Field phenotyping for water-limited conditions

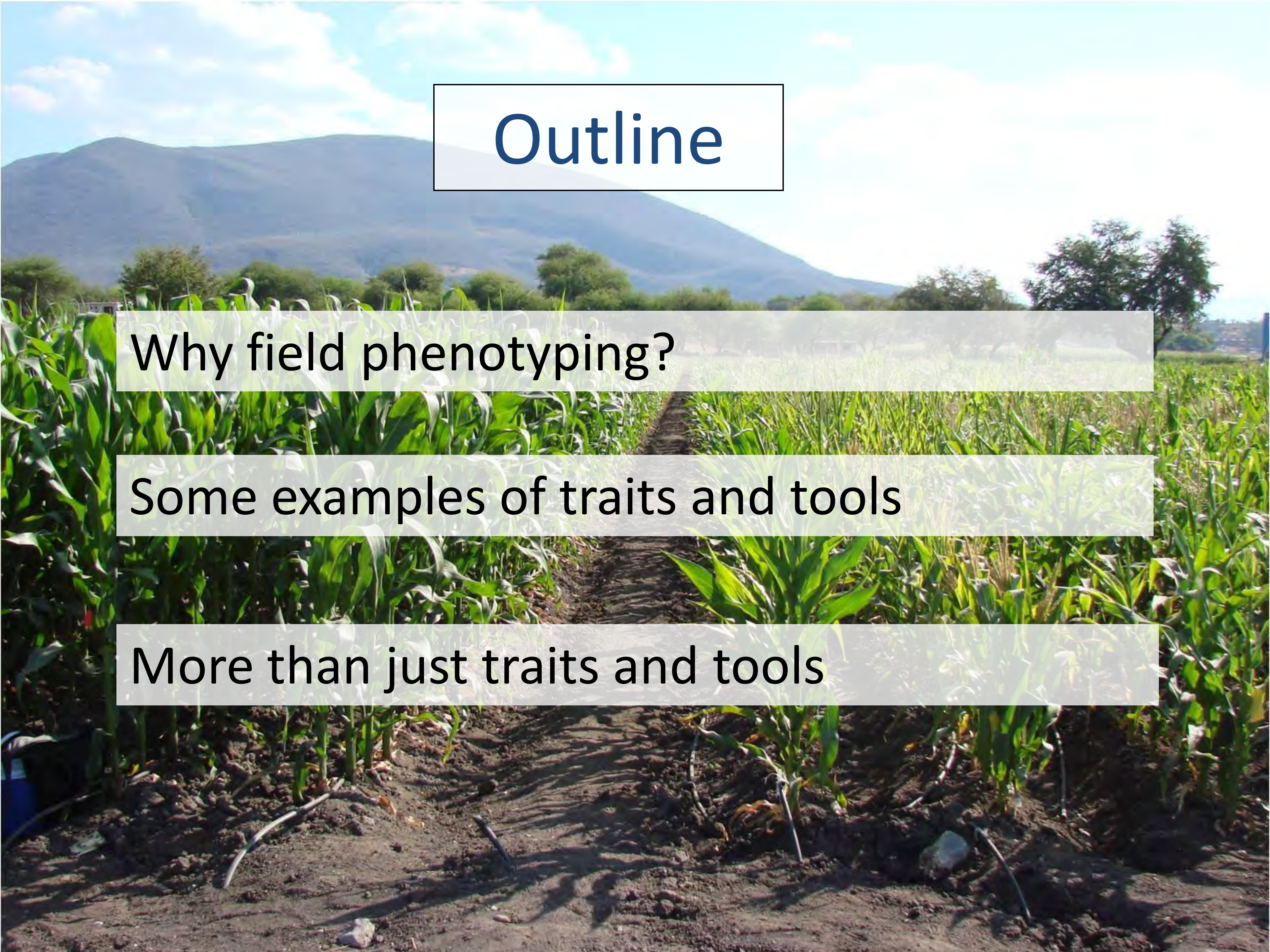
"Genomic, physiological and breeding approches for enhancing drought resistance in crops

Field phenotyping for water-limited conditions

J.L. Araus, J. Bort, M.D. Serret, J.E. Cairns

UNIVERSITAT DE BARCELONA

CIMMYT



Outline

Why field phenotyping?

Some examples of traits and tools

More than just traits and tools

Outline

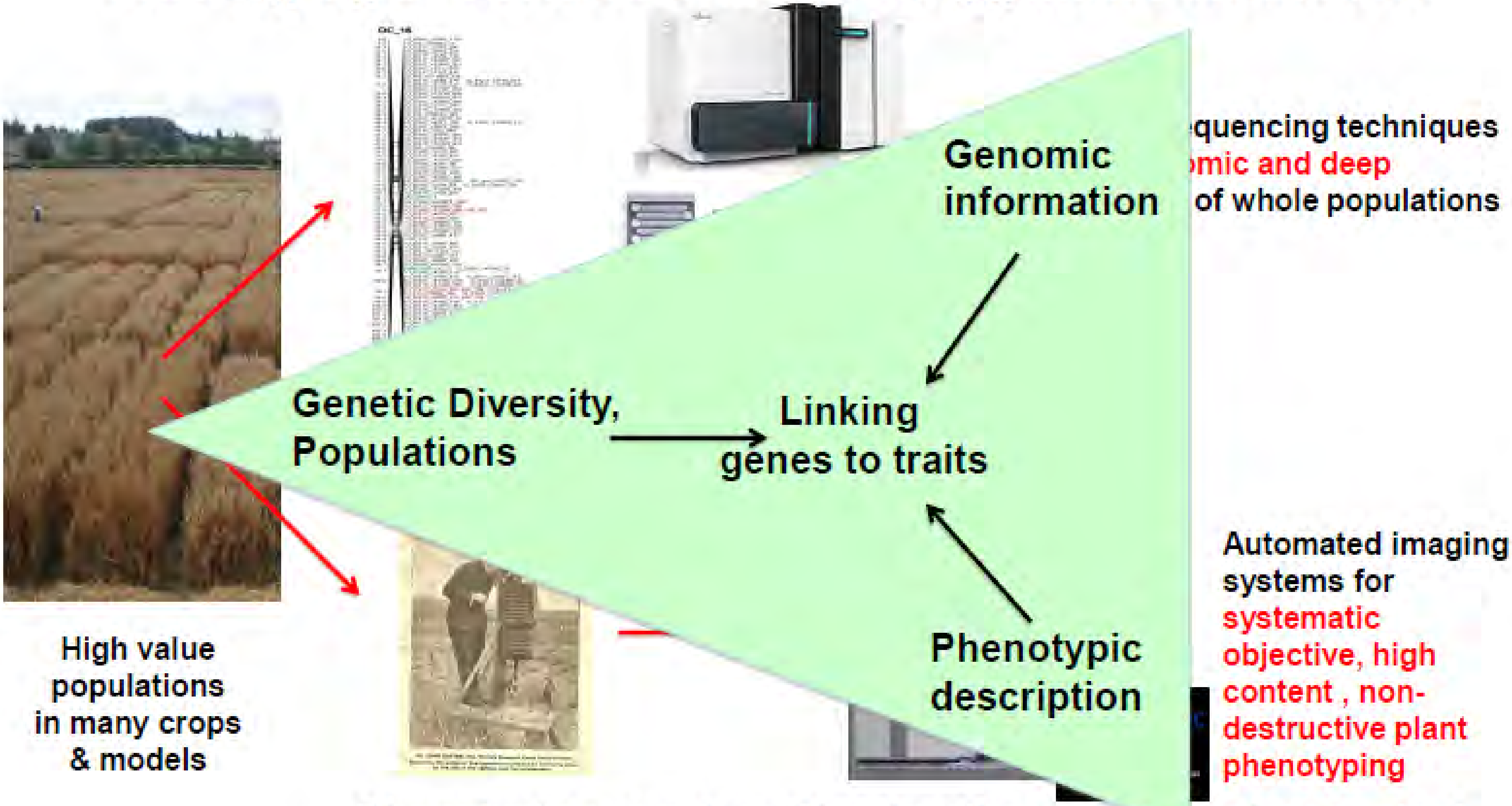
Why field phenotyping?

Some examples of traits and tools

More than just traits and tools

What is phenomics and why do we need it?

Phenotyping as a bottleneck in exploiting genomic information



Phenotyping remains either low throughput, or low content, and can be variably subjective – needs a step change to match genomics

Phenomic platforms

automated
plant phenotyping facility

LemnaTec

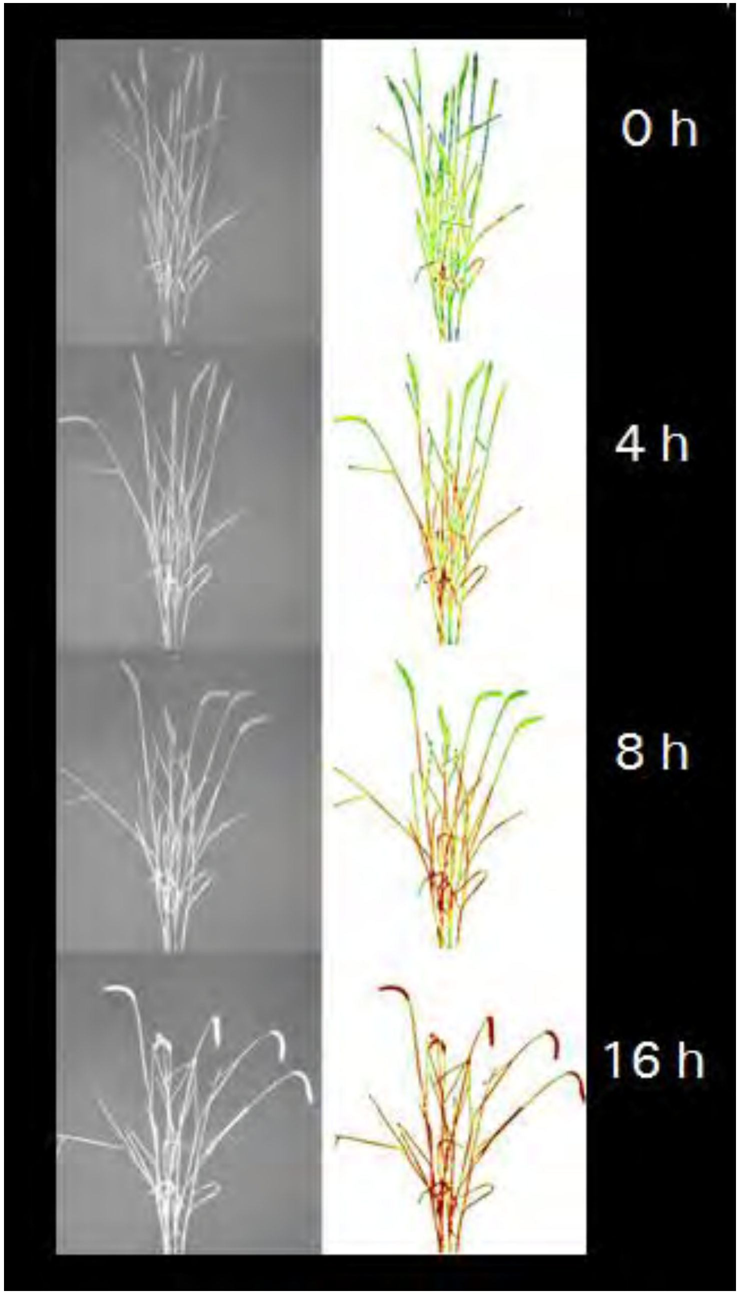


Figure 1: A bunch of wheat dries down in warm ambient conditions. NIR-imaging shows a strong increase in reflectance as the water in the leaves is extremely reduced. Blue/green false colours represent high water content, while yellow/red colours symbolize low water content (high reflectance).

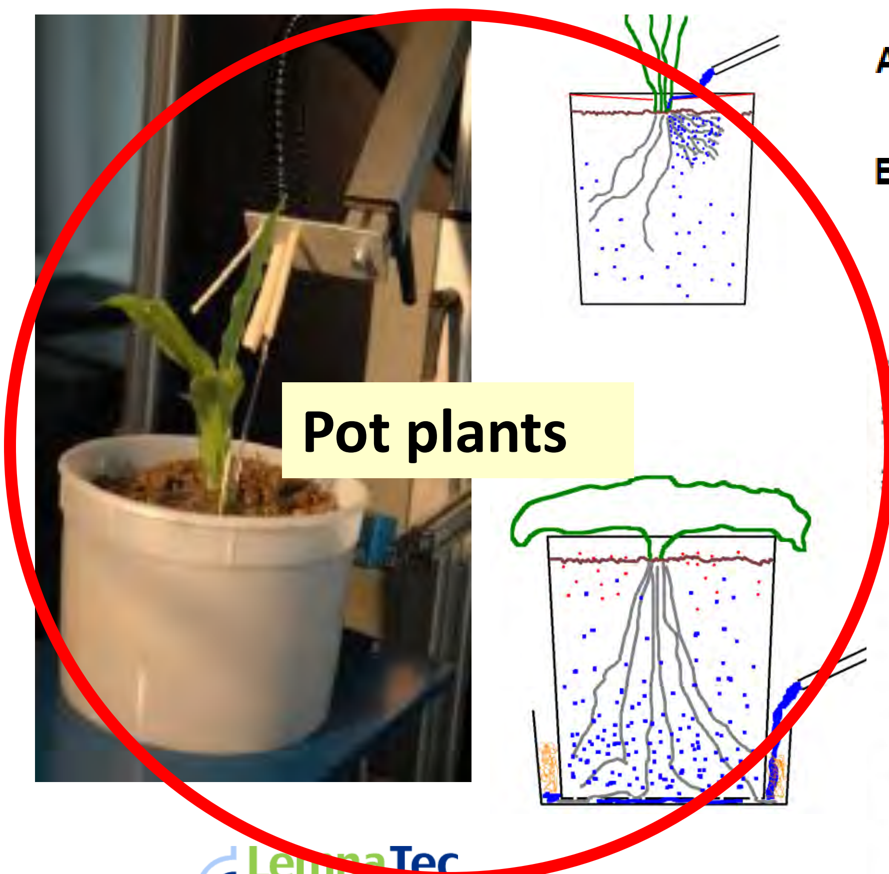
High Resolution Plant Phenomics

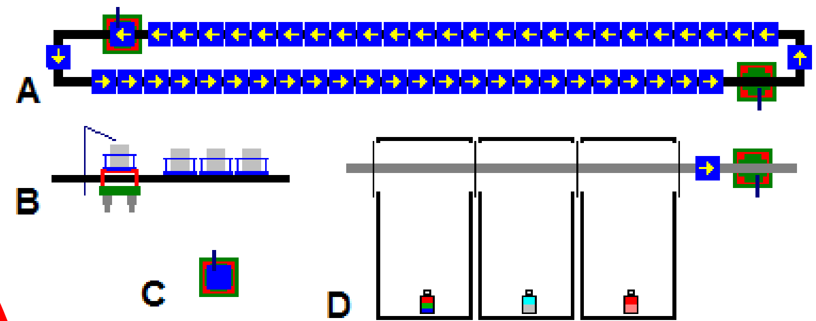
The Plant Accelerator

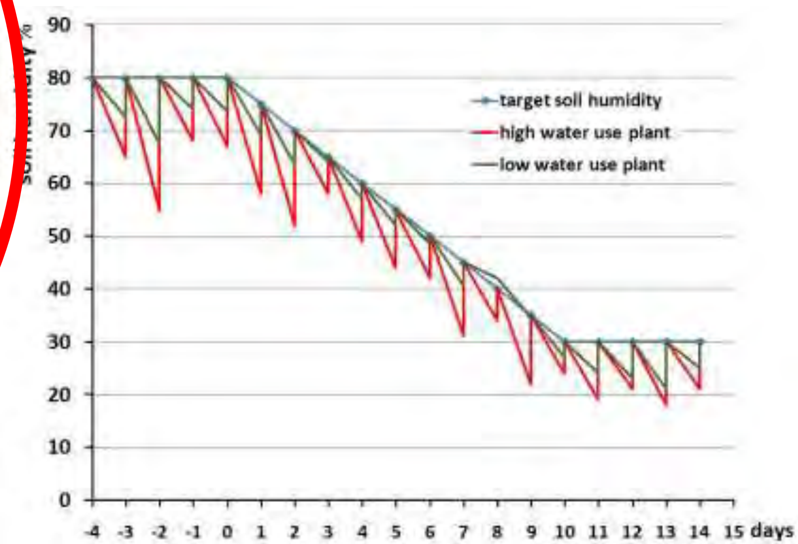
http://www.plantphenomics.org.au/

Phenomic platforms

- **Watering and precision stress management**







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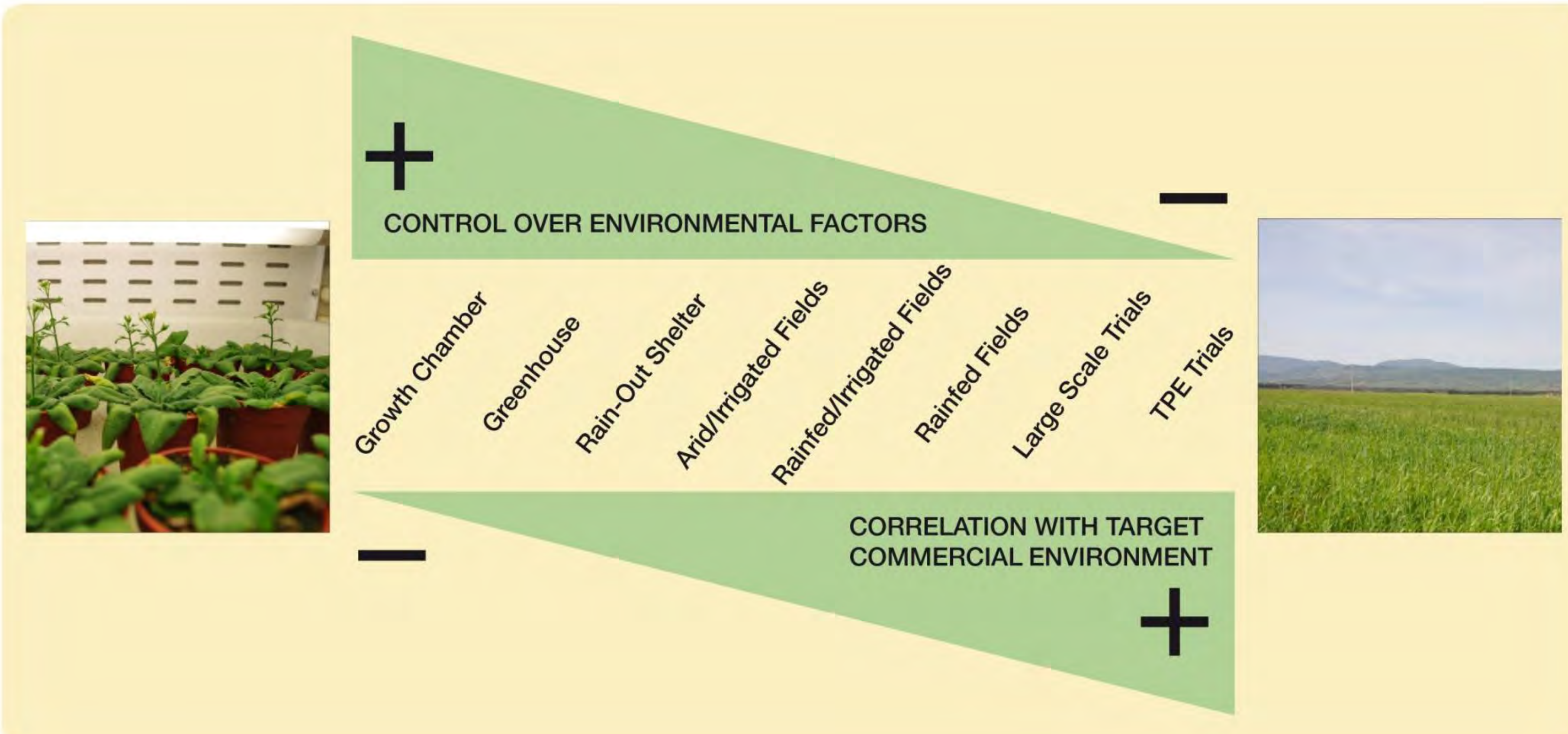


+
CONTROL OVER ENVIRONMENTAL FACTORS
—
Growth Chamber
Greenhouse
Rain-Out Shelter
Arid/Irrigated Fields
Rainfed/Irrigated Fields
Rainfed Fields
Large Scale Trials
TPE Trials
—
CORRELATION WITH TARGET
COMMERCIAL ENVIRONMENT
+

“It’s one thing to use a glasshouse for a trait that is expressed early in development and at the individual plant level, but a lot of traits that we are interested in are expressed at the community scale, which means you have to be working in field plots”

CSA News March 2013

Outline

Why field phenotyping?

Examples of traits and tools

More than just traits and tools

Yield Components

General Determinant

Yield = IR x AR x PE x HI

Photosynthetic Efficiency

Biomass

In Water-limiting Conditions (*Passioura 1977*)

