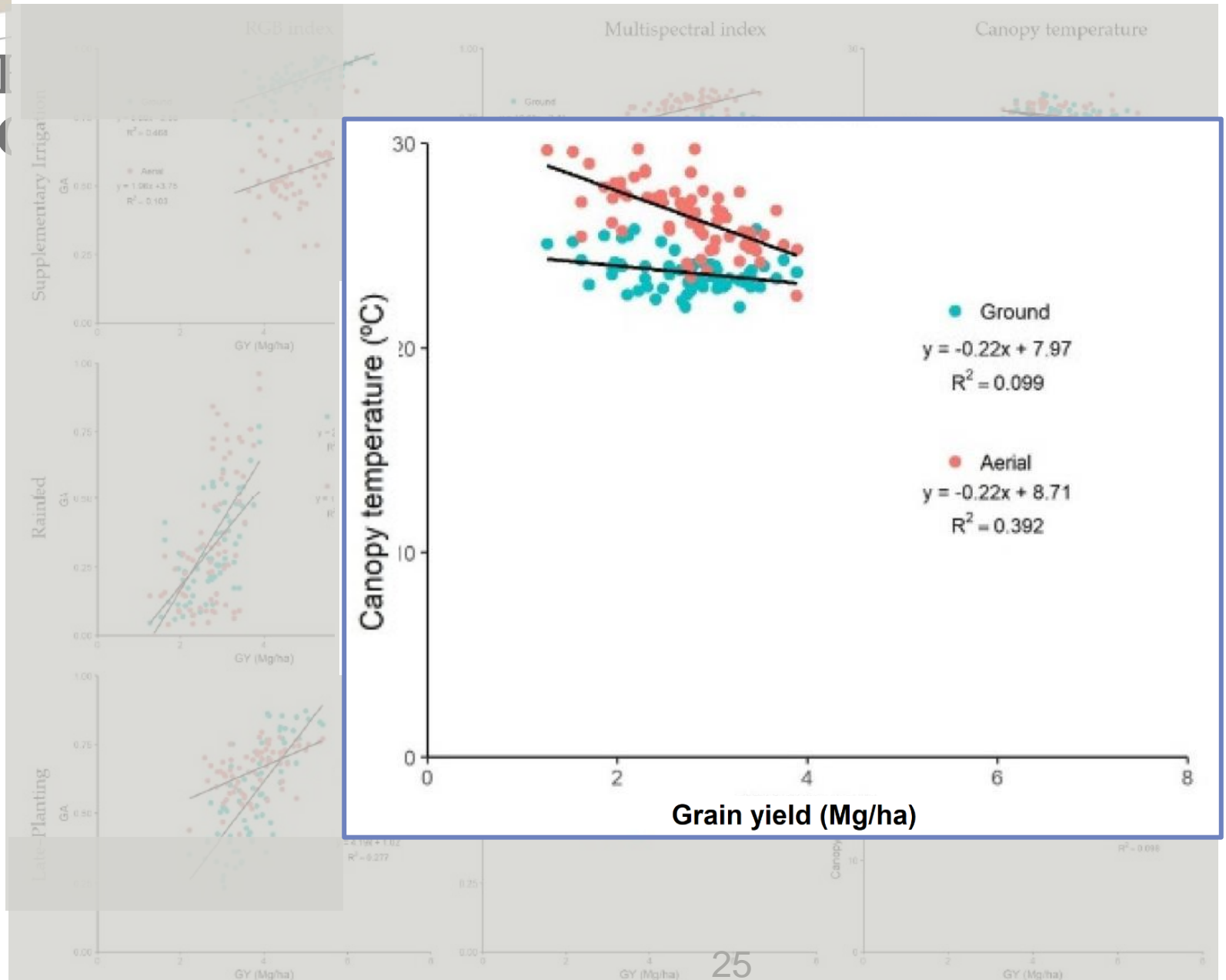
Ground level
(<1 m)



