→ MEASUREMENTS AND OBSERVATIONS IN THE 21ST CENTURY CONFERENCE

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Brain Gain Program, Ministry of Research,

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Smart farms in the 21st century: Agriculture and forestry intelligent systems

November 21, 2016

ESA – ESRIN | Frascati, Rome (Italy)

MOXXI Measurements & Observations in the 21st Century

Working Group - International Association of Hydrological Sciences

European Space Agency | European Space Research Institute

TREE IMPROVEMENT PROGRAM

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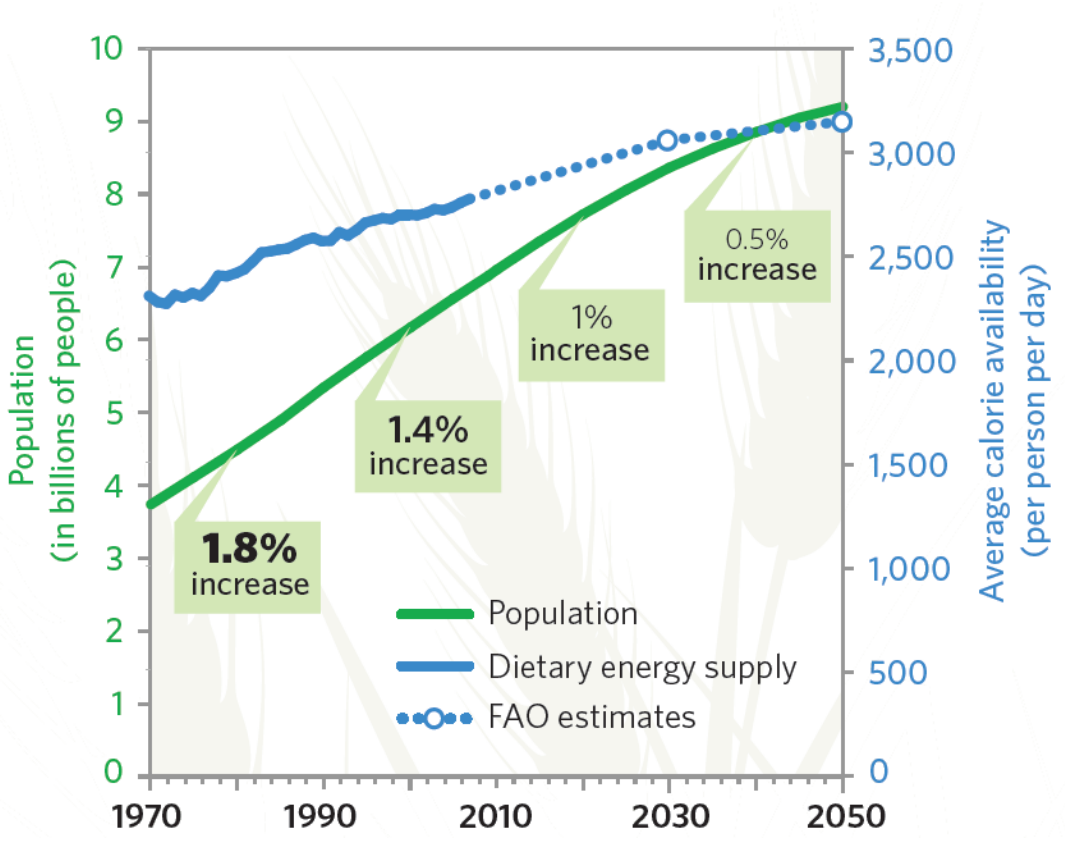
What **Challenges** do agriculture and silviculture face today?

