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Evaluating the performance of different commercial and pre-commercial maize varieties under low nitrogen conditions using affordable phenotyping tools

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CIMMYT

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Introduction

- Maize
  - Important in Africa (FAO, 2017)
- Low Nitrogen
  - Low N and low money in Africa (Cairns et al., 2013)
- Breeding Strategy
  - Breeding genetic gains specific to low N

AIM

We evaluated the selection of maize varieties using a set of remote sensing indices derived from RGB images acquired from a UAV (Unmanned Aerial Vehicle) and at the ground level compared with the performance of the field-based NDVI and SPAD sensors, and then we tested their capacity for yield estimation both alone and in combination with standard agronomical variables, such as ASI (Anthesis Silking Data), AD (Anthesis Data), and Plant Height (PH).

Materials and Methods

Case Study

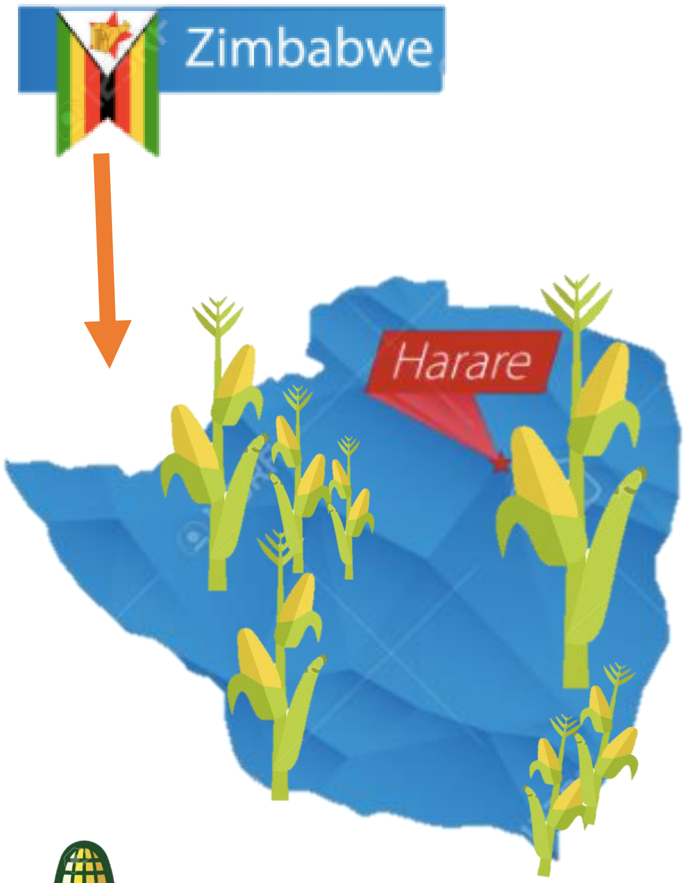
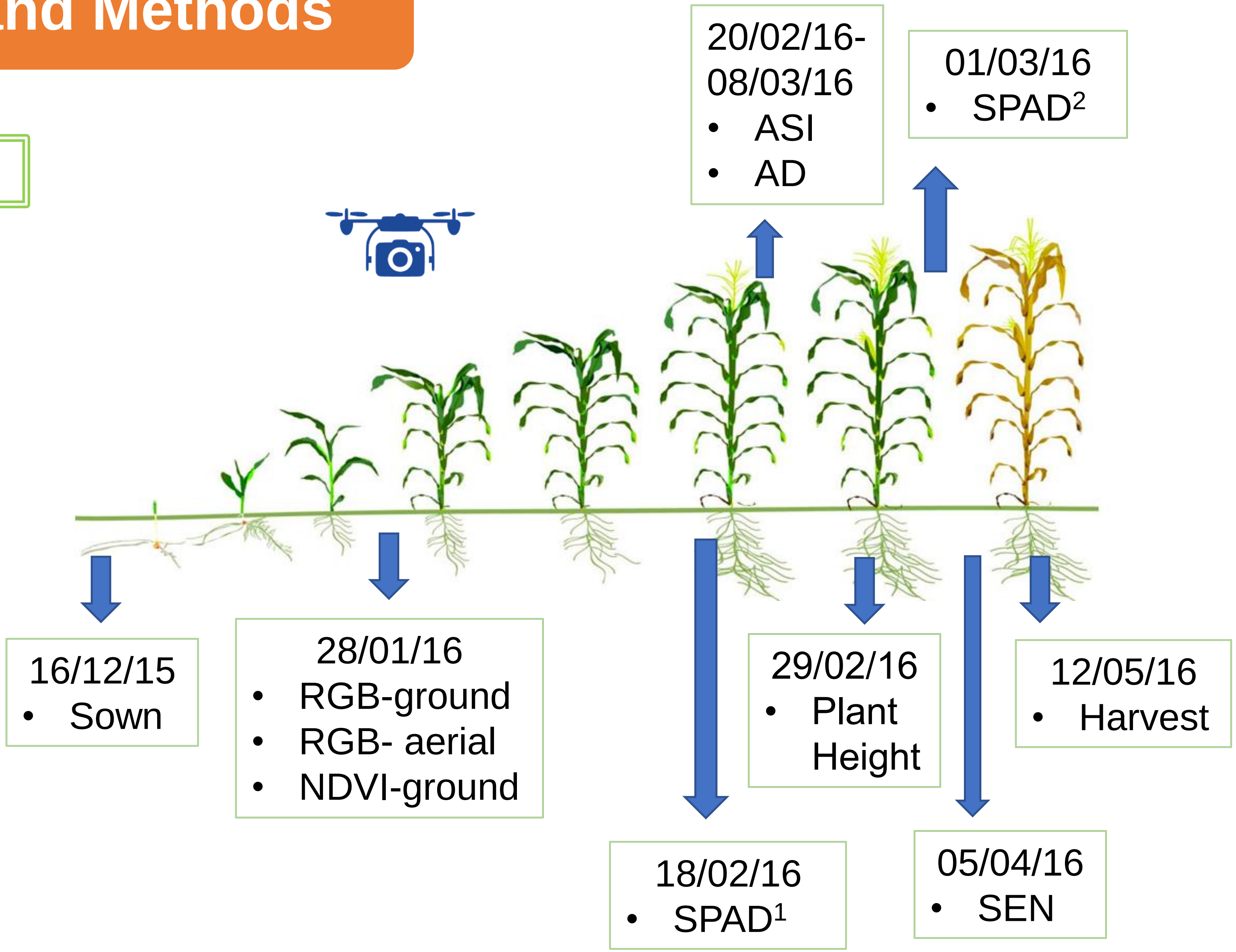


