Smartphone-based application for plant phenotyping

Roberto Confalonieri, Livia Paleari, Ermes Movedi, Marco Foi

University of Milan, Cassandra lab

roberto.confalonieri@unimi.it

www.cassandralab.com

Uncertainty and phenotyping

- **Hundreds of genotypes** under evaluation could **turn into long time** for measuring traits (White et al., 2011)
  - ✓ Often, **few instruments** available (costly)
  - ✓ **Phenotyping** on many genotypes should be "**synchronous**"
  - ✓ Time needed for phenotyping could lead to use "**small**" **sample sizes** (**to save time**)
- **A-synchronous phenotyping** on different genotypes and/or **sub-optimal sample sizes** could generate **uncertainty**
  - ✓ that could be **larger** than **differences between genotypes**

Uncertainty and phenotyping

- Greenhouse and field platforms, robots

Uncertainty and phenotyping

- Greenhouse and field platforms, robots

Uncertainty and phenotyping

- Greenhouse and field platforms, robots
  - ✓ Cost?
  - ✓ Which kind of traits can be actually quantified

…what do we mean by "trait"?

Uncertainty and phenotyping

- "**Trait**":
  - ✓ First time defined by Darwin (1859)?
  - ✓ Development of disciplines
    - quantitative genetics
    - ecophysiology
    - functional ecology

→ **"Dialects"?**

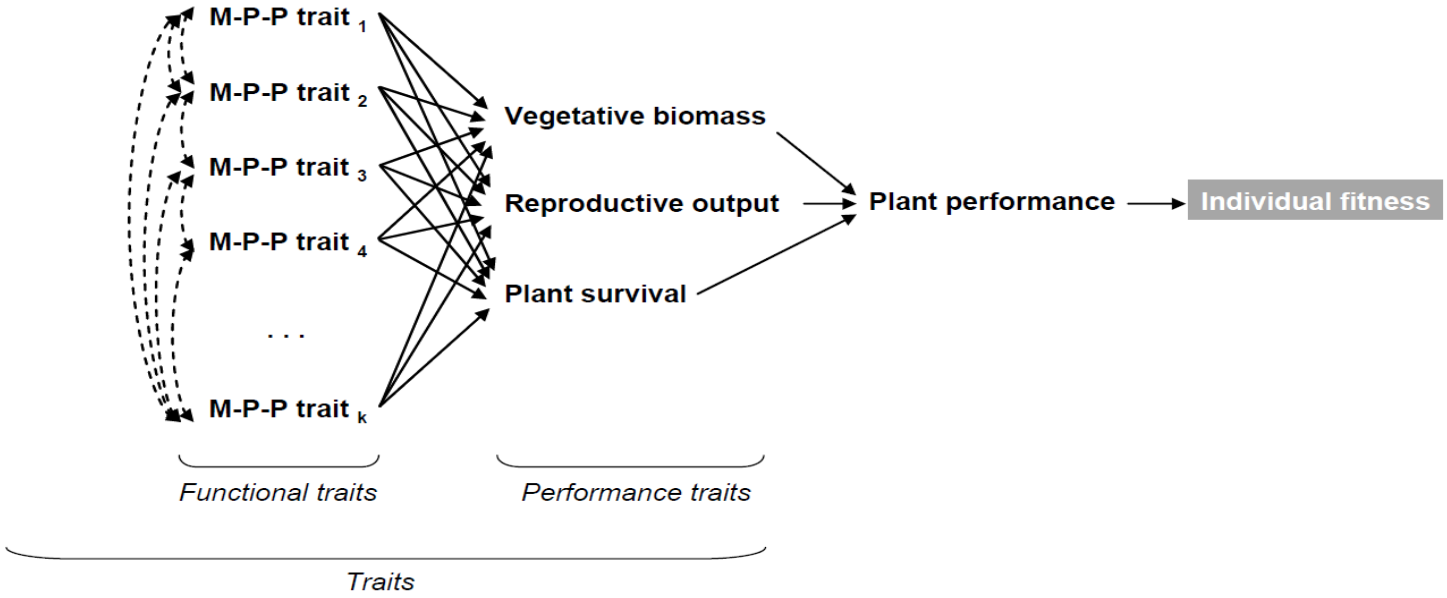
→ The term assumed a variety of connotations…

…the underlying concept is sometimes (often?) unclear (Violle et al., 2007)

Solutions:

- **Classification** frameworks based on the **trait role** in determining **individual fitness** (e.g., Arnold, 1983; Violle et al., 2007)

Uncertainty and phenotyping



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Uncertainty and phenotyping

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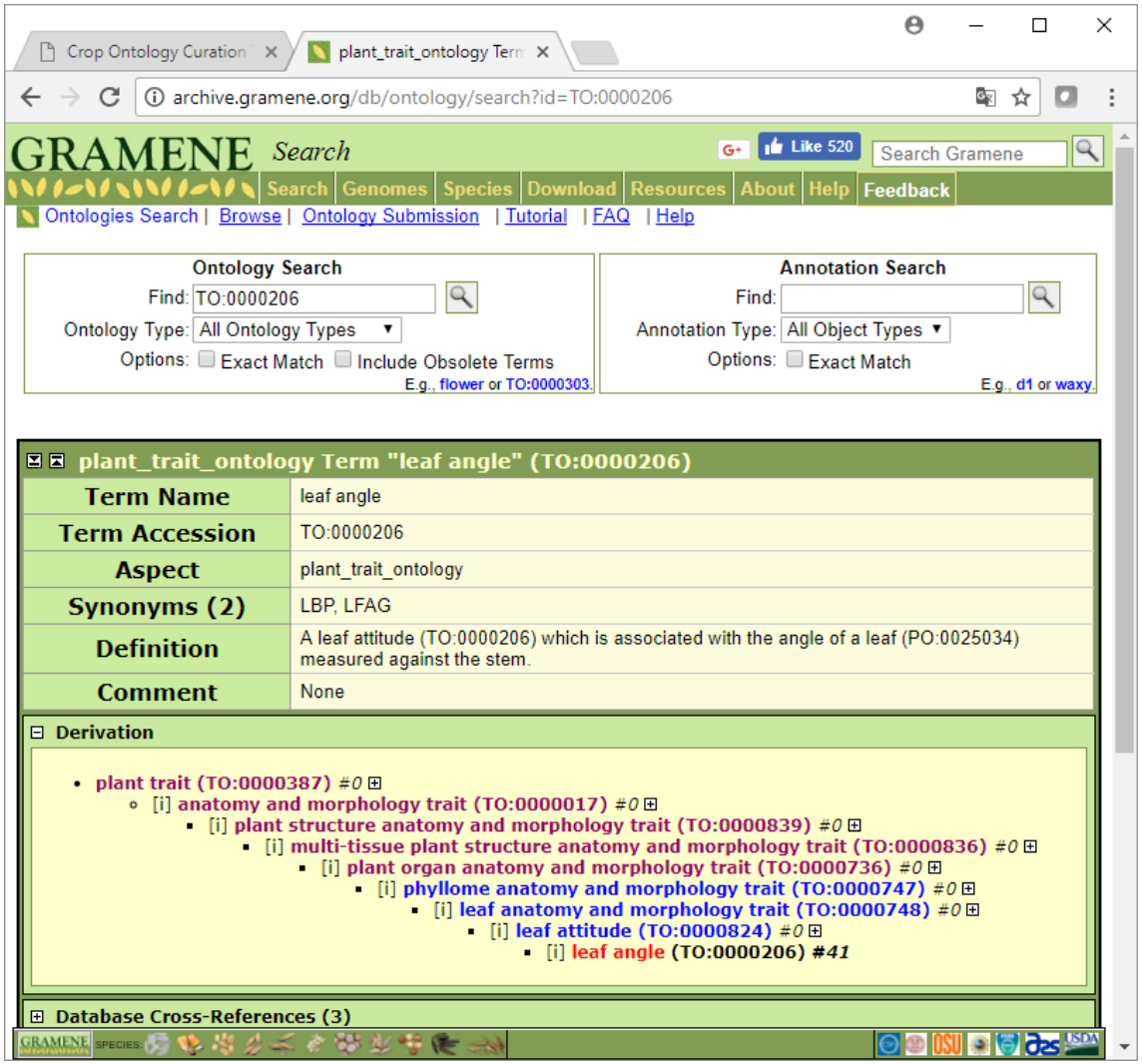
- Trait ontologies…

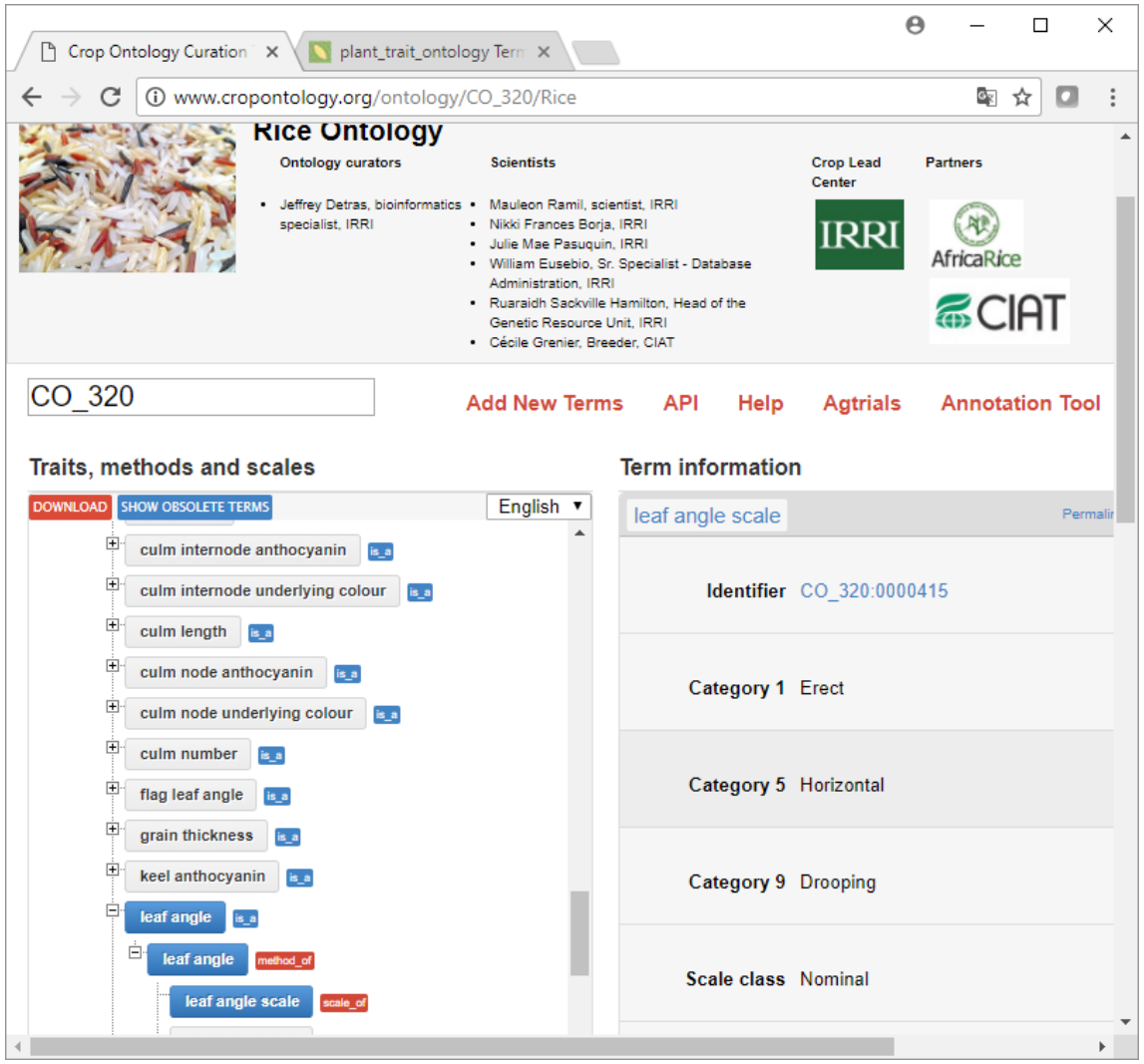
Uncertainty and phenotyping

- Trait ontologies:



Uncertainty and phenotyping

- Trait ontologies:



Uncertainty and phenotyping

- Trait ontologies:
  - ✓ They **appear as good solutions** but unfortunately they are **not as good as they would like** to be
    - **Definitions** are **not** completely **unambiguous**
    - Sometimes **traits** are **not** described in a **quantitative** way
- **…Breeders** have to
  - ✓ phenotype **hundreds** of **lines**
  - ✓ in a **short** interval of **time**

⇨ **Trait** = "something that can be measured easily and rapidly"

This is a **potential source** of **misunderstandings** and **uncertainty**

Uncertainty and phenotyping

- Greenhouse and field platforms, robots
  - ✓ Cost?
  - ✓ Which kind of traits can be actually quantified
  - ✓ G × E interaction?
    - Greenhouse platforms
      - → plants in pots
      - → "environmental" conditions…
      - → gradients inside the greenhouse
    - Field platforms
      - → transport them?
      - → how many?