Population growth

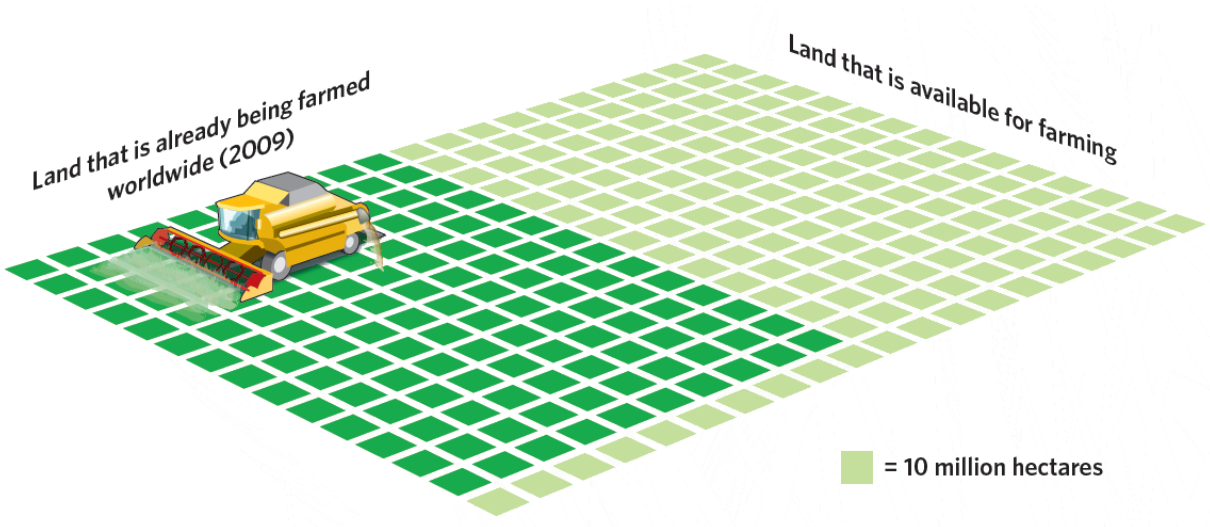


Sources: UN population division; FAO

News Feature Food: Nature, Vol 466:29 July 2010

nature International weekly journal of science

Arable land shortage



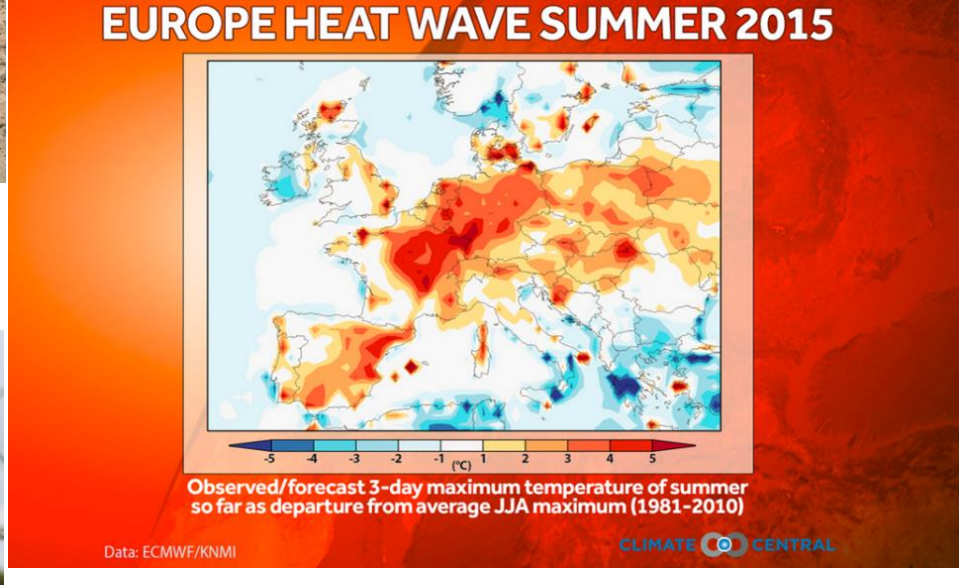
Source: FAO/OECD

News Feature Food: Nature, Vol 466:29 July 2010

nature International weekly journal of science

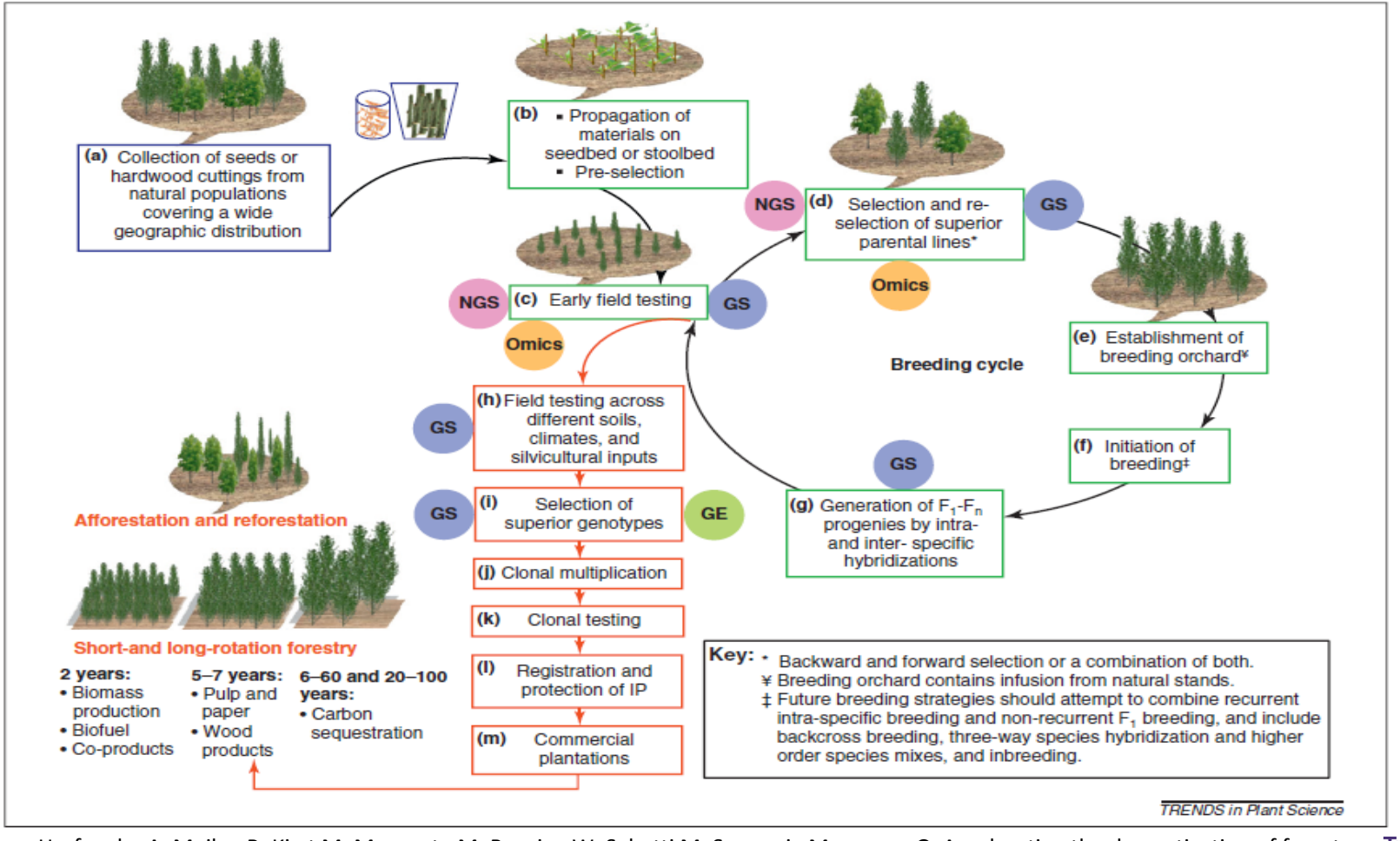
Climate change – Water scarcity & Heatwave

The ongoing drought in California has led to low water levels in many lakes and reservoirs, including Lake Oroville



What **Solutions** are available to face these challenges?

Accelerating the domestication of forest trees in a changing world



Harfouche A, Meilan R, Kirst M, Morgante M, Boerjan W, Sabatti M, Scarascia Mugnozza G: Accelerating the domestication of forest trees in a changing world. Trends Plant Sci 2012, 17:64–72.

What tools does UAV-based Phenomics offer?

UNIVERSITÀ DEGLI STUDI DELLA Tuscia

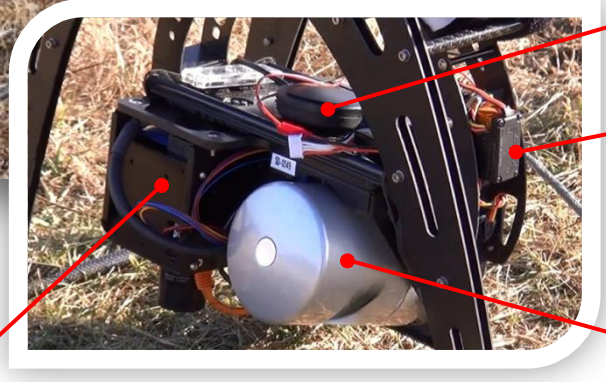
DIBAF Department for Innovation in Biological, Agrofood and Forest systems

