Advanced agromechanics and Digital Agriculture: *research and innovation in Italy and at CREA*

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It is the most important Italian research institution in the agro-food, supervised by Ministry of Agricultural Food and Forestry Policies:

- *5000 ha farm*
- *advanced instruments and labs*
- *1800 employees*
- *600 researchers*

6 disciplinary CENTERS:
- *Genomics and bioinformatics*
- *Agriculture and environment*
- *Plant protection and certification*
- **Engineering and agro-food processing**
- *Food and Nutrition*
- *Policies and the bio-economy*

6 supply chain CENTERS :
- *Cereal and industrial crops*
- *Olive, citrus and tree fruit*
- *Viticulture and enology*
- *Vegetable and ornamental crops*
- *Animal production and aquaculture*
- *Forestry and wood*

CREA-IT carries out activities in the field of biosystems engineering, agroindustrial and food processing, especially of fruit and vegetables, cereals and olives, for the sustainable management of the agro-ecosystems, agricultural, agro-food and agro-industrial sectors.

role	TOT
Researchers	55
Technicians	53
administratives	22
Non permanent	25
Tot	155

MILANO
Fruit and vegetables processing: quality, postharvest conservation, biocomponents extraction, new processing techniques (i.e solar dehydration)

TREVIGLIO (BG)
agricultural engineering applications: tractors, operative machines, testing OCSE code, mechanization, precision and smart farming, digital agriculture

PESCARA
Olive oil and table olive processing: quality analysis and certification

TORINO
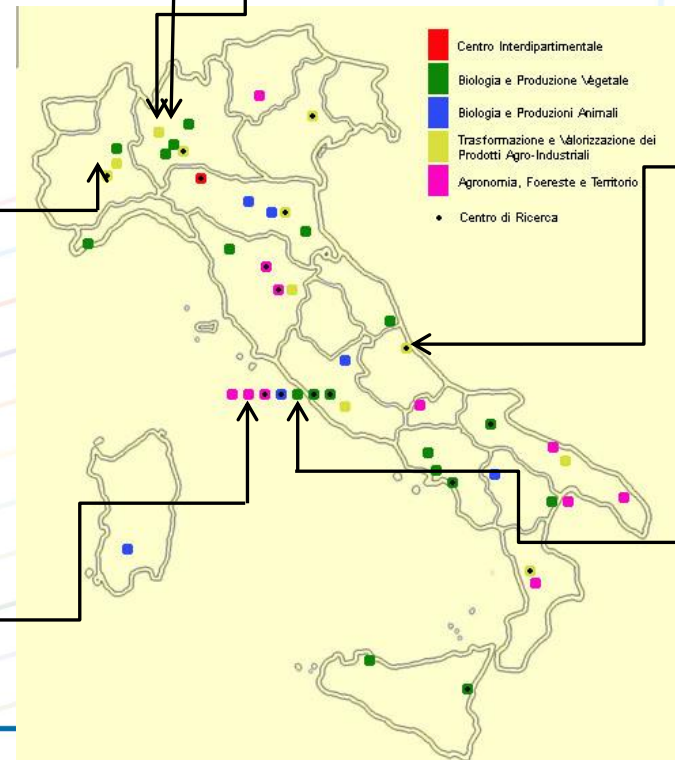Microbiology and food quality

MONTEROTONDO (RM)
agricultural engineering applications: tractors, operative machines, testing, mechanization, precision and smart farming, digital agriculture

ROMA
Cereal processing: durum wheat quality and pasta production

Centro Interdipartimentale
Biologia e Produzione Vegetale
Biologia e Produzioni Animali
Trasformazione e Valorizzazione dei Prodotti Agro-Industriali
Agronomia, Foereste e Territorio
Centro di Ricerca

- **Sustainability of agri-food systems**: circular economy, climate change mitigation and adaptation, biodiversity, forestry, resilience of agri-food systems, food quality and safety.

- Inclusiveness in agriculture: women, young farmers, smallholders.

- Innovation: advanced agromechanics, digital sensors, artificial intelligence applications, certification of food products, data access and availability, technology transfer, cutting edge technologies, bioenergies

crea
Consiglio per la ricerca in agricoltura
e l'analisi dell'economia agraria

number of Italian researches

Scopus search based on the key word: precision agriculture

Refining the search, on a total of 860 papers, since the year 2000, only 60 are strictly related to agricultural machineries. The primary focus of these researches are related to:

- Spraying system on grapewine
- GNSS automatic guidance
- Grapewine yield
- Modification of conventional sprayers for PA applications
- Intra-row weeding systems
- Comfort variation in tractors equipped for PA
- Autonomous machines

Plant specific autonomous sprayer

Kit of reader of dead plants and rows for selective spraying

Sprayer with recovery systems capable to reduce until 80% the product distributed

Selevtive intra row weeding system

A lack of research is identified for the aspects related to the real and quantifable advantages of the adoption of precision agriculture machines. Data should be compared with perfomace declared by constructors.