Uncertainty and phenotyping

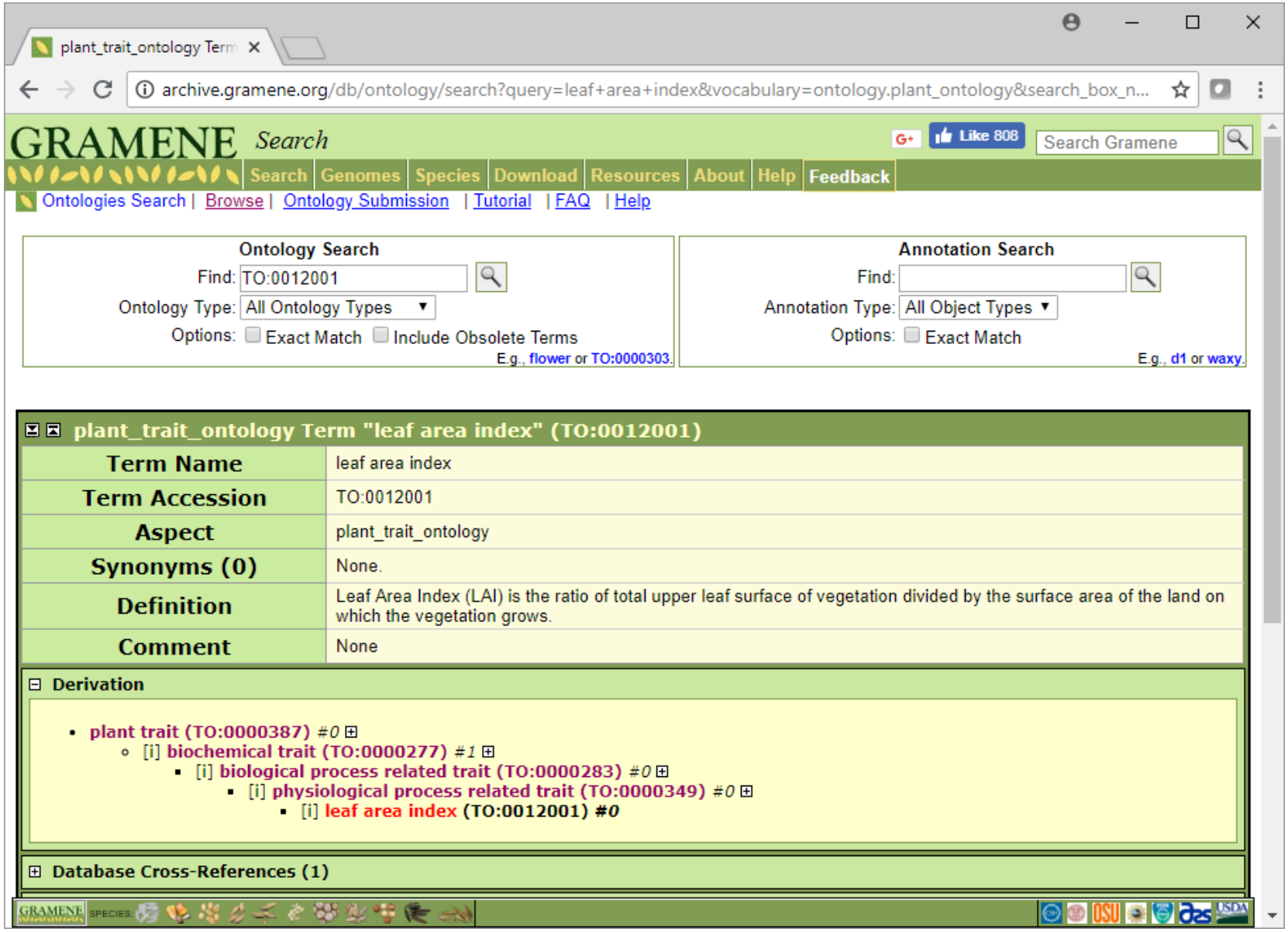
- We are traveling along a different road:
  - ✓ **Low cost → many instruments →** parallel work
  - ✓ **Clear** what a **trait** is
  - ✓ Integrated **ecosystem of tools** to support
    - phenotyping
    - "tagging" measurements
    - storing/pre-processing/exporting data

Which traits?

We propose **a suite of apps for smartphone** for estimating the following traits:

Trait	App name	References (examples of studies where the traits was estimated)
Leaf area index (LAI)	PocketLAI	e.g., Royo et al. (2004)
Leaf angle/leaf angle distribution	PocketPlant3D	e.g., Li et al. (2015)
Leaf N content (or greenness)	PocketN	e.g., Graziani et al. (2010)
Resistance to pathogen/% tissue affected	PocketDisease	e.g., Kongprakhon et al. (2009)

Leaf area index



Cassandra
models for change

Leaf area index

Smart technologies for phenotyping - Milan, 28 June 2018

Crop Ontology Curation Tool

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Crop Ontology
for agricultural data

Wheat Ontology

Ontology curators
- Rosemary Shrestha, CIMMYT
- Julian Pietragalla, IBP GCP

Scientists
- Carlos Guzmán, CIMMYT
- Hector González, CIMMYT
- Enrique Autrique, CIMMYT
- Javier Pena, CIMMYT
- Pawan Singh, CIMMYT
- Matthew Reynolds, CIMMYT
- Tom Payne, CIMMYT
- Velu Govindan, CIMMYT

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CGIAR research program: CGIAR Research Program on WHEAT

CO_321

Add New Terms API Help Agtrials Annotation Tool Register Login

Traits, methods and scales

DOWNLOAD SHOW OBSOLETE TERMS English

- Infertile spike number
- Infertile tiller number
- Leaf area index
  - LAI Computation (method_of)
    - index (scale_of)
- Lodging incidence
- Peduncle neck break
- Plant early vigour
- Plant growth habit
- Plant height
- Plant hybrid necrosis incidence
- Plant stand
- Plant vigour

Term information

LAI Computation | Permalink | General | 0 Comments

Identifier CO_321:0000362

Formula (LAI = leaf area / ground area, m2 / m2)

Method class Computation

Method description LAI can be determined directly by taking a sample of canopy from a plant canopy, measuring the leaf area per sample plot with an area meter or image scanner and dividing it by the plot land surface area. Indirect methods use ceptometer to measure canopy geometry or light extinction and relate it to LAI. (LAI = leaf area / ground area, m2 / m2).

Leaf area index

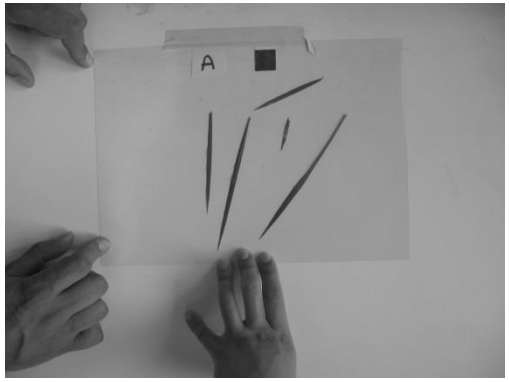
Type of measurement	Instrument (examples)	References (e.g.)
Direct	Planimeter	e.g., Borrel et al. (2000)
Indirect-proximal	Digital/hemispherical photography	e.g., Casedeus and Villegas (2014)
Indirect-remote	Reflectance (relationships with vegetation indices)	e.g., Haboudane et al. (2004)

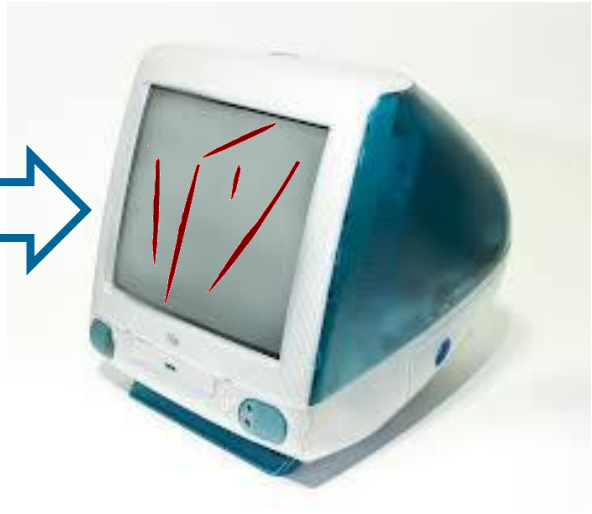
Leaf area index

Total one-sided area of leaf tissue per unit ground surface

Leaf area index

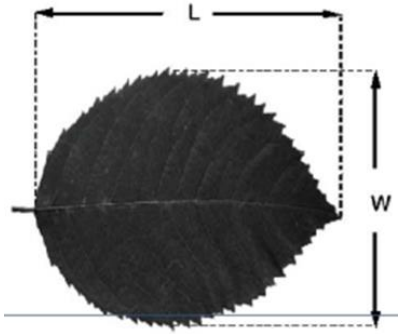
- It can be **measured**
  1. collection of leaves
  2. measurement of their area
     - ✓ dedicated instruments
     - ✓ acquiring and processing leaf images





Leaf area index

- It can be **estimated** (indirect methods)
  - allometric relationships
  - inversion of light transmittance models
    - ✓ LAI-2000, LAI-2200
    - ✓ ceptometers (AccuPAR, SUNSCAN)
    - ✓ hemispherical camera



Leaf area index

LAI-2000 (now LAI-2200) and ceptometers

- quite **expensive** (4000 – more than 10000 $)
- characterized by **low portability** (12×24×109 - 65×14×43 cm; 4.15 - 6.5 kg – with cases)
- long and expensive **maintenance services** in case of damages

…field campaigns can be interrupted!

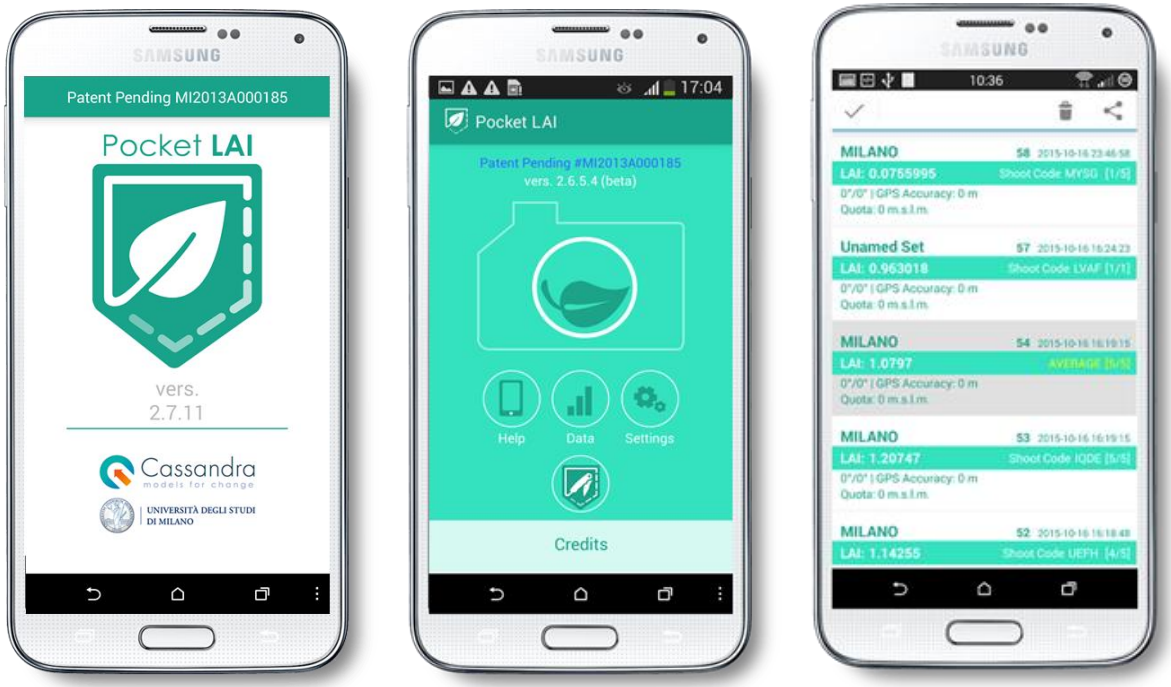
PocketLAI

Ministero dello Sviluppo Economico

Direzione generale per la lotta alla contraffazione

Ufficio Italiano Brevetti e Marchi

ATTESTATO DI BREVETTO PER INVENZIONE INDUSTRIALE



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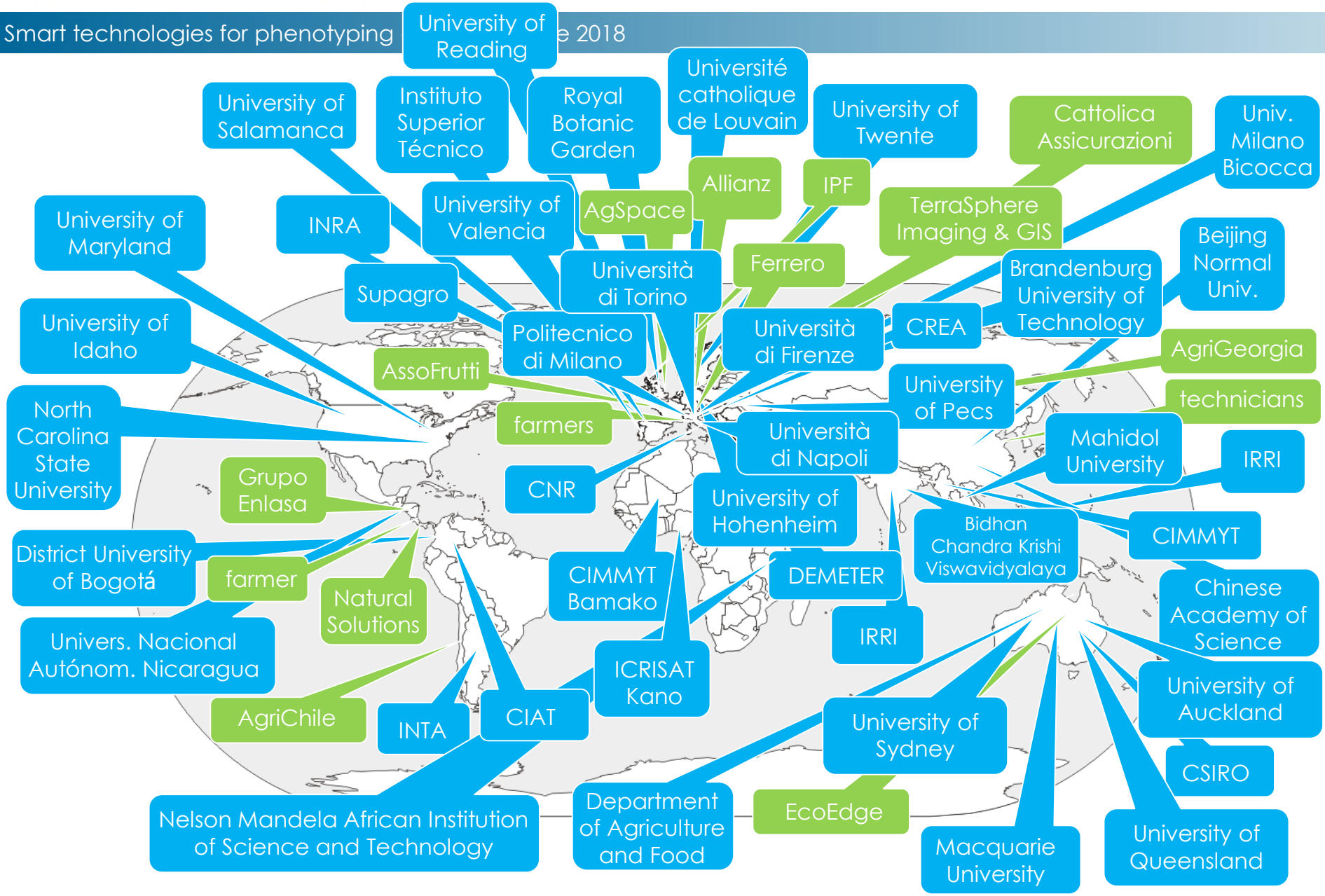
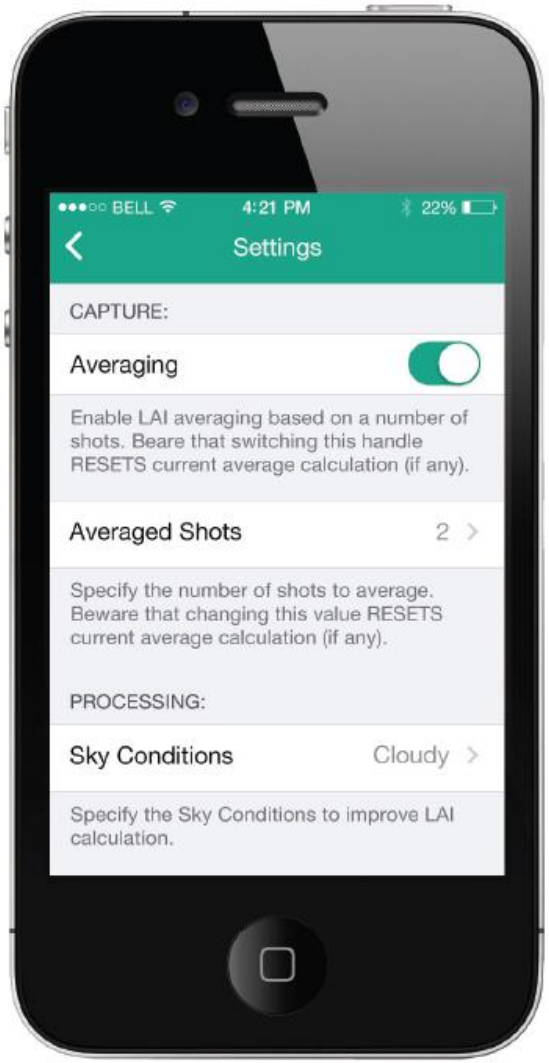
models for change