PHENOBOTIX™

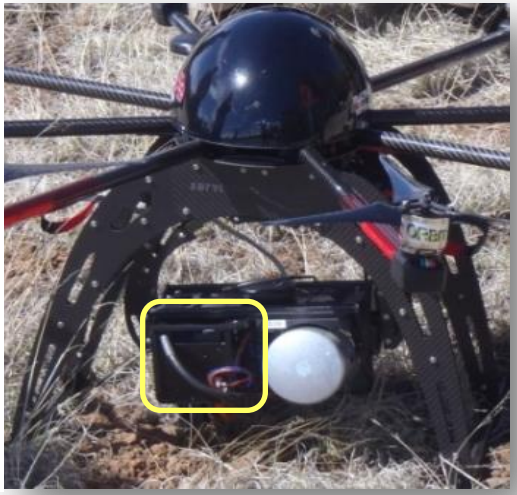
Tuscia Plant Phenomics Laboratory

Innovation for Our Agriculture Future

Field-based phenomics platform
The PhenoBotix Lab's PhenoDrone™:
Unmanned aerial vehicle imaging system architecture



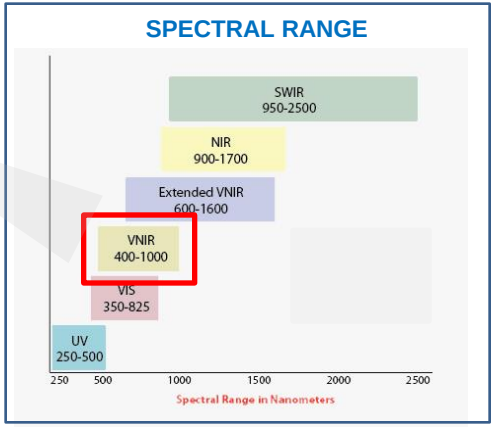
PhenoDrone™: High resolution hyperspectral UAV imagery for precision assessment of plant response to environmental stress



Completely integrated miniaturized and lightweight VNIR hyperspectral sensor package for UAV Applications

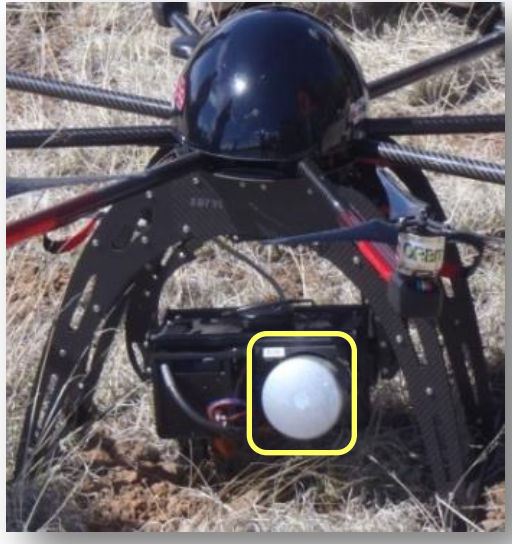
TECHNICAL DATA (Nano-Hyperspec®)	
Dimension	7,6 cm x 7,6 cm x 12 cm
Wavelenght range	400-1000 nm
Spatial bands	640
Spectral bands	270
Spectral sampling interval	~ 2,2 nm
Spectral resolution	5 nm
Lens	17 mm
Frame rate (fps – full frame)	200-480
Storage capacity	480 GB (~ 130 min. at 100 fps)
Sensor weight	0,680 Kg

On-board data-processing, storage and GPS/IMU



PhenoDrone™: micro-LiDAR - light detection and ranging sensor

TECHNICAL DATA (HDL-32E)	
Dimension	Ø 8,5 cm, H. 14,9 cm
Frame rate	10 Hz
Measurement range	1m to typically 100 m
Wavelength	905nm
Vertical Field of View (degrees)	+10,67 to -30,67
Horizontal Field of View (degrees)	360
Accuracy	< 2 cm
Vertical angular resolution	~ 1,33°
Horizontal angular resolution	~ 0,16° at 600 rpm
Sensor weight	1,050 Kg



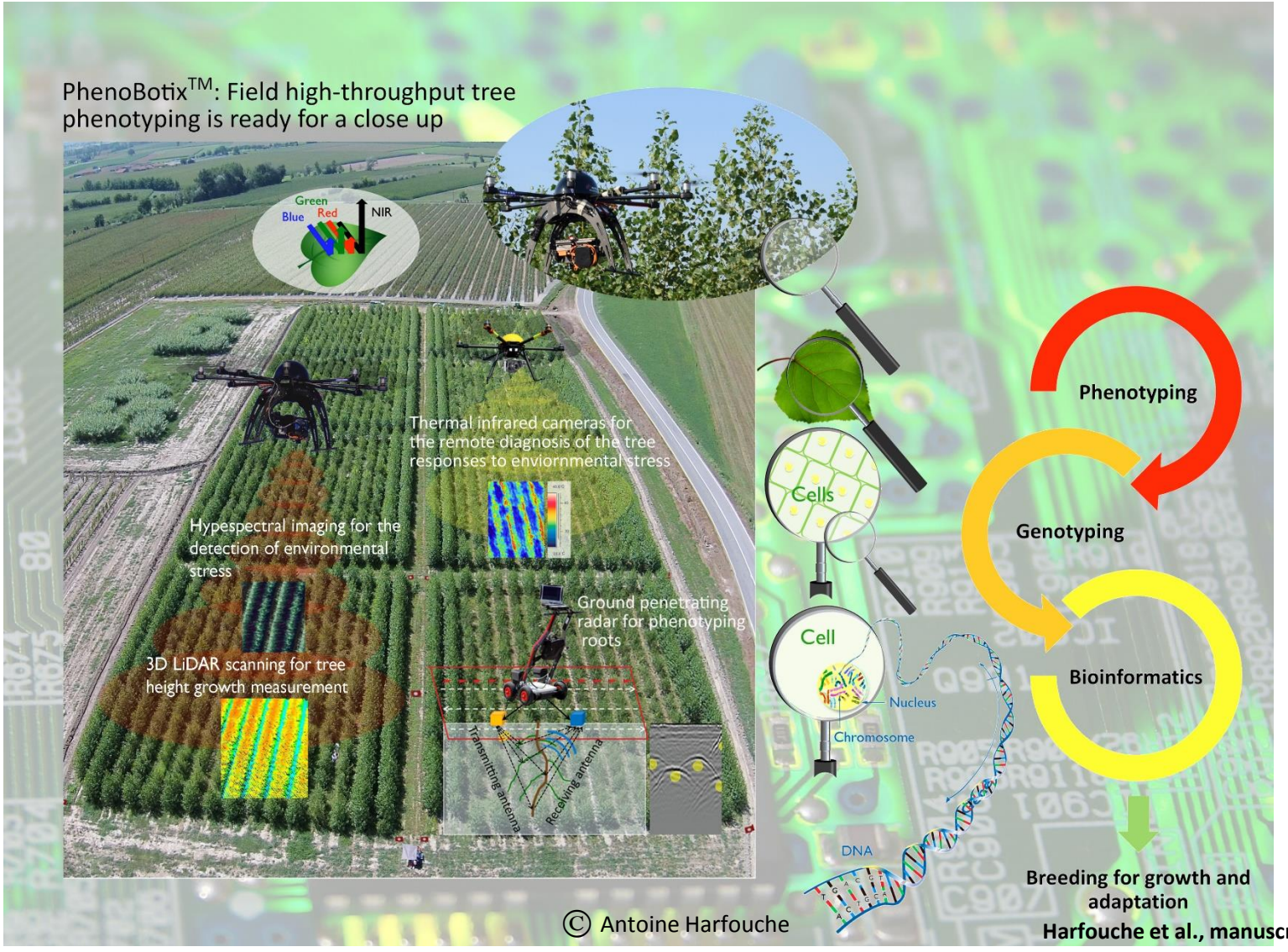
- Very high definition LiDAR
- Real time LiDAR data
- 3D LiDAR capture