Yield = W x WUE x HI

Water use efficiency

Water use

Different categories of traits

J.W. White et al. / Field Crops Research 133 (2012) 101–112 105

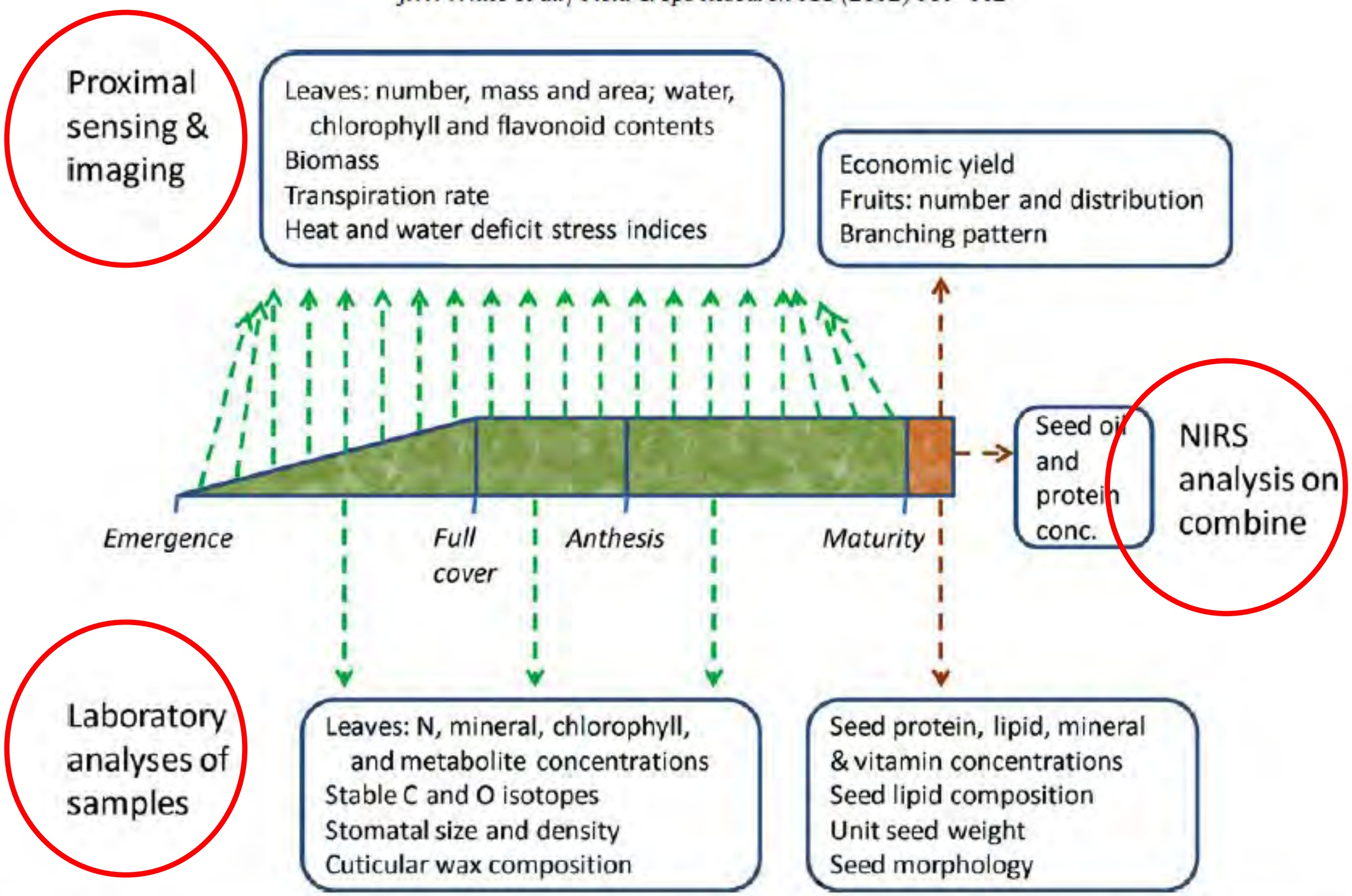
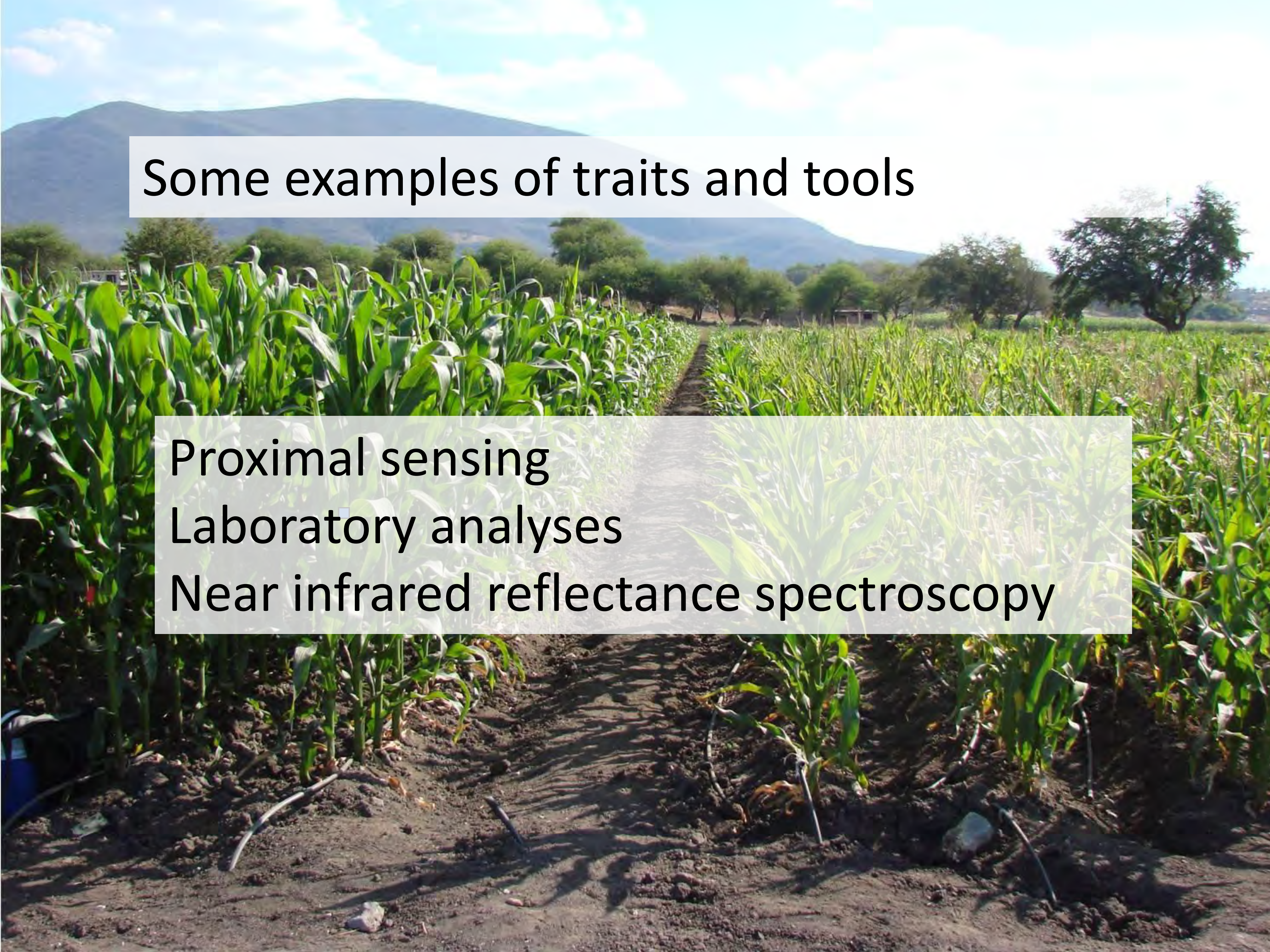
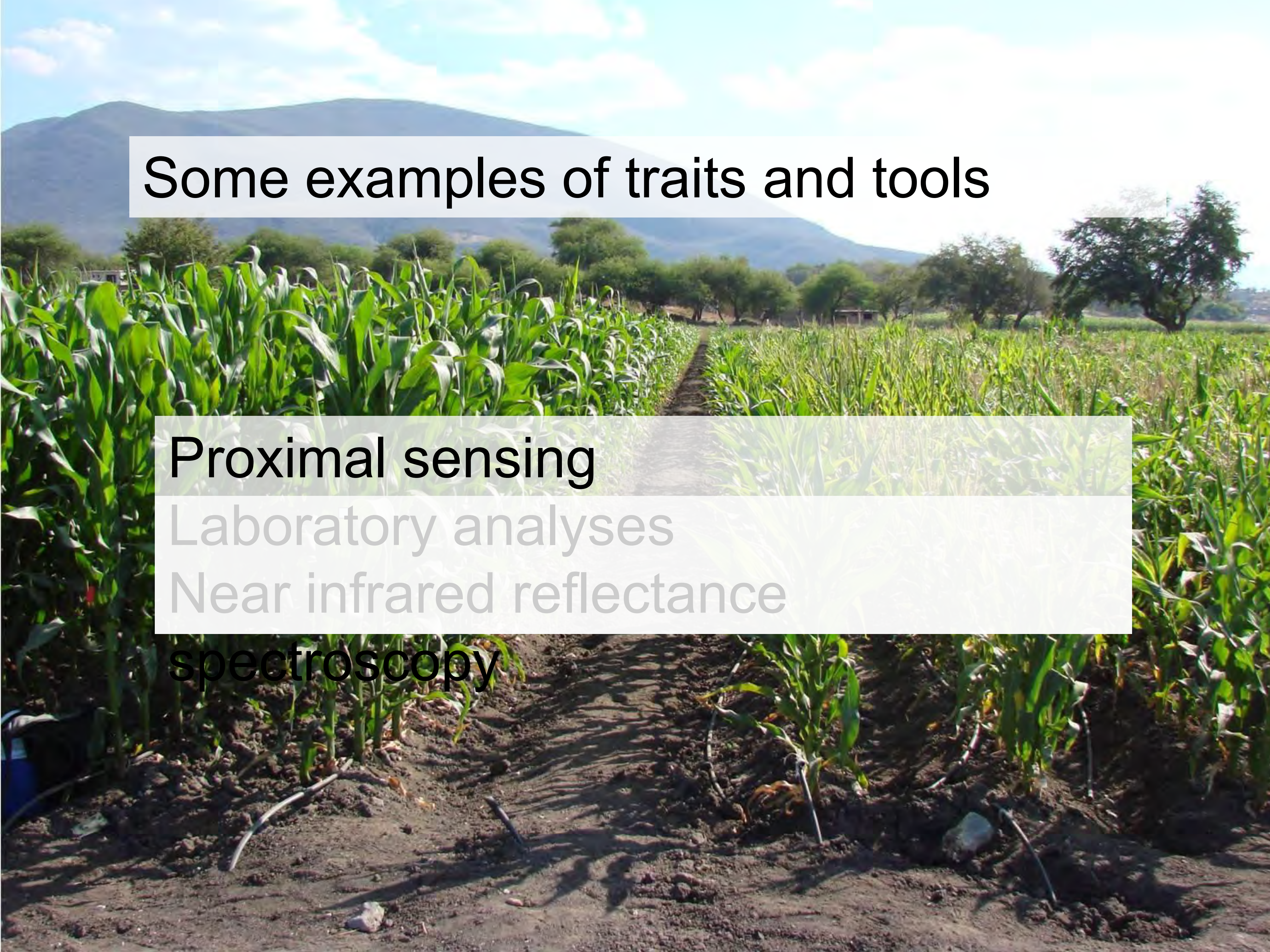


Fig. 2. Diagram of possible flows of data in relation to traits measured over the life-cycle of an annual seed crop. Types of data acquisition include: proximal sensing and imaging at frequent intervals, laboratory analyses of samples taken at specific intervals, and near-infrared spectroscopy (NIRS) of seed for oil or protein content during combine harvesting.



Some examples of traits and tools

Proximal sensing
Laboratory analyses
Near infrared reflectance spectroscopy


Some examples of traits and tools
Proximal sensing
Laboratory analyses
Near infrared reflectance spectroscopy

Proximal sensing & imaging

LAB

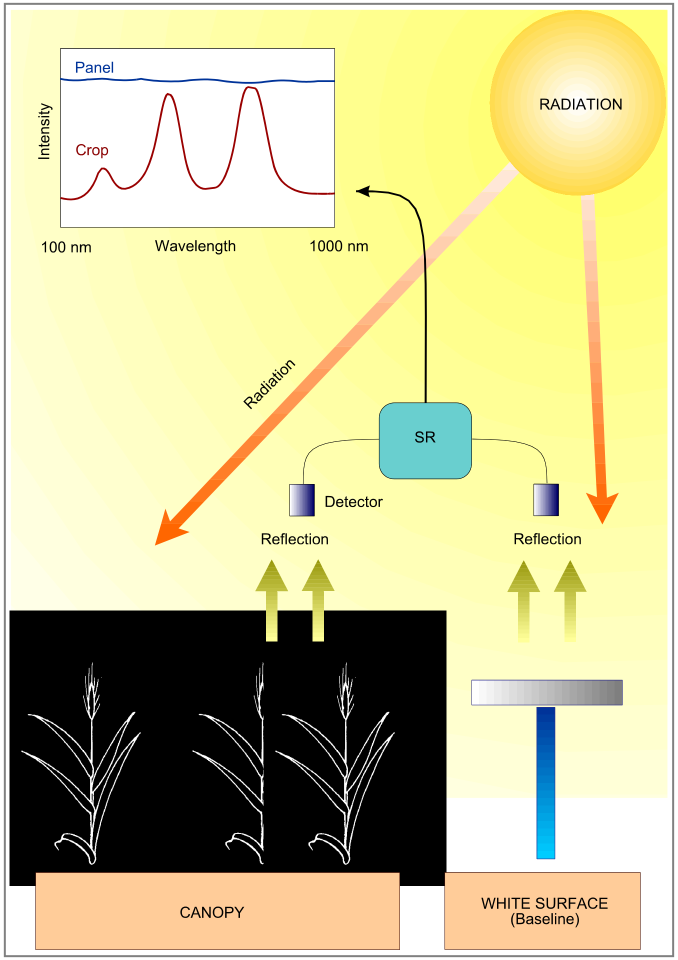
Parameter	Sensor
Architecture	Radar LIDAR 3D stereo imaging MRI
Biomass - shoot and root	Radar Laser scanning MRI PET
Plant water status	Sub-THz Thermography MRI Gas exchange
Stress effects / 'Health' status	Hyperspectral VOC & NO (Chl.-) fluorescence
Fluxes of matter, interior structures	MRI PET Thermography
Composition, metabolites	Hyperspectral Fluorescence VOC

FIELD

Parameter	Sensor
Architecture	Radar LIDAR Stereo imaging Laser scanning
Biomass - above and below ground	Radar MRI GPR Sub-THz Spectroscopy VIS-NIR Spectroscopy
Plant water status	Hyperspectral analysis Thermography Chl Fluorescence
'Health' status	Thermography Fluorescence Chl fluorescence
Composition, metabolites	Hyperspectral Fluorescence VOC
Photosynthesis	Chl fluorescence Hyperspectral

Spectroradiometry

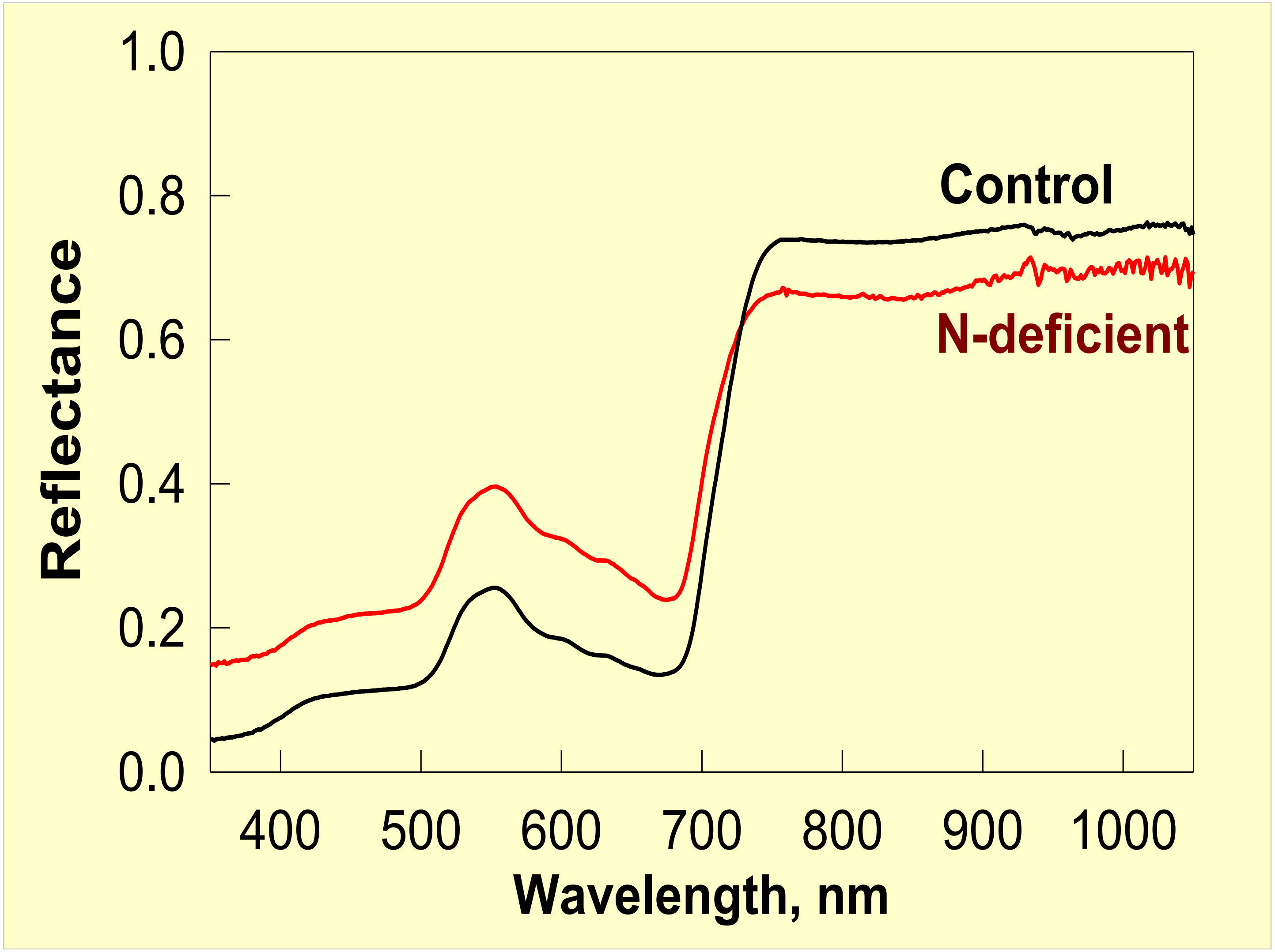
Spectroradiometrical Reflectance Indices



Different levels of assessment:

- Canopy
- Seedlings
- Leaves

Spectroradiometrics and Nitrogen Status



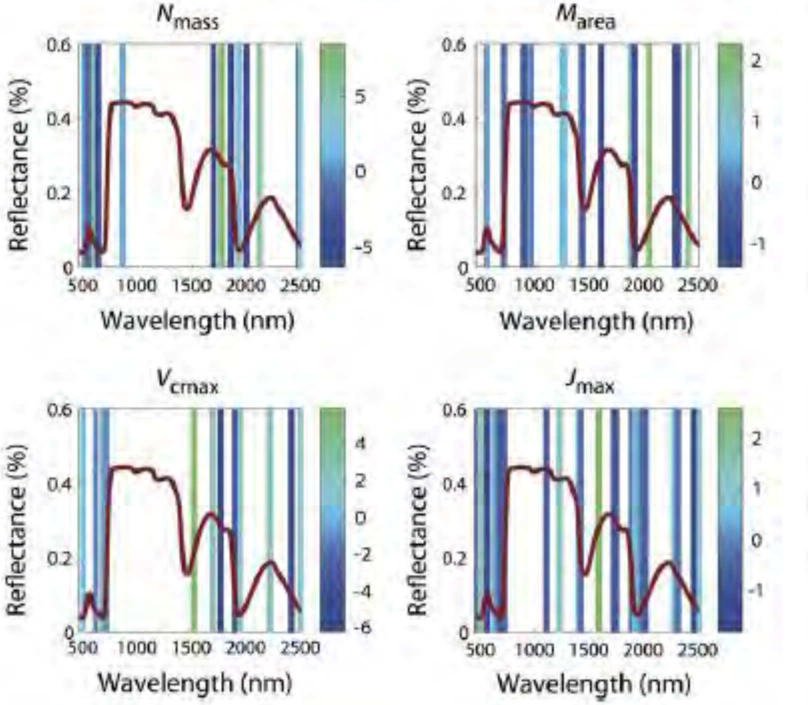
GreenSeeker SPAD

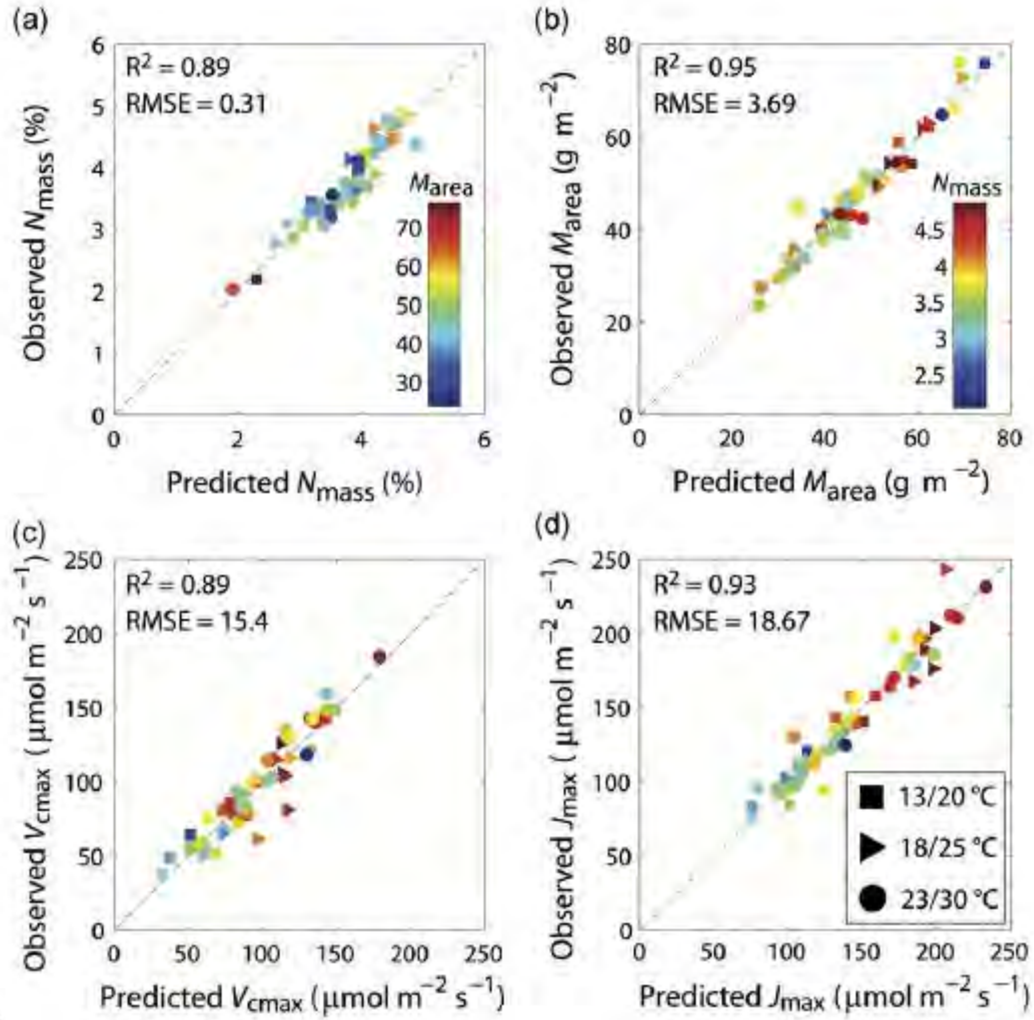
Spectroradiometrical Indices

Some indices for remote sensing of crop status.

Physiological parameter	Radiometric Index
Leaf area, [Chl], Green Biomass, etc.	$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{red}}$ $SR = R_{NIR} / R_{red}$ $SAVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{red} + L}(1 + L)$ (where L=0.5 for most crops)
Chl degradation	$NPQI = \frac{R_{415} - R_{435}}{R_{415} + R_{435}}$
Car/Chl	$SIPI = \frac{R_{800} - R_{435}}{R_{415} + R_{435}}$
PRUE	$PRI = \frac{R_{531} - R_{570}}{R_{531} + R_{570}}$
Water Content	$WI = \frac{R_{900}}{R_{970}}$

Full-range (λ 350 – 2500 nm) Vis/NIR Spectroradiometers





Journal of Experimental Botany, Vol. 63, No. 1, pp. 489–502, 2012
doi:10.1093/jxb/err294 Advance Access publication 6 October, 2011
This paper is available online free of all access charges (see http://jxb.oxfordjournals.org/open_access.html for further details)

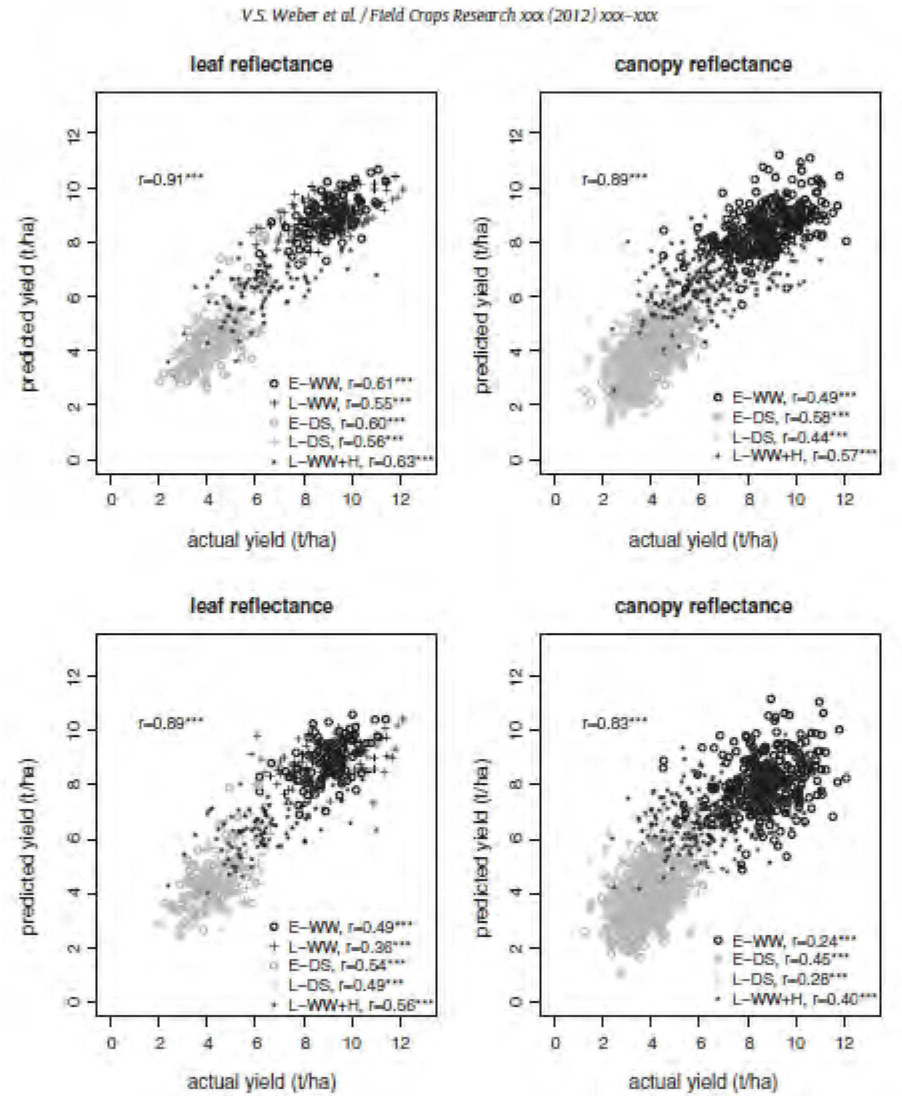
Journal of Experimental Botany
www.jxb.oxfordjournals.org

RESEARCH PAPER

Leaf optical properties reflect variation in photosynthetic metabolism and its sensitivity to temperature