PocketLAI

Smart technologies for phenotyping e 2018



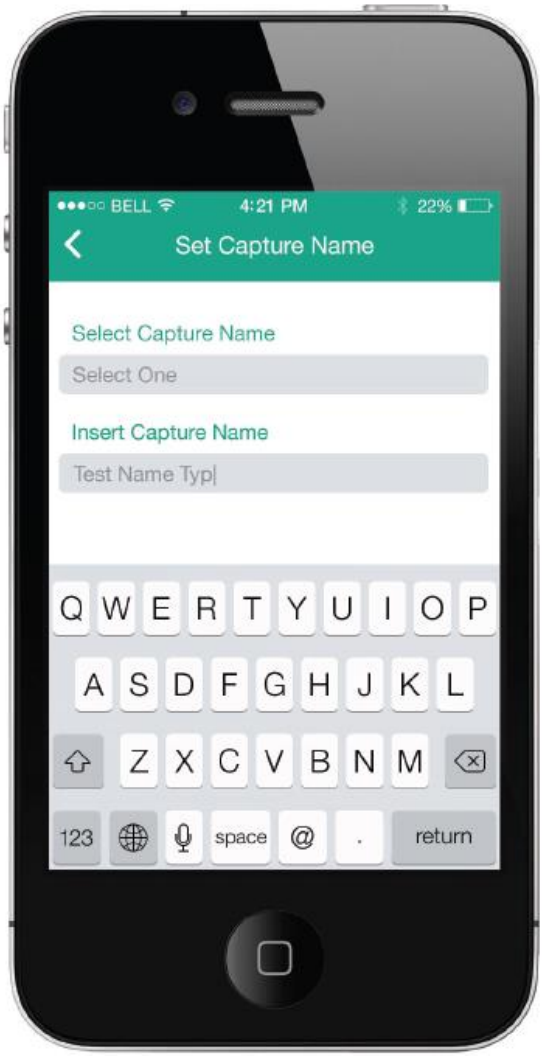
START


BELL
4:21 PM
22%
Settings
CAPTURE:
Averaging
Enable LAI averaging based on a number of shots. Beare that switching this handle RESETS current average calculation (if any).
Averaged Shots
2
Specify the number of shots to average. Beware that changing this value RESETS current average calculation (if any).
PROCESSING:
Sky Conditions
Cloudy
Specify the Sky Conditions to improve LAI calculation.

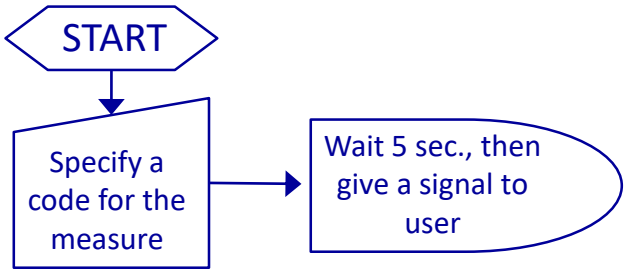

BELL
4:21 PM
22%
Pocket LAI
User Guide
Data
Credits

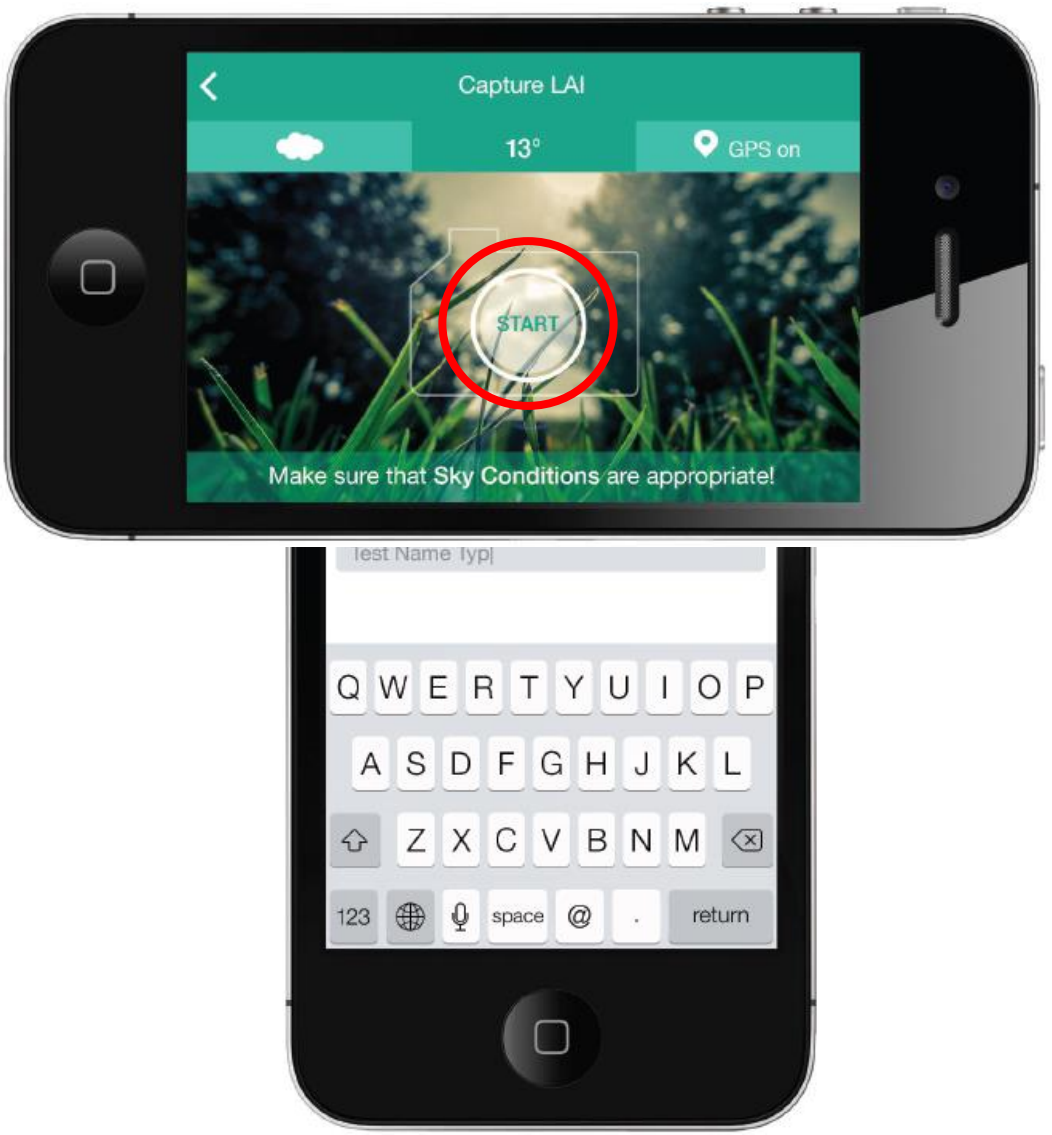
START

Specify a code for the measure

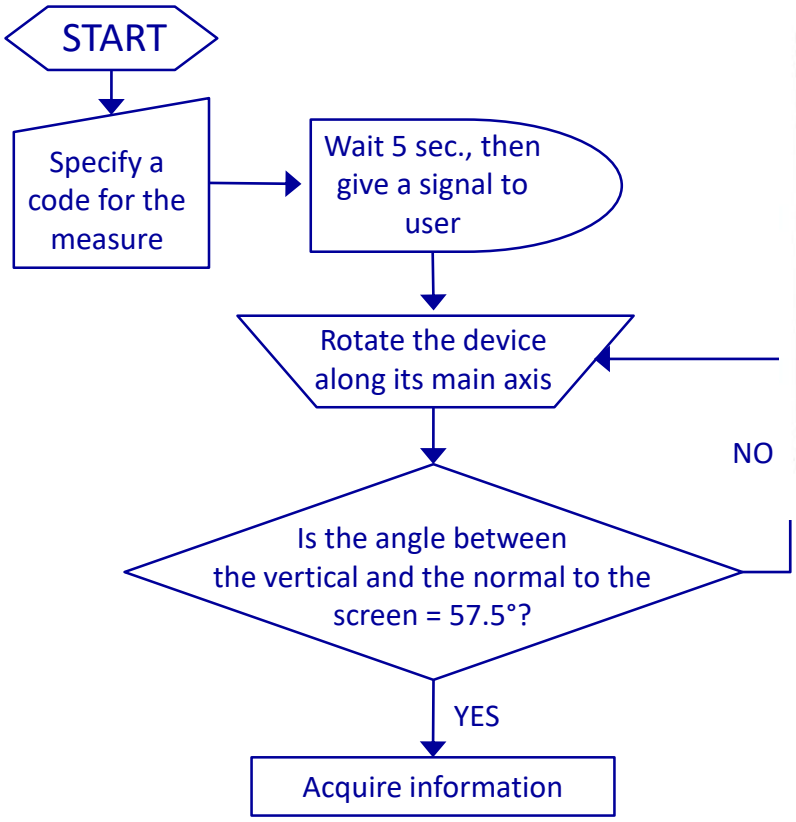


PocketLAI

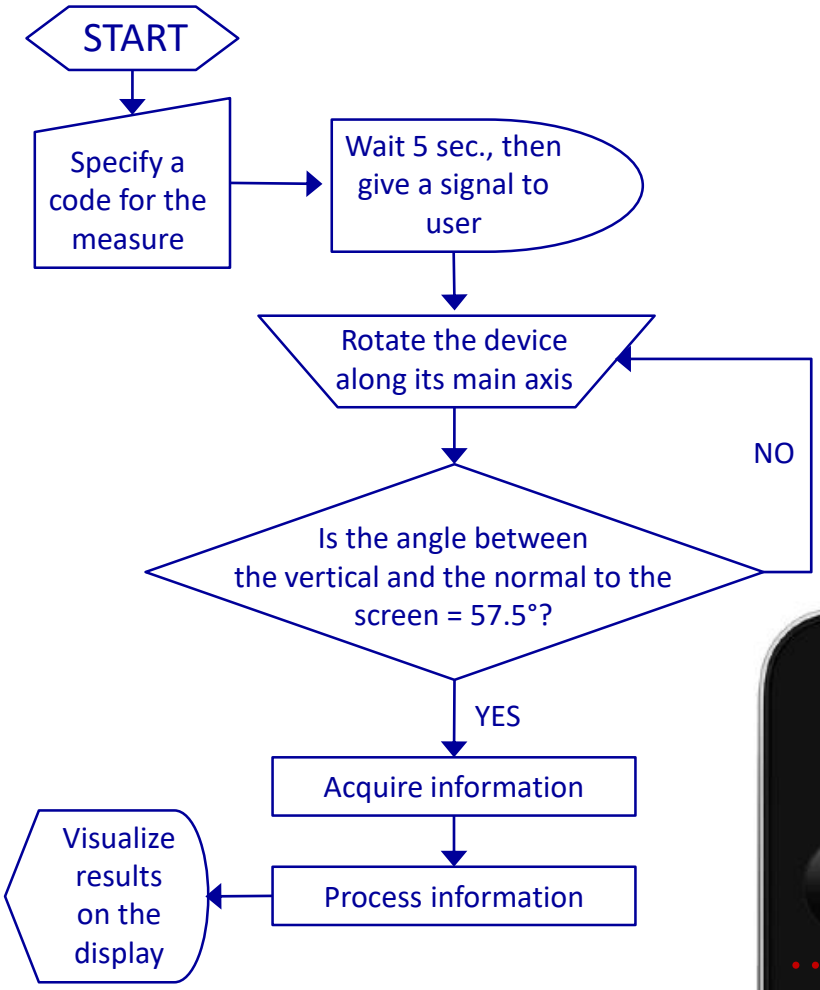

START
Specify a code for the measure
Wait 5 sec., then give a signal to user


Capture LAI
13°
GPS on
START
Make sure that Sky Conditions are appropriate!
Test Name Typ
Q W E R T Y U I O P
A S D F G H J K L
Z X C V B N M
123
space
@
.
return