PhenoDrone™: Applying high-throughput field-based phenotyping to plant drought stress: picturing more resistant crops with thermal infrared sensor

Thermal Imager Lightweight Kit

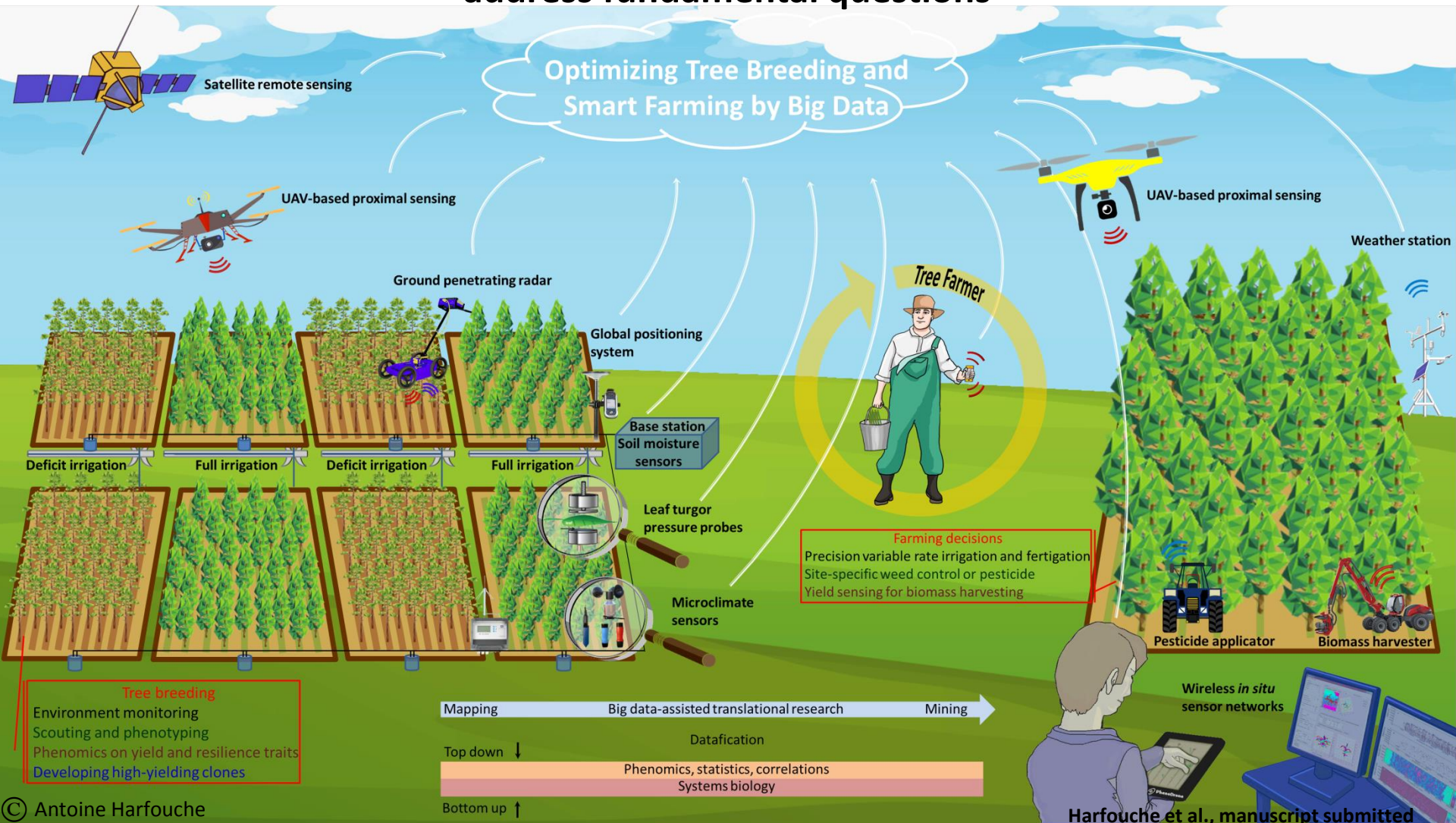
TECHNICAL DATA (Optris PI 640)	
Dimension	7,6 cm x 7,6 cm x 12 cm
Optical resolution	640x480 pixels
Spectral range	7.5 - 13 µm
Frame rate	32 Hz
Accuracy	±2°C
Thermal sensitivity	75 mK
Weight	0,320 Kg

Bridging genomics with phenomics: the solution



Harfouche et al., manuscript submitted

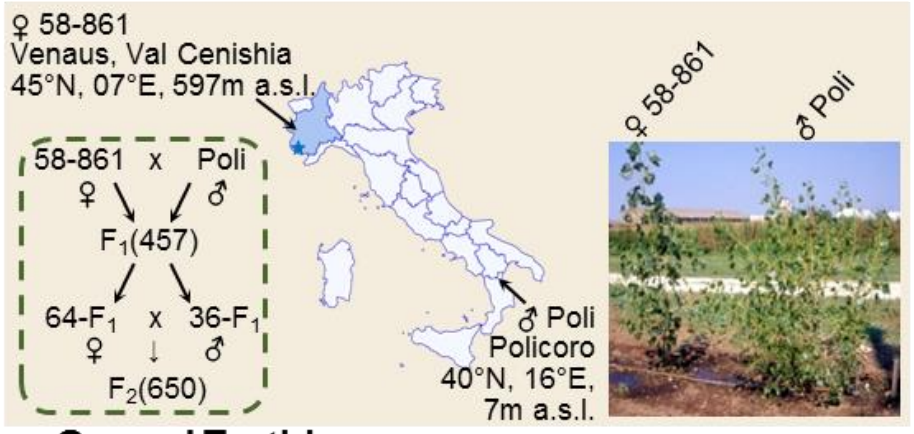
Next-generation agriculture and forest sciences: putting big data to work to address fundamental questions