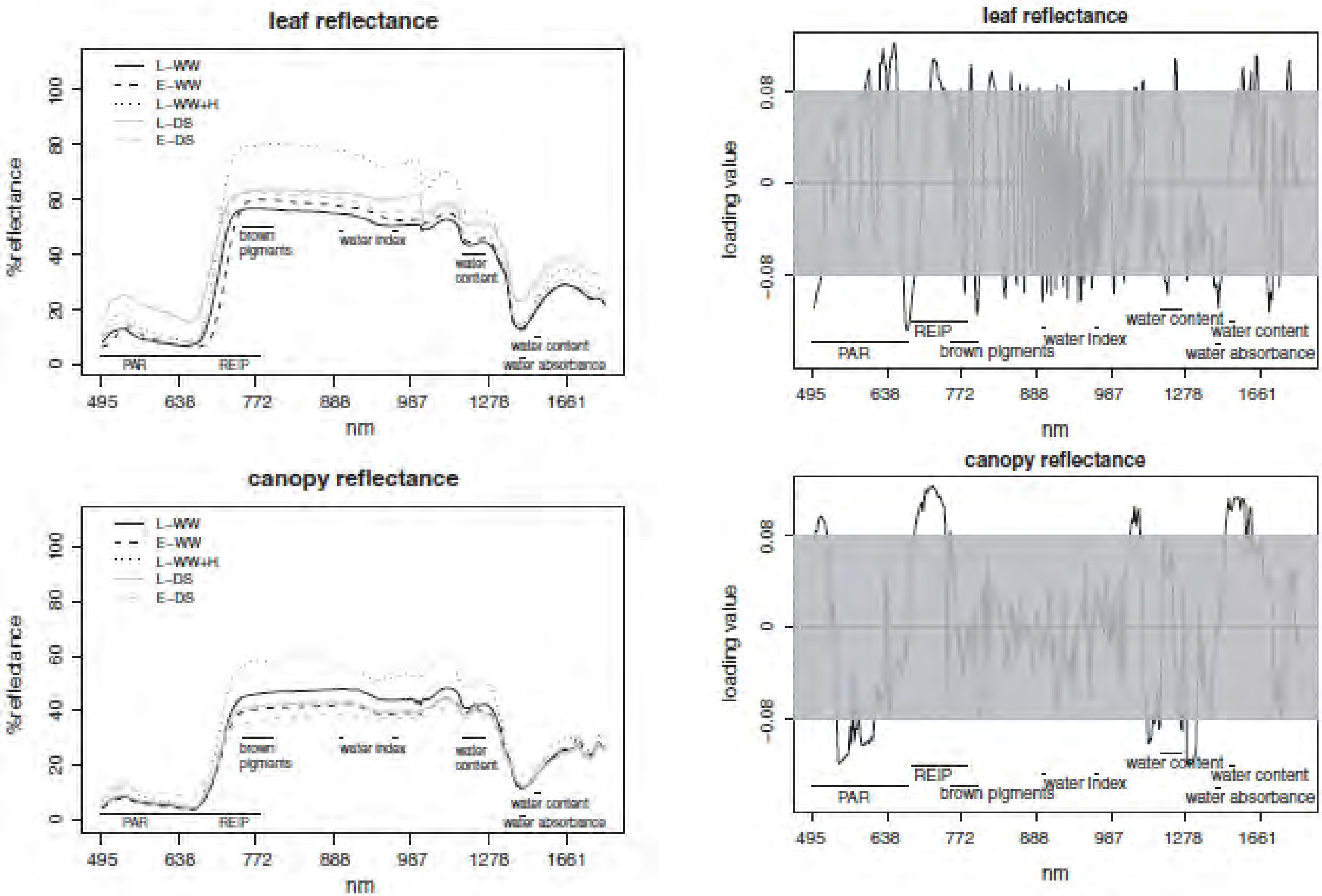
Shawn P. Serbin*, Dylan N. Dillaway†, Eric L. Kruger and Philip A. Townsend

Direct spectroradiometrical assessment of GY in the field



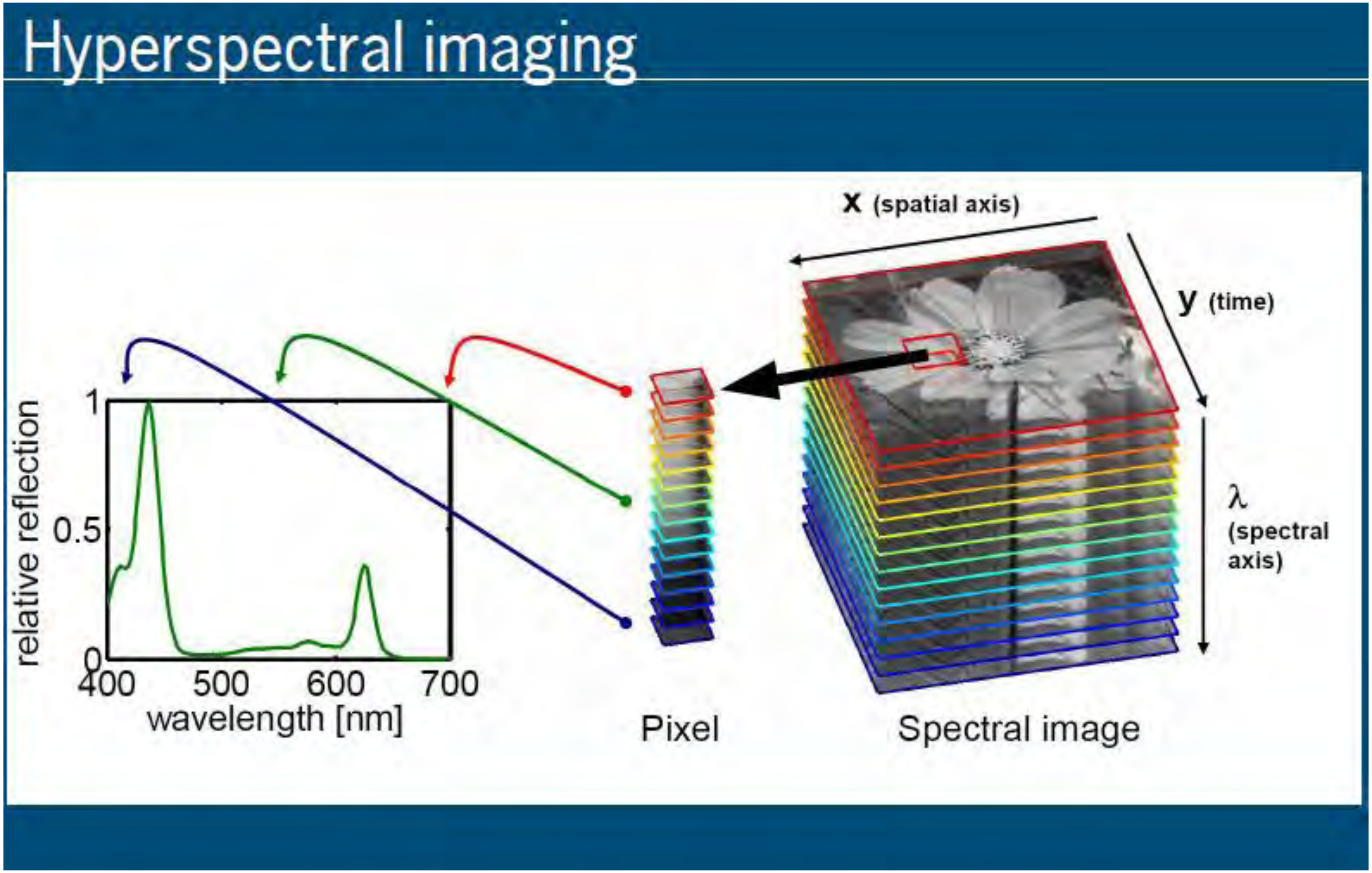
Weber *et al*. 2012 FCR 128: 82-90.

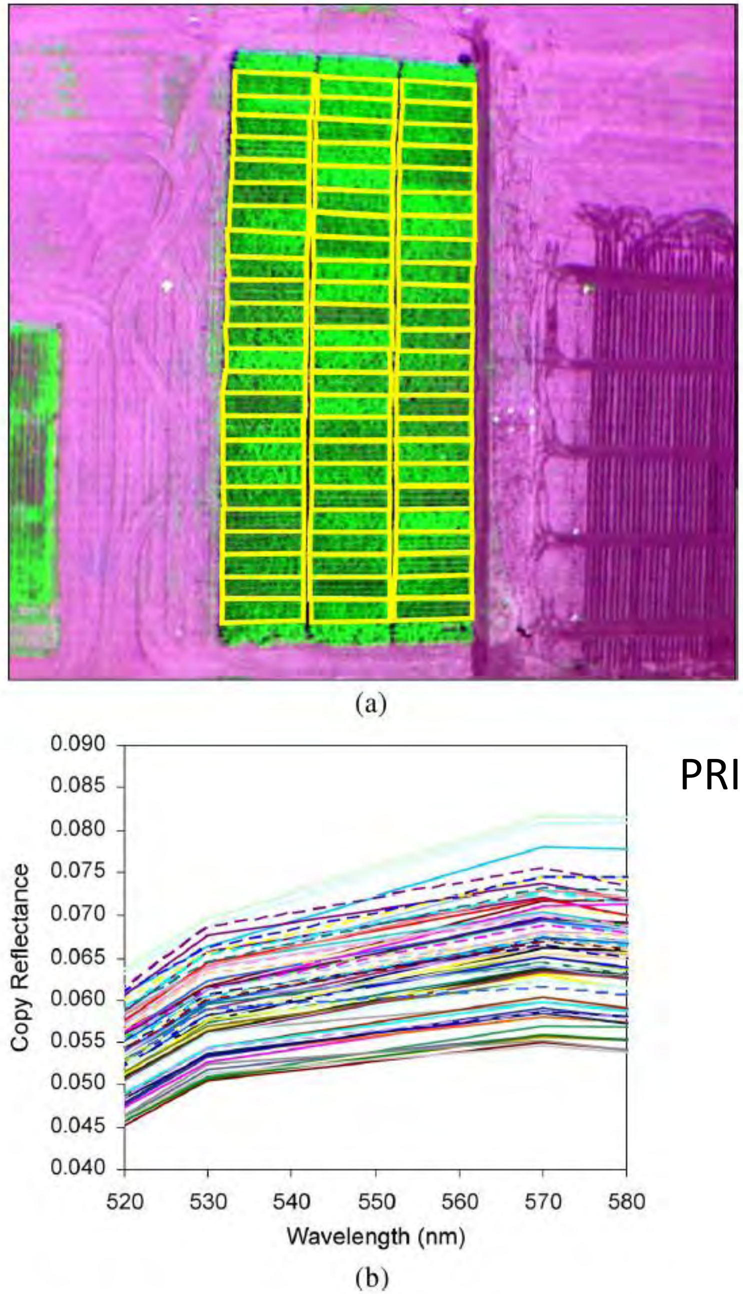
Direct spectroradiometrical assessment of GY in the field



Weber *et al*. 2012 FCR 128: 82-90.

Multispectral – hyperspectral imaging



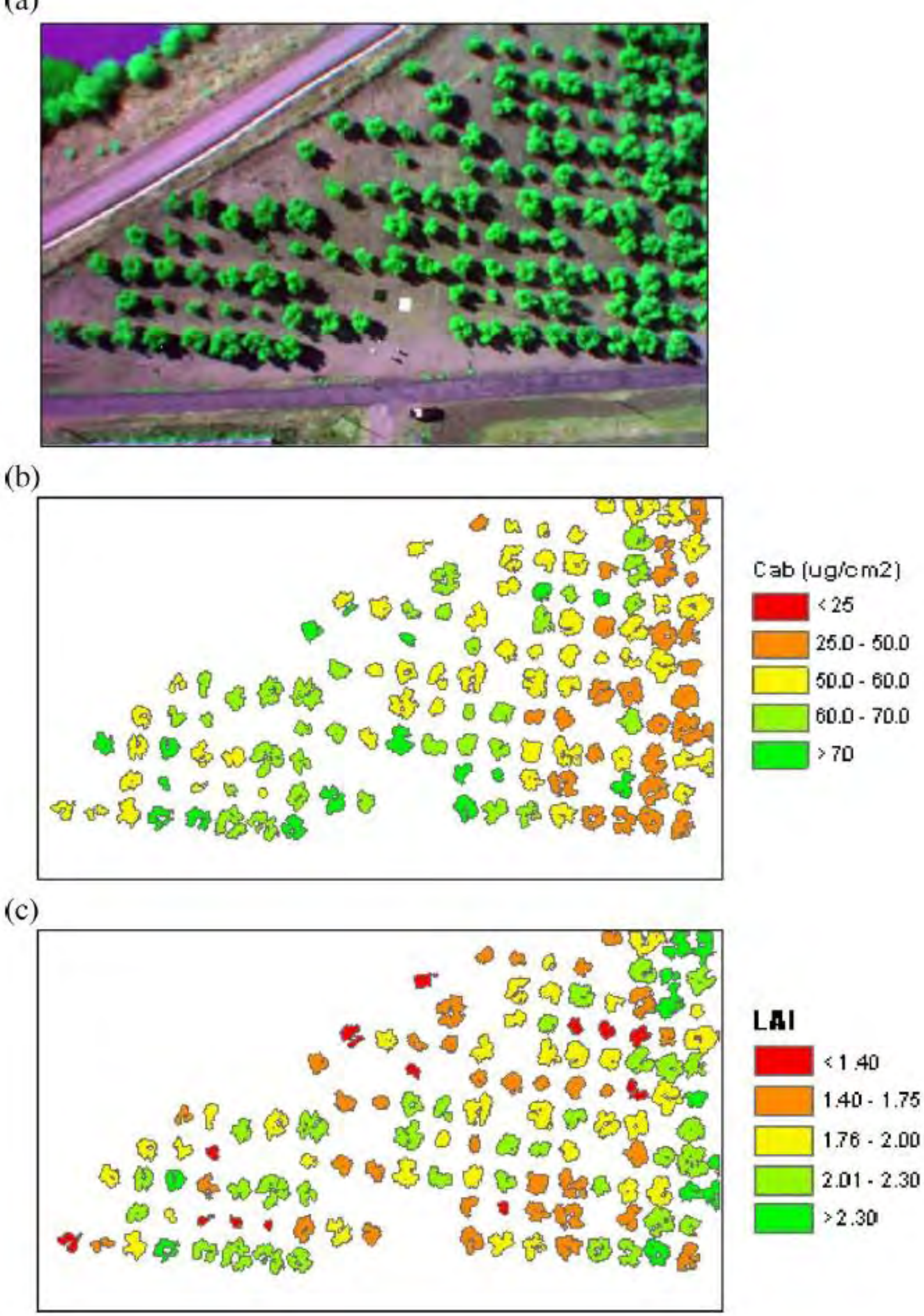


PRI

Fig. 12. (a) Corn plots of different varieties imaged by the MCA-6 camera onboard the UAV system. (b) Extracted reflectance spectra in the 530–570-nm spectral region for the calculation of the PRI index used for stress detection.

Multispectral Camera: MCA-6 Tetracam

Bernie et al. 2009 IJRS 47**:** 722 - 738



Multispectral Camera: MCA-6 Tetracam

Bernie et al. 2009 IJRS 47**:** 722 - 738

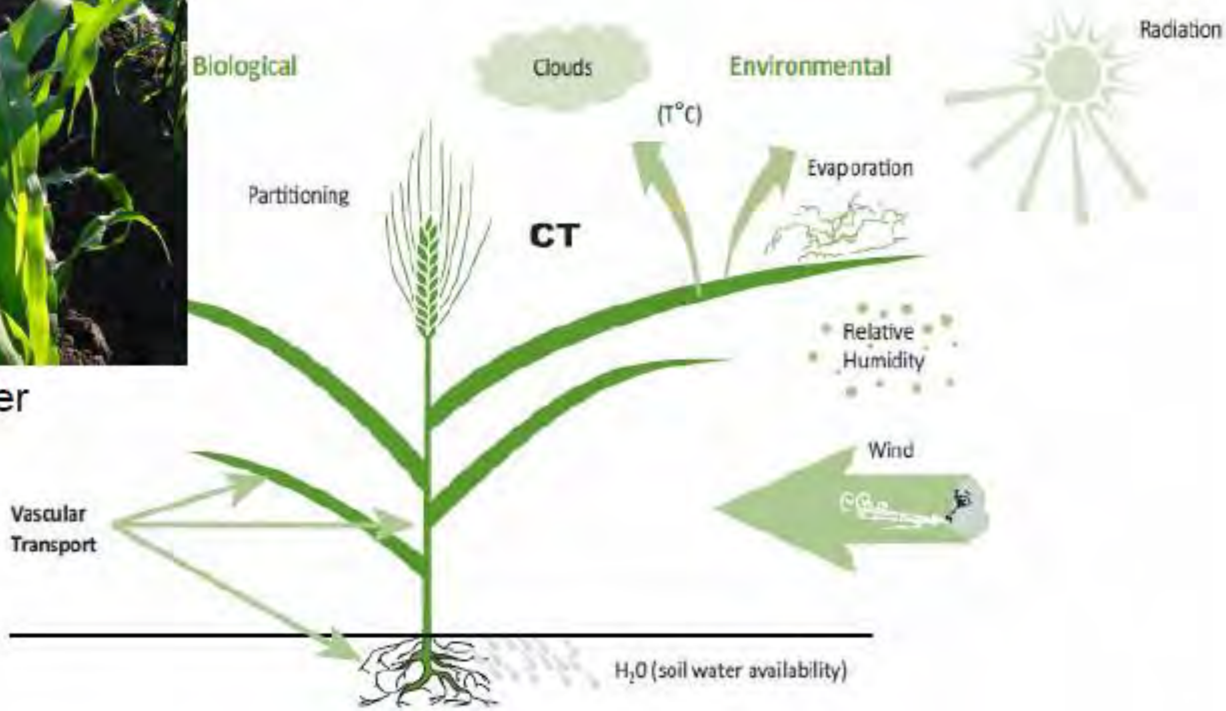
Fig. 18. Sample multispectral imagery acquired over an olive orchard with the MCA-6 camera at 10-nm FWHM bandwidths onboard the UAV platform (0.15-m spatial resolution), showing the chlorophyll content and LAI maps obtained.

Plant temperature

Transpiration as a cooling system: IR thermometry

IR Thermometer

With quiet air (i.e. limited air-cooling), differences of several degrees in fully irradiated leaves with changes in stomatal conductance



Reynolds, Pask & Mullan 2012

Figure 6.1. Biological (physiological) and environmental factors affecting canopy temperature (Adapted from Reynolds *et al.*, 2001).

CTD and Yield

Trial	n	Correlation of CTD with yield			
		Aerial		Hand-held	
		Phenotypic	Genetic	Phenotypic	Genetic
RILs (Seri82*7C66)	81	0.40**	0.63**	0.50**	0.78**
Advanced lines	58	0.34**	-	0.44**	-

**statistical significance at 0.01 level of probability
- genetic correlations not calculated due to design restrictions

Reynolds *et al.*, 1999

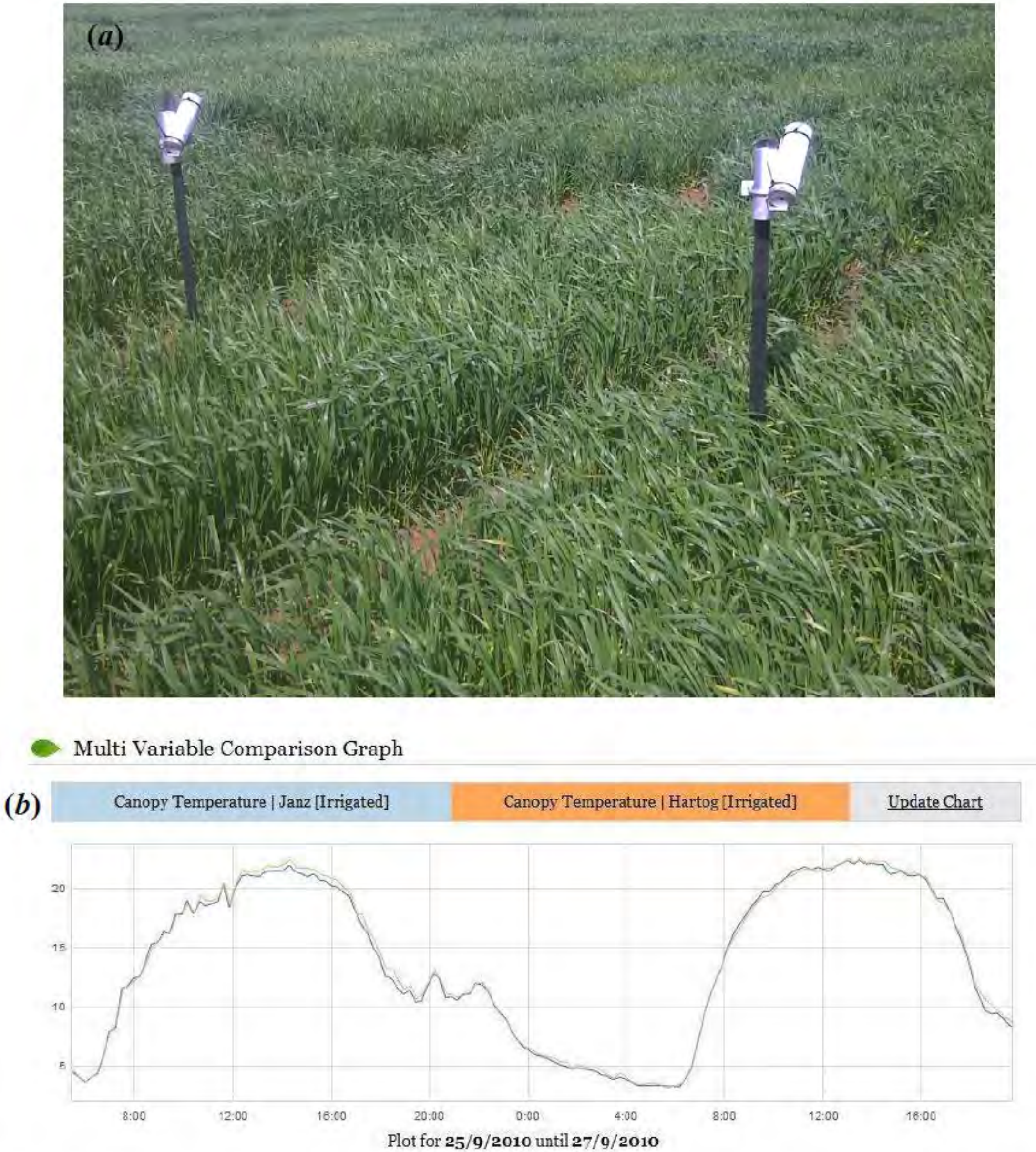
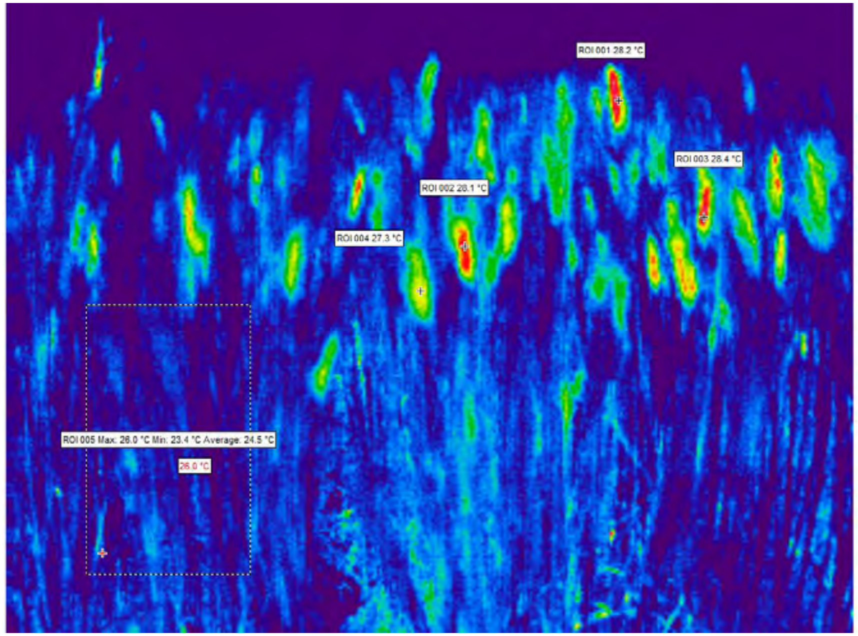


Fig. S2. Use of the Phenonet in monitoring of canopy temperature for multiple genotypes: (*a*) infra-red thermometers (Melexis®, 10 deg field of view) used for monitoring canopy temperature at the Yanco MEF; and (*b*) screen shot of the Phenonet visualisation and analysis system for near-real time recording of canopy temperature (here of wheat cultivars Janz (blue) and Hartog (orange) assessed under irrigated conditions).