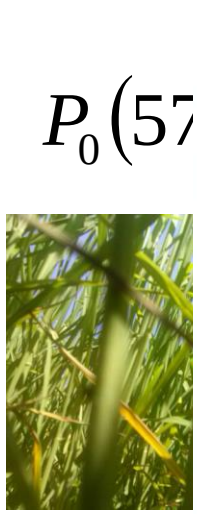
PocketLAI

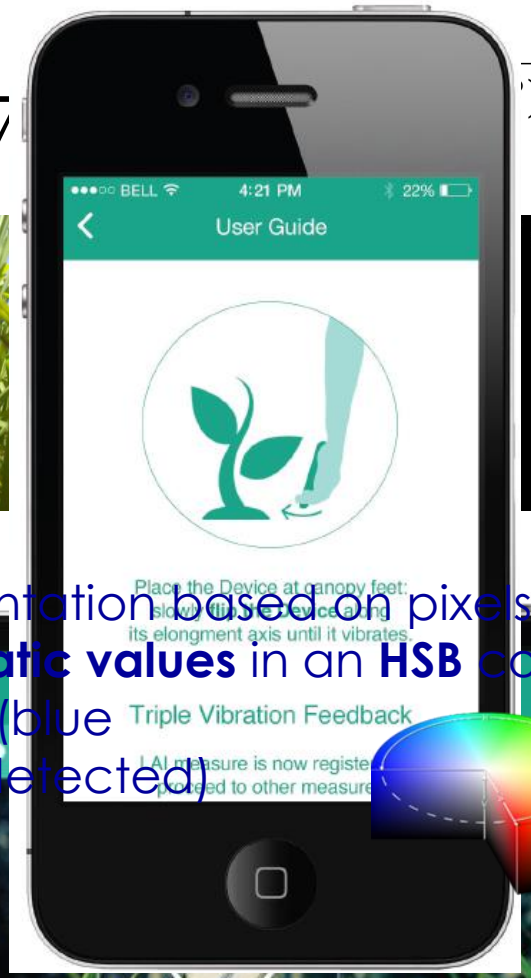


…images automatically acquired at 57.5° while the user is rotating the device

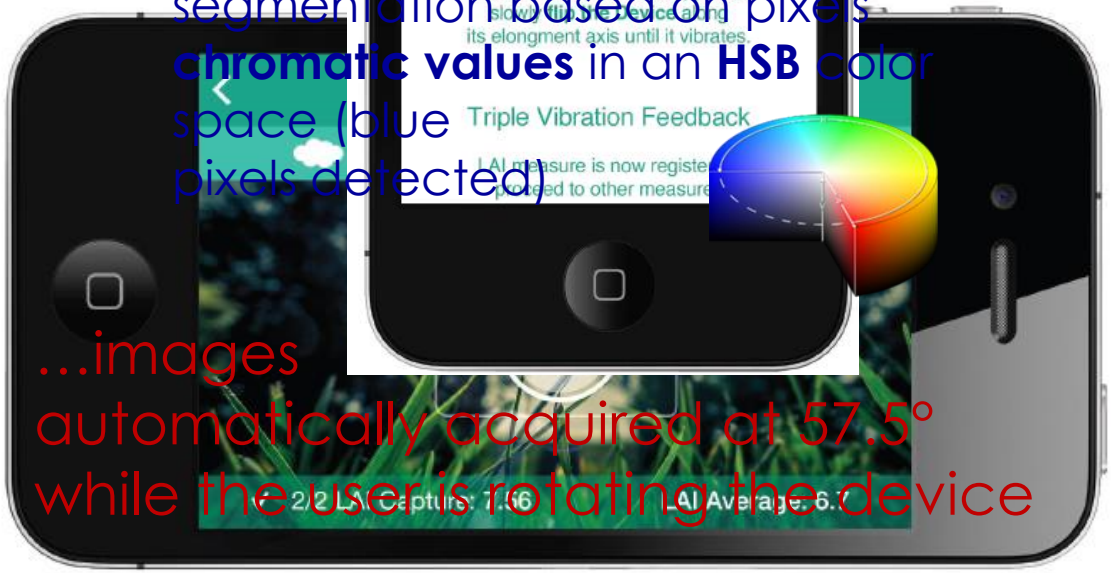


$P_0(57$



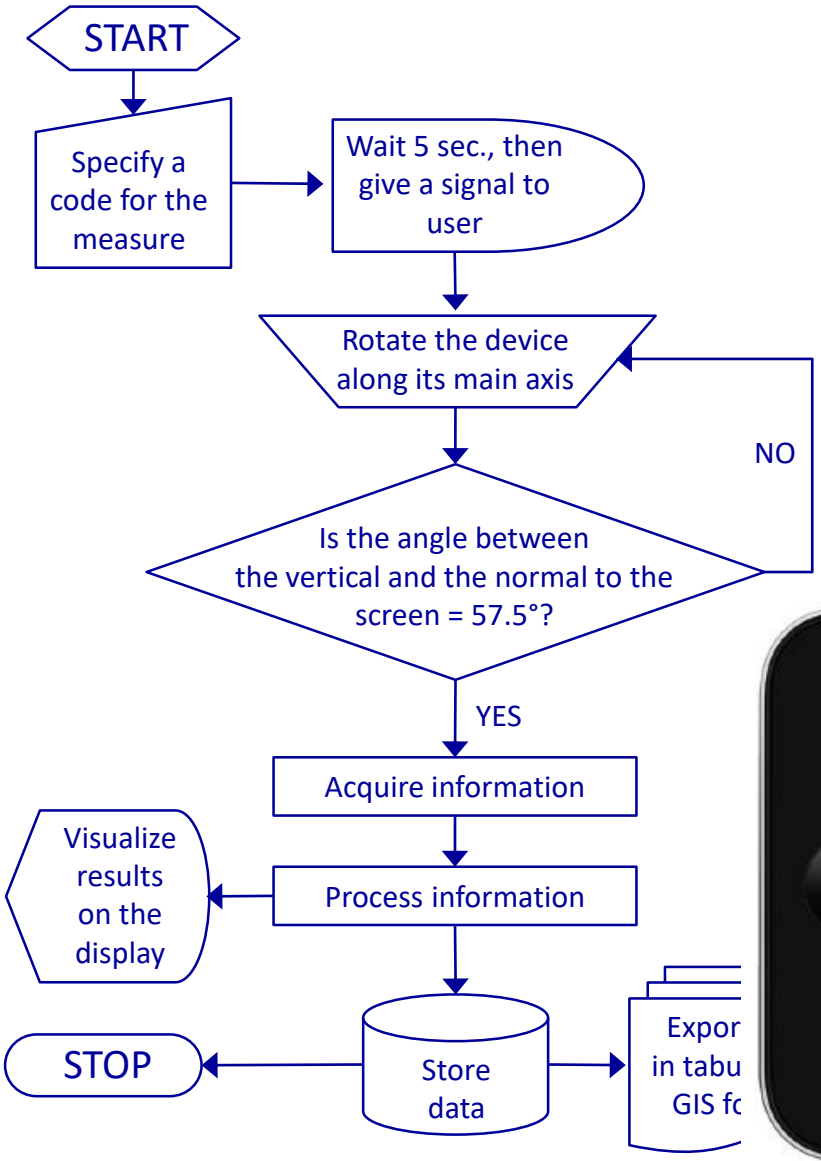


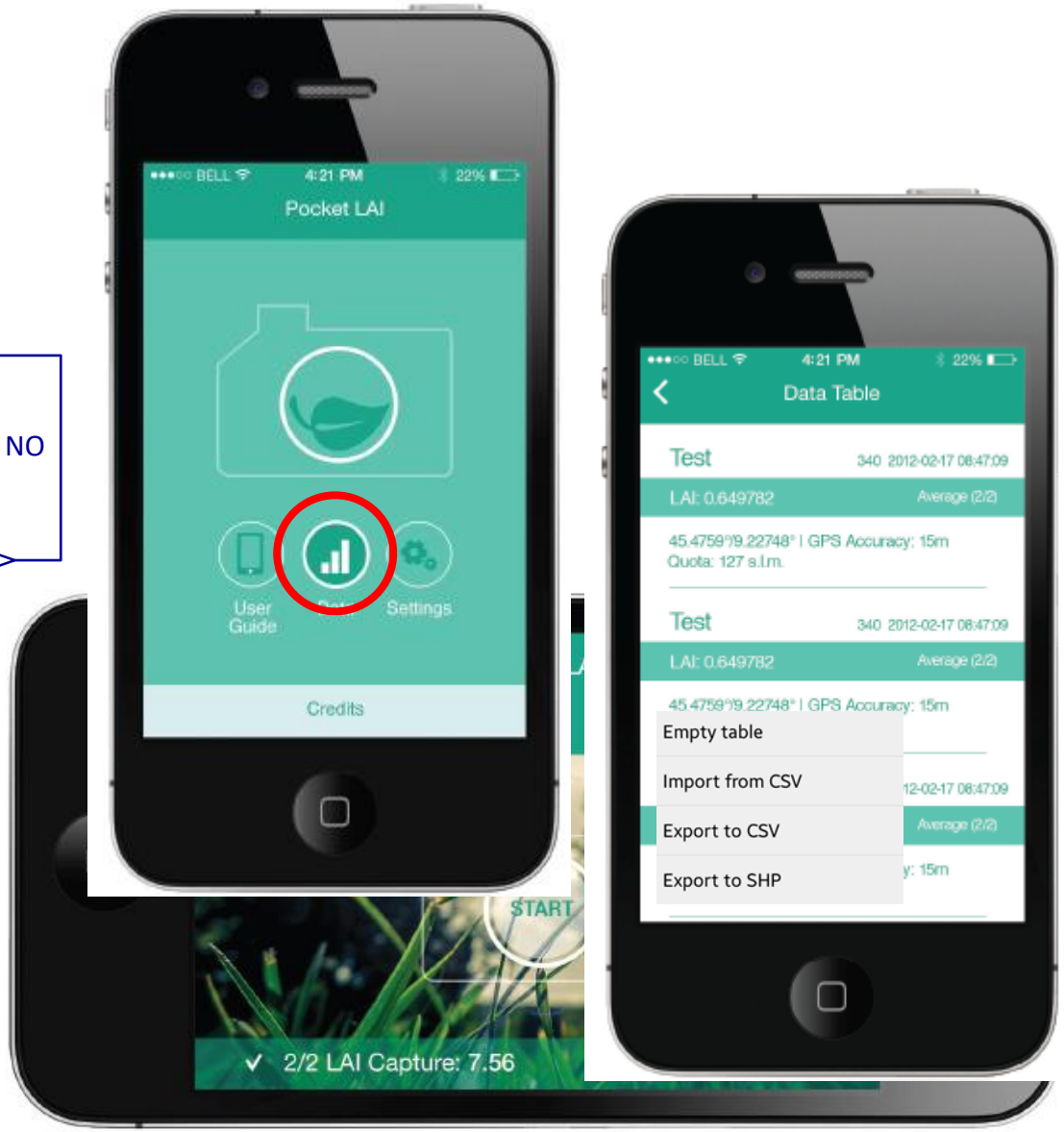
segmentation based on pixels **chromatic values** in an **HSB** color space (blue pixels detected)



...images automatically acquired at 57.5° while the user is rotating the device

PocketLAI

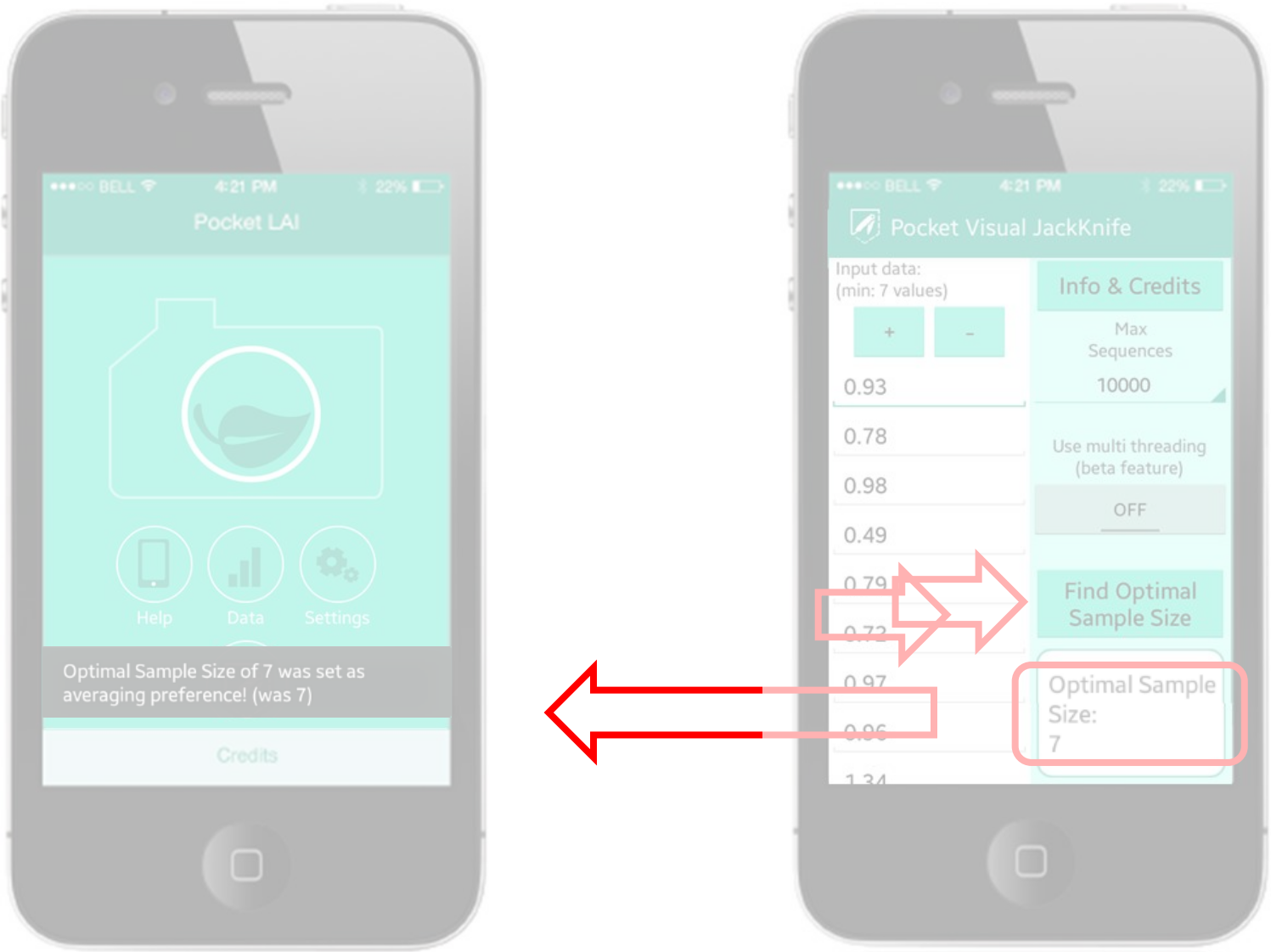

START
Specify a code for the measure
Wait 5 sec., then give a signal to user
Rotate the device along its main axis
NO
Is the angle between the vertical and the normal to the screen = 57.5°?
YES
Acquire information
Process information
Visualize results on the display
Store data
STOP
Expor
in tabu
GIS fo


Pocket LAI
User Guide
Settings
Credits
START
2/2 LAI Capture: 7.56
Data Table
Test
LAI: 0.649782
Empty table
Import from CSV
Export to CSV
Export to SHP

How many readings?

Confalonieri et al. (2006) Field Crop. Res. 97, 135-141

How many readings?