Thanks to the tax credit started in 2020, there has been a strong boost in **digital farming (4.0)** technologies adoption, even if large margins remain for the full application of the related technologies.

Since the last five years there is a growing interest in the **electrification of the full line** of agricultural machinery with about 10 manufacturers involved on tractors engines (full electric, hybrid), machinery and emerging topic (standardization, safety, maintenance, work rate and autonomy).

For livestock robotization, Italy has recorded great interest in milking (about 1200 farms), feeding (about 150 farms), cleaning and climate control automation and robotization
For agriculture robotization, since 2021 some Italian companies entered into agreements with international producers of Ag robots. Particularly interesting are the applications for the vineyard or for the mechanical weeding in organic farming.

- Improving farm tractor safety on the roll-over protective structure (ROPS, OECD Standard Code 4 and 6)
- Risk of falling object protective structure (FOPS) of agricultural tractor (OECD Standard Code 10)
- Foldable ROPS (maximum force allowed for raising and lowering the structure, operator position)
- Ageing
- Safety zone definition, seat index point (SIP)
- Lateral stability of the agricultural machines (OECD Code 6)
- whole Body Vibration on Tractors" (OECD, 2016-2017)
- Ergonomic and safety on tractors

(Cutini et al., 2018)

Optimizing tractor efficiency is TOPIC FOR INDUSTRY (emission and energy saving).
Tractors: fast development in terms of transmission, tires and engine management.
Fundamental the tractor-implement correct coupling and utilization.

Our tests show that with orrect implementation
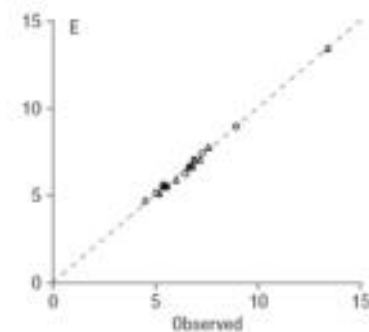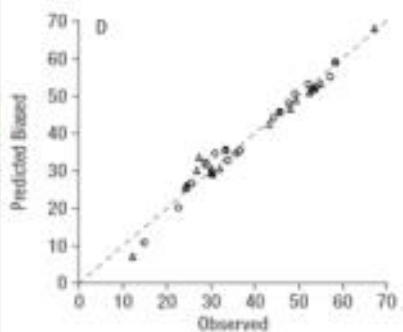**possible fuel saving up to 30%.**
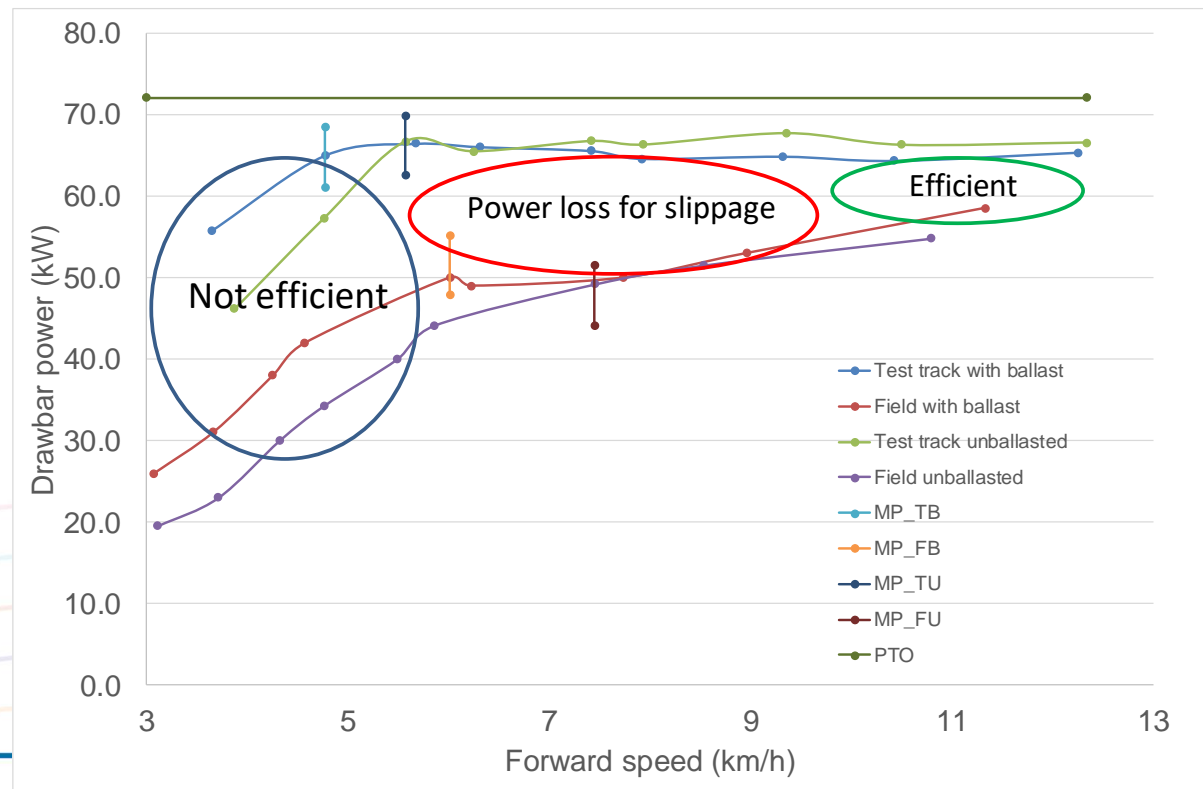
(Bisaglia et al., 2017)