Figure 1. RGB aerial orthomosaic of the plot images under managed low nitrogen.

- December 2015- May 2016
- 49 pre-commercial varieties of Centro Internacional de Mejoramiento de Maiz Y Trigo (CIMMYT).
- 15 commercial varieties of private company.
- In Low managed nitrogen
- 192 plots (5.25m^2) with 3 replica per varieties

Materials and Methods

Plot Sampling



Materials and Methods

Remote Sensing

RGB images at ground level

Taken with an Olympus OM-D, holding the camera about 80 cm.

RGB images at aerial level

Taken with an UAV Mikrokopters OktoXL, flying under remote control at about 50 m. The digital camera used for aerial imaging was a Lumix GX7, Panasonic.

Materials and Methods

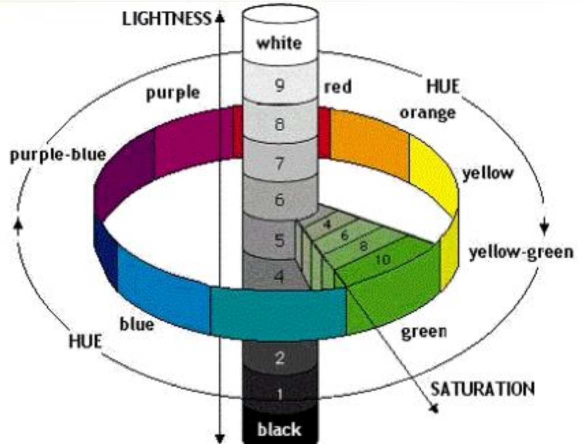
Image processing → **FIJI** → **Maize Scanner**

Maize Scanner → **Breedpix**, **Canopy Macros**

Breedpix

(Casadesús et al., 2007)