PocketLAI – Tests (1)

Computers and Electronics in Agriculture 96 (2013) 67–74

Contents lists available at SciVerse ScienceDirect

Computers and Electronics in Agriculture

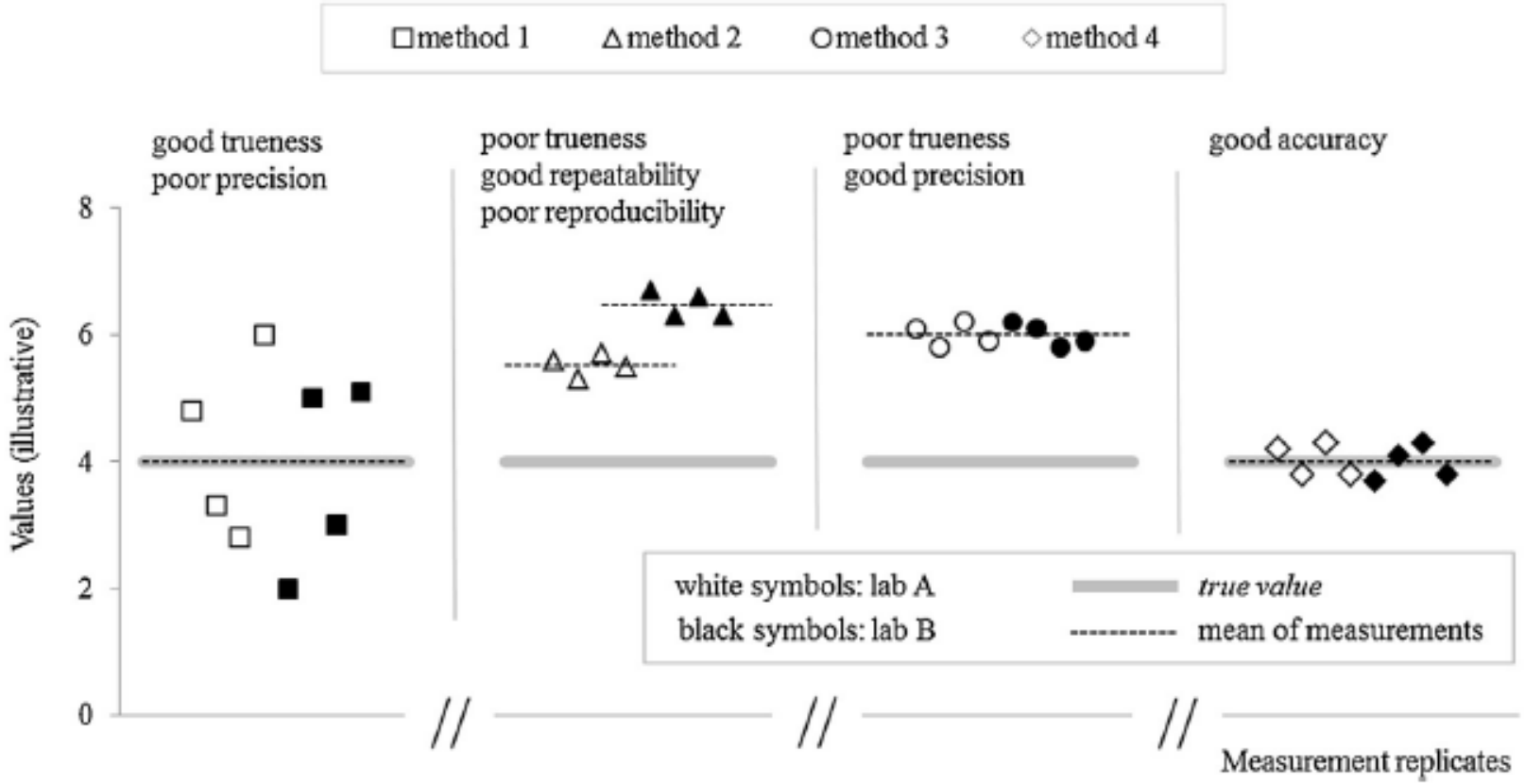
journal homepage: www.elsevier.com/locate/compag

Development of an app for estimating leaf area index using a smartphone. Trueness and precision determination and comparison with other indirect methods

R. Confalonieri [a,*], M. Foi [b], R. Casa [c], S. Aquaro [d], E. Tona [d], M. Peterle [d], A. Boldini [d], G. De Carli [d], A. Ferrari [d], G. Finotto [d], T. Guarneri [d], V. Manzoni [d], E. Movedi [d], A. Nisoli [d], L. Paleari [d], I. Radici [d], M. Suardi [d], D. Veronesi [d], S. Bregaglio [a], G. Cappelli [a], M.E. Chiodini [a], P. Dominoni [a], C. Francone [a], N. Frasso [a], T. Stella [a], M. Acutis [a]

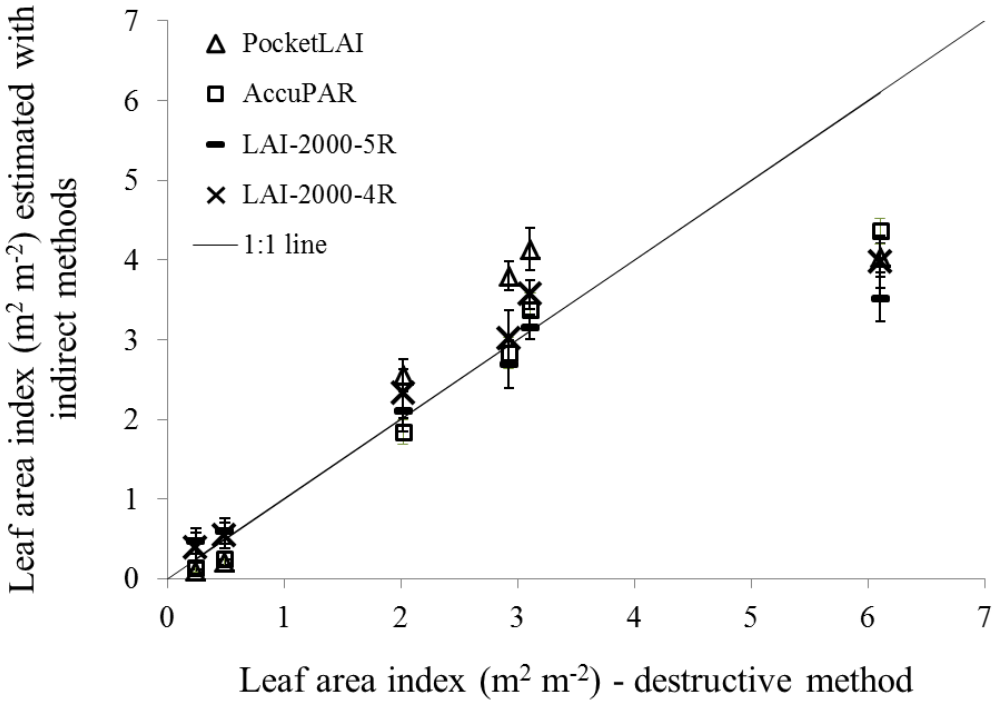
PocketLAI – Tests (1)

The **ISO 5725-2 protocol** was **adapted** for in vivo field methods, to derive Accuracy, i.e., Trueness & Precision (Repeatability & Reproducibility)



Confalonieri et al. (2014) Field Crop. Res. 161, 128-136

PocketLAI – Tests (1)



- The methods present **similar performances**
- They have the same tendency to **underestimate high LAI** values

PocketLAI – Tests (1)

PocketLAI:
one of the most precise,
for both
- repeatability
- reproducibility

Date	Plot	Method	Mean LAI (m^2 m^{-2})		Repeatability		Reproducibility	
			Destructive	Estimated	r[a]	RSD_r[b]	R[c]	RSD_R[d]
11/6/2012	D1	PocketLAI	0.49	0.20	0.16	28.33	0.18	31.04
		AccuPAR		0.24	0.48[f]	70.03[f]	0.48	70.03
		LAI-2000 5R		0.60[e]	1.04[f]	63.30[f]	1.04	63.30
		LAI-2000 4R		0.54	0.88	54.79	0.91	56.99
	D2	PocketLAI	0.25	0.09	0.15	57.76	0.15	57.94
		AccuPAR		0.13	0.28[f]	75.00[f]	0.28	75.00
		LAI-2000 5R		0.47	0.89[f]	68.14[f]	0.89	68.14
		LAI-2000 4R		0.39	1.04[f]	95.60[f]	1.04	95.60
9/7/2012	D1	PocketLAI	3.11	4.13	1.45[f]	12.50[f]	1.45	12.50
		AccuPAR		3.37	1.16	12.30	1.19	12.56
		LAI-2000 5R		3.16	0.83[f]	9.43[f]	0.83	9.43
		LAI-2000 4R		3.56	0.98[f]	9.85[f]	0.98	9.85
	D2	PocketLAI	2.02	2.55	1.11[f]	15.54[f]	1.11	15.54
		AccuPAR		1.84	0.84[f]	16.36[f]	0.84	16.36
		LAI-2000 5R		2.11	1.42[f]	24.04[f]	1.42	24.04
		LAI-2000 4R		2.32	1.67[f]	25.70[f]	1.67	25.70
30/7/2012	D1	PocketLAI	6.10	4.03	0.97	8.56	1.03	9.12
		AccuPAR		4.37	0.79	6.43	0.95	7.74
		LAI-2000 5R		3.51	1.51[f]	15.39[f]	1.51	15.39
		LAI-2000 4R		3.98	1.78[f]	16.01[f]	1.78	16.01
	D2	PocketLAI	2.92	3.80	0.96	9.03	1.02	9.58
		AccuPAR		2.84	0.84	10.62	1.17	14.74
		LAI-2000 5R		2.69	1.58	20.93	1.70	22.59
		LAI-2000 4R		3.02	1.86	22.05	2.01	23.79

[a]: repeatability limit.
[b]: relative standard deviation of repeatability.
[c]: reproducibility limit.
[d]: relative standard deviation of reproducibility.
[e]: laboratory 3 is an outlier according to the Cochran test.
[f]: corrected value (s_r set equal to s_R in case $s_r > s_R$; Orwitz, 1995; Scaglia et al., 2011).

PocketLAI – Tests (2)

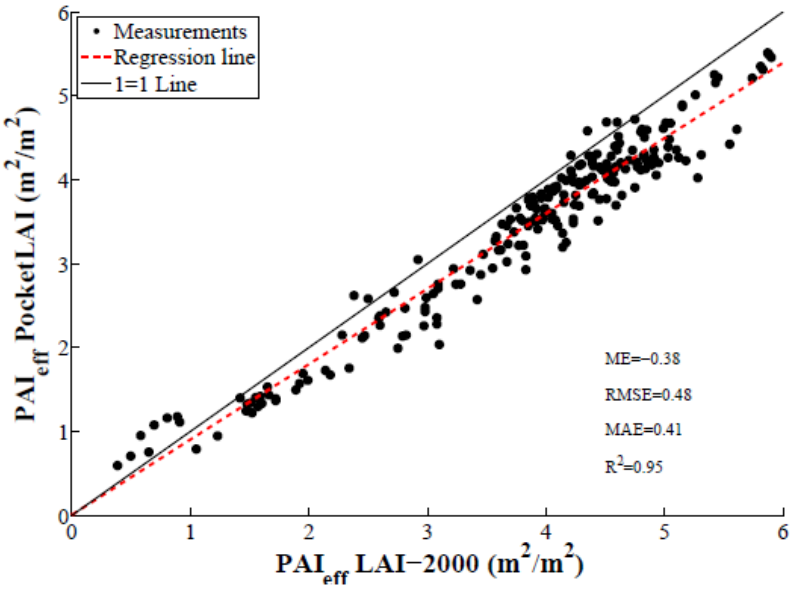
remote sensing

MDPI

Article

Multitemporal Monitoring of Plant Area Index in the Valencia Rice District with PocketLAI

Manuel Campos-Taberner [1,*], Franciso Javier García-Haro [1], Roberto Confalonieri [2], Beatriz Martínez [1], Álvaro Moreno [1], Sergio Sánchez-Ruiz [1], María Amparo Gilabert [1], Fernando Camacho [3], Mirco Boschetti [4] and Lorenzo Busetto [4]



PocketLAI – Tests (3, 4)

Field Crops Research 155 (2014) 38–41

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Short communication

Comparison of leaf area index estimates by ceptometer and PocketLAI smart app in canopies with different structures☆

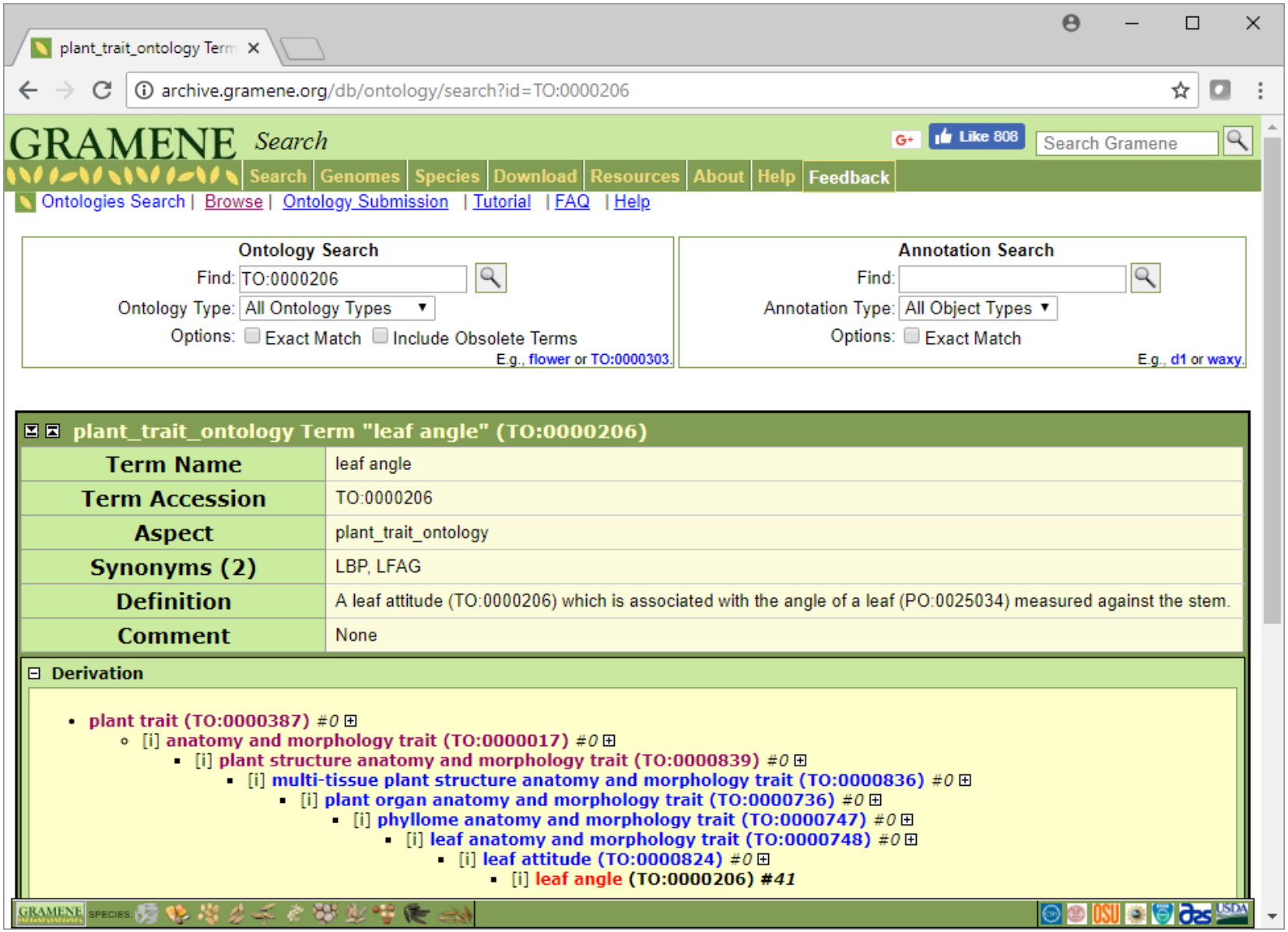
C. Francone[a], V. Pagani[a], M. Foi[b], G. Cappelli[a], R. Confalonieri[a,*]

Applied Vegetation Science **18** (2015) 716–723

Estimating leaf area index in tree species using the PocketLAI smart app

Francesca Orlando, Ermes Movedi, Livia Paleari, Carlo Gilardelli, Marco Foi, Michele Dell'Oro & Roberto Confalonieri

Leaf angle/distribution



Leaf angle/distribution

Crop Ontology Curation Tool

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Crop Ontology for agricultural data