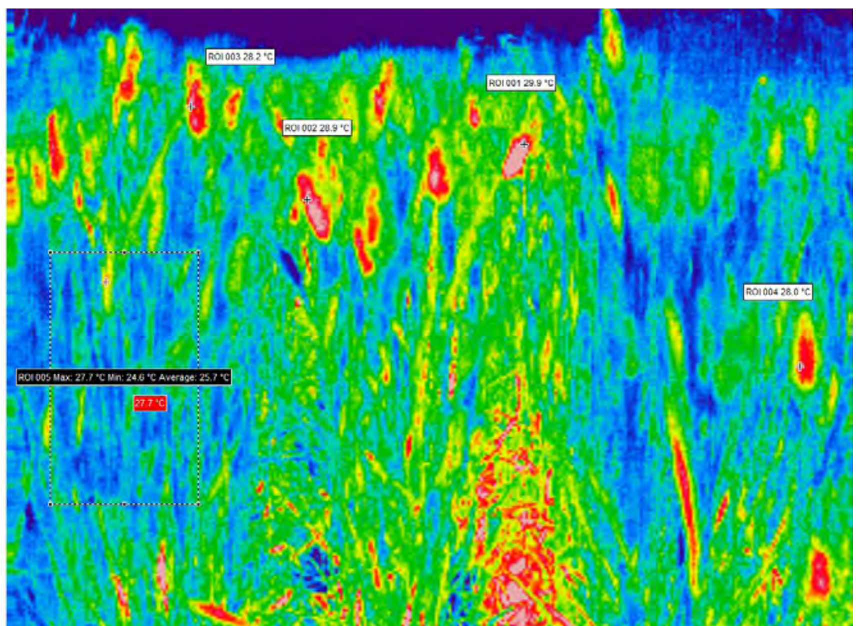
Rebetzke et al. 2013 FPB 40: 1-13

Ears/shoots

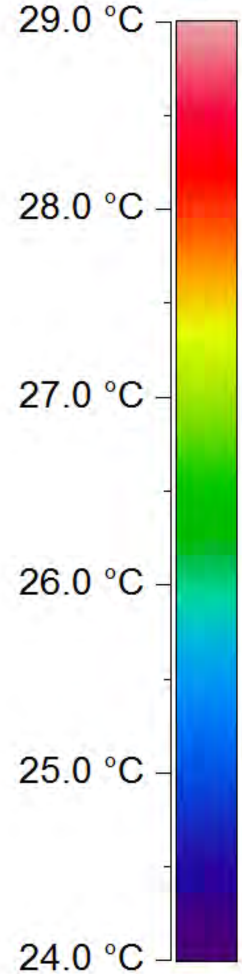
Supplemental irrigation



Rainfed



DIAS
Infrared Systems



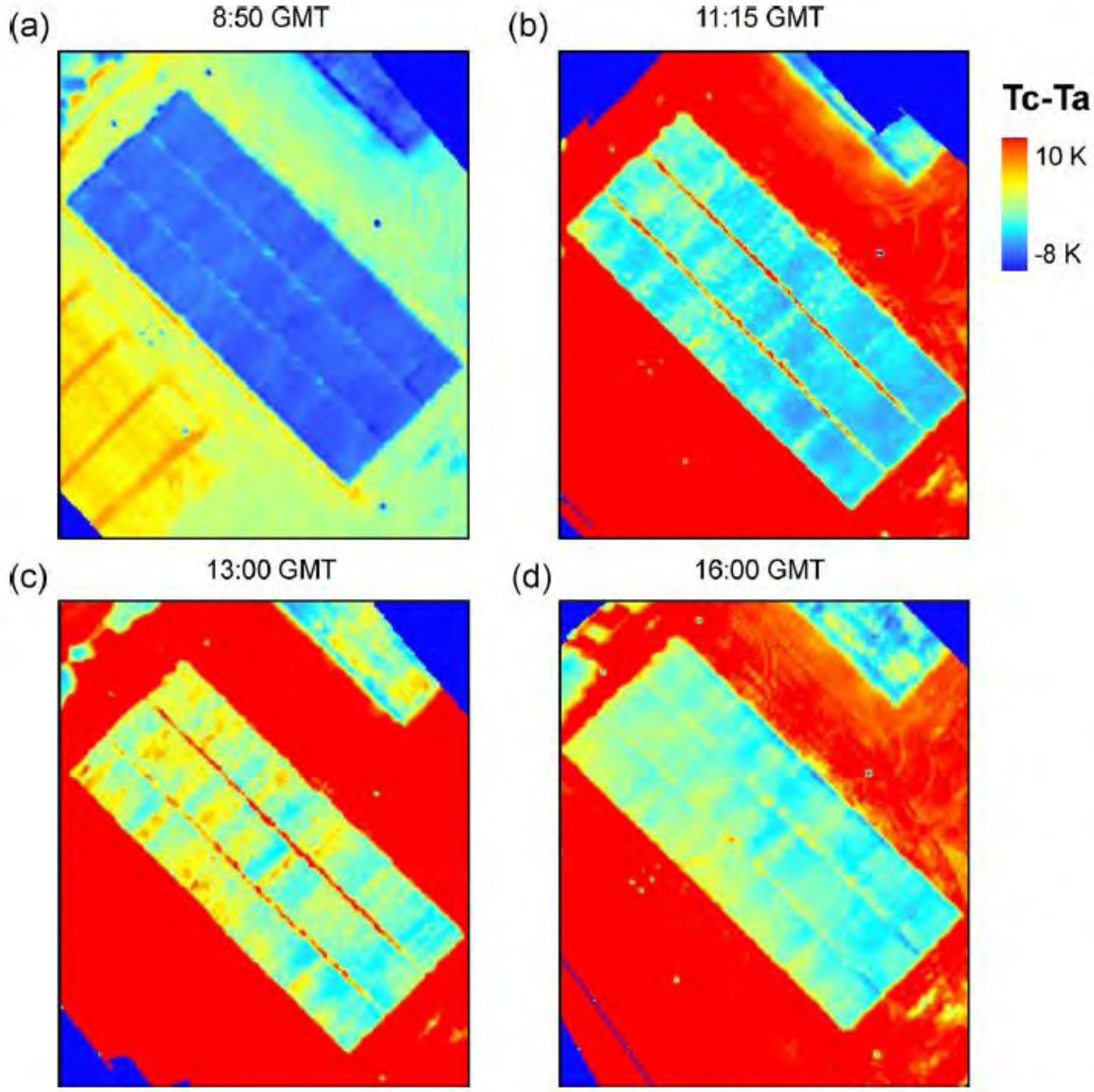


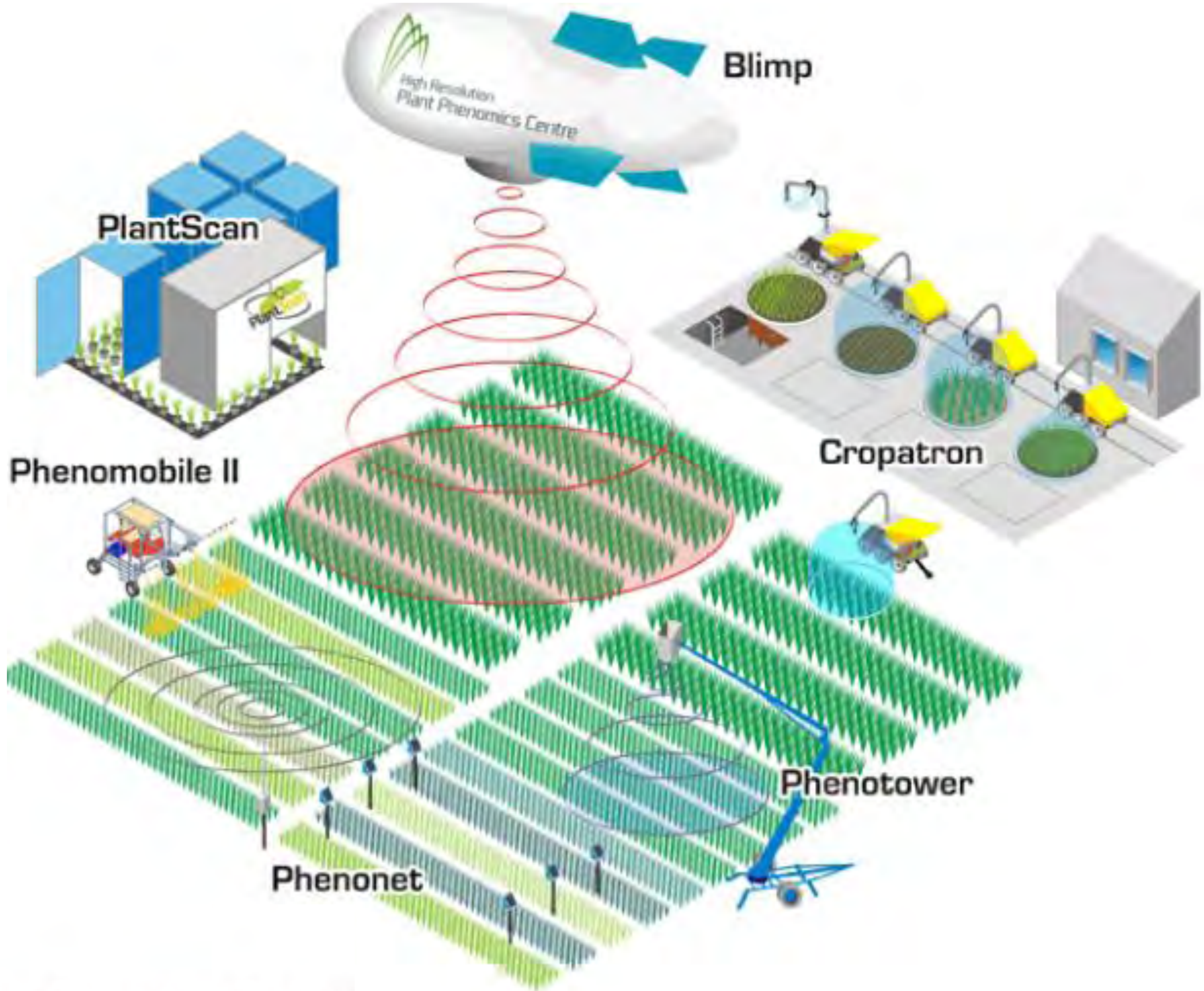
Fig. 14. Thermal images acquired over the corn field at 0.4-m pixel resolution showing the $T_c - T_a$ changes at four different times of day. The greatest thermal variability between corn variety plots is obtained at midday, continuing during the afternoon.

Bernie et al. 2009 IJRS 47**:** 722 - 738

How to implement proximal sensing in practice?

HRPPC Phenomics Technology

The High Resolution Plant Phenomics Centre (HRPPC) located in Canberra at CSIRO Plant Industry and the Australian National University is developing next generation research tools to probe plant function and performance, under controlled conditions from growth cabinets to the field. These new technologies include the **Phenonet**, **Phenomobile**, **Phenotower**, **Tethered Blimp**, **Cropatron** and the **PlantScan**.



Australian Plant Phenomics Facility

Phenomobiles

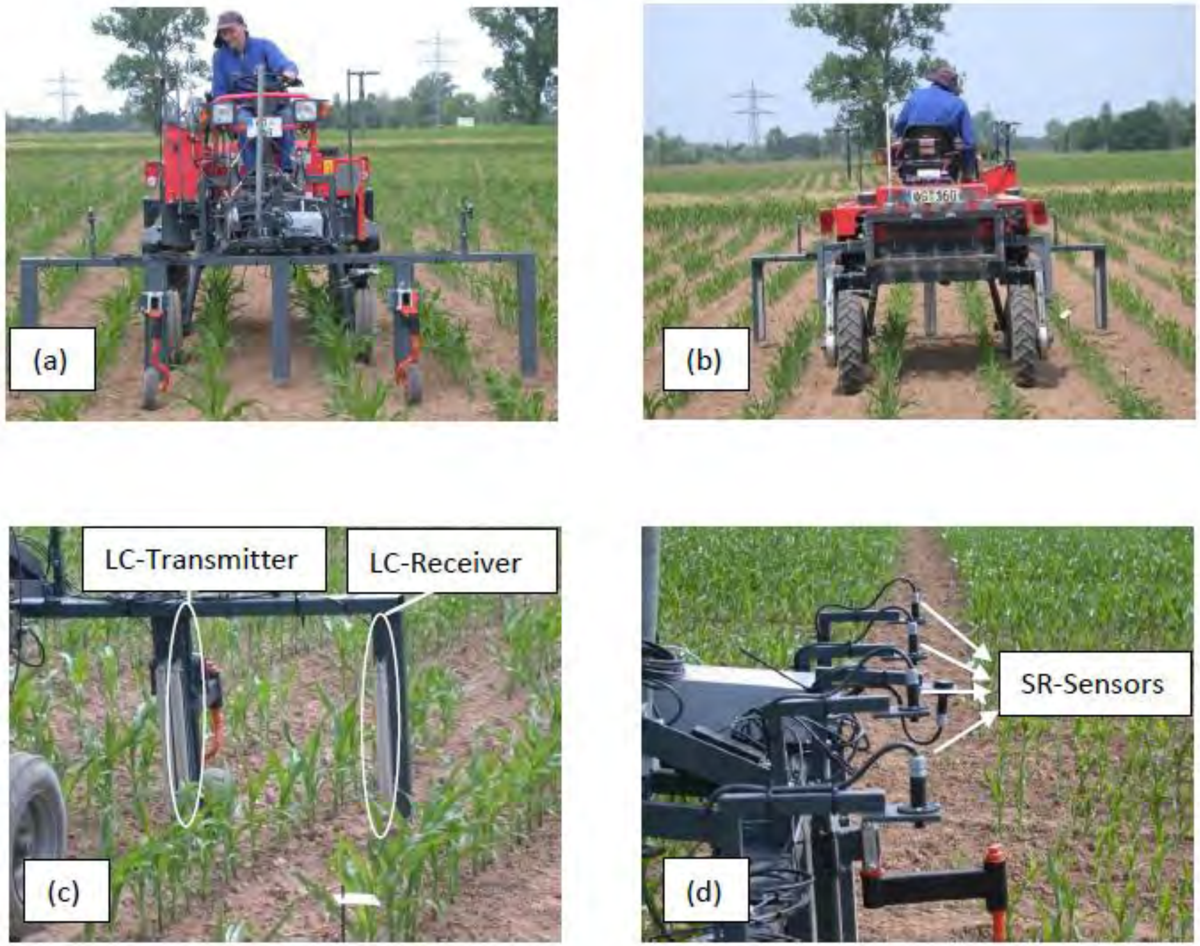


Fig. S1. (a) Front and (b) back view of the sensor platform in driving position and closer view of the (c) light curtains (LC) and (d) spectral reflectance (SR) sensors.

Montes et al. 2011. High-throughput non-destructive biomass determination during early plant development in maize under field conditions. Field CropsResearch121: 268–273

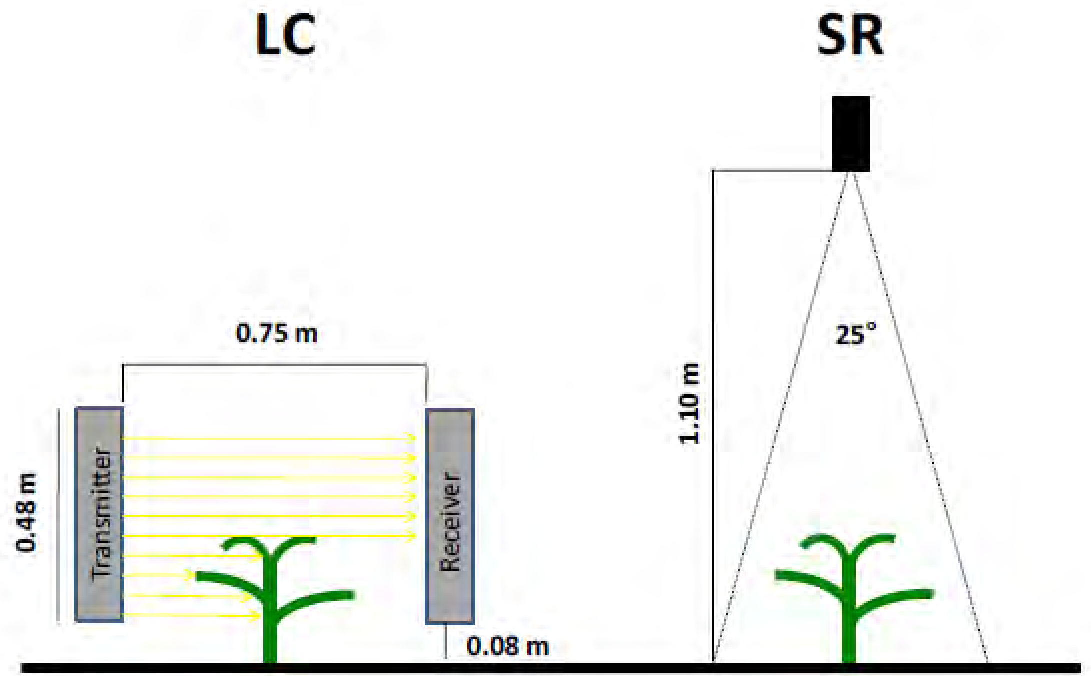


Fig. S2. Technical information of the light curtains (LC) and spectral reflectance (SR) sensors.

Montes et al. 2011. High-throughput non-destructive biomass determination during early plant development in maize under field conditions. Field CropsResearch121: 268–273

Hyperspectral imaging of grassland

velocity 0.3-0.5 m/s

WAGENINGEN UR
For quality of life

Fig. S3. Purpose built crop monitoring buggy fitted with: four RGB cameras for measurement of ground cover and plant establishment; LiDAR sensors to measure plant height and bio-volume; spectral radiometer from 300 to 2500 nm to measure NDVI and various spectral vegetation indices; three infra-red temperature sensors for crop canopy temperature. Rebetzke et al. 2013 FPB 40: 1-13

DIAPHEN

Installation for:	medium/large plants in the field
Environmental monitoring:	soil water potential, micrometeorological variables, apex temperature
Parameters:	N content, transpiration (FIR), leaf area index
Capacity:	seasonal dynamics of plots in the field
Average experiment duration:	200 days

European Plant Phenotyping Network
EPPN

INRA, France

White et al. 2012 FCR 133:101–112

Fig. 1. High-clearance tractor in operation over young cotton plants at Maricopa, AZ. Replicated sets of sensors allow simultaneous measurement of canopy height, temperature, and spectral reflectance at three bandwidths. Real time kinematic GPS provides positional accuracy under 2 cm.

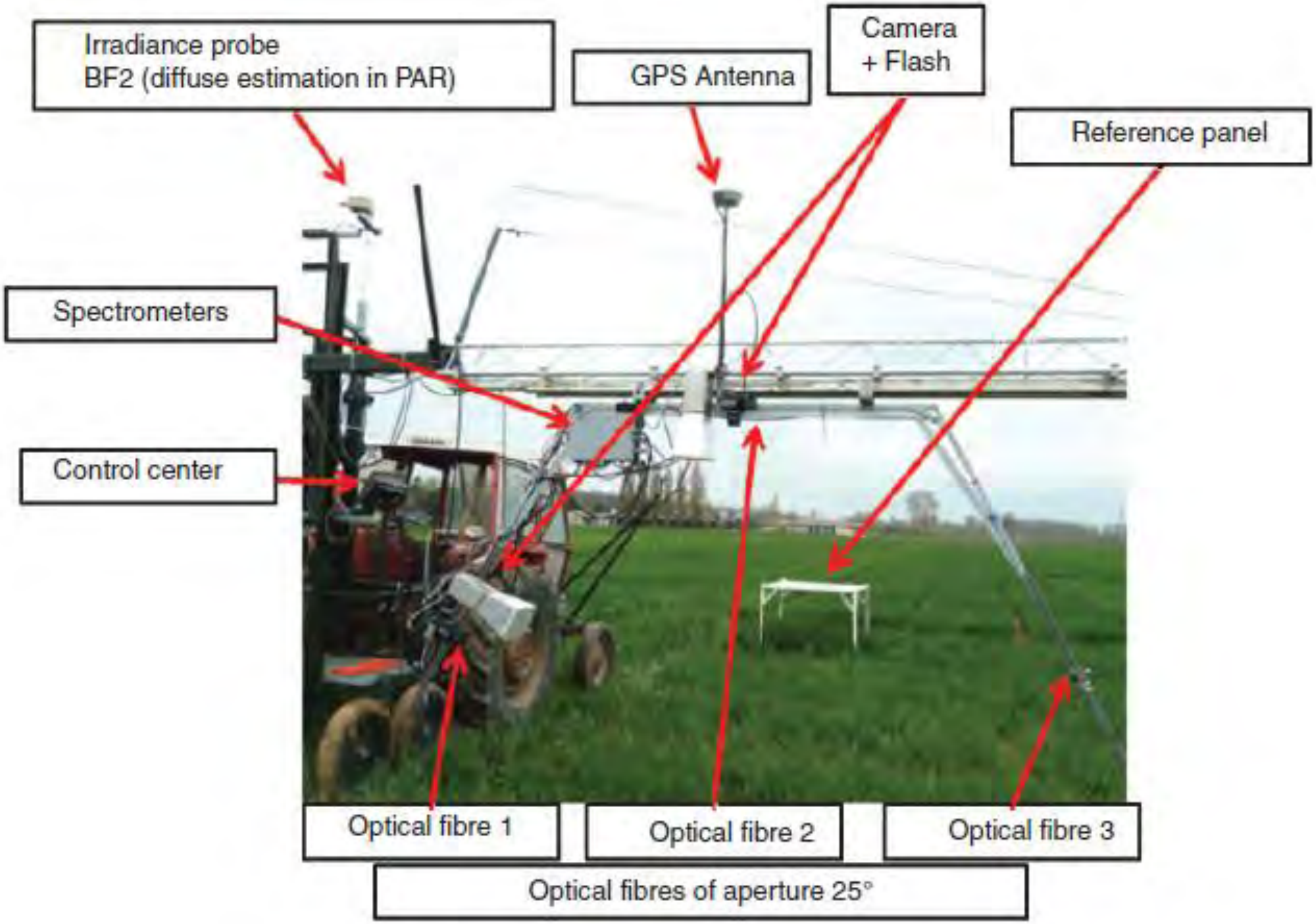


Fig. 1. The system used to sample the micro-plots.

Comar et al. 2012 *FPB* 39: 914-924

Aerial platforms


Pro
LLEIDA
EC-DNX
ESTEVE
Pro
LLEIDA

Phenotower

From 16m above the canopy the Phenotower collects infra-red themography and colour imagery of a field plot. This data is used for spatial comparison of canopy temperature, leaf greenness and groundcover between genotypes at a single point in time.

Australian Plant Phenomics Facility

The canopy: structure-function relationships

flexible system – cherry picker

SLR-cameras on a sliding bar
+ hyperspectral imaging

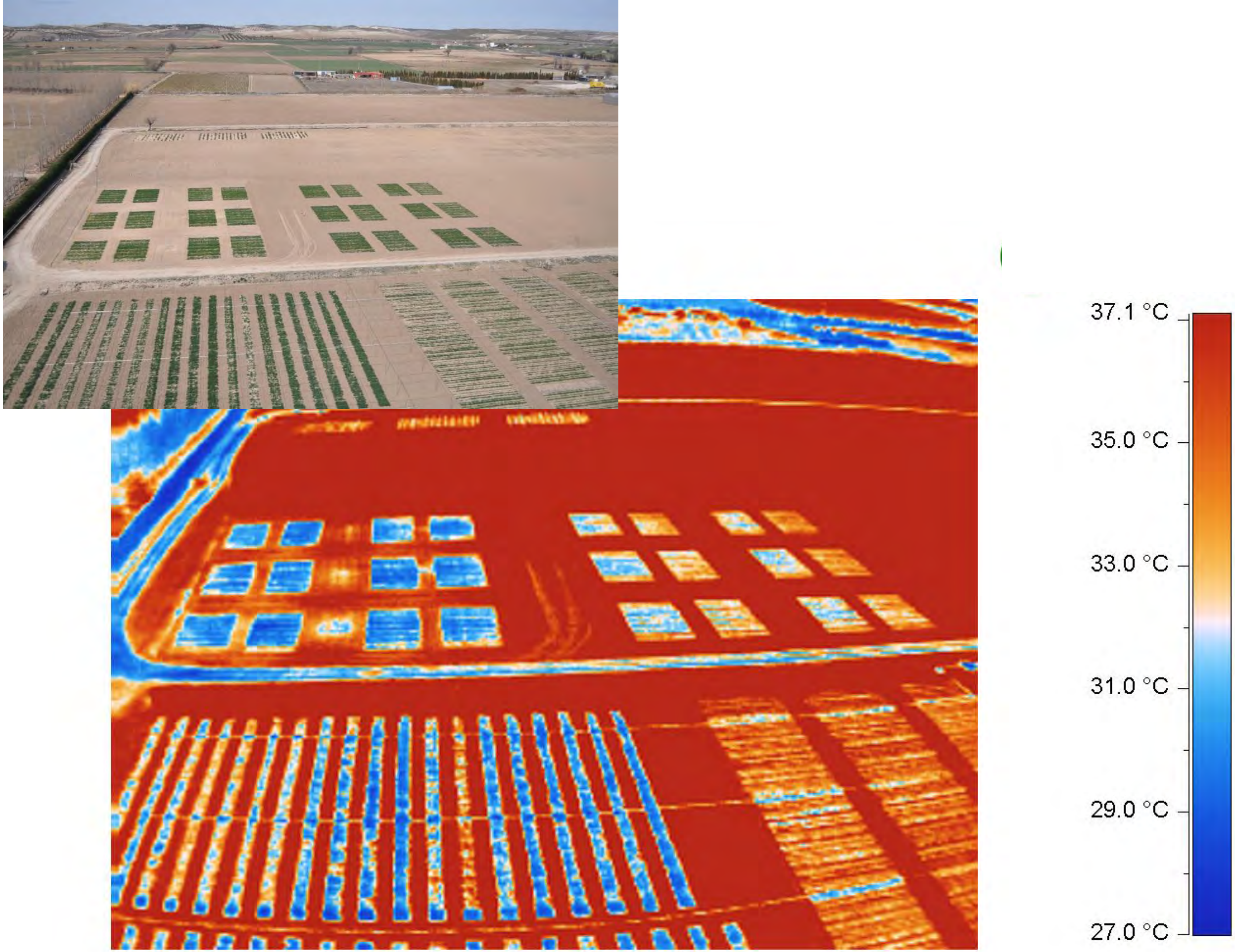
Laser / LIDAR – detailed maps of the outer canopy

3D Stereo imaging: structural features – e.g. leaf orientation

Hyperspectral imaging:
- NDVI - chlorophyll
- PRI - photosynthestic efficiency - influenced by chlorophyll and canopy structure

Stereo imaging – quantitative description of relevant canopy elements

Rascher et al. 2011, FPB 38: 968-983



37.1 °C
35.0 °C
33.0 °C
31.0 °C
29.0 °C
27.0 °C

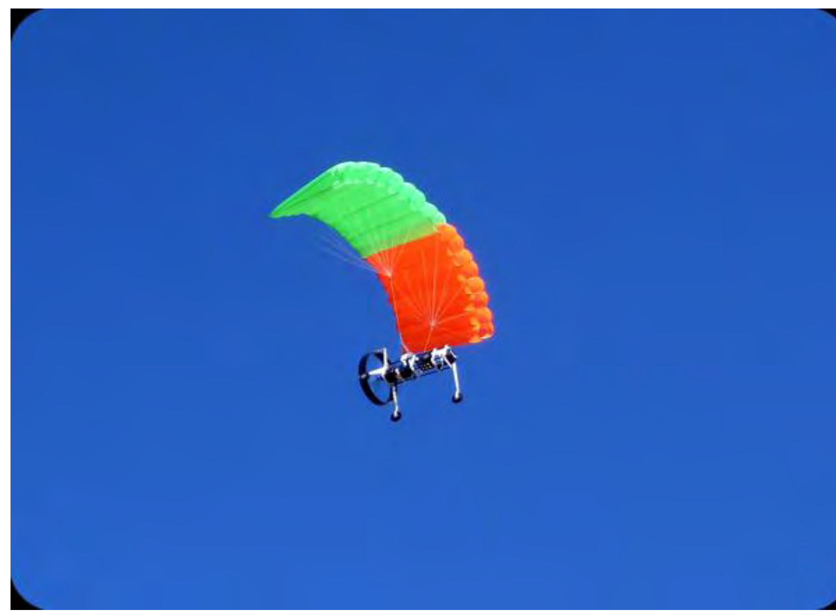
Tethered Blimp

For imaging an entire field at one point in time a 6m tethered blimp able to lift 3kg is under development. As an aerial imaging platform the blimp will carry both infrared and digital colour cameras operating in a height range of 30-80m above the field. The infra-red thermography and colour images will indentify the relative differences in canopy temperature indicating plant water use, an important trait to understand.