Aerial level
(50 m)



Faster assessment of
large number of plots



Development of applications to facilitate the transfer of information from the platform



MosaicTool

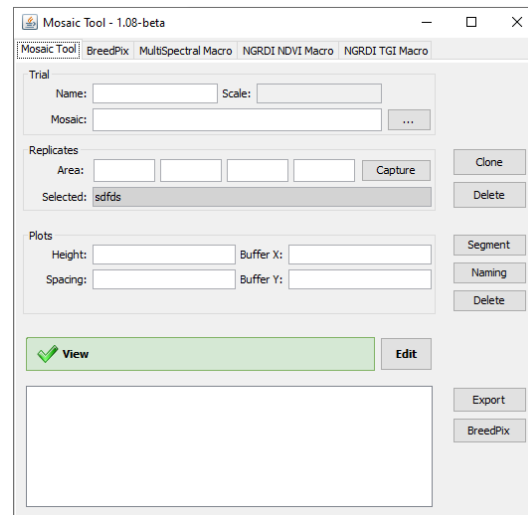
Project ID: 3184730

Uav Crop Phenotyping Multispectral Rgb + 2 more

28 Commits 1 Branch 0 Tags 10.6 MB Files 10.6 MB Storage

Data extraction and processing workflow for RGB, VNIR and TIR UAV crop phenotyping.

- Dr. Shawn Kefauver
 - Project Principal Investigator, [University of Barcelona](#)
- Adrian Gracia-Romero, [University of Barcelona](#)
- Prof. José Luis Araus, [University of Barcelona](#)
- George El-Haddad
 - Software Engineer, [Postlight](#)

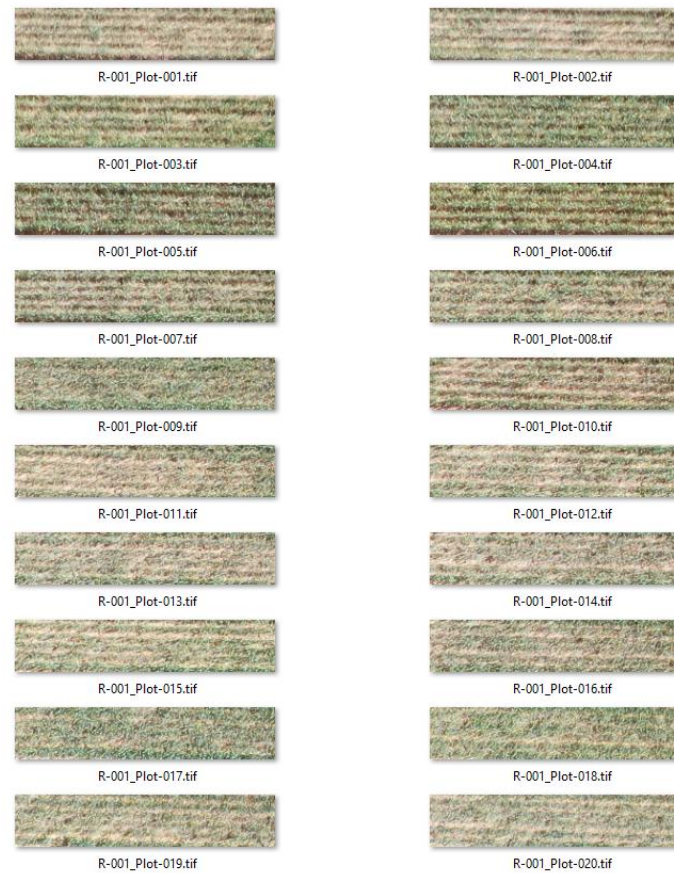
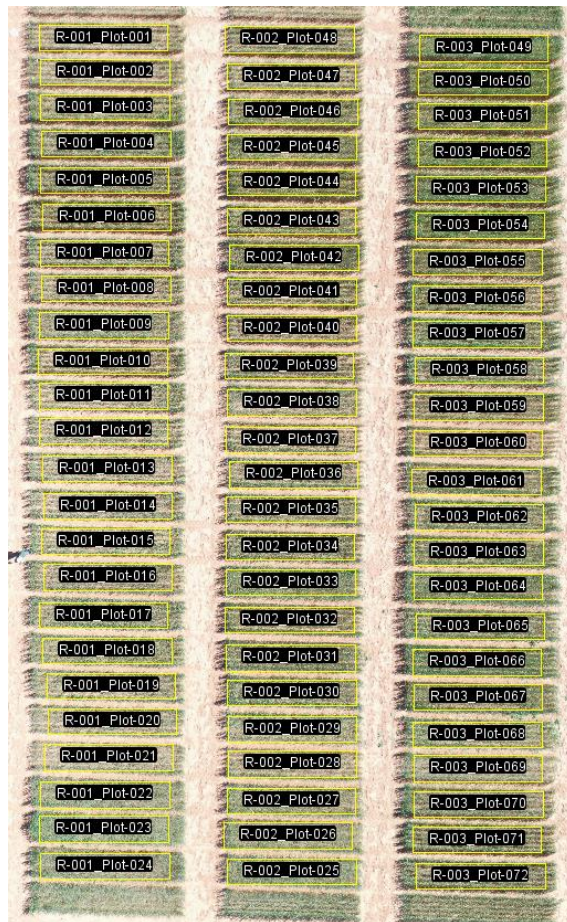