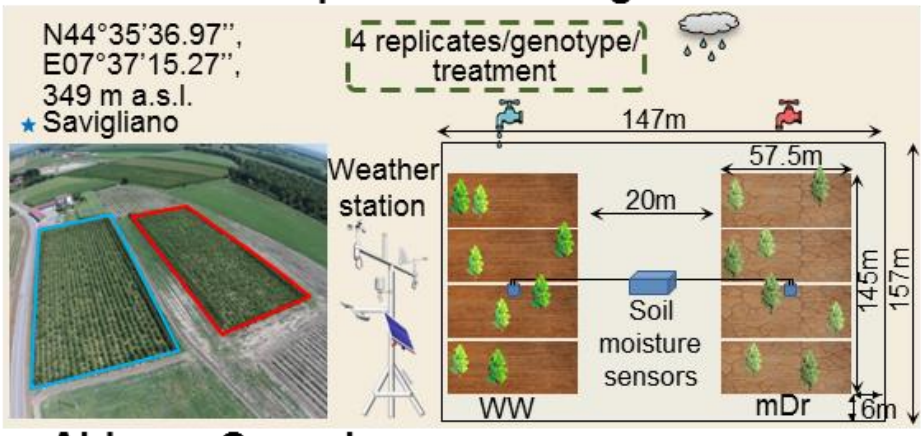
Harfouche et al., manuscript submitted

Thermography to explore drought stress responses using Phenodrone™

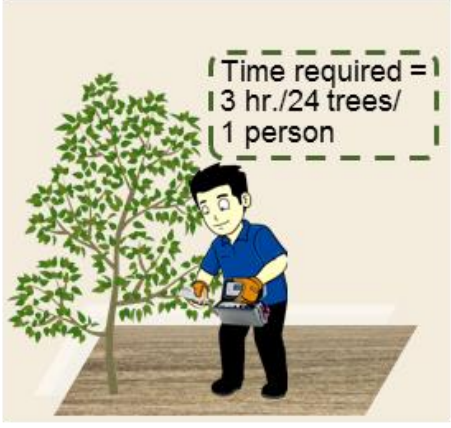
Plant Material



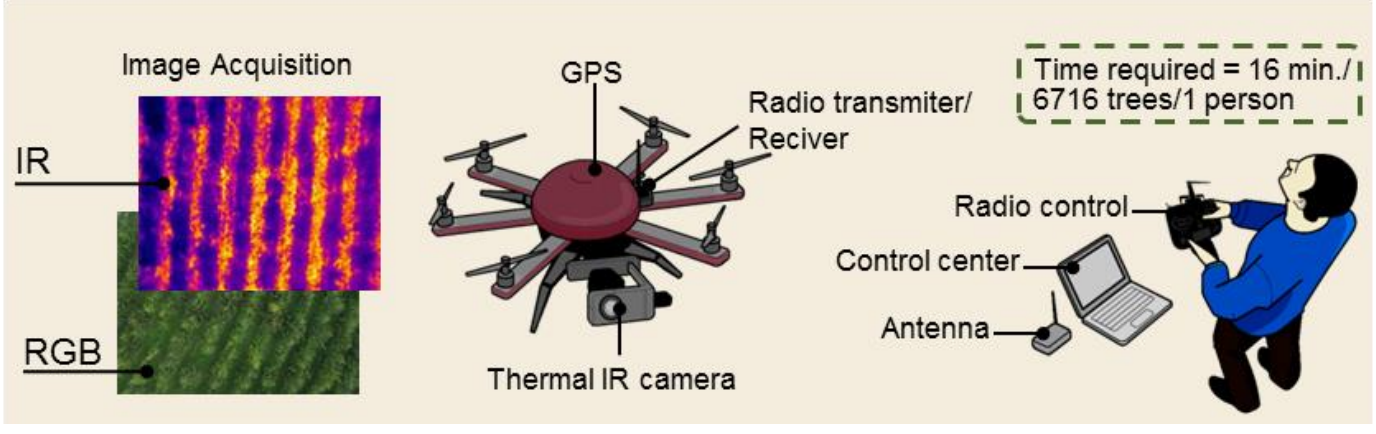
Experimental Design



Ground Truthing



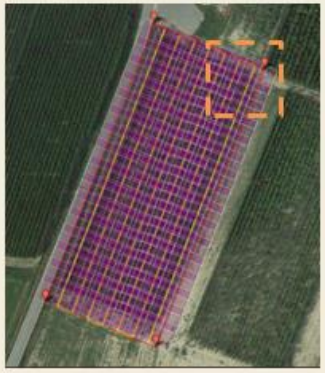
Airborne Campaign

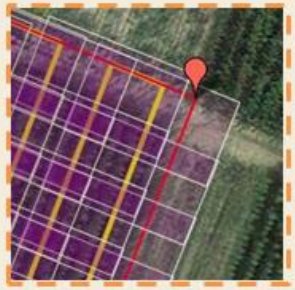


Ludovisi, Tauro et al., manuscript in preparation

UAV Flight Planning

Flight parameters
Flight height: 25m
Flight speed: 3m.s^{-1}
Field of view: 8.9 (V) x 11.1 (H)
Spatial resolution: 6cm