WHEAT PHYSIOLOGY

Unmanned aerial vehicles

Unmanned aerial vehicles



to Fly from Udrones

more info

Price: **$765.00**

This item comes fully assembled and ready to fly!

New Products

Camera "L" shaped cable connector
Price: **$2.75**

Pre-crimped cables 5cm (set of 5, red)
Price: **$2.00**

DF13 3 Position Connector 19 cm
Price: **$2.00**


ASCTECFALCON 8
WWW.ASCTEC.DE


Color Display Monitor
TFT LCD
FX-30
Futaba
Zoom
Start/Stop
Auto
ASCTEC
45C

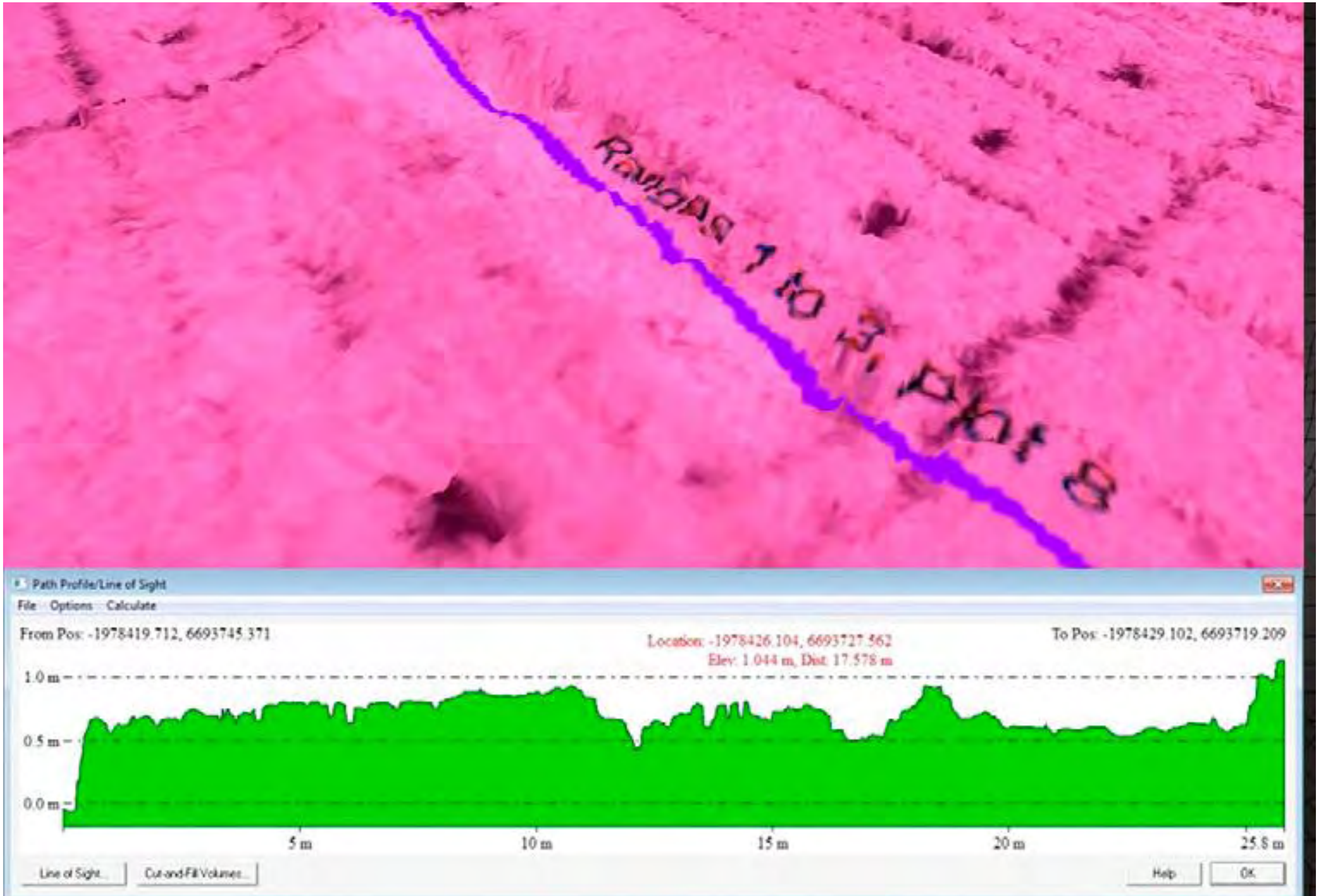
Aerial Remote Sensing Equipment

- Astec Falcon 8, 8-rotar Unmanned Aerial Vehicle (UAV).
  - Remote controlled.
  - 650 g payload.
  - Max wind speed 10 m/s.
  - Max flight height approx 130 m.

Cameras		
Tetracam ACD Light Multispectral Camera	• Resolution: 2048 x 1536 • Spectral Range: 3 bands in Green, Red and NIR	
FLIR Tau 640 LWIR Uncooled Thermal Imaging Camera	• Resolution: 640 x 512 • Spectral Range: 7.5-13 µm	

CSA News March 2013

Researchers at CSIRO use a remotecontrolled gas-powered model helicopter called the "phenocopter" to measure plant height, canopy cover, lodging, and temperature throughout a day. Pictured here are Scott Chapman (left), a principal research scientist at CSIRO, and Torsten Merz, developer of the phenocopter.



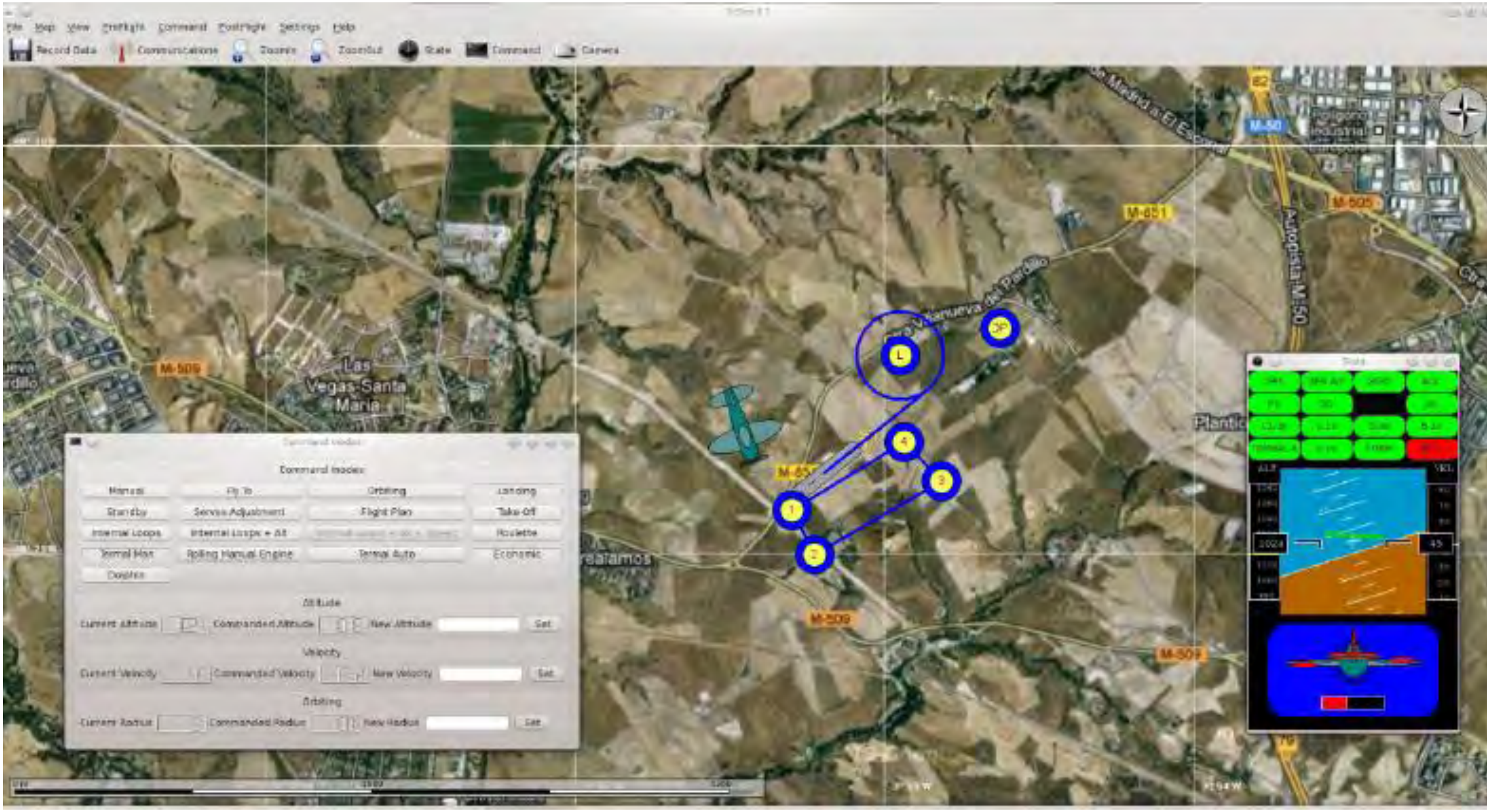
Plant height data collected by the near-infrared camera on the phenocopter can be used to estimate lodging across plots. *Images courtesy of Scott Chapman, CSIRO*.

Unmanned aerial vehicle

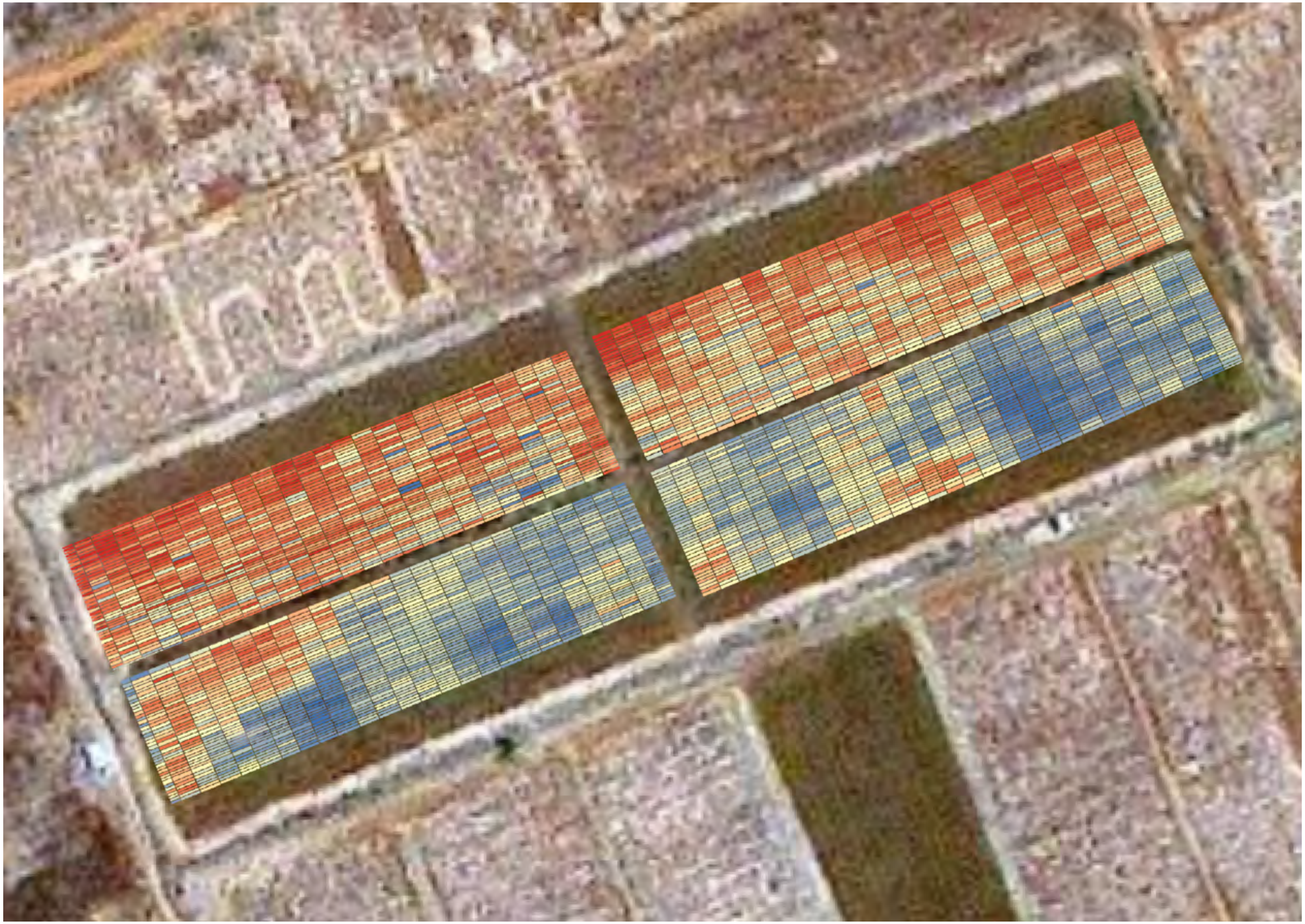
Miricle 307 KS sealed infrared camera. 640x480

307K – 640x480 detector resolution: 307,200 pixels and 25µm pitch
KS


skyflite



Record Data
Communications
Camera
Las Vegas Santa Maria
M-509
M-651
M-505
M-50
Autopista M-50
Command Modes
Manual
Orbiting
Landing
Standby
Flight Plan
Take Off
Internal Loops
Roulette
Rolling Manual Engine
Economic
Altitude
Current Altitude
Commanded Altitude
New Altitude
Set
Velocity
Current Velocity
Commanded Velocity
New Velocity
Set
Orbiting
Commanded Radius
New Radius
Set

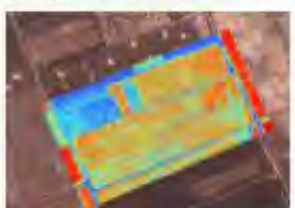


CIMMYT
International Maize and Wheat Improvement Center

informa
No. 1833 • 01 - 08 March 2013

"Sky Walker" advances phenotyping in Southern Africa

To free phenotyping of the varietal development bottleneck label, many new tools have been developed to enable an easier plant growth and development characterization and field variability. Until recently, these tools' potential has been limited by the scale on which they can be used, but this is changing: a new affordable field-based phenotyping platform combining cutting edge aeronautics technology and image analysis was developed through collaboration between researchers from the University of Barcelona, Spain; Crop Breeding Institute, Zimbabwe; Instituto Nacional de Innovación Agraria, Peru; AirElectronics; and Sustainable Agricultural Institute of the High Research Council, Spain. The project was funded by MAIZE CRP as part of Strategic Initiative 9 activities focusing on new tools and methods for national agricultural research systems and small and medium enterprises to increase genetic gains in maize breeding.



The new platform uses 'Sky Walker,' an unmanned aerial vehicle which can fly at over 600-meter with an average speed of 45 km/h. The vehicle has thermal and spectral cameras mounted under each wing, and its flight path and image capturing are controlled via a laptop using Google Earth images. Jill Cairns and Mainassara Zaman-Allah tested the platform at CIMMYT-Harare along with José Luis Araus (University of Barcelona), Antón Fernández (AirElectronics president), and Alberto Hornero (Sustainable Agricultural Institute of the High Research Council) to establish the optimal flight path (distance between plane passes and height) for plot level measurements. Field experiments were phenotyped for spectral reflectance and canopy temperature within minutes; these will be compared to results from the GreenSeeker.

The measurement speed of the new platform helps to overcome problems associated with changes in cloud cover and the sun position. It will be used by the Crop Breeding Institute to assist in developing new maize hybrids with heat stress and drought stress tolerance under elevated temperatures.

Also in this issue

Proximal sensing: Low cost approaches

Canopy senescence – visual score

Measurement:

- score from 0-10, divide the % of estimated total leaf area that is dead by 10
- initiation & rate of canopy senescence

1 (10%)

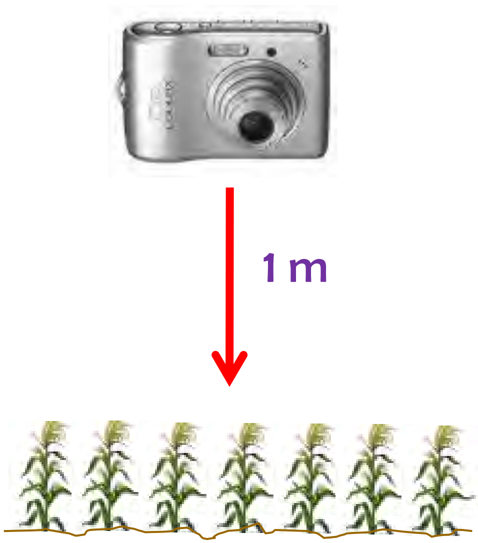
3 (30%)

5 (50%)

7 (70%)

9 (90%)

Digital photography

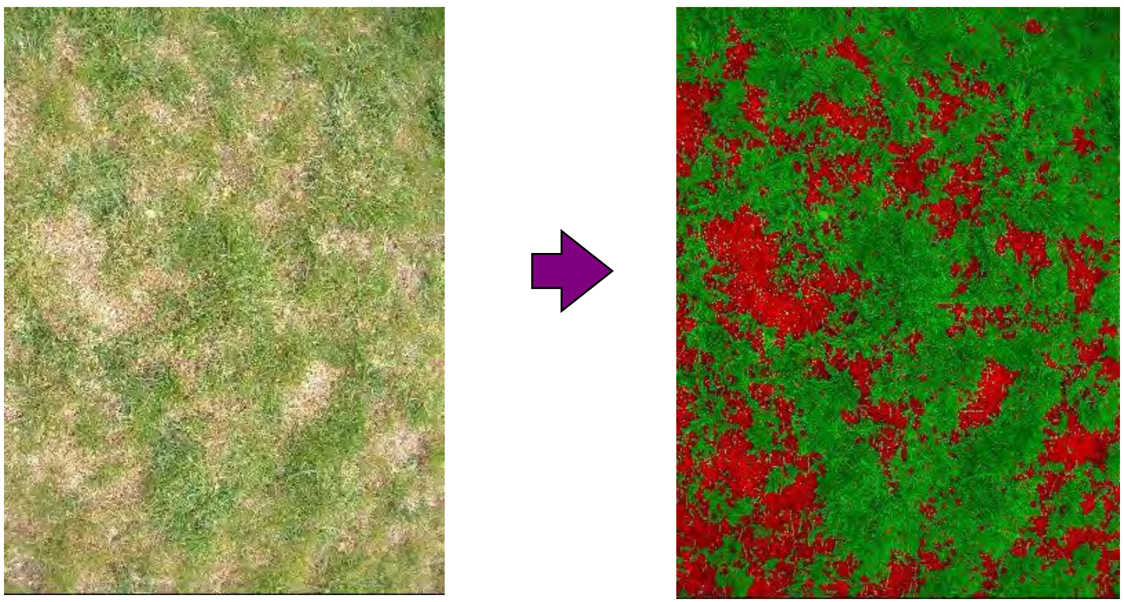


green biomass

Conventional digital photography

A much cheaper surrogate: pictures from conventional digital cameras.

Some applications of digital photography: Ratio of green area to total area.
Easy-to-calculate estimator of green cover



$$\frac{\text{Num. green pixels}}{\text{Num. total pixels}}$$

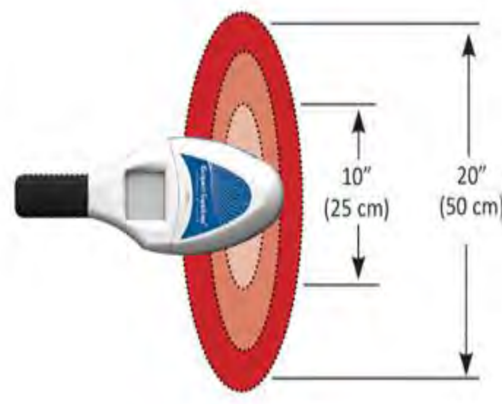
where green pixels:
$40^{\circ} < \text{Hue} < 128^{\circ}$

Casadesús et al. 2007 Ann. Appl. Biol.

New!

GreenSeeker®

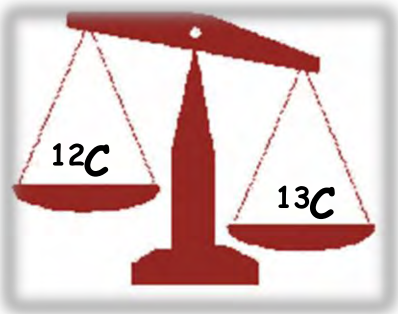
HANDHELD CROP SENSOR



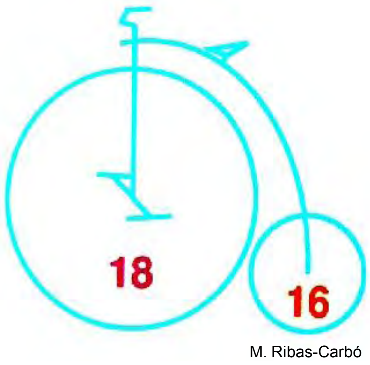
Some examples of traits and tools

- Proximal sensing
- Laboratory analyses
- Near infrared reflectance spectroscopy

C and O stable isotopes in cereal breeding



- Reflects variation in water-use efficiency (*WUE*)
- Has been proposed as a selection criterion for improved *WUE* and yield in C_3 cereals (few reports in C_4 cereals??)



- Can be used in C_3 and C_4 cereals (independent on *A*)
- Integrative indicator of genotypic differences in g_s and yield
- May help in separating the independent effects of *A* and g_s on $\Delta^{13}C$ and then on *WUE* in C_3 cereals

Ways to ameliorate yield in water-limited environments

The Passioura's identity (1977)

$$GY = WU \times WUE \times HI$$

Capturing more soil water

Economizing water use (more crop per drop)

Improving partitioning to grains

WU = total water used by the crop

$\Delta^{18}O$ (Transpiration)

$\Delta^{13}C$ (C to H_2O used)

WUE = ability of the crop to produce biomass per unit of water used

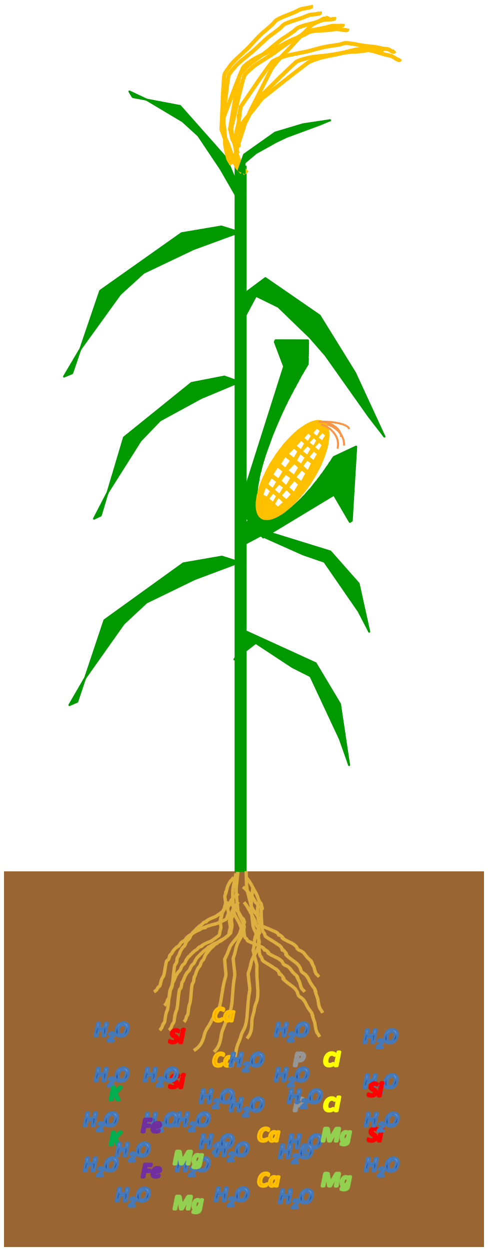
HI = fraction of the total dry matter harvested as yield

Stable Isotopes: $\Delta^{13}C$ & Yield

'Drysdale (2002) and Rees (2003) are drought tolerant wheat varieties bred by CSIRO scientists using innovative gene selection criteria. The DELTA technique gives plant breeders the ability to breed varieties of wheat that more efficiently exchange atmospheric carbon dioxide for water during photosynthesis'

They were selected for low $\Delta^{13}C$ increased WUE as crop mostly grows on storage water which exhausted through the growing season