Rice Ontology

Ontology curators

- Jeffrey Detras, bioinformatics specialist, IRRI

Scientists

- Mauleon Ramil, scientist, IRRI
- Nikki Frances Borja, IRRI
- Julie Mae Pasuquin, IRRI
- William Eusebio, Sr. Specialist - Database Administration, IRRI
- Ruaraidh Sackville Hamilton, Head of the Genetic Resource Unit, IRRI
- Cécile Grenier, Breeder, CIAT

Crop Lead Center: IRRI

Partners: AfricaRice, CIAT

CGIAR research program: CGIAR Global Rice Science Partnership

CO_320

Add New Terms API Help Agtrials Annotation Tool Register Login

Traits, methods and scales

DOWNLOAD SHOW OBSOLETE TERMS English

- grain thickness
- keel anthocyanin
- leaf angle
  - leaf angle (method_of)
    - leaf angle scale (scale_of)
    - leaf angle scale (scale_of)
- leaf blade anthocyanin
- leaf blade greenness
- leaf blade pubescence
- leaf length

Term information

leaf angle scale | Permalink | General | 0 Comments

Identifier	CO_320:0000415
Category 1	Erect
Category 5	Horizontal
Category 9	Drooping

Leaf angle/distribution

Type of measurement	Instrument (examples)	References (e.g.)
Direct	Inclinometer	e.g., Deckmyn et al (2000)
Indirect-proximal	LAI-2000	e.g., Zou et al. (2014)
Indirect-remote	Stereo imaging	e.g., Biskhup et al. (2007)

Leaf angle/distribution

- E.g., Pioneer

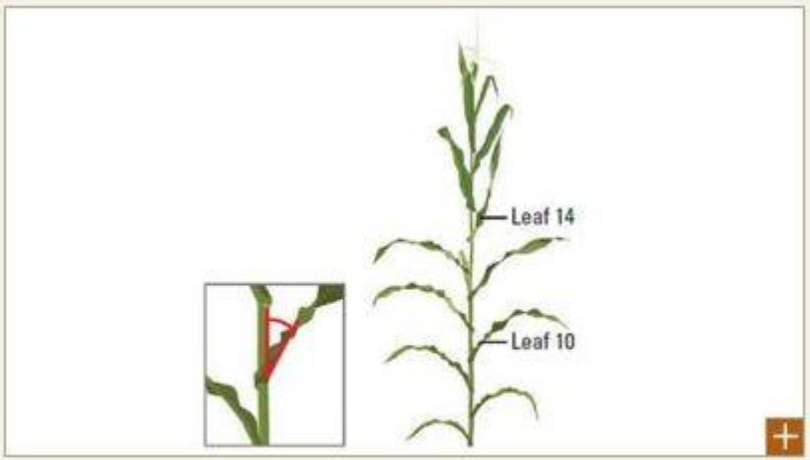

Figure 1. Leaf angle measurements on leaf 10 and leaf 14.

Figure 2. Leaf angle measurements were taken using a clinometer smartphone app.

- This does not represent the angle of photosynthetic tissues…

- We developed a smart app for
  - ✓ Measuring angle of leaf **insertion**
  - ✓ Measuring angles of **photosynthetic tissues**
  - ✓ Deriving synthetic **parameters** of **distributions** of the angles of photosynthetic tissues (**3D canopy scan**)

Leaves can bend!

Cassandra
models for change

PocketPlant3D

Smart technologies for phenotyping - Milan, 28 June 2018

BIOSYSTEMS ENGINEERING 164 (2017) 1–12

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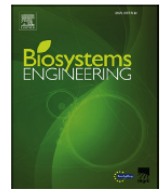
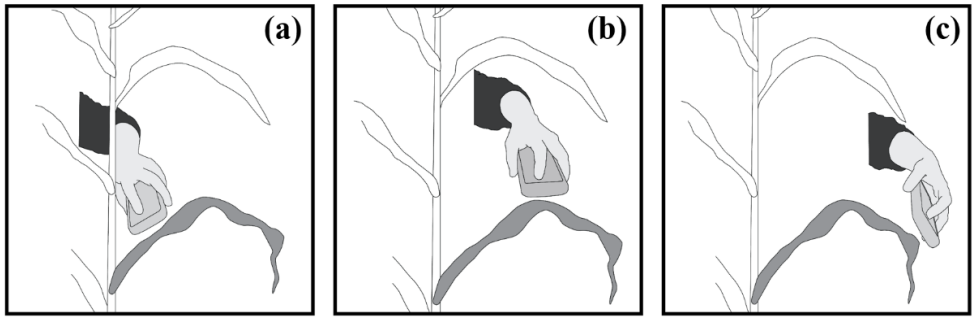


Research Paper

PocketPlant3D: Analysing canopy structure using a smartphone

Roberto Confalonieri [a,*], Livia Paleari [a], Marco Foi [b], Ermes Movedi [c], Fosco M. Vesely [a], William Thoelke [a,d], Cristina Agape [d], Giulia Borlini [d], Irene Ferri [d], Federico Massara [d], Roberto Motta [d], Riccardo A. Ravasi [d], Sofia Tartarini [d], Camilla Zoppolato [d], Luca M. Baia [d], Andrea Brumana [d], Davide Colombo [d], Antonio Curatolo [d], Valerio Fauda [d], Denise Gaia [d], Andrea Gerosa [d], Antonio Ghilardi [d], Enrico Grassi [d], Andrea Magarini [d], Francesco Novelli [d], Fatima B. Perez Garcia [d], Andrea Rota Graziosi [d], Michele Salvan [d], Tommaso Tadiello [d], Laura Rossini [e]

[a] University of Milan, DESP, Cassandra Lab, Italy
[b] University of Milan, Ardito Desio Earth Sciences Department, Cassandra Lab, Italy
[c] University of Milan, DiSAA, Cassandra Lab, Italy
[d] University of Milan, Cropping Systems MS Course, Italy
[e] University of Milan, DiSAA, Italy



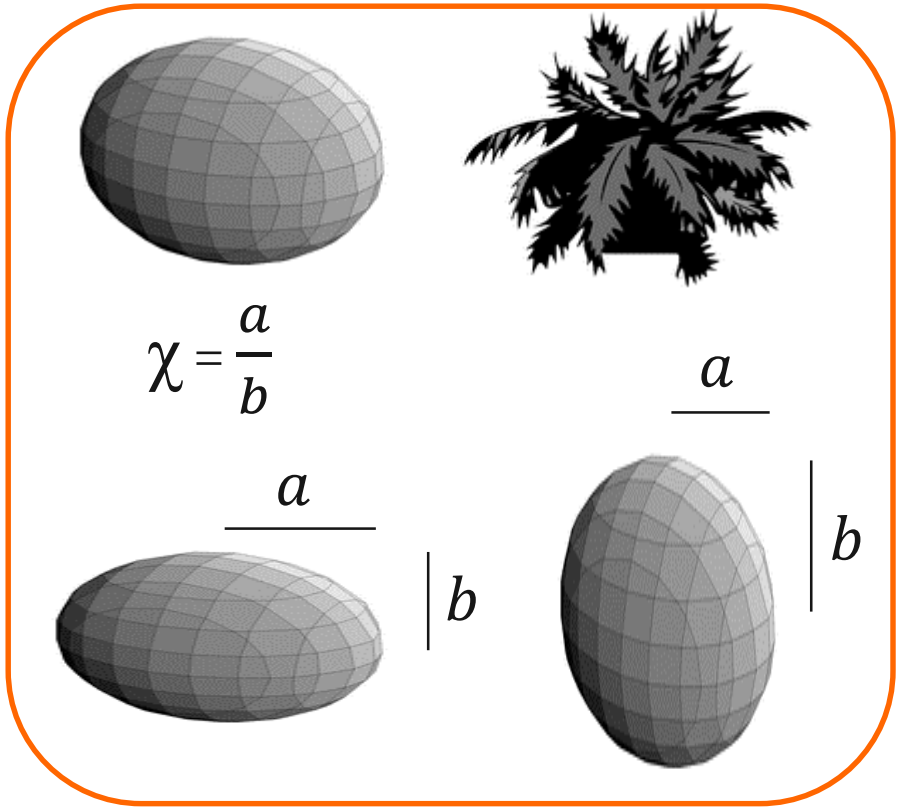
- Campbell's ellipsoidal distribution (Campbell, 1986)

$$G = \frac{(x^2 \cos^2\theta + \sin^2\theta)^{0.5}}{Ax}$$

$$A = 1 + \frac{\ln[(1+\varepsilon_1)/(1-\varepsilon_1)]}{2\varepsilon_1 x^2} \quad \text{for } x > 1$$

$$A = 1 + \frac{\sin^{-1}\varepsilon_2}{x\varepsilon_2} \quad \text{for } x < 1$$

$$A = 2 \quad \text{for } x = 1$$

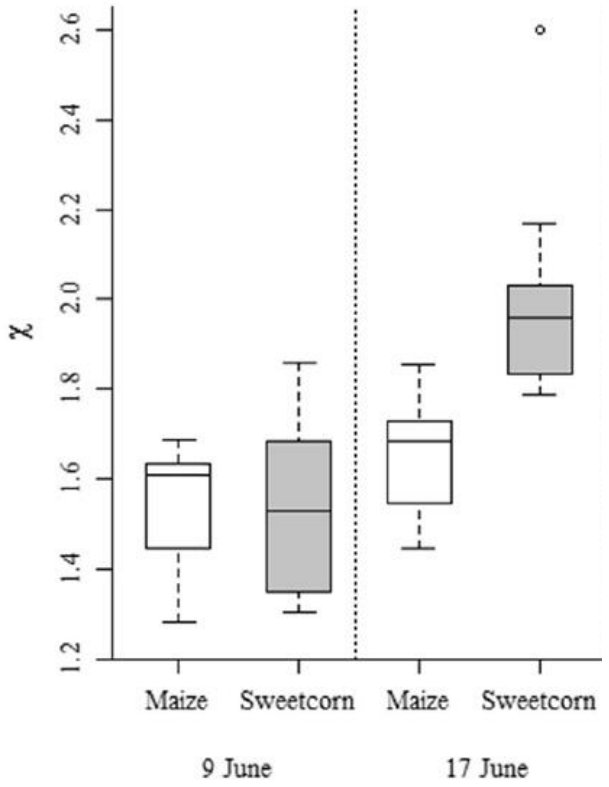


$$\chi = \frac{a}{b}$$

$$k = \frac{\sqrt{\chi^2 + \tan^2\theta_L}}{A}$$

$$A \approx \chi + 1.774\,(\chi + 1.182)^{-0.733}$$

- Campbell's ellipsoidal distribution (Campbell, 1986)



- β-distribution (Goel and Strebel, 1984; Pisek et al., 2011)

$$f(t) = \frac{1}{\beta(\mu,\nu)}(1-t)^{\mu-1}t^{\mu-1}$$

$$t = 2\cdot\theta_L/\pi$$

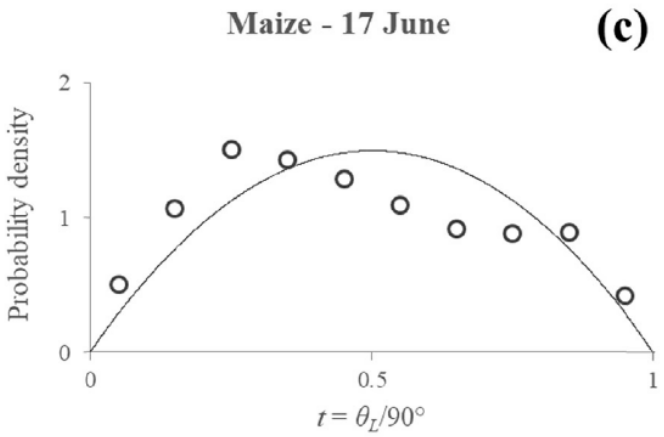
$$\beta(\mu,\nu) = \frac{\Gamma(\mu)\Gamma(\nu)}{\Gamma(\mu+\nu)}$$

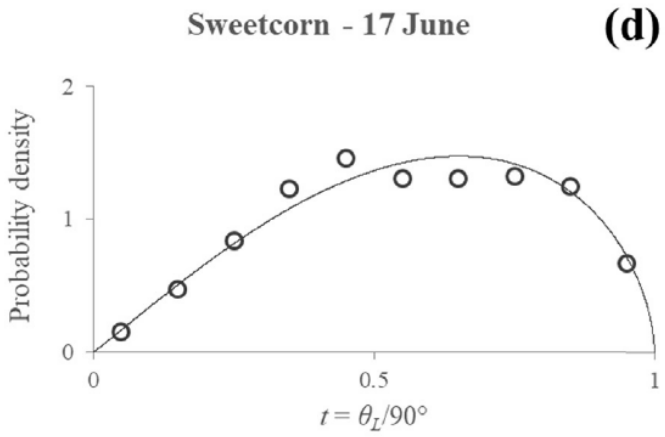
$$\mu = (1-\bar{t})\left(\frac{\sigma_0^2}{\sigma_t^2}-1\right)$$

$$\nu = \bar{t}\left(\frac{\sigma_0^2}{\sigma_t^2}-1\right)$$

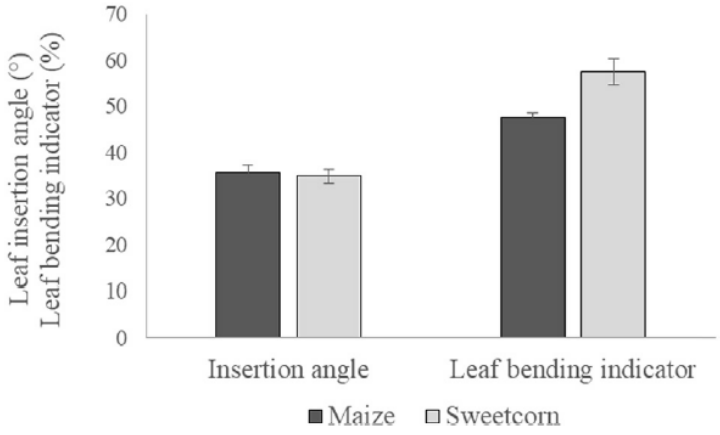
$$\sigma_0^2 = \bar{t}(1-\bar{t})$$

- β-distribution (Goel and Strebel, 1984; Pisek et al., 2011)