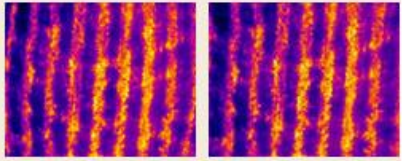




Footprint for UAV images = single image frames + overlapping

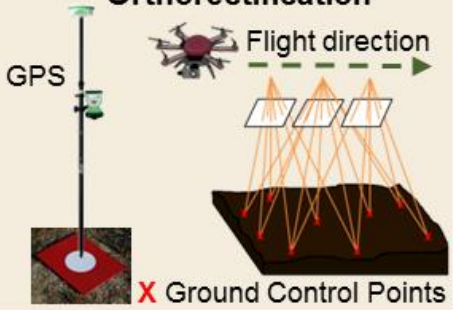
Image Processing

Image Calibration

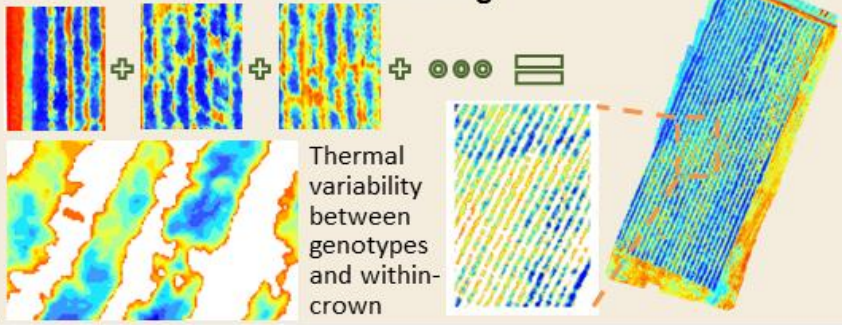


Before After

Georeferencing and Orthorectification

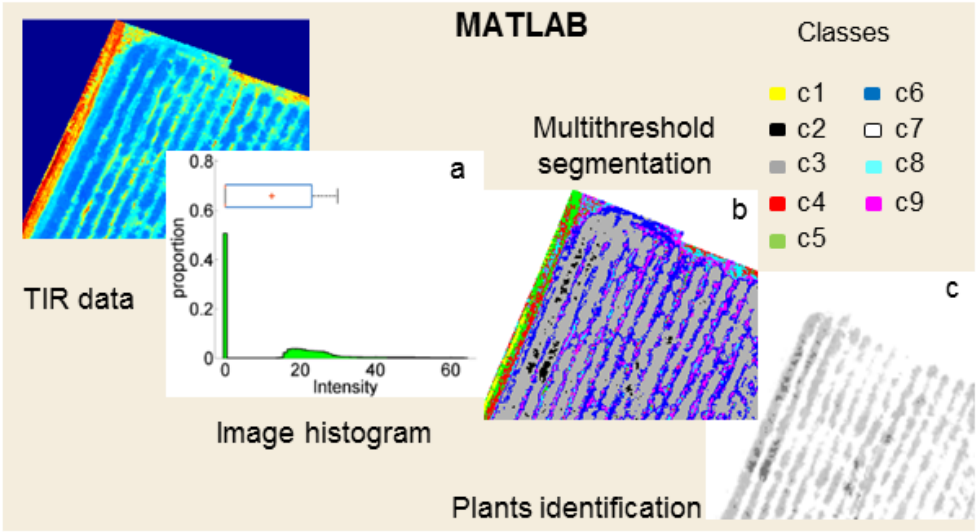


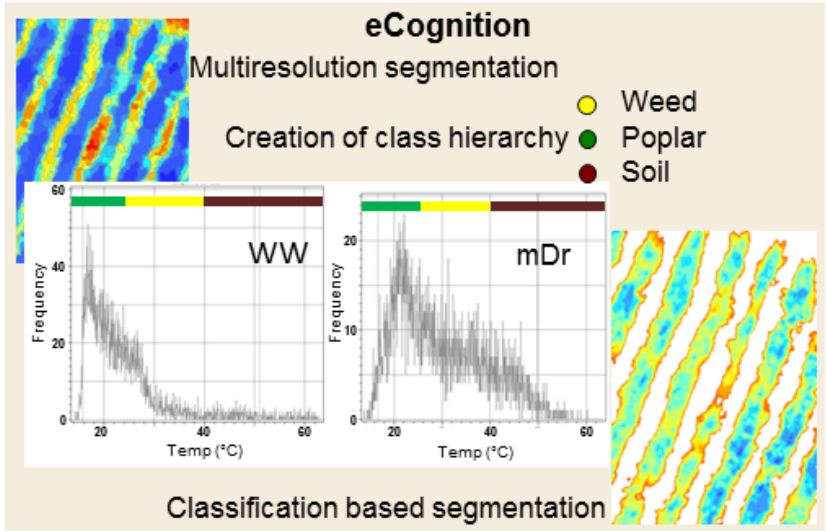
Mosaicking



Ludovisi, Tauro et al., manuscript in preparation

Segmentation Analysis



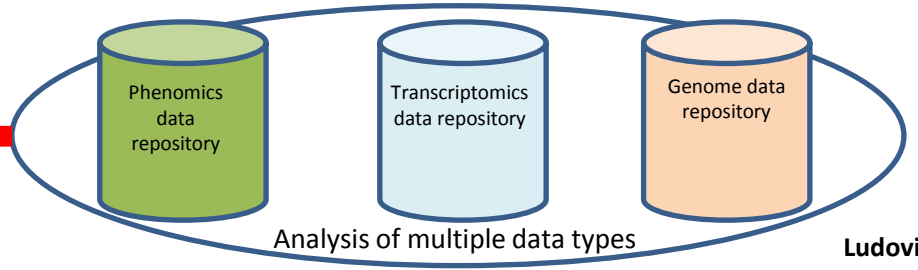


Results/End products

Data extraction
Statistical analysis of field-truth/UAV data correlations

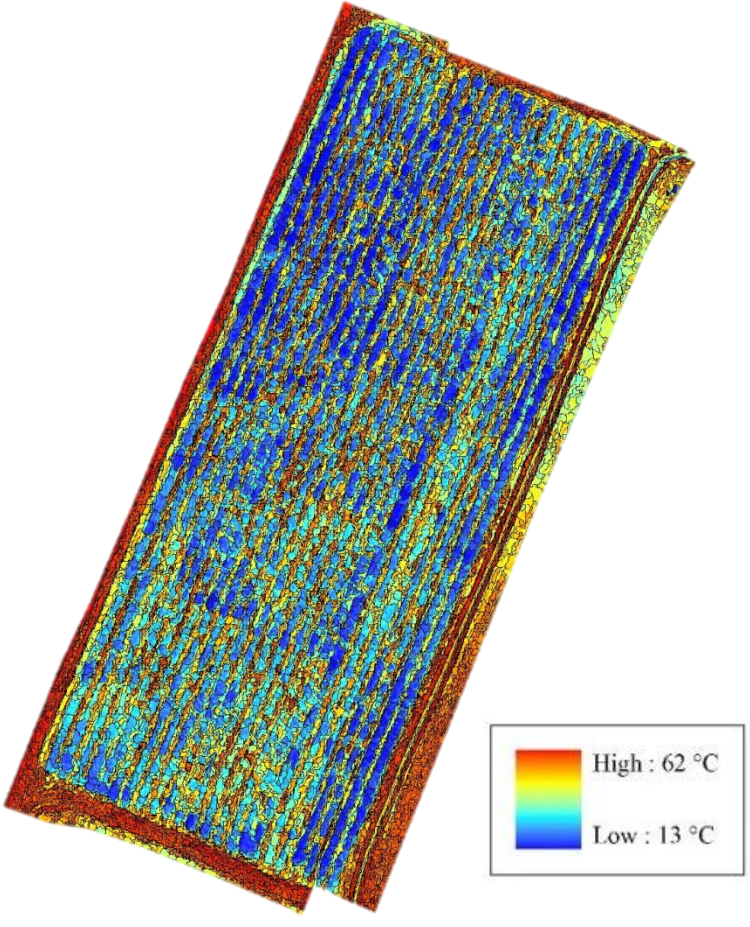
Map desired variables of plant trait or status