Mineral accumulation: Vegetative tissues

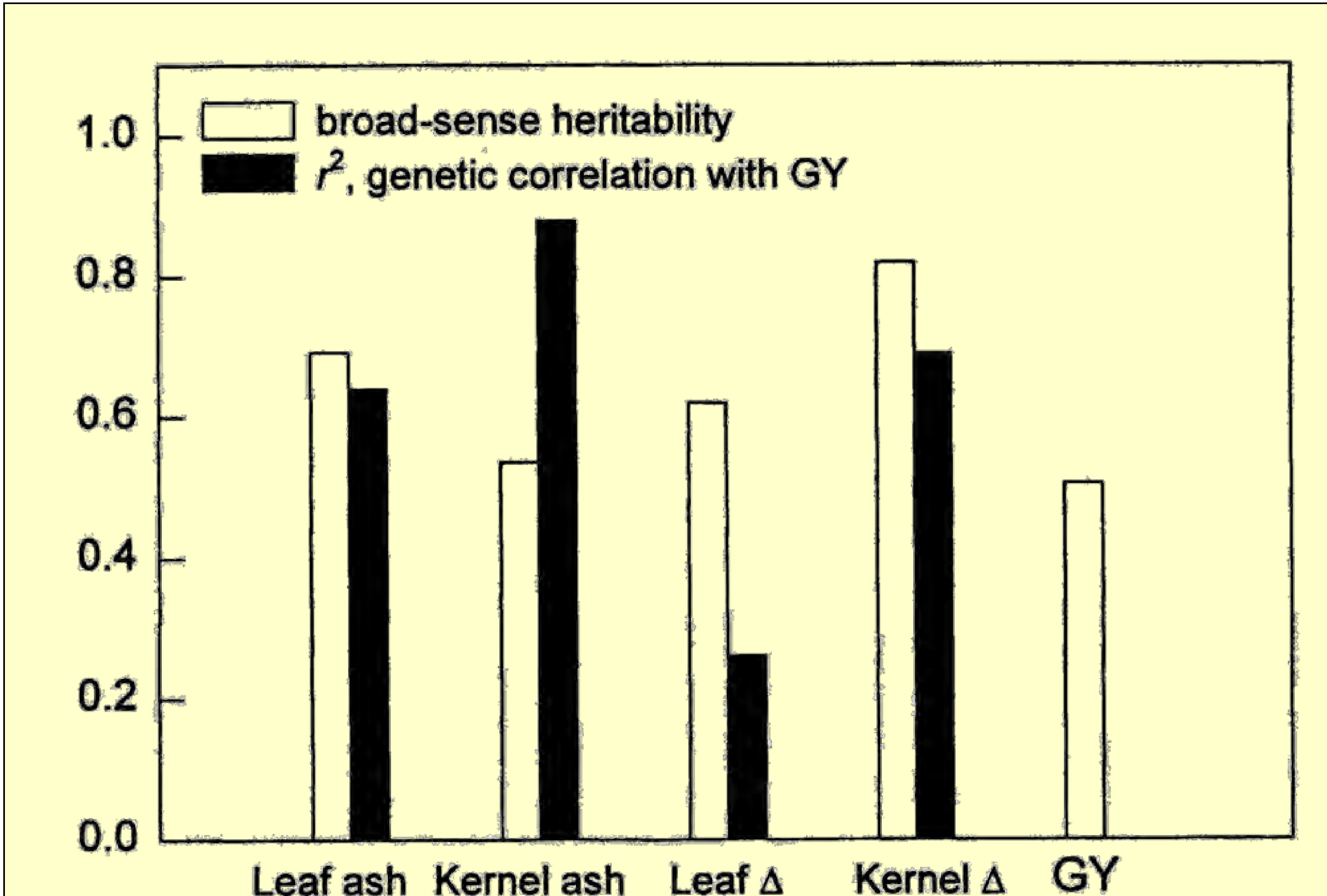


↑Transpiration

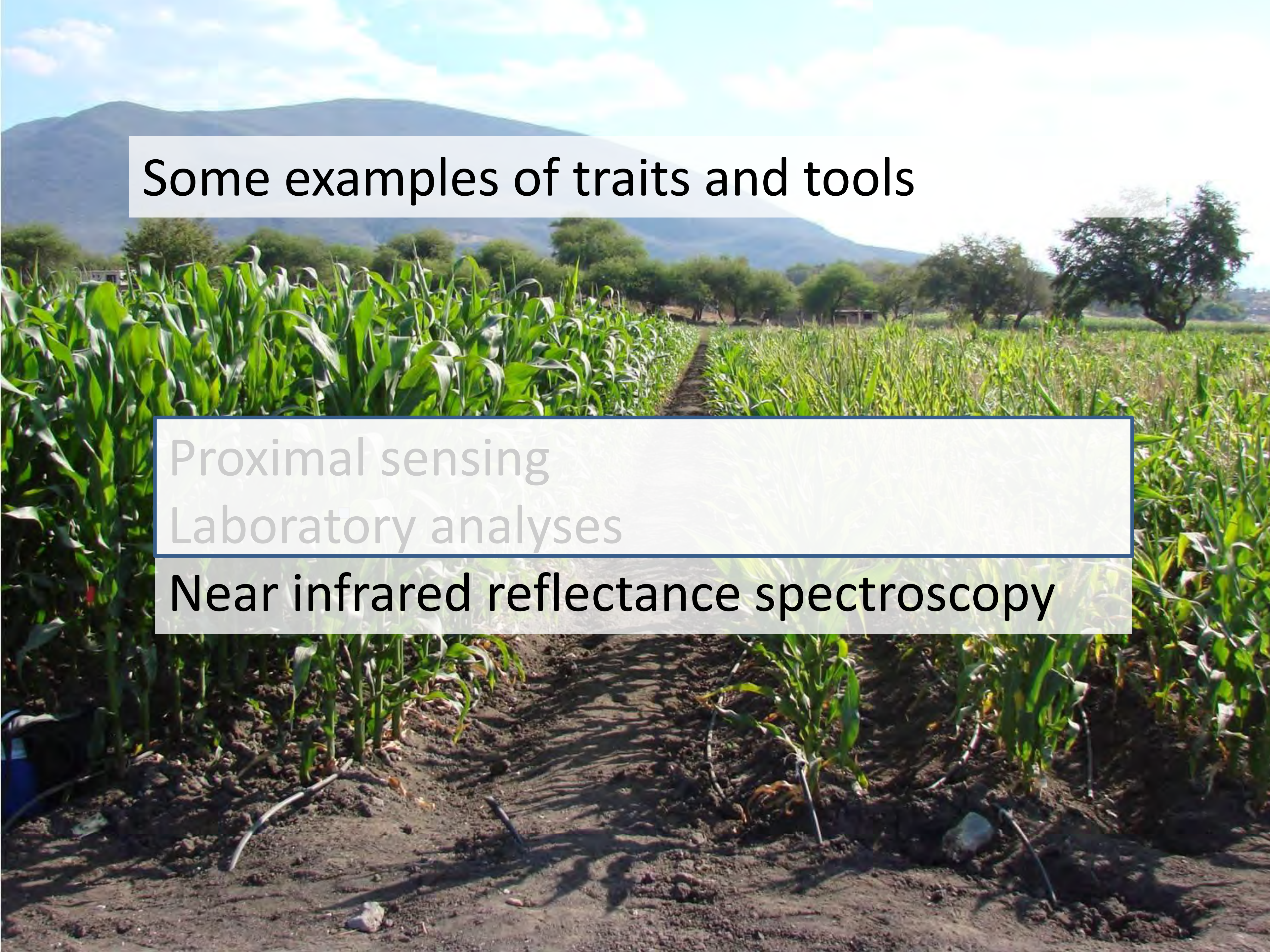
↑ Mineral accumulation in leaves

Transported through transpirational stream

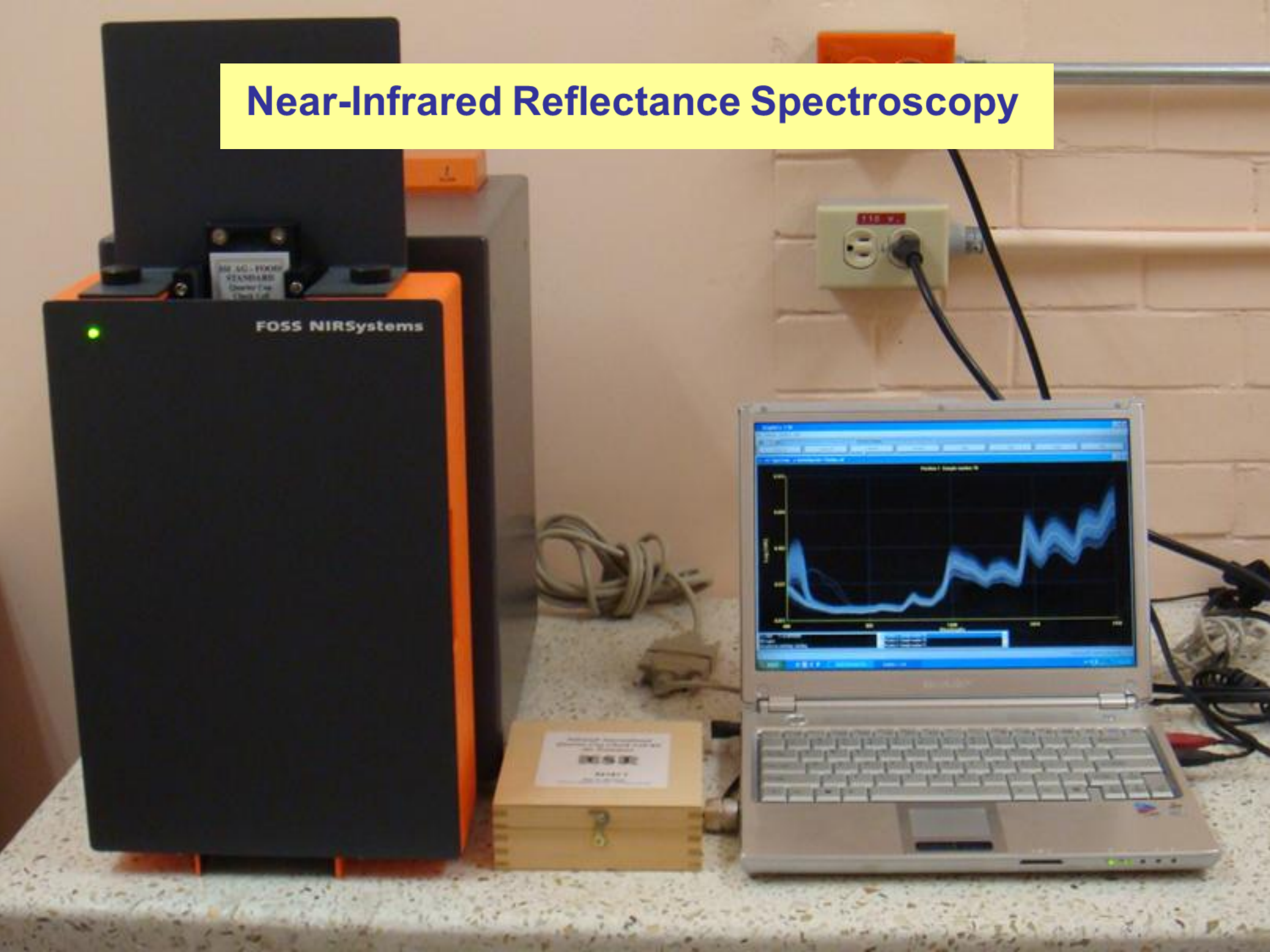
$\Delta^{13}C$ and Ash vs Yield



Araus et al., 1998 Aust. J. Plant Physiol.


Some examples of traits and tools
Proximal sensing
Laboratory analyses
Near infrared reflectance spectroscopy

Near-Infrared Reflectance Spectroscopy

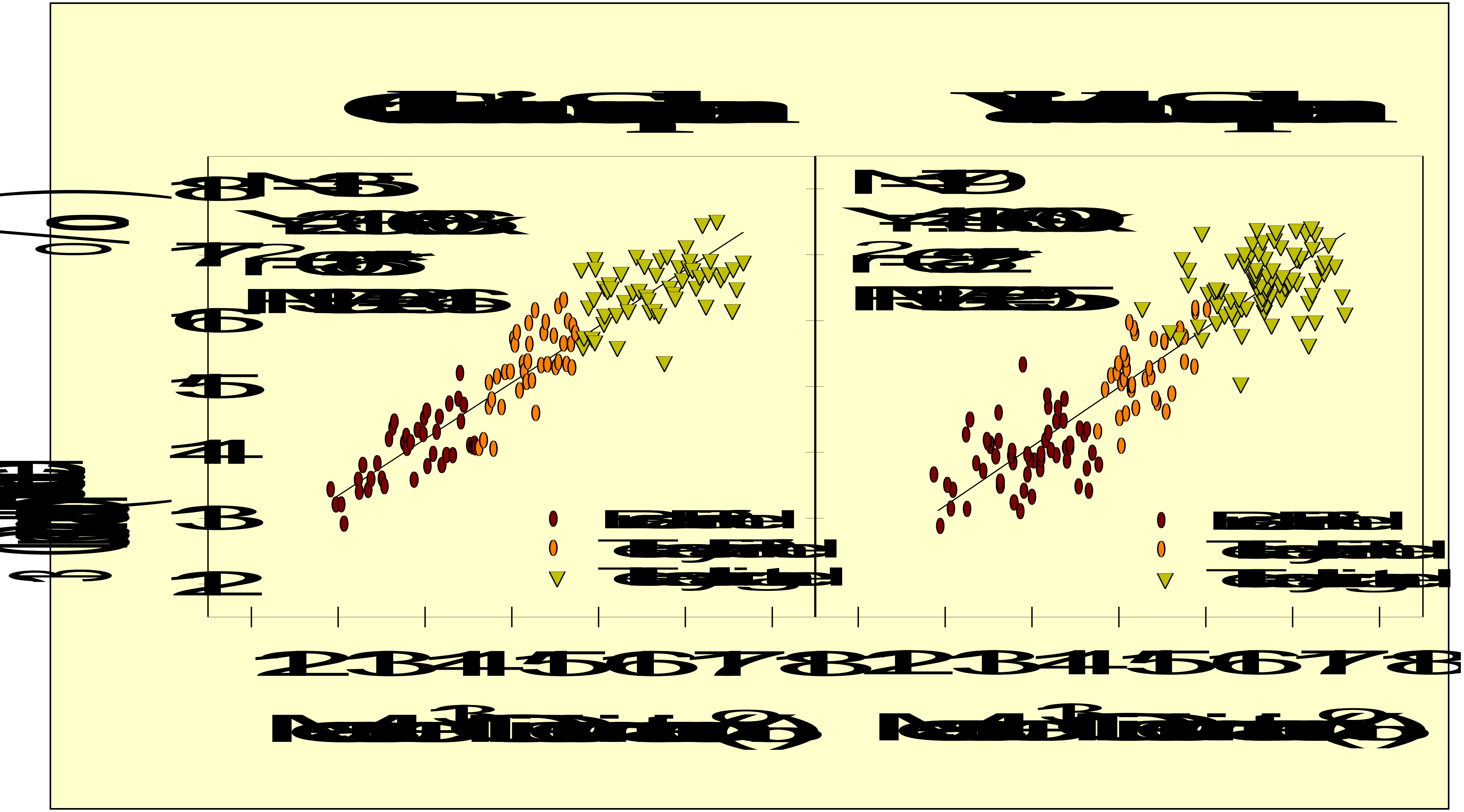


Comparative of cost and time

Technique	IRMS		EA	AACC Method	NIRS-prediction			
Parameter	$\delta^{13}C$	$\delta^{18}O$	N content	Ash content	$\delta^{13}C^{*}$	$\delta^{18}O$	Ash	N
Cost per sample	10€	20€	3€	1.5€	0.5€			
Time	<10 min	<10 min	<10 min	≈24 h	≈3 min			
Equipment	EA-IRMS		EA	Muffle furnace	NIR spectrometer			

*previously reported by Clark *et al*. 1995; Ferrio *et al*. 2001; Kleinebecker *et al*. 2009

NIRS a surrogate analysis of Δ¹³C



Ferrio et al., 2001 Aust. J. Agric. Res. 52: 809-816.

NIRS prediction of ash content and δ^{18}O

Calibration statistics for global sample sets (including **inbred lines and hybrids**) for N, ash content and δ^{18}O in kernels and leaves

Trait	*N*	Mean	*SD*	Range	*CV*	*SEC*	*R*^{2}c	*SECV*	*R*^{2}cv	*RPD*	Slope
$N_{kernels}$	126	1.81	0.24	1.15-2.38	13.4	0.09	0.87	0.09	0.87	2.76	0.90
N_{leaves}	152	1.57	0.22	1.04-2.05	14.1	0.10	0.80	0.12	0.72	1.86	0.80
$ASH_{kernels}$	129	1.47	0.24	0.91-1.90	16.2	0.11	0.79	0.13	0.72	1.89	0.79
ASH_{leaves}	150	14.31	2.89	8.78-21.46	20.2	0.54	0.97	0.65	0.95	4.42	0.98
$δ^{18}O_{kernels}$	128	31.69	1.43	28.05-34.99	4.5	0.82	0.66	1.04	0.49	1.38	0.66
$δ^{18}O_{leaves}$	151	32.97	1.25	29.37-36.46	3.8	0.79	0.54	1.00	0.38	1.26	0.57

Calibration statistics for **hybrid sample set** for leaf and kernel N and ash content and kernel δ^{18}O

Trait	*N*	Mean	*SD*	Range	*CV*	*SEC*	*R*^{2}c	*SECV*	*R*^{2}cv	*RPD*	Slope
$N_{kernels}$	73	1.73	0.24	1.15-2.24	13.71	0.07	0.87	0.08	0.87	2.79	0.87
N_{leaves}	86	1.49	0.22	0.92-1.95	14.71	0.08	0.86	0.09	0.83	2.46	0.86
$ASH_{kernels}$	75	1.37	0.27	0.91-1.80	19.71	0.10	0.82	0.14	0.70	1.92	0.82
ASH_{leaves}	84	14.89	2.92	10.02-20.82	19.64	0.49	0.97	0.78	0.93	3.76	0.98
$δ^{18}O_{kernels}$	70	31.03	1.05	29.06-33.53	3.37	0.50	0.77	0.76	0.51	1.38	0.77

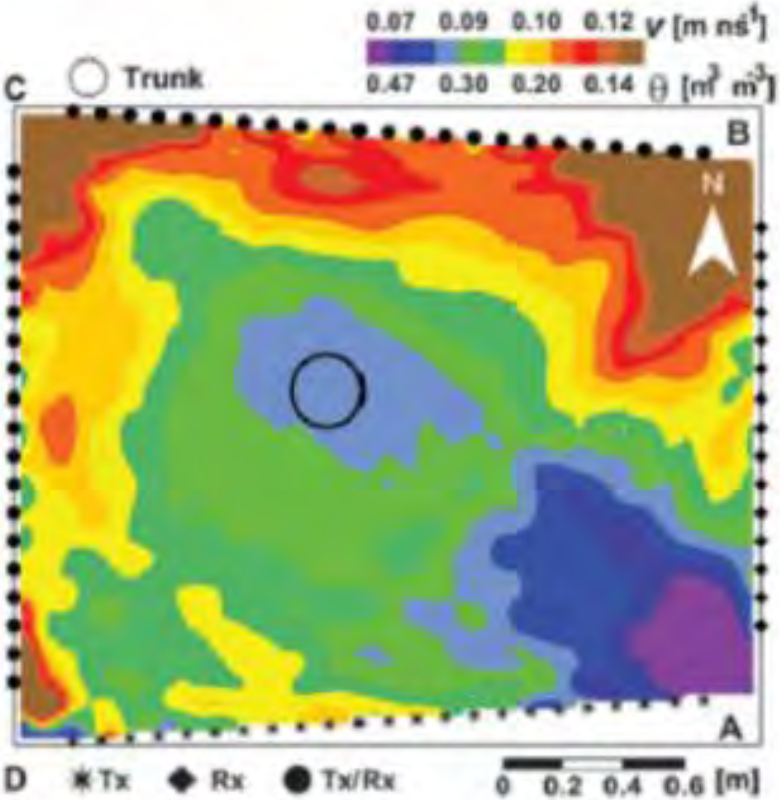
N, number of samples; *SD*, standard deviation; *CV*, coefficient of variation; *R*^{2}c, determination coefficient of calibration; *R*^{2}cv, determination coefficient of cross-validation; *RPD*, ratio of performance deviation; *SEC*, standard error of calibration; *SECV*, standard error of cross calibration. All correlations were significant at *P*<0.001 level.

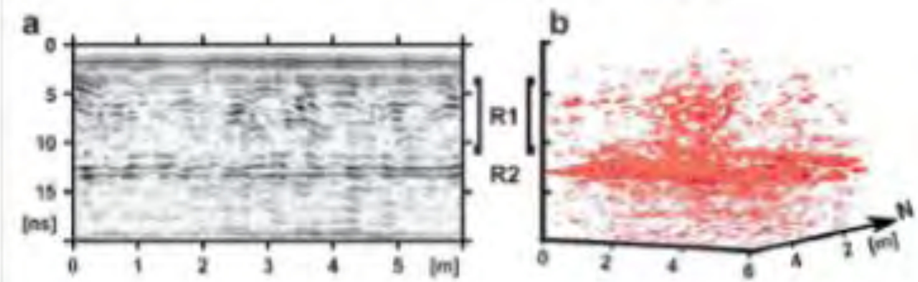
Cabrera-Bosquet et al. 2011. J. Agric. Food Chem. 59: 467–474

Roots: the hidden part

Ground-penetrating radar (*GPR*)

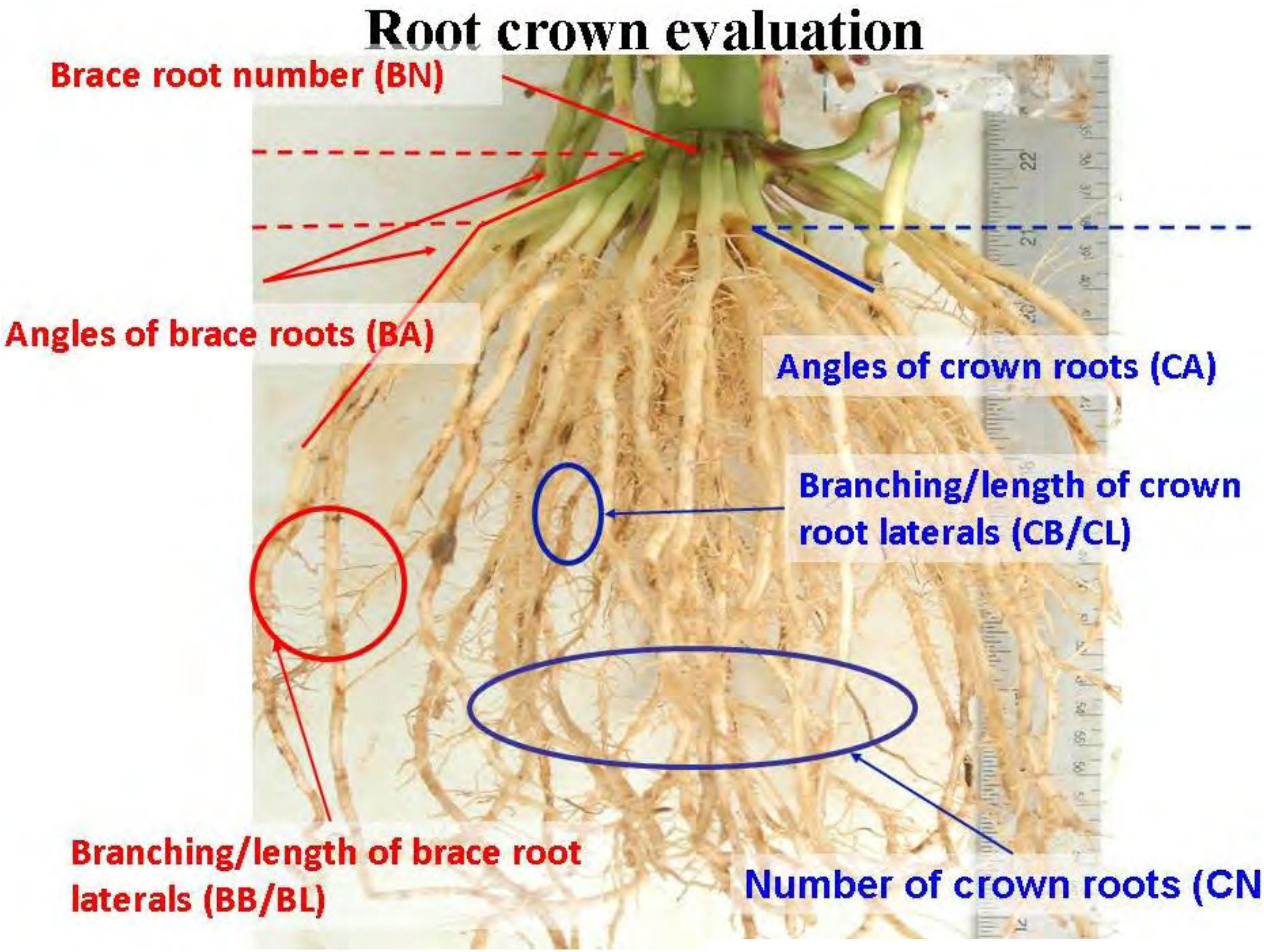
Roots and Water at Depth: GPR





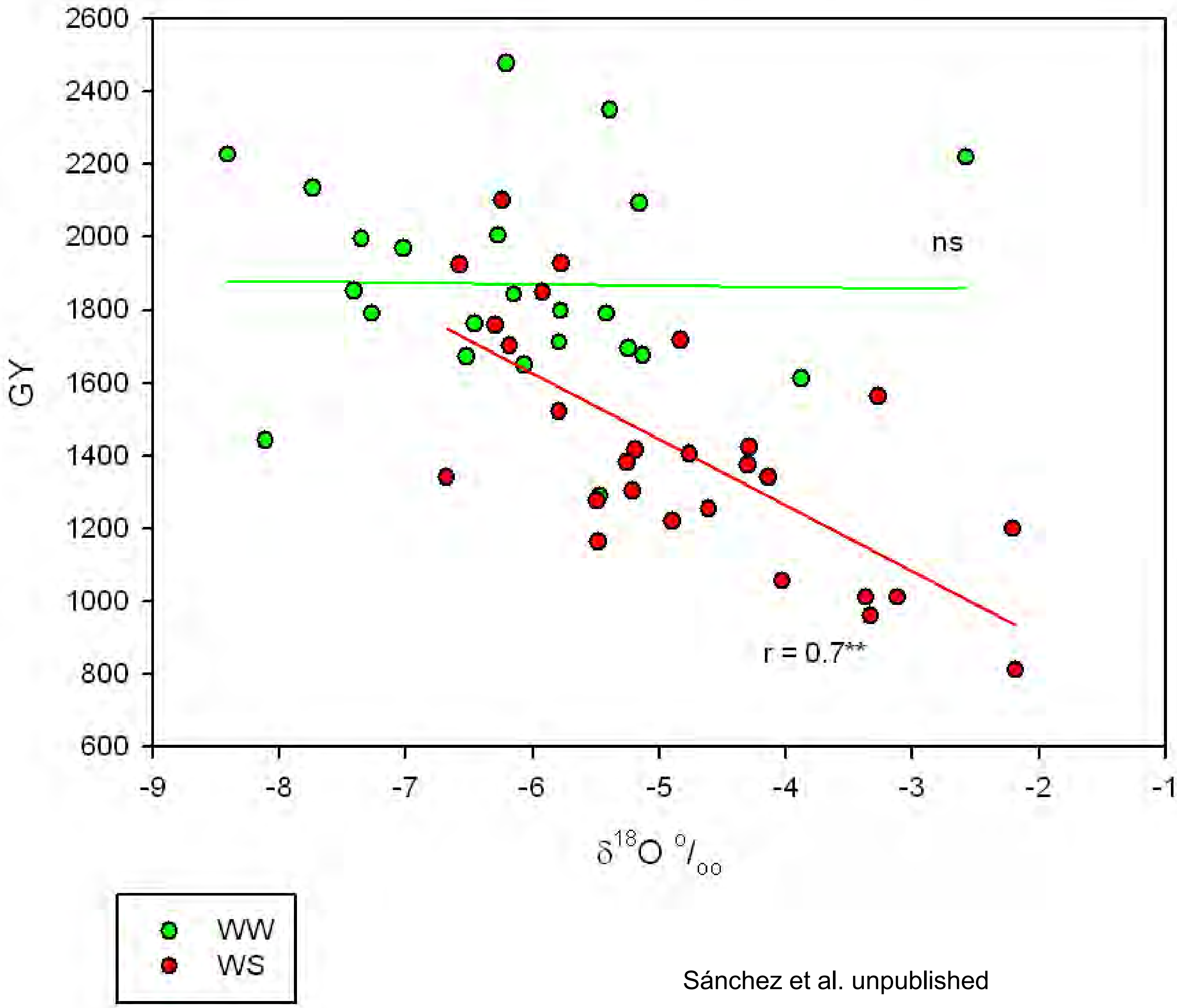
Australian Plant Phenomics Facility

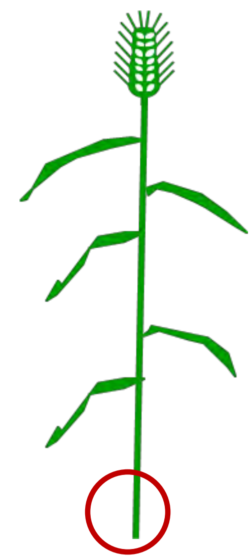
"Shovelomics"