Semi-automatic segmentation of aerial images and to formulate VIs for both RGB, multispectral and thermal images

Scan the QR to get more info and download “MosaicTool”



Development of applications to facilitate the transfer of information from the platform

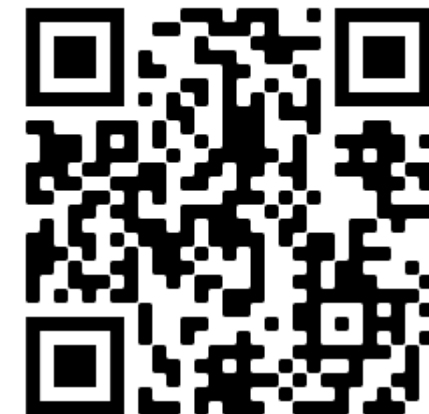


MosaicTool

Project ID: 3184730

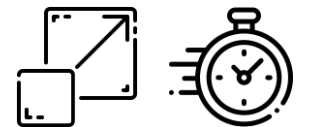
Uav Crop Phenotyping

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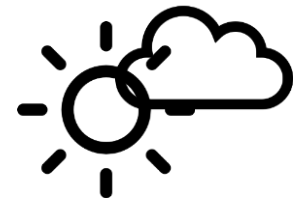
Conclusions and take-home messages

- Imaging methodologies play a vital role for the phenotyping data collection of complex traits related to the growth, yield and adaptation to abiotic stress.
- Increasing the throughput capacity of phenotyping platforms is key for reducing the efforts associated to measuring elevated numbers of plots in a frequent basis.
- UAVs present an excellent opportunity to monitor large areas with high spatial and temporal resolution.



Conclusions and take-home messages

- Advances in remote sensing technologies have enhanced the phenotyping process through the development of low-cost and easy-to-handle tools.
- Incorporating imaging methodologies into aerial-based platforms permits to cover larger experimental areas in less time, minimizing the temporal variation in environmental variables.



Acknowledgements

Integrative Crop Ecophysiology Group

José Luis Araus – Shawn C. Kefauver – Rut Sanchez-Bragado
Omar Vergara – Fadia Chairi – Jose A. Fernandez Gallego
Luisa Buchailot – Fatima Zahra Rezzouk – Joel Segarra – Melissa Chang
Susan Medina – Cristina Caldelas
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<https://integrativecropecophysiology.com/about/>




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Moltes gràcies per la vostra atenció
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Many thanks for your attention