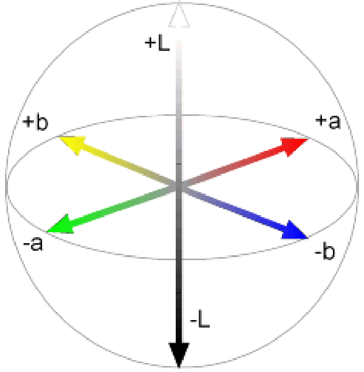
HIS color space



- Green Area (GA) (pixels with 60 º < Hue < 180º)
- Greener Green Area (GGA) (pixels with 80º < Hue < 180º)
- Crop senencence index (CSI) $\frac{100 \times (GA - GGA)}{GA}$

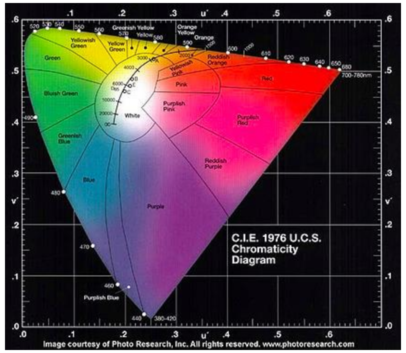
(Zaman-Allah et al., 2015)

Cie-Lab



- a*
- b*

Cie-Luv



- u*
- v*

Canopy Macros

$$Triangular\ Greennes\ Iindex\ (TGI) = -0.5\ [190(R670 - R550) - 120(R670 - R480)]$$

(Hunt et al., 2012)

$$Normalized\ Green - Red\ Difference\ Index\ (NGRDI) = \frac{(Green\ DN - Red\ DN)}{(Green\ DN + Red\ DN)}$$

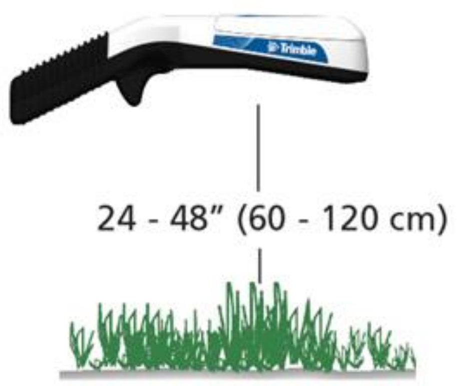
(Hunt et al., 2005)

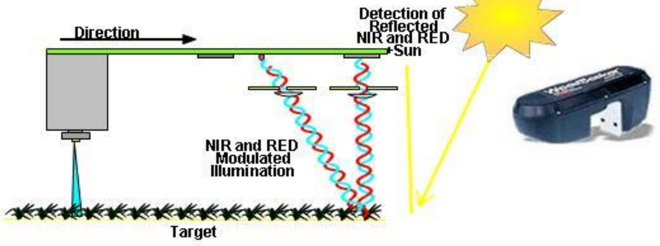
Materials and Methods

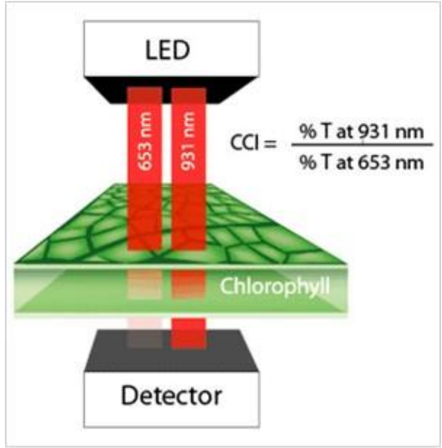
Field Sensors

Relative Chlorophyll Content measured with Minolta SPAD-502 chlorophyll meter

Normalized Difference Vegetation Index (NDVI) measured with GreenSeeker







NDVI = (R840-R670)/(R840+R670) (Rouse et al., 1973)

Results and Discussion

The effect of optimal condition and low managed nitrogen on grain yield.