Trachsel et al. 2011 Plant and Soil 341: 75-87

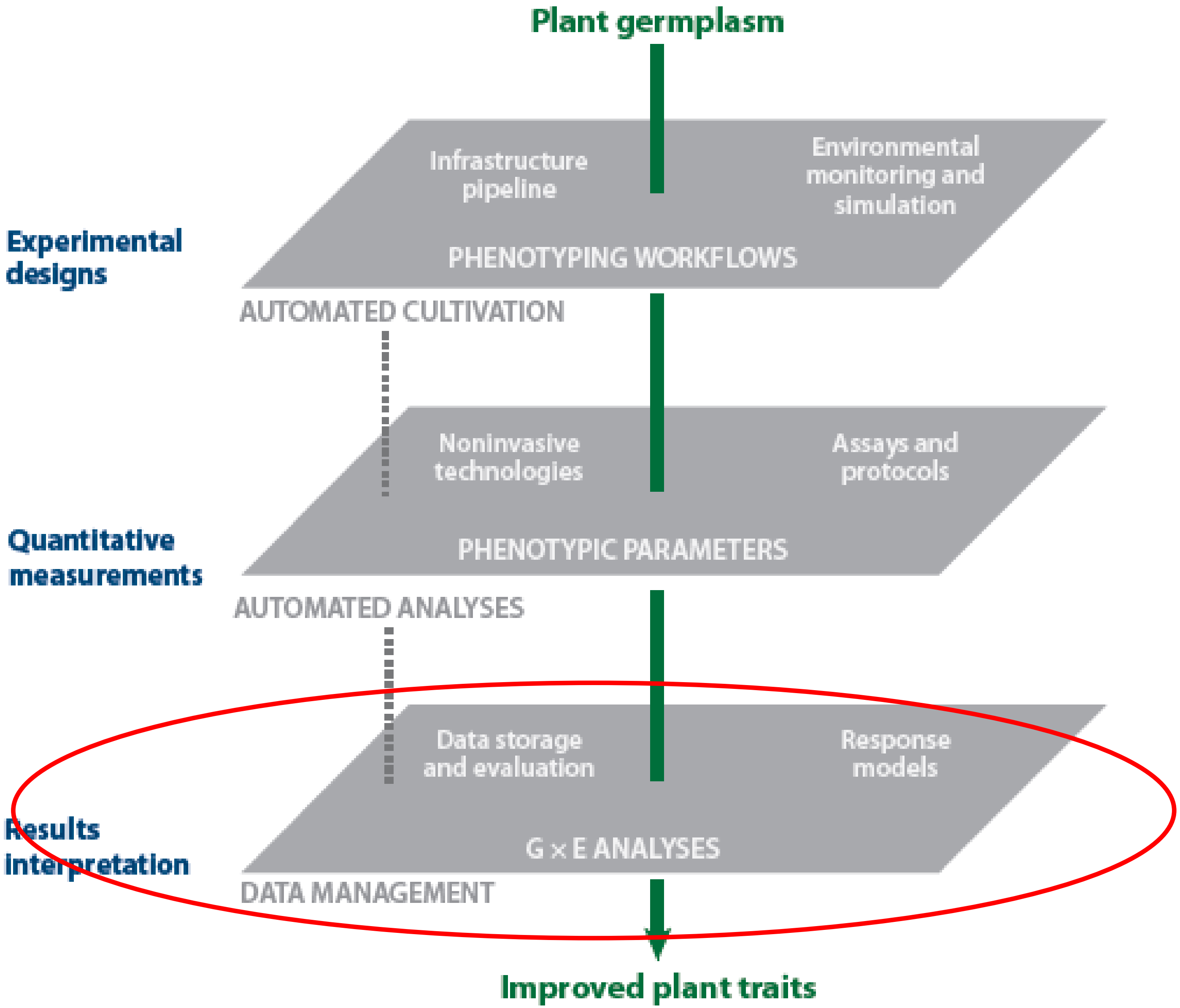
$\delta^{18}O$ stem water





Sánchez et al. unpublished


Some examples of traits and tools
Present bottleneck and the way ahead



Fabio Fiorani and Ulrich Schurr Annu. Rev. Plant Biol. 2013. 64:17.1–17.25

Data explosion

- We generate far too much data to handle manually
- Simple summary statistics as means and standard deviations do not suffice
- Advanced analysis tools are required


JIPB Journal of Integrative Plant Biology

Invited Expert Review

High-Throughput Phenotyping and Genomic Selection: The Frontiers of Crop Breeding Converge

Llorenç Cabrera-Bosquet[1], José Crossa[2], Jarislav von Zitzewitz[3], Maria Dolors Serret[4] and José Luis Araus[4,*]

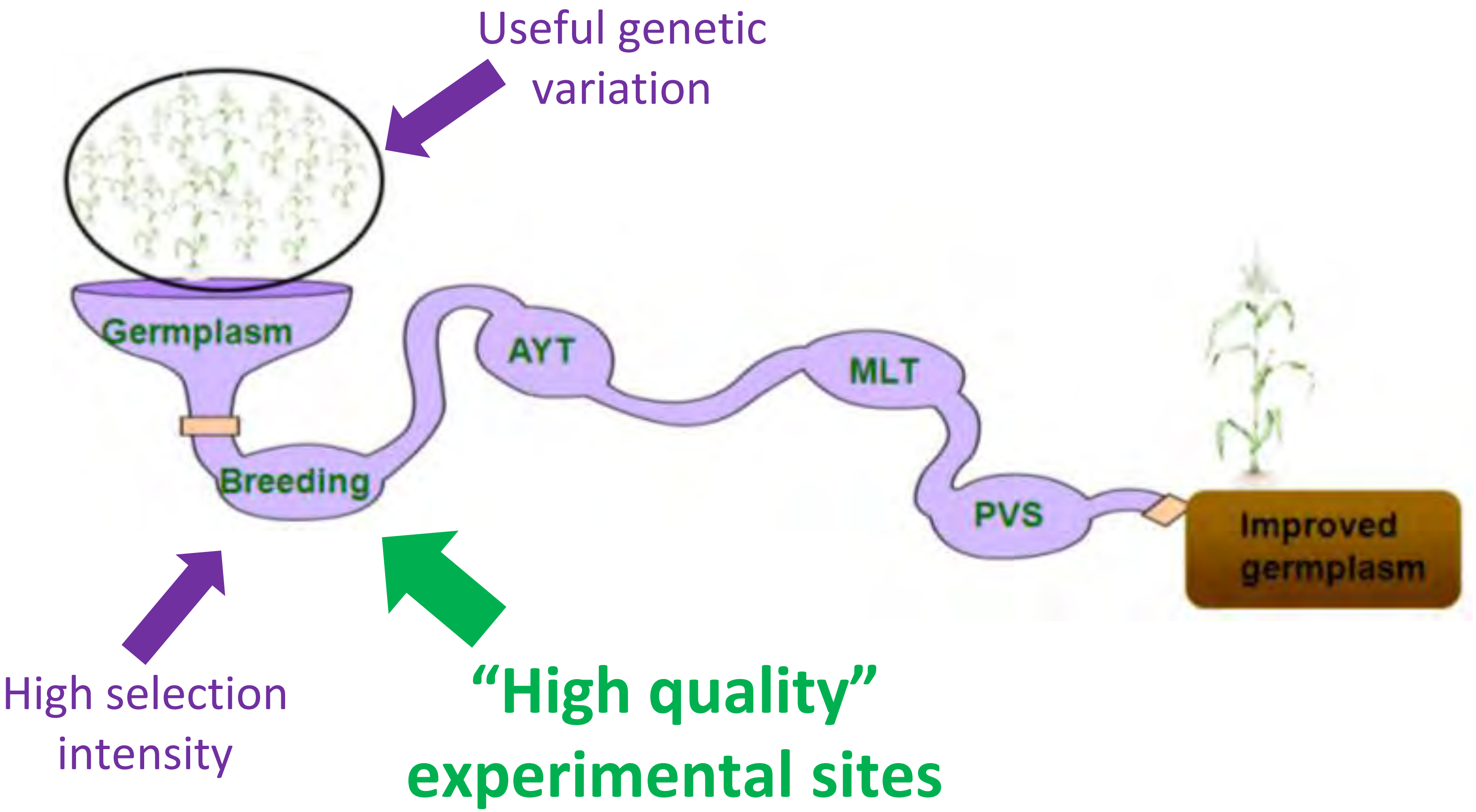
Outline

Why field phenotyping?

Some examples of traits and tools

More than just traits and tools

Cornerstone of development of improved germplasm



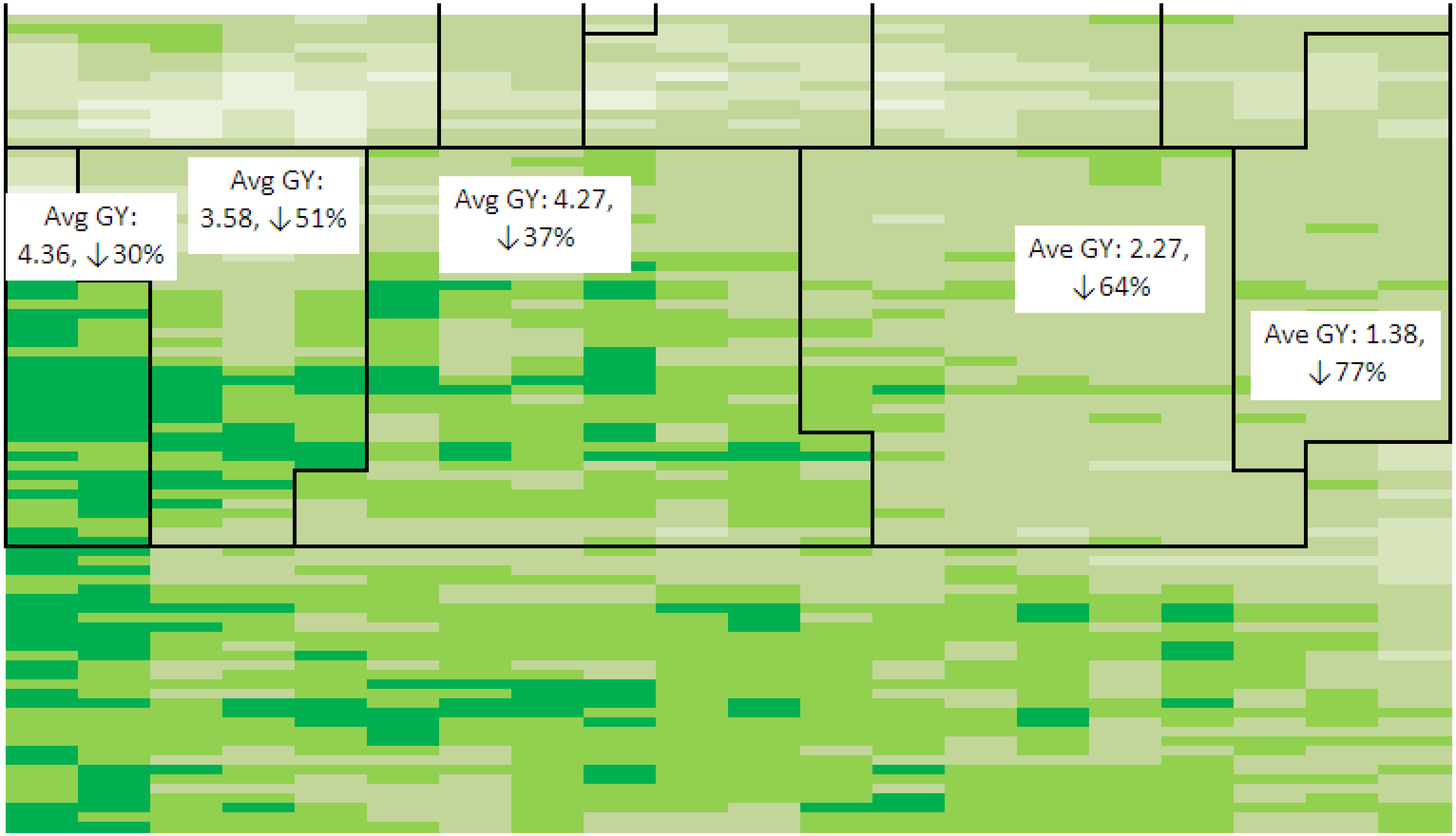
Jill Cairns, CIMMYT.

Prior phenotyping we need to characterise experimental sites for environmental variability

Environmental variability

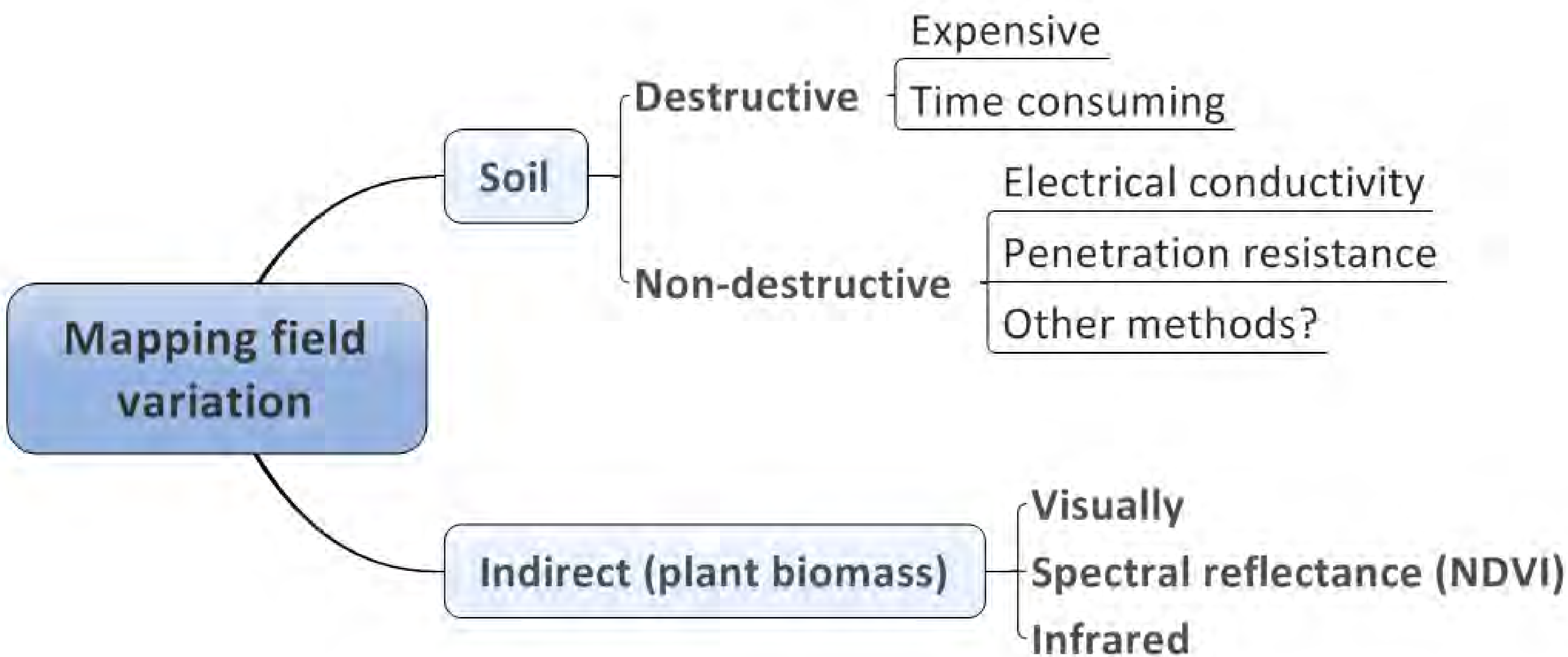
- **within site variability**

Soil variability within drought screening sites



B. Das CIMMYT-Kenya

Mapping field variation



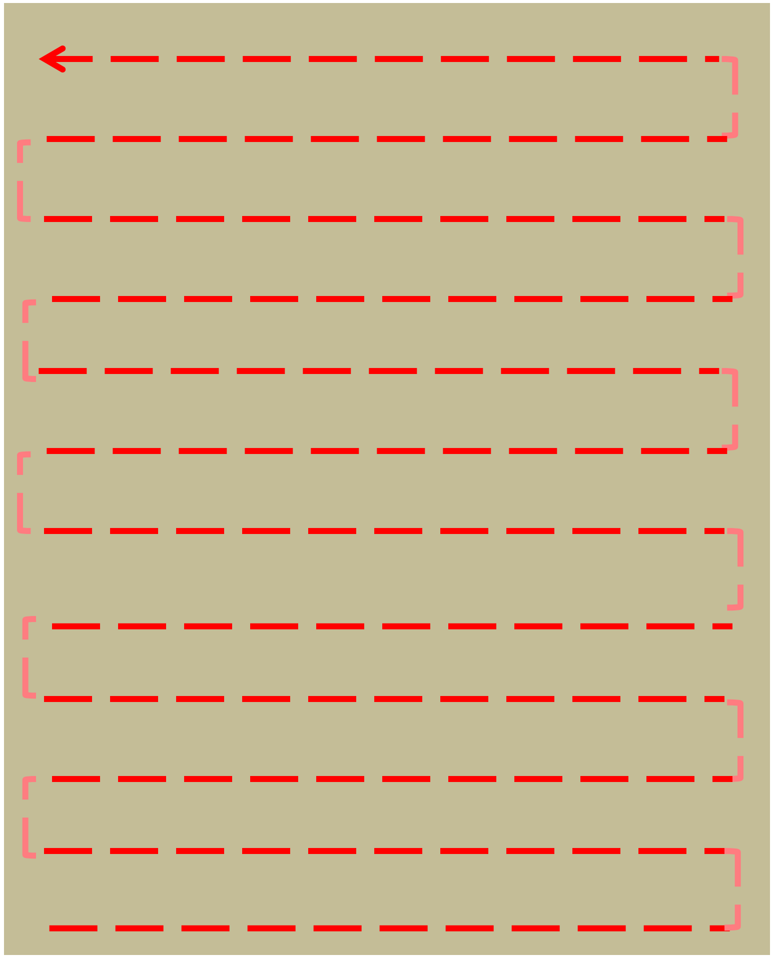
EM38 soil sensor

EM38 sensor

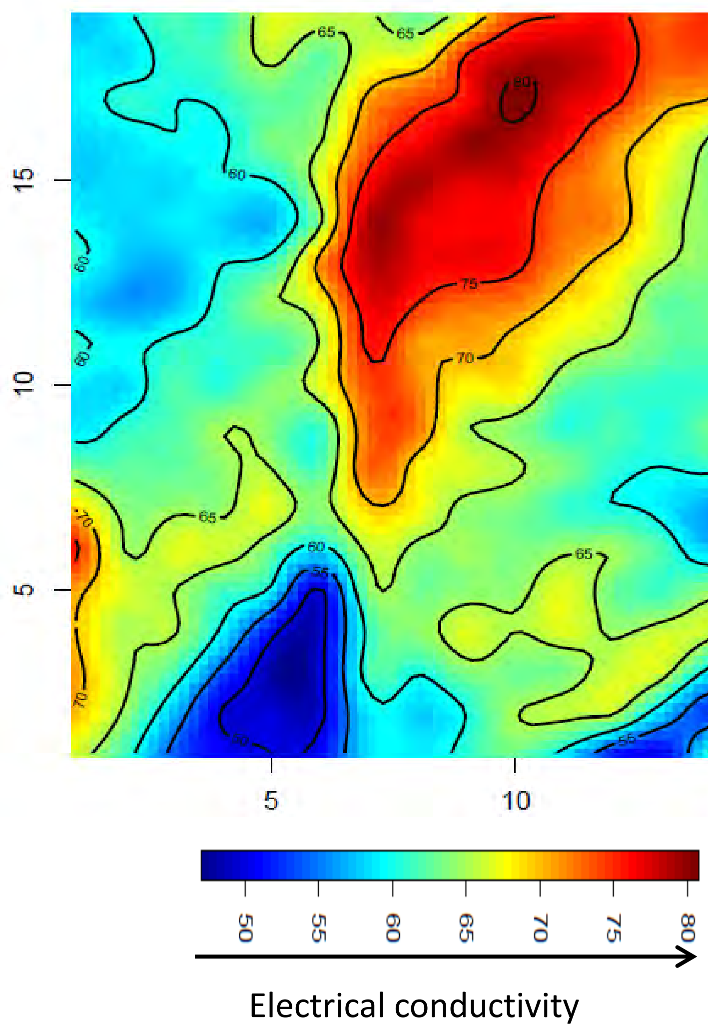
- Measures soil conductivity
    - The sensor detects induced electric currents at depth in response to an external time-varying (primary) magnetic field
- Max depth 0.75 cm (horizontal)
- Identifies variation in soil properties, particularly salinity and moisture content