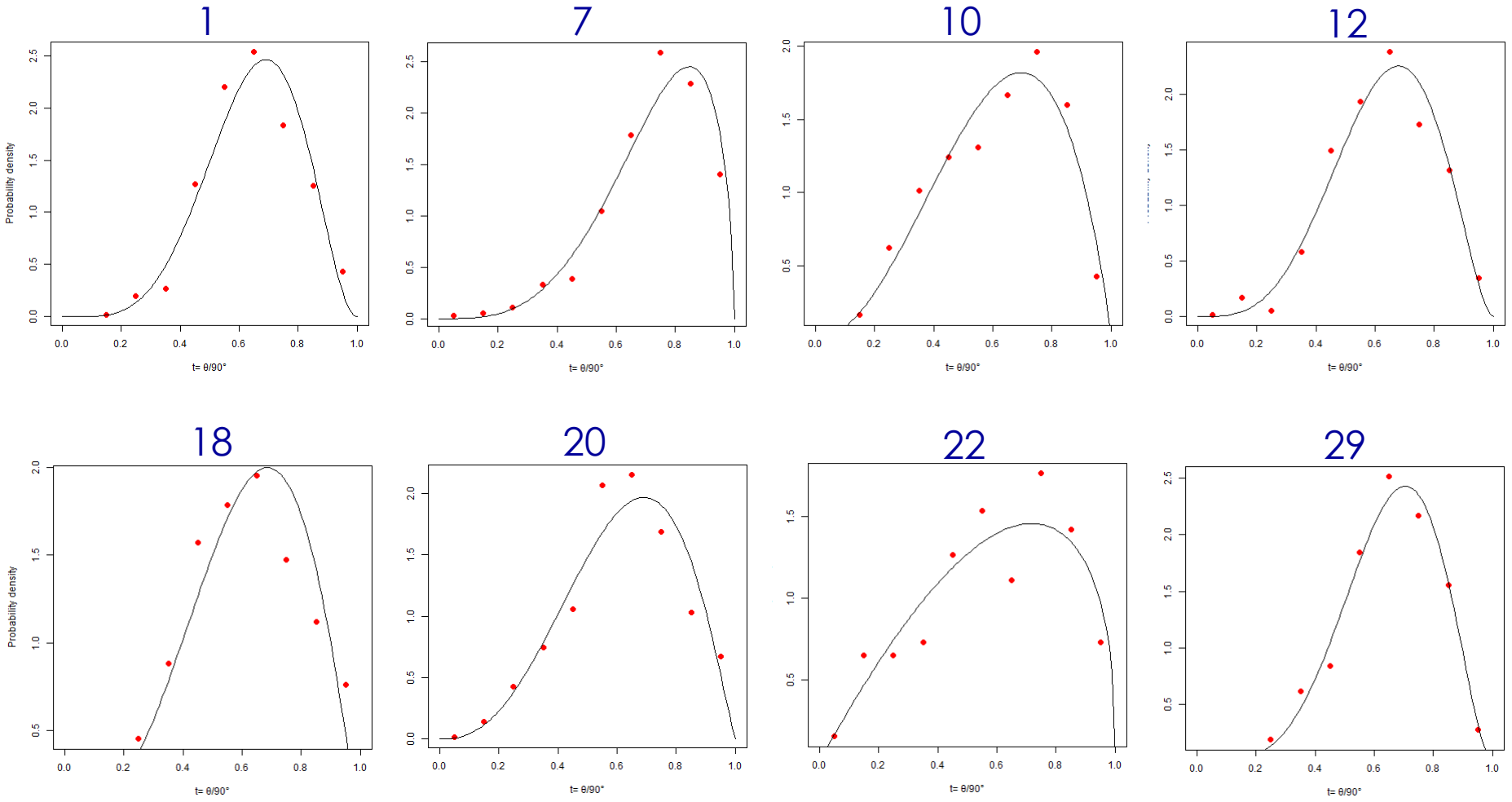




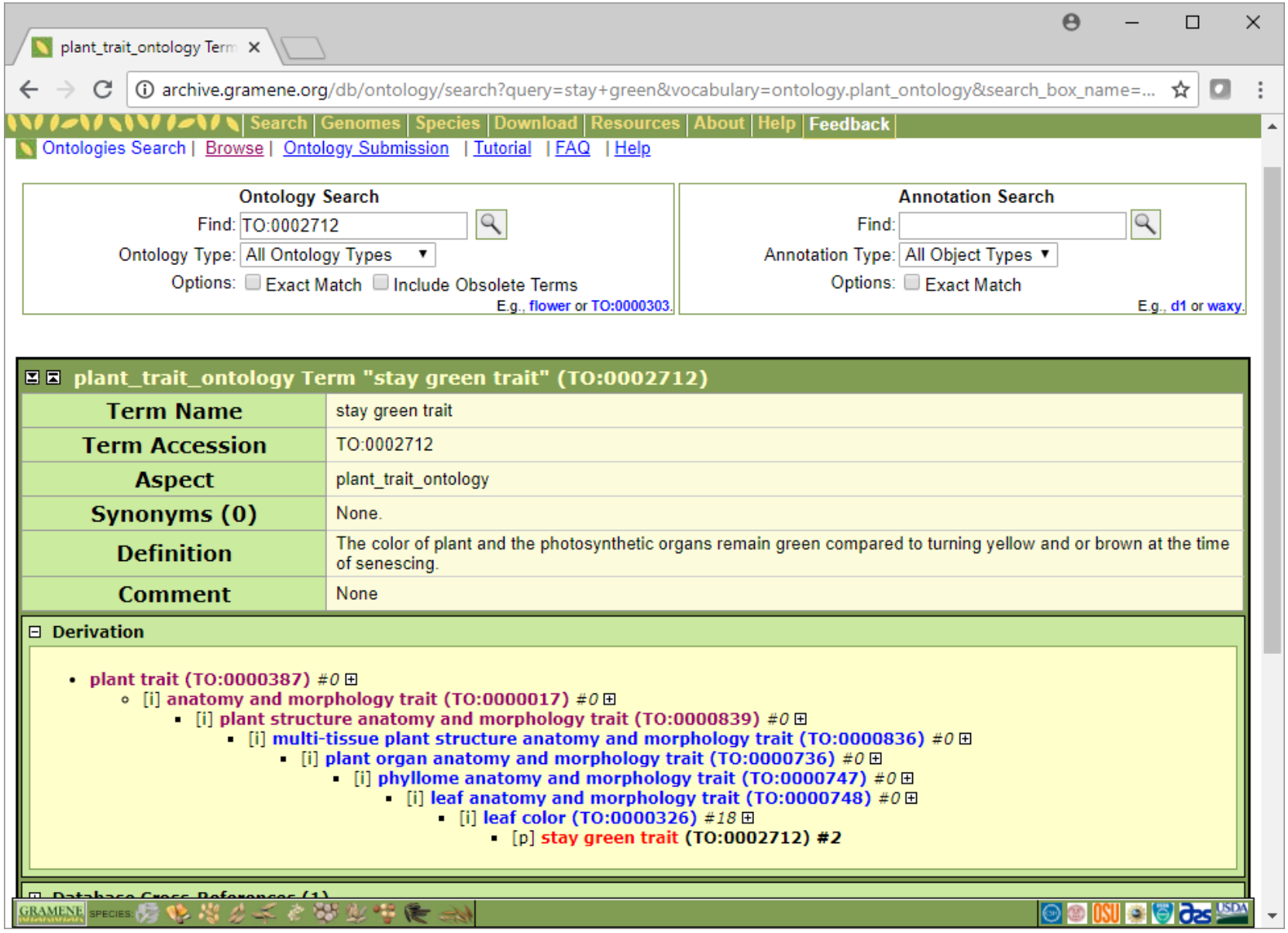
Leaf bending!



- Phenotyping bean lines



Leaf N content/greenness



Leaf N content/greenness

Smart technologies for phenotyping - Milan, 28 June 2018

Crop Ontology Curation Tool

Home About Feedback

Crop Ontology for agricultural data

Rice Ontology

Ontology curators

- Jeffrey Detras, bioinformatics specialist, IRRI

Scientists

- Mauleon Ramil, scientist, IRRI
- Nikki Frances Borja, IRRI
- Julie Mae Pasuquin, IRRI
- William Eusebio, Sr. Specialist - Database Administration, IRRI
- Ruaraidh Sackville Hamilton, Head of the Genetic Resource Unit, IRRI
- Cécile Grenier, Breeder, CIAT

Crop Lead Center IRRI

Partners AfricaRice, CIAT

CGIAR research program CGIAR Global Rice Science Partnership

CO_320

Add New Terms API Help Agtrials Annotation Tool Register Login

Traits, methods and scales

DOWNLOAD SHOW OBSOLETE TERMS English

- culm node underlying colour
- culm number
- flag leaf angle
- grain thickness
- keel anthocyanin
- leaf angle
- leaf blade anthocyanin
- leaf blade greenness
  - leaf blade greenness (method_of)
    - leaf blade greenness scale (scale_of)
- leaf blade pubescence

Term information

leaf blade greenness scale — Permalink | General | 0 Comments

Identifier CO_320:0000577

Category 0 000= Not visible under anthocyanin

Category 3 061= Light green

Category 3 060= Medium Green

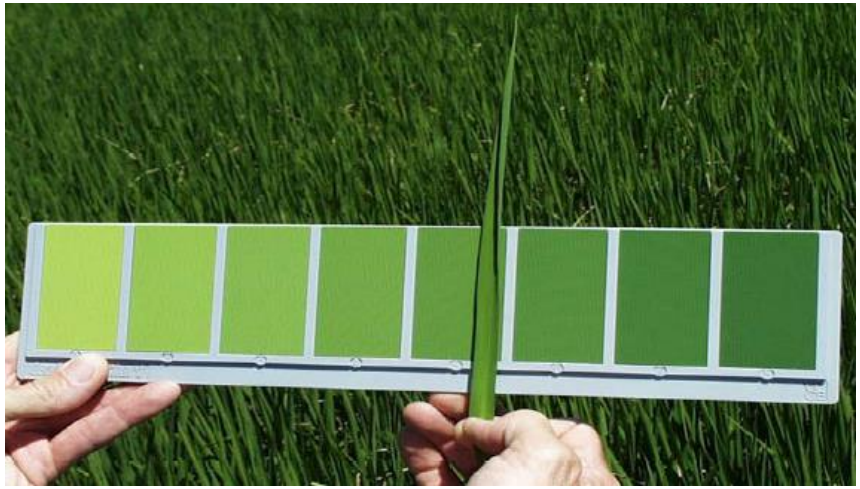
Category 7 063= Dark green

Leaf N content/greenness

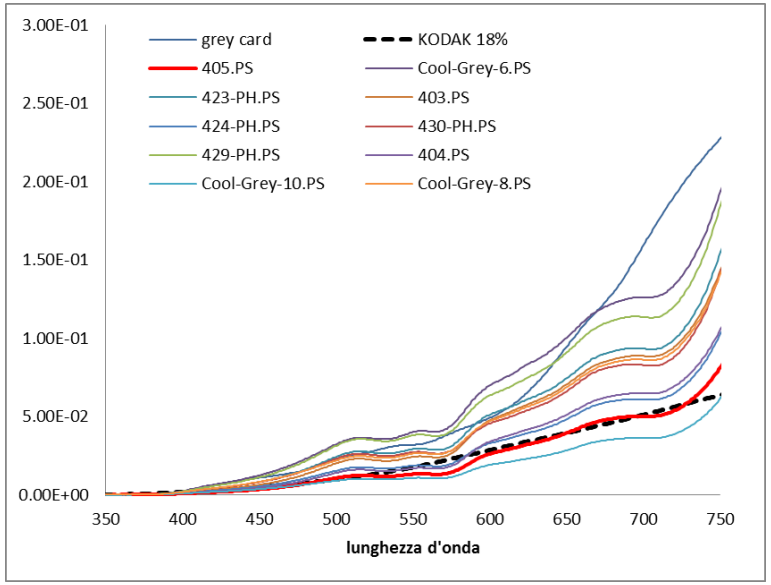
Type of measurement	Instrument (examples)	References (e.g.)
Direct	Elemental analyzer	e.g., Vigneau et al. (2011)
Indirect-proximal	SPAD	e.g., Cabangon et al. (2011)
Indirect-remote	Reflectance (relationships with vegetation indices)	e.g., Babar et al., (2006)

Leaf N content/greenness

- Leaf color chart (LCC)
- KONICA MINOLTA SPAD-502
- Force-A Dualex 4



- Image processing (**greenness**)
- Background panel to guarantee **flat reflectance** under a wide range of light conditions



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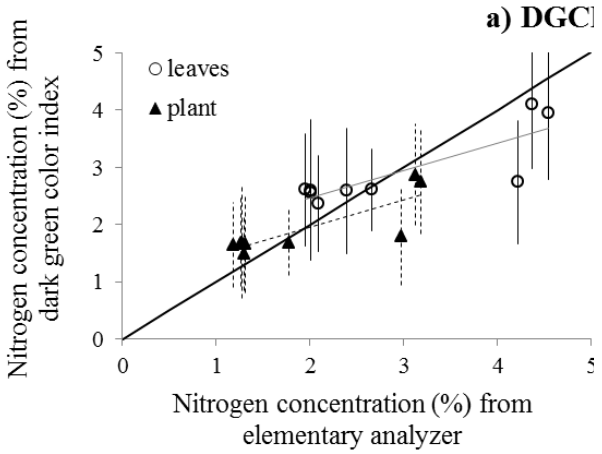
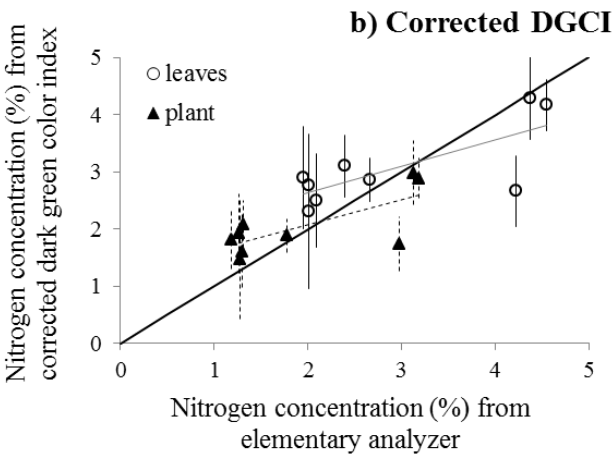
Research Paper

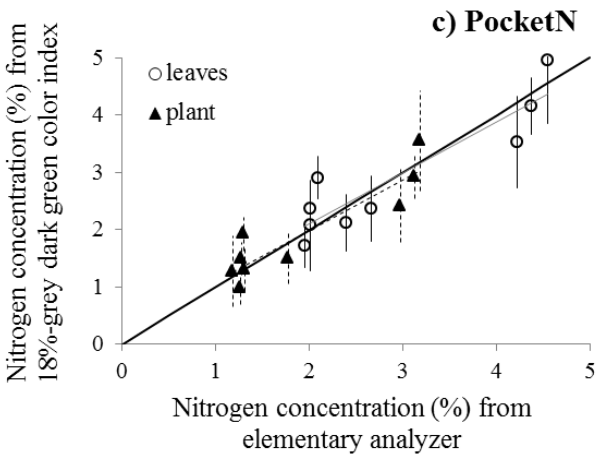
Improving *in vivo* plant nitrogen content estimates from digital images: Trueness and precision of a new approach as compared to other methods and commercial devices