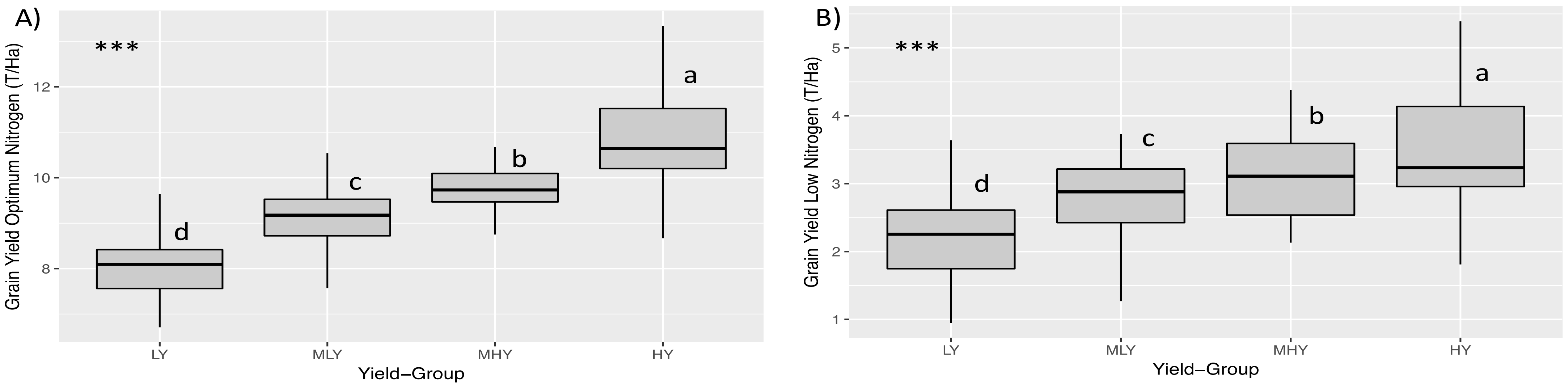


Figure 2. LY (Low Yield), MLY (Medium Yow yield), MHY (Medium High Yield) and HY (High Yield) maize variety in two different conditions: (A) Optimum Nitrogen (OP) and (B) Low Nitrogen (LOW). Each value is the mean ± SD for each genotype (n= 48 per quartile with 16 different variety). Bars with the different letters are significantly at P<0.001.

Results and Discussion

Performance of remote sensing indices and field sensors assessing grain yield

Table. 3 Grain yield correlations with all proximal remote sensing variables from the RGB images taken from the UAV aerial platform, RGB images from the ground, and SPAD and NDVI field sensors. These indices are defined in the Introduction and Materials and Methods. Levels of significance: *, *P* < 0.05; ***, P<0.001.

GY								
RGB indices/ aerial	R	*P*	**RGB indices/ ground**	R	*P*	**Additional Field Sensors**	R	*P*
GGA	0.1978	***	GGA	0.2339	***	SPAD[1] (18/02/16)	0.2936	***
GA	0.1659	***	GA	0.2175	***	SPAD[2] (01/03/16)	0.2564	***
Hue	0.1449	***	Hue	0.2351	***	NDVI	0.1404	***
Intensity	0.0932	***	Intensity	0.0090				
Saturation	0.1819	***	Saturation	0.0515	*			
Lightness	0.0848	***	Lightness	0.0208	*			
a*	0.1275	***	a*	0.1467	***			
b*	0.1573	***	b*	0.0080				
u*	0.1470	***	u*	0.2021	***			
v*	0.0884	***	v*	0.0002				
CSI	0.1830	***	CSI	0.1031	***			
TGI	0.0527	*	TGI	0.0019				
NGRDI	0.1645	***	NGRDI	0.0007				

Results and Discussion

Multivariate Yield Estimations

Measurement Combinations	R^2	*P*
RGB ground + Field sensors	0.403	***
RGB aerial + Field sensors	0.384	***
Agronomic + RGB ground	0.559	***
Agronomic + RGB aerial	0.560	***

Table 5. Multilinear regression (stepwise) of Grain Yield (GY) as the dependent variable the different categories of remote sensing traits RGB ground and aerial level (these indices are defined in the Introduction), agronomic data like ASI (Anthesis Silking Interval), AD (Anthesis Data), MOI (Moisture), SEN (Canopy Senescence) and PH (Plant Height) NDVI (Normalized Different Vegetation Index) and SPAD (relative chlorophyll content). R^2, determination coefficient; Level of significance: ***; $P<0.001$.

Conclusions

- Maize hybrid technology may show promise for improving much-needed GY in low N environments and the current range of variability in performance suggests the possibility of potential for further improvements.
- For HTPP, RGB sensors can be considered as functional technology from the ground or a UAV, but also, similar to SPAD, NDVI or any other agronomic or general plant physiological measurement
- Measurements must be carefully planned for an adequate growth stage in order to optimize their benefits to plant breeding. Possible gains with new technologies with regards to equipment and time costs, especially in larger breeding platforms.
- We need to take advantage of known effects of low N on physiological processes to focus our efforts to bring HTPP to low N breeding.

Acknowledgements

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