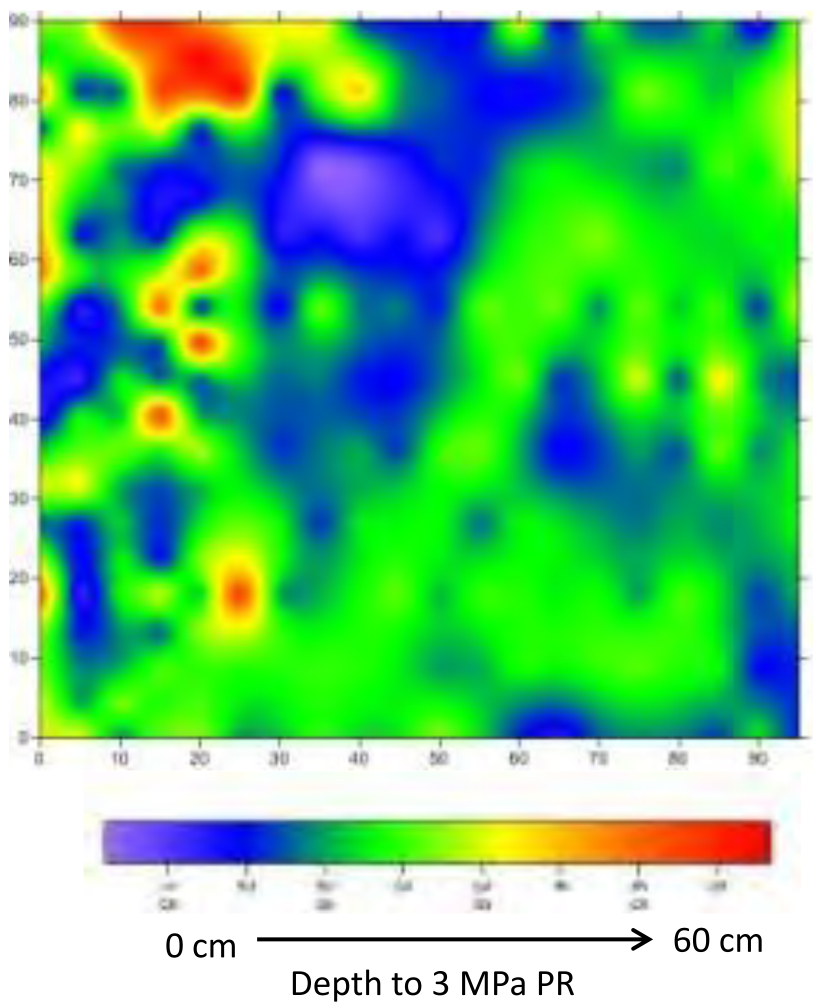
Jill Cairns – CIMMYT Mexico

Measuring soil variability using EM38



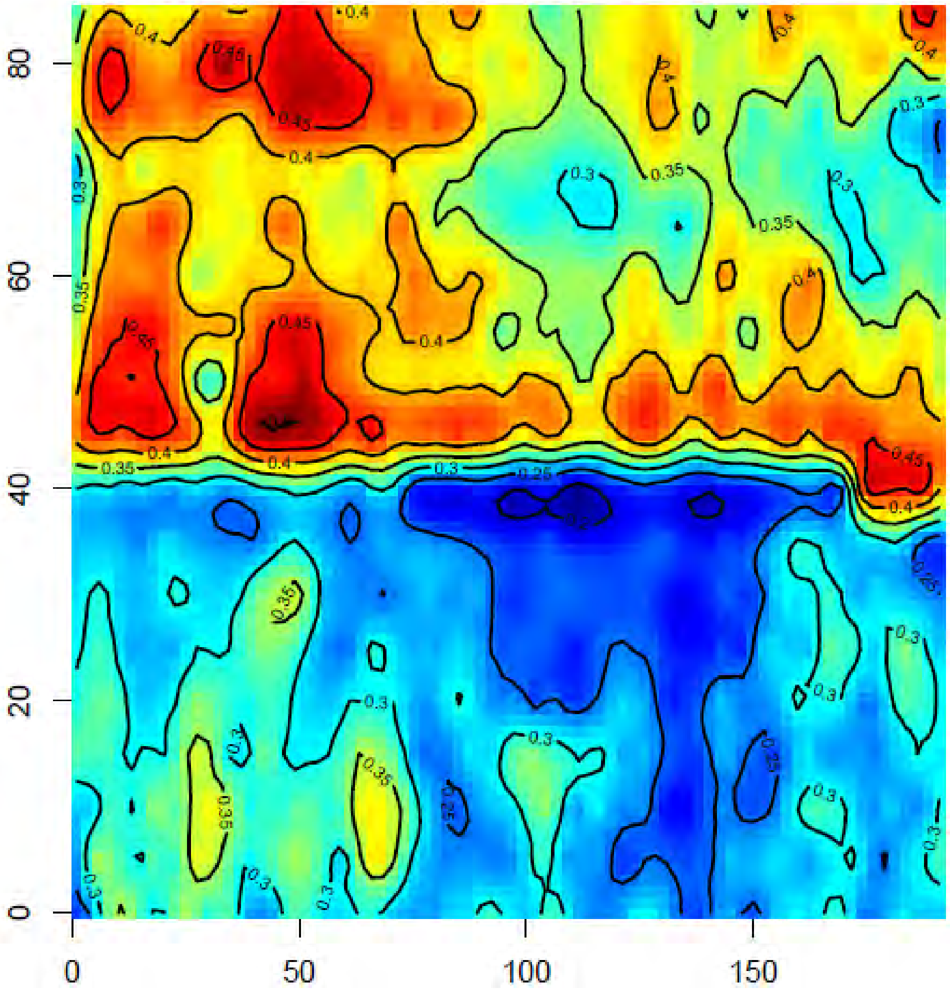
Mapping field variation: non-destructive

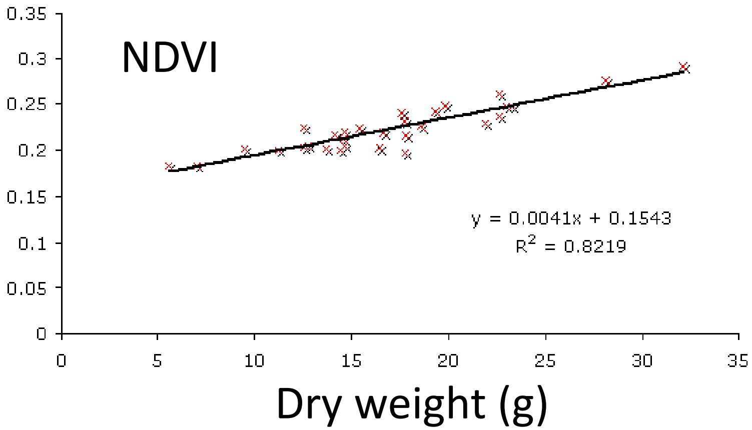




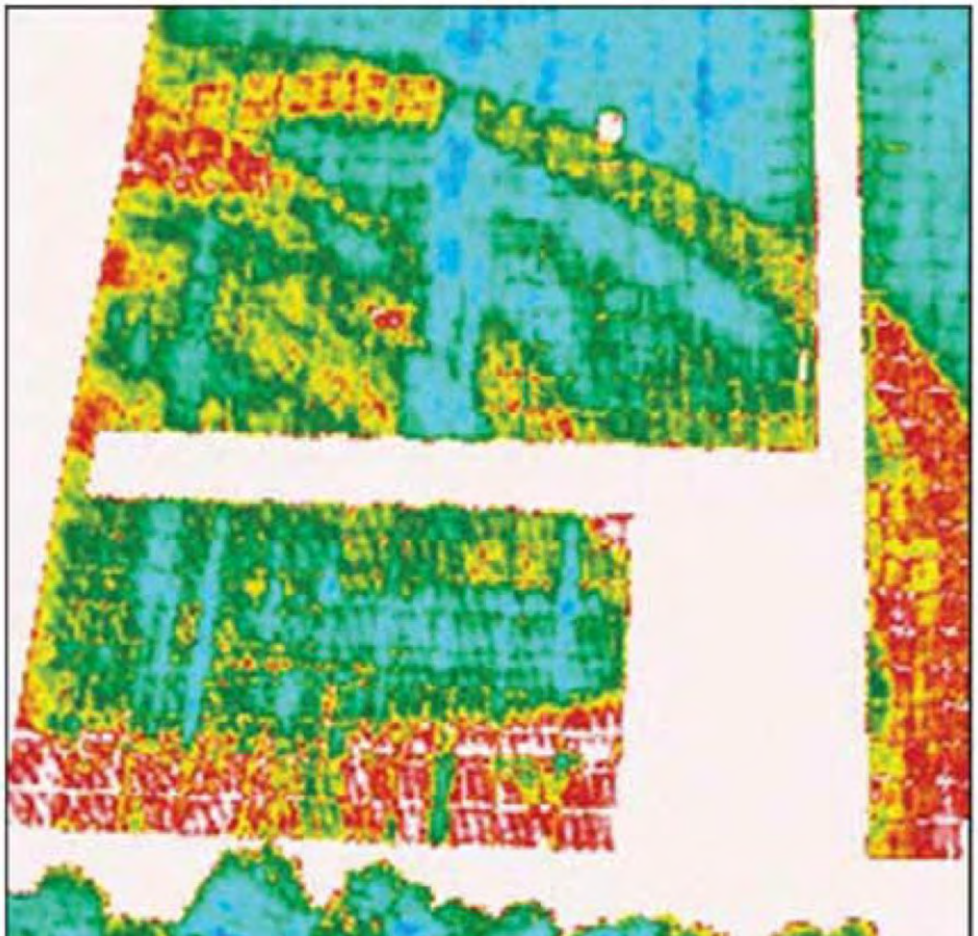
Prasanna et al. 2013

Soil variability map using NDVI



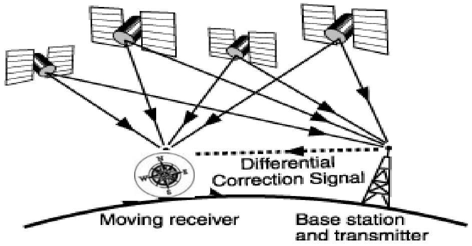


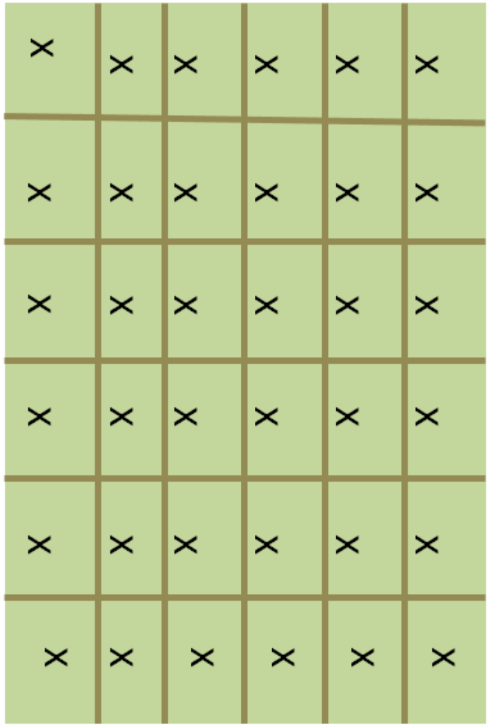
Mapping variability using infrared thermography



Campos GCP Phenotyping Manual, 2011

Consolidating data inc yield





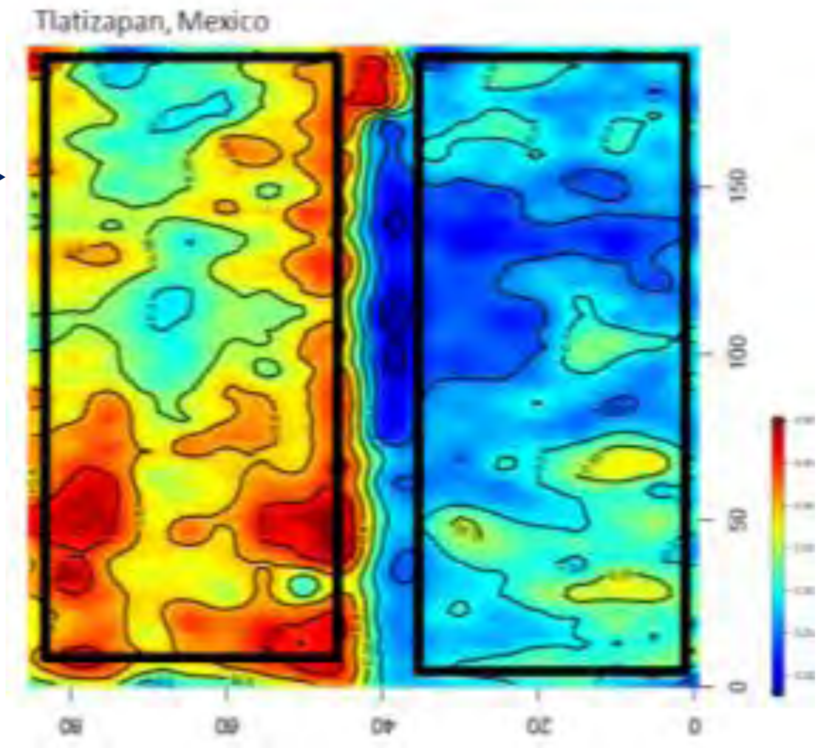
Develop comprehensive site maps

Link to specific coordinates using base stations or GPS correction facilities

Reducing the effects of field variation

EM38 (1 ha = ~ 3 hours)

Identify field gradients → incorporate into field design



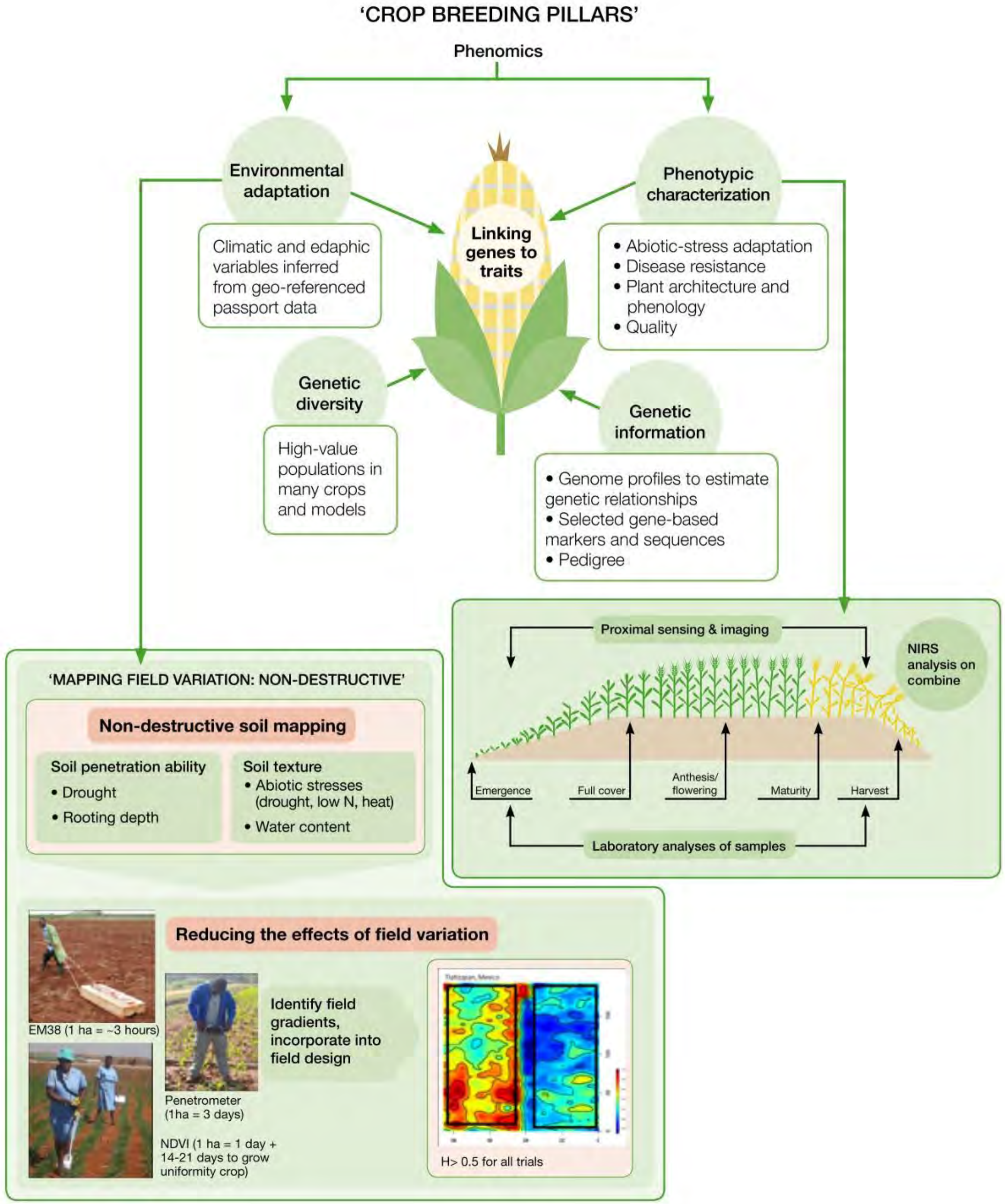
H > 0.5 for all trials

Penetrometer (1 ha = 3 days)

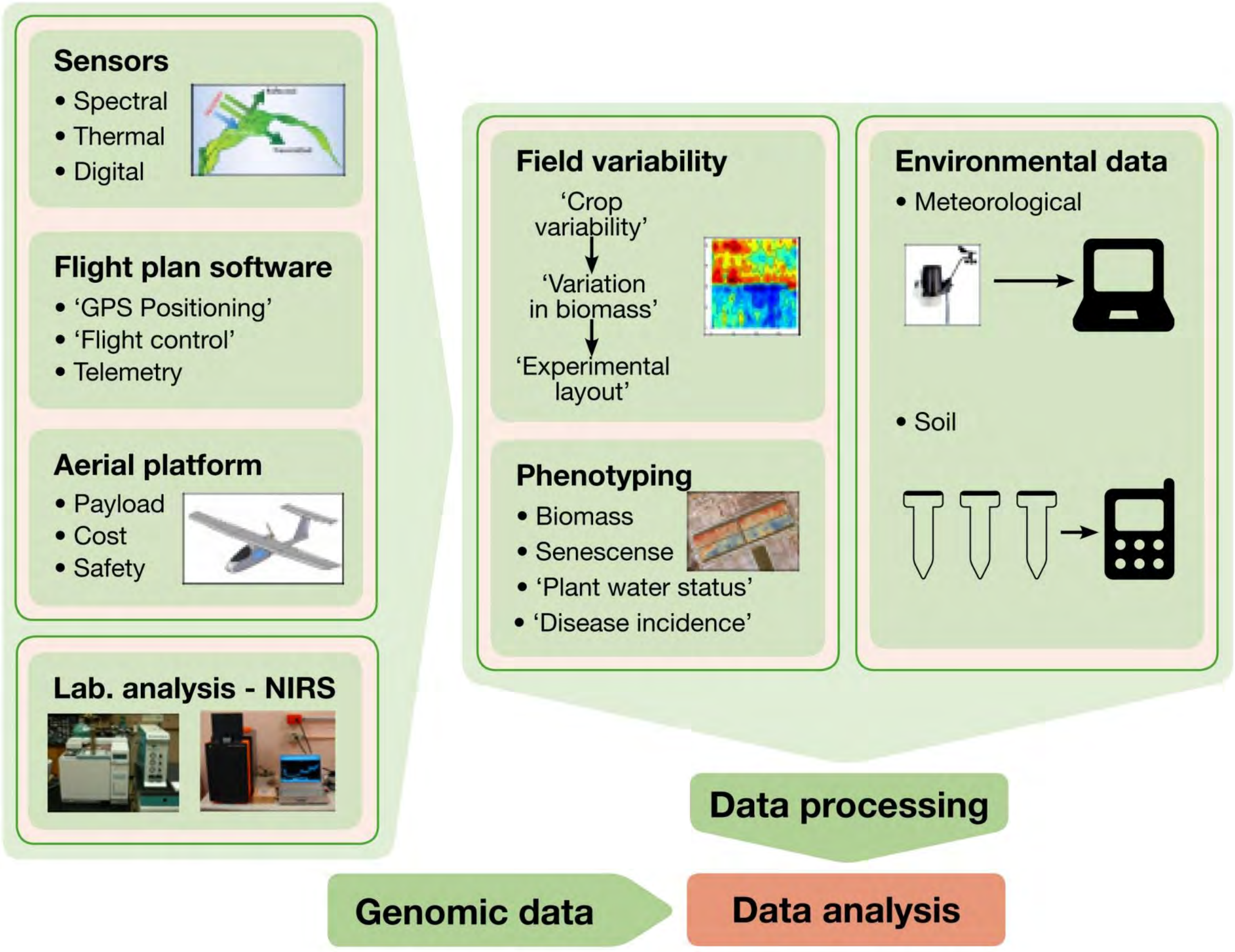
NDVI (1 ha = 1 days, + 14-21 days to grow uniformity crop)

Masuka et al. Journal of Integrative Plant Biology 2012


Summary



'CROP BREEDING PILLARS'
Phenomics
Environmental adaptation
Climatic and edaphic variables inferred from geo-referenced passport data
Phenotypic characterization
• Abiotic-stress adaptation
• Disease resistance
• Plant architecture and phenology
• Quality
Linking genes to traits
Genetic diversity
High-value populations in many crops and models
Genetic information
• Genome profiles to estimate genetic relationships
• Selected gene-based markers and sequences
• Pedigree
Proximal sensing & imaging
NIRS analysis on combine
Emergence
Full cover
Anthesis/ flowering
Maturity
Harvest
Laboratory analyses of samples
'MAPPING FIELD VARIATION: NON-DESTRUCTIVE'
Non-destructive soil mapping
Soil penetration ability
• Drought
• Rooting depth
Soil texture
• Abiotic stresses (drought, low N, heat)
• Water content
Reducing the effects of field variation
EM38 (1 ha = ~3 hours)
Penetrometer (1ha = 3 days)
NDVI (1 ha = 1 day + 14-21 days to grow uniformity crop)
Identify field gradients, incorporate into field design
H> 0.5 for all trials

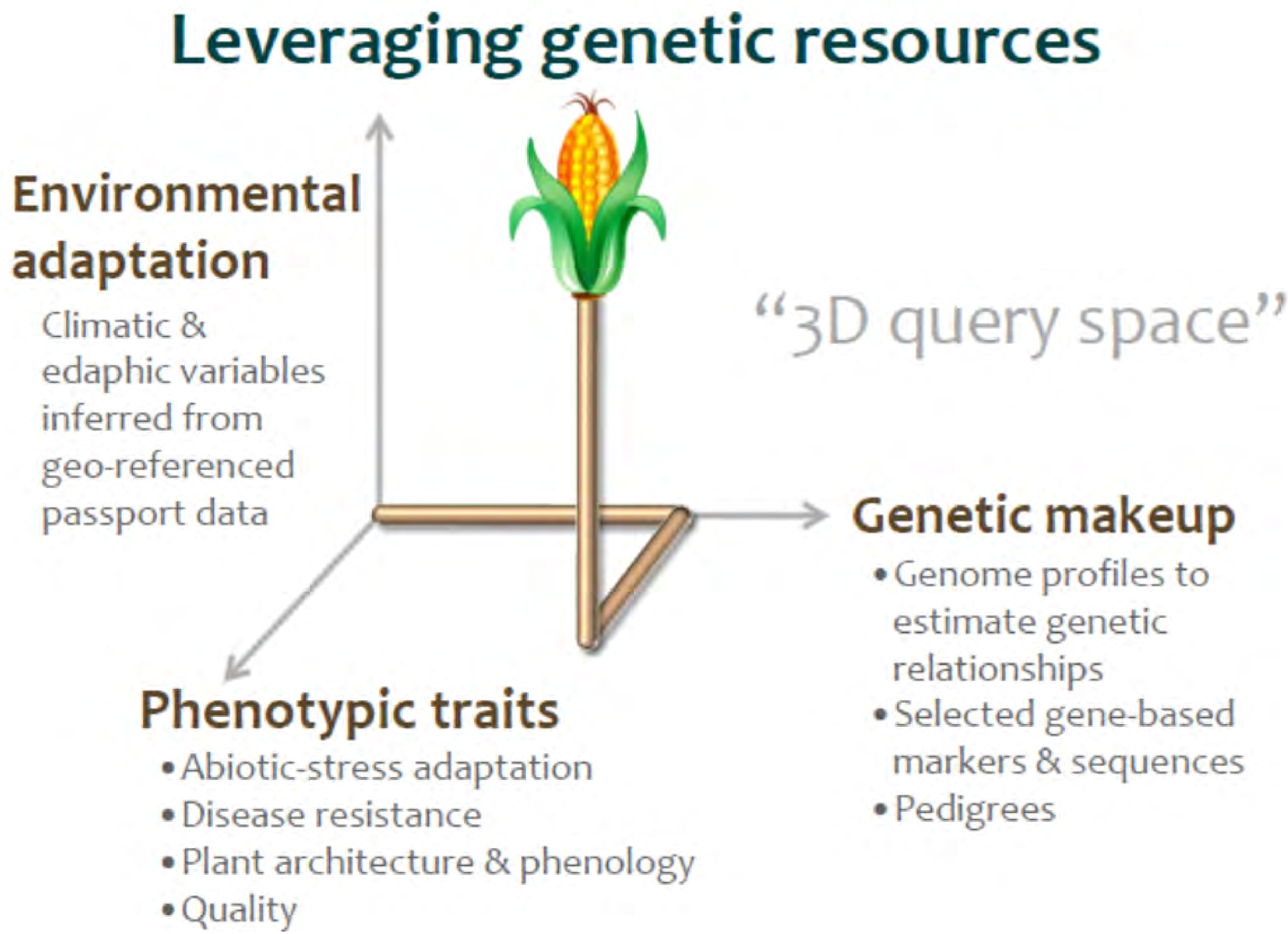

Sensors
• Spectral
• Thermal
• Digital
Flight plan software
• 'GPS Positioning'
• 'Flight control'
• Telemetry
Aerial platform
• Payload
• Cost
• Safety
Lab. analysis - NIRS
Field variability
'Crop variability'
'Variation in biomass'
'Experimental layout'
Phenotyping
• Biomass
• Senescense
• 'Plant water status'
• 'Disease incidence'
Environmental data
• Meteorological
• Soil
Data processing
Genomic data
Data analysis

Ackowledgements

- **Affordable field-based high Throughput Phenotyping Platforms (HTPPs**). Maize Competitive Grants Initiative. CIMMYT
- **Adaptation to Climate Change of the Mediterranean Agricultural Systems – ACLIMAS.**. EuropeAid/131046/C/ACT/Multi. European Commission
- **Durum wheat improvement for the current and future Mediterranean conditionsMejora del trigo duro para las condiciones mediterráneas presentes y futuras.** AGL2010-20180 Spain.
- **Breeding to Optimise Chinese Agriculture (OPTICHINA).** FP7 Cooperation, European Commission - DG Research. Grant Agreement 26604 .


Many thanks….

Importance of phenotyping



“Handling large amounts of data and making sense of it presents a big challenge for high-throughput phenotyping. A major problem is that right now we don’t have a good data management system in place”

“We don’t even have a physical concept of what some of those numbers mean other than length, width, and color. They’re all just mathematical transformations of numbers, but perhaps some linear combination of them will actually, for reasons we don’t understand, have some correlation with important traits such as leaf angle, planting density, and so on”

CSA News March 2013