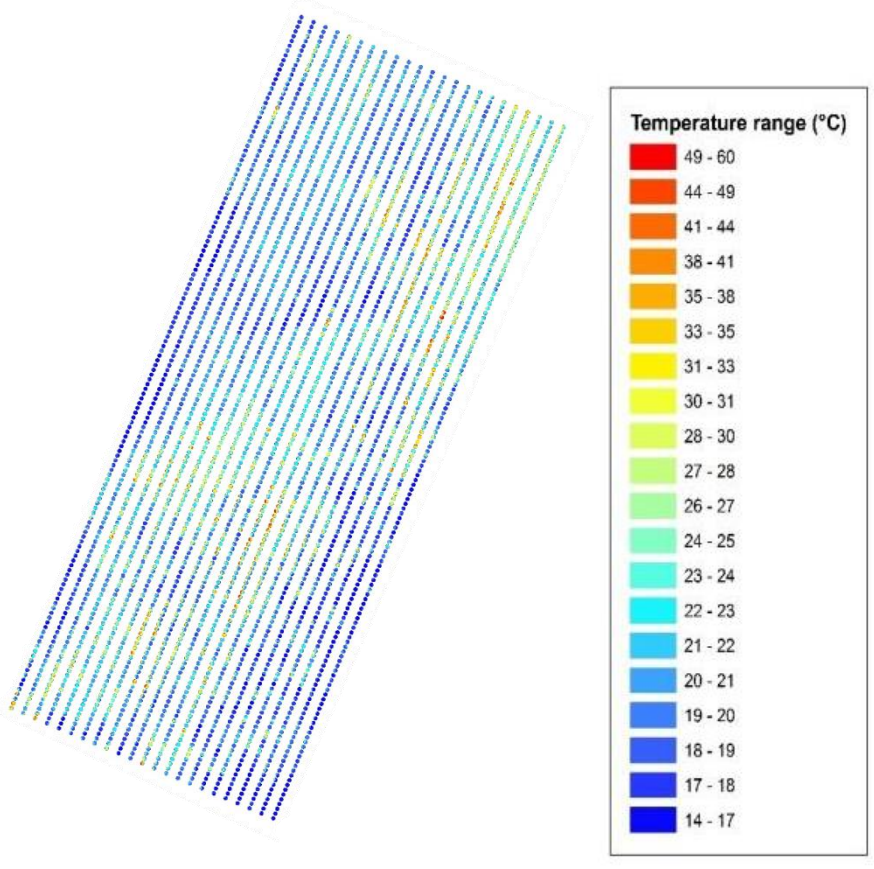
Specialized analysis by expert users



Ludovisi, Tauro et al., manuscript in preparation

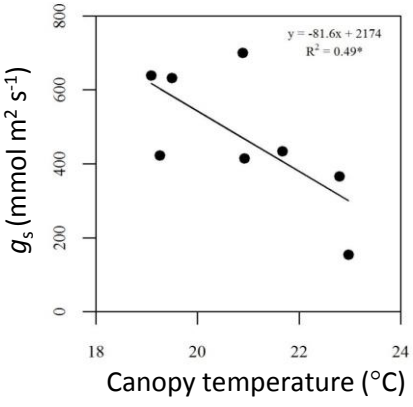
Thermal imaging: applications in forest tree breeding

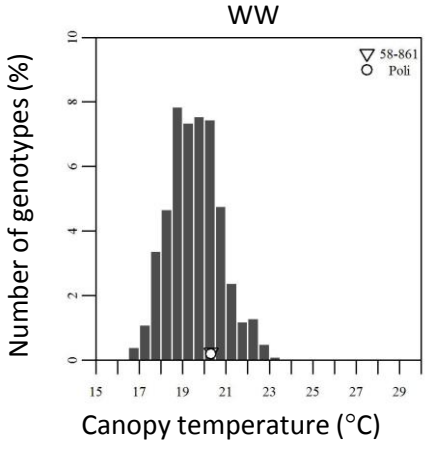


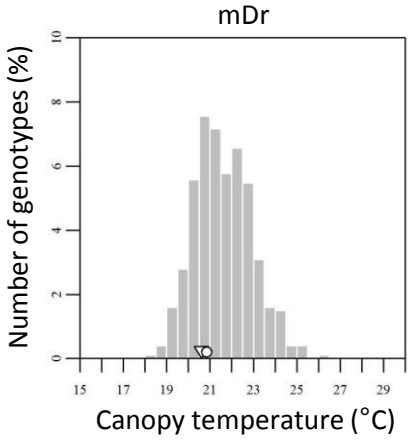


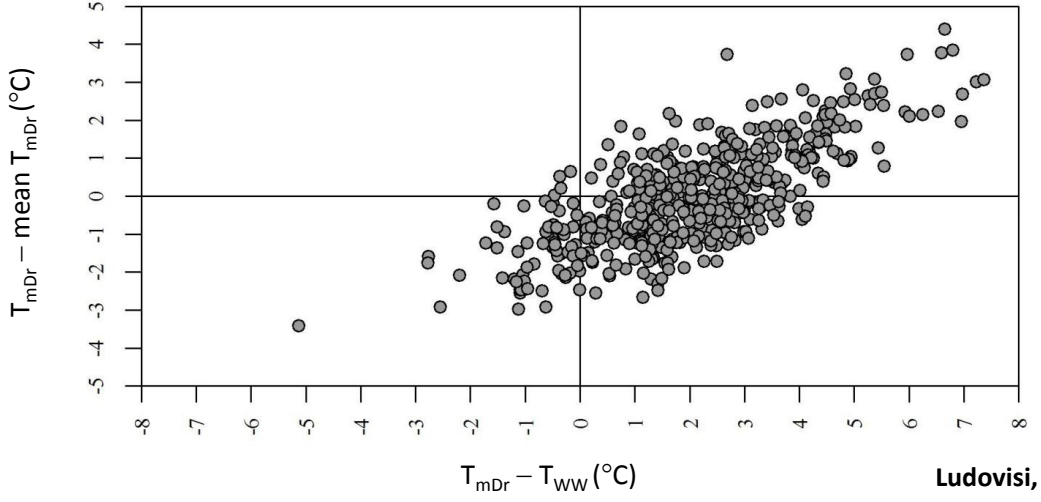
Ludovisi, Tauro et al., manuscript in preparation