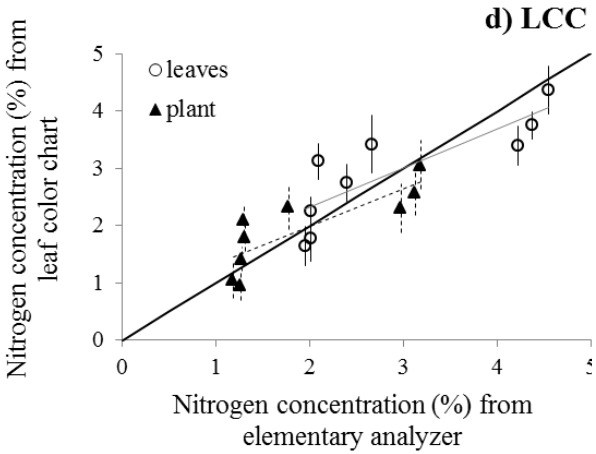
Roberto Confalonieri [a,*], *Livia Paleari* [a], *Ermes Movedi* [a], *Valentina Pagani* [a], *Francesca Orlando* [a], *Marco Foi* [b], *Michela Barbieri* [c], *Michele Pesenti* [c], *Oliver Cairati* [c], *Marco S. La Sala* [c], *Riccardo Besana* [c], *Sara Minoli* [c], *Eleonora Bellocchio* [c], *Silvia Croci* [c], *Silvia Mocchi* [c], *Francesca Lampugnani* [c], *Alberto Lubatti* [c], *Andrea Quarteroni* [c], *Daniele De Min* [c], *Alessandro Signorelli* [c], *Alessandro Ferri* [c], *Giordano Ruggeri* [c], *Simone Locatelli* [d], *Matteo Bertoglio* [a], *Paolo Dominoni* [a], *Stefano Bocchi* [a], *Gian Attilio Sacchi* [a], *Marco Acutis* [a]

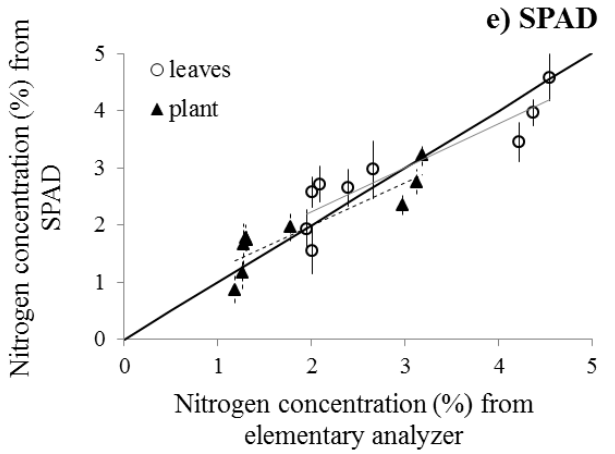
PocketN – Tests (1)

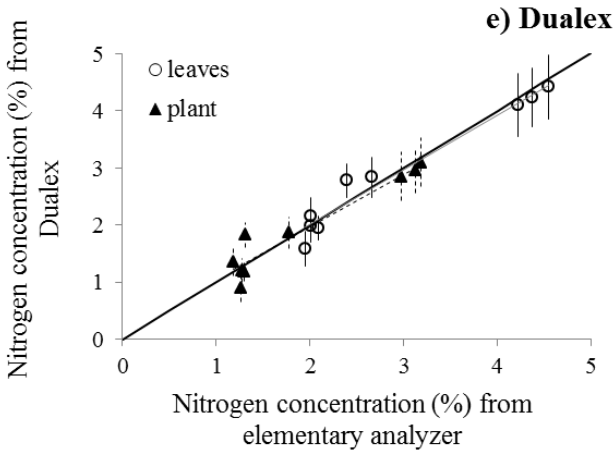




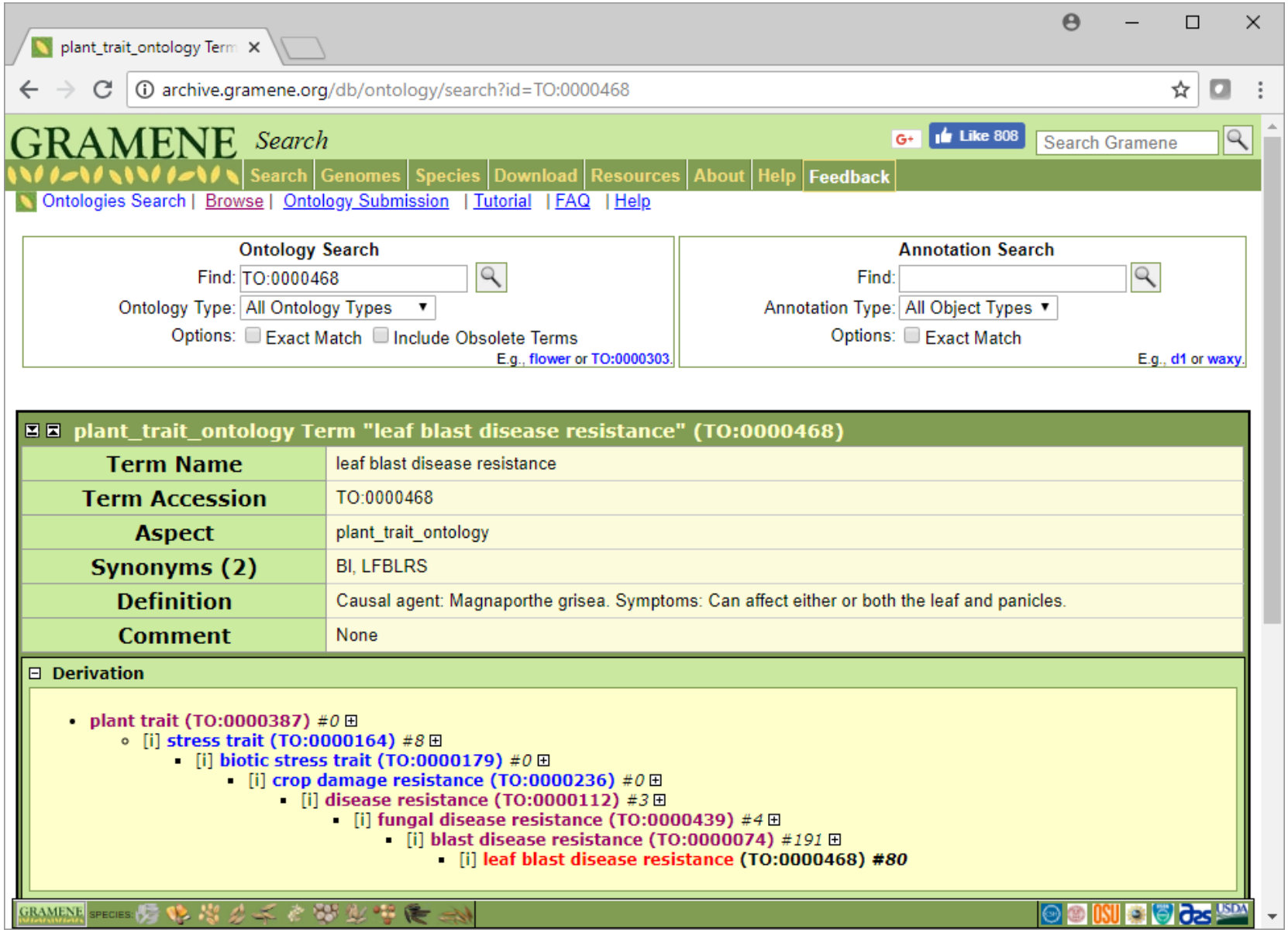








Disease resistance/% tissue dis.



Disease resistance/% tissue dis.

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Add New Terms API Help Agtrials Annotation Tool Register Login

Traits, methods and scales

DOWNLOAD SHOW OBSOLETE TERMS English

- Rice traits
  - Abiotic stress
  - Agronomical
  - Biochemical
  - Biotic stress
    - Leaf blast damage
      - leaf blast damage amount (method_of)
      - leaf blast damage estimation (method_of)
        - leaf blast damage scale (scale_of)
      - leaf blast damage type (method_of)
    - bacterial blight damage

Term information

leaf blast damage scale — Permalink — General — 0 Comments

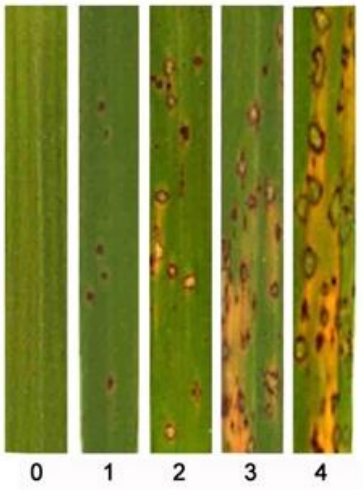
Identifier	CO_320:0000341
Category 0	No lesions observed
Category 9	More than 75% leaf area affected
Category 1	Small brown specks of pin-point size or larger brown specks without sporulating center
Category 2	Small roundish to slightly elongated, necrotic gray

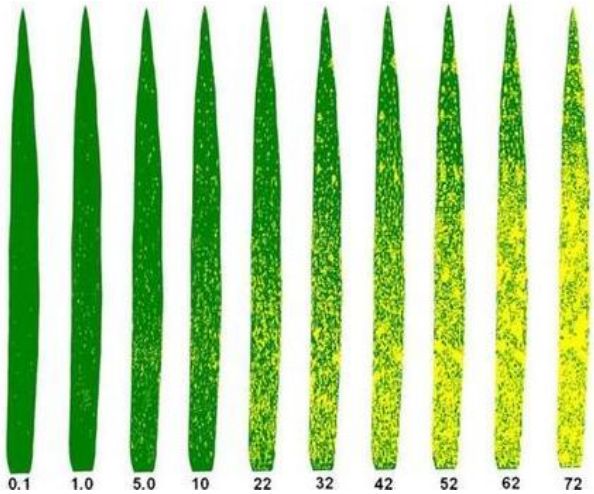
Disease resistance/% tissue dis.

Type of measurement	Instrument (examples)	References (e.g.)
Direct	"Visual"	e.g., Faivre-Rampant et al. (2010)
Indirect-proximal	Spectral reflectance	e.g., Huang et al. (2007)
Indirect-remote	Hyper-spectral imaging	e.g., Huang et al. (2007)

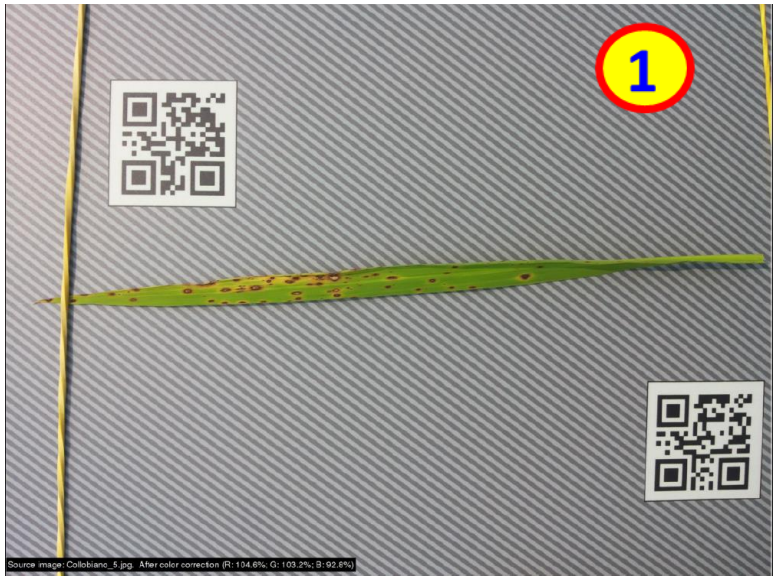
Disease resistance/% tissue dis.

- Often, **visual assessments** are carried out, by means of **reference panels** like the one below:



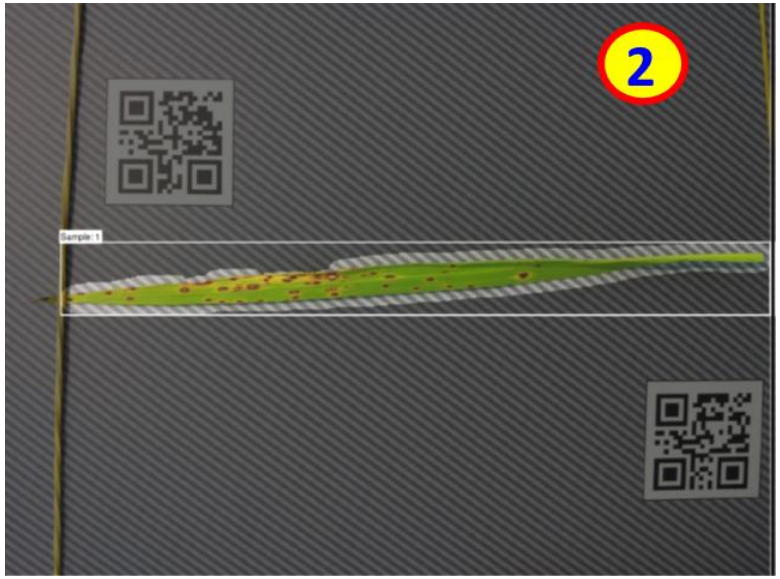


PocketDisease



Leaf pictures taken on a **dedicated background panel**:

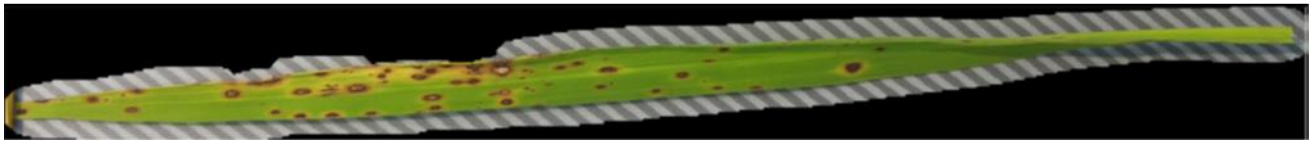
- "flat reflectance" on a wide range of light conditions
- **weft** to speed **focus**
- **QR codes** for **normalizing picture size** regardless of the distance from the panel/angle



Automatic recognition of the **region** where the **leaf** is

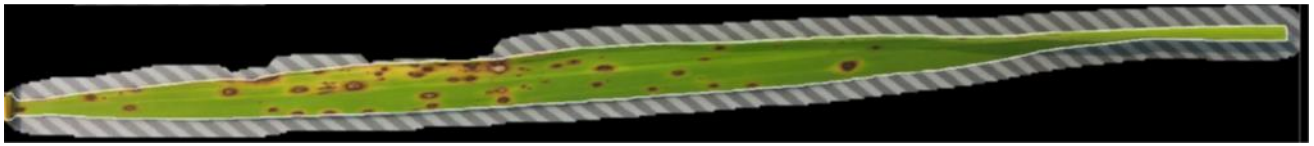
PocketDisease

3



Refining the detection of the image **region of interest**

4



Detection of **leaf borders** (marked in white)

5

Identification of lesions and **measure of their area**

PocketDisease

- It is based on **neural networks** for image processing
- Currently **under development**
  - ✓ Transferring the **network on the device** to **avoid backend** services (sometimes no Wi-Fi in field)

Simplicity is complexity resolved

(C. Brâncuşi)

Thanks so much for your kind attention

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