Development of water stress indicators based on PhenoDrone™ thermal imagery for field phenotyping a heterogeneous tree population for response to water constraints





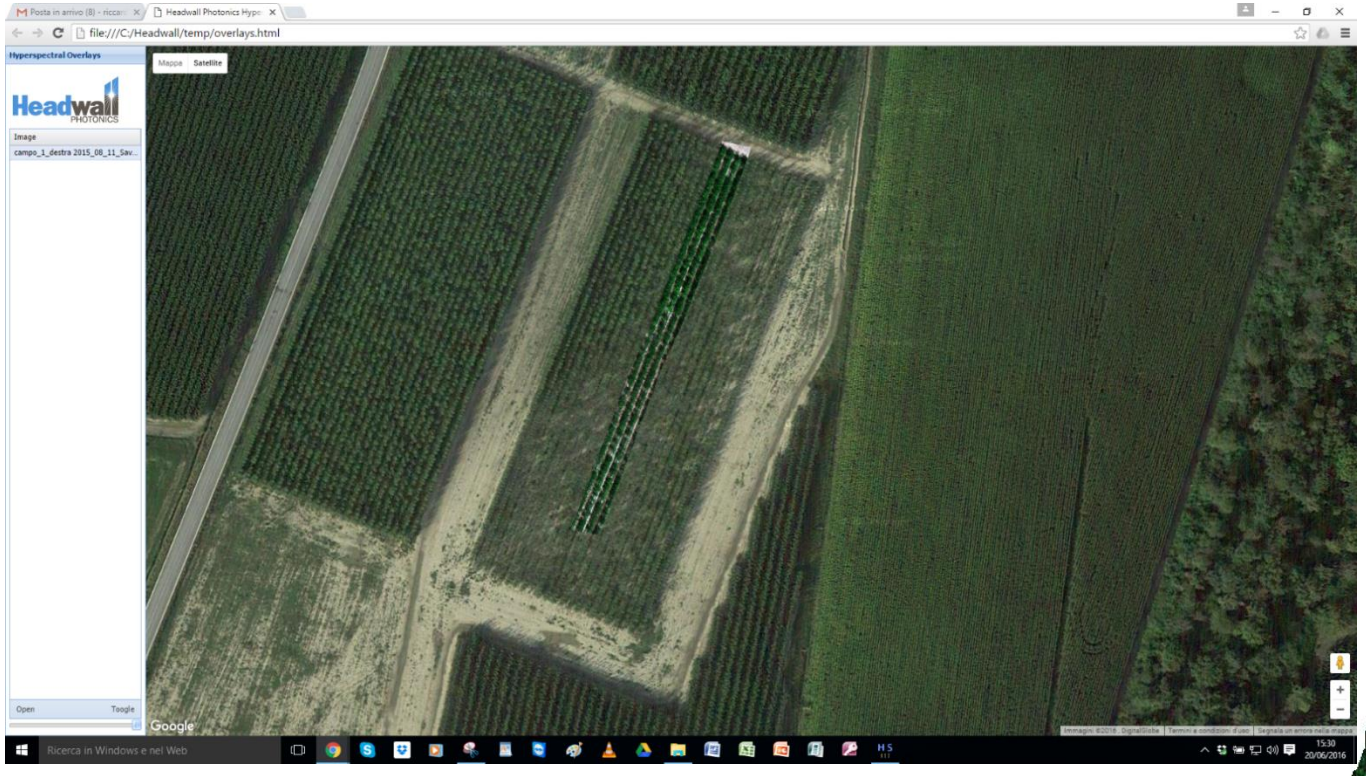




Genotypic ranking

Ludovisi, Tauro et al., manuscript in preparation

Field-based phenomics: Hyperspectral imaging for the detection of drought stress in black poplar F_2 mapping population



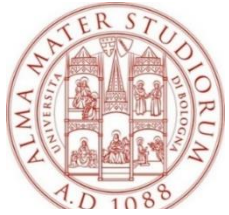
By increasing the throughput, precision, and dimensionality of these measures, hyperspectral has the potential to revolutionize poplar breeding programs for environmental stress tolerance

Harfouche et al., manuscript in preparation

The EU WATBIO:
DEVELOPING DROUGHT-TOLERANT BIOMASS CROPS FOR EUROPE

Dr Kai-Uwe Schwarz

YARA ZIM Plant Technology GmbH



Unmanned Aerial Vehicles as Mobile Multi-Sensor Platforms for Innovative and Sustainable Management of Agro-Environmental Ecosystems

AgroEnVision™

LAZIO INNOVA

The EU AGROF-MM: Agroforestry Mediterranean and Mountains

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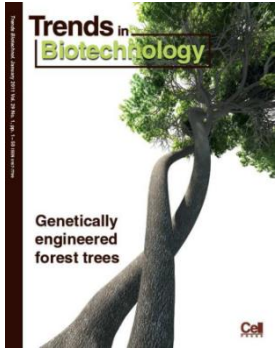
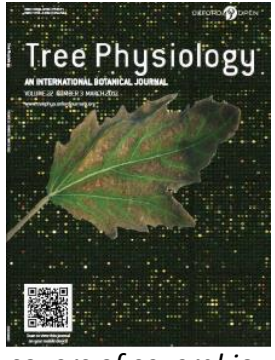
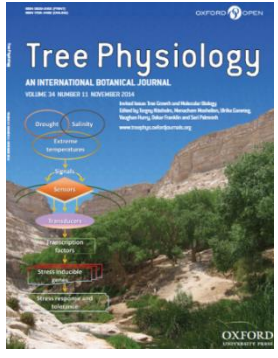
Salvatore Grimaldi


Flavia Tauro







Our work has been featured on the covers of several journals

SEVENTH FRAMEWORK PROGRAMME

Education and Culture Lifelong Learning Programme

Knowledge Alliances

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Thank you
WeDIBAF