Processing times
observed/predicted through Artificial Neural Networks based on different field shapes
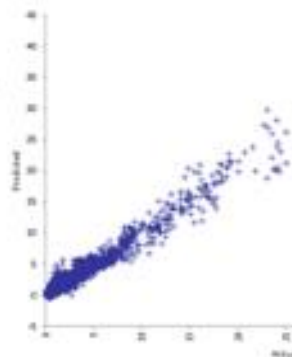
91% - 98% correct prediction!
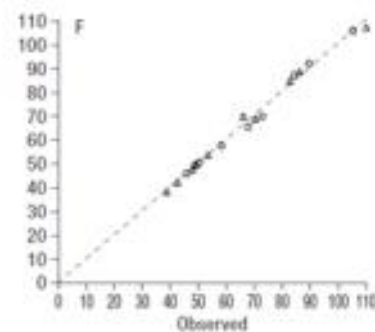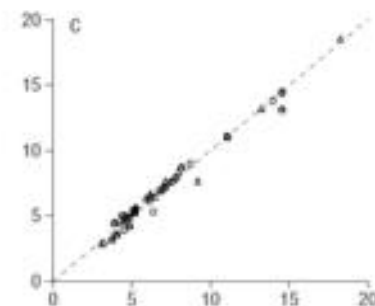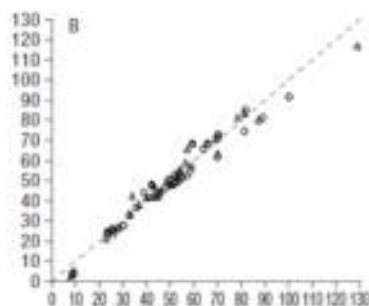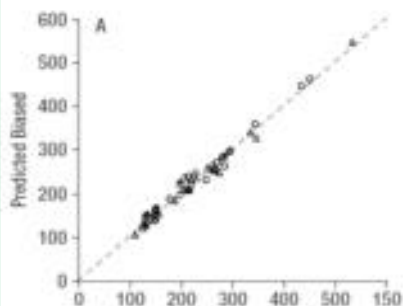
Observed/predicted costs
from PLS models for different agricultural processing: A. tillage, B. weeding, C. fertilization, D. sowing, E. harrowing, and F. shredding

(Costa et al., 2017)

- Electrification is a major challenge for the agricultural machinery industry and its evolution (CETIM and Tech2Market, 2013)
- New opportunities both for manufacturers and users (new technical functions, increase of performances, decrease of energy cost in particular when self produced, simplified machinery, new comfort and environmental standards)
- Interesting application in tractors (both for open field operations and **specialized orchard** use) and **livestock farming** as robot or self-propelled solutions for feeding cows and bulls where first tests have showed reduction **in energy use of 30-40%** with electrical systems compared with conventional diesel-fueled solutions


Example of Automatic feeding systems (AFS) fully electric powered

Example of self propelled electric powered mixer wagon (18+15 kW engines power)

(Bisaglia et al., 2017)

- Biomethane is produced from livestock wastes and other organic wastes, it **reduces the emissions of GHG by 84-86%**

- CREA (Treviglio) carried out lab&field tests comparing two similar tractors (fueled by diesel or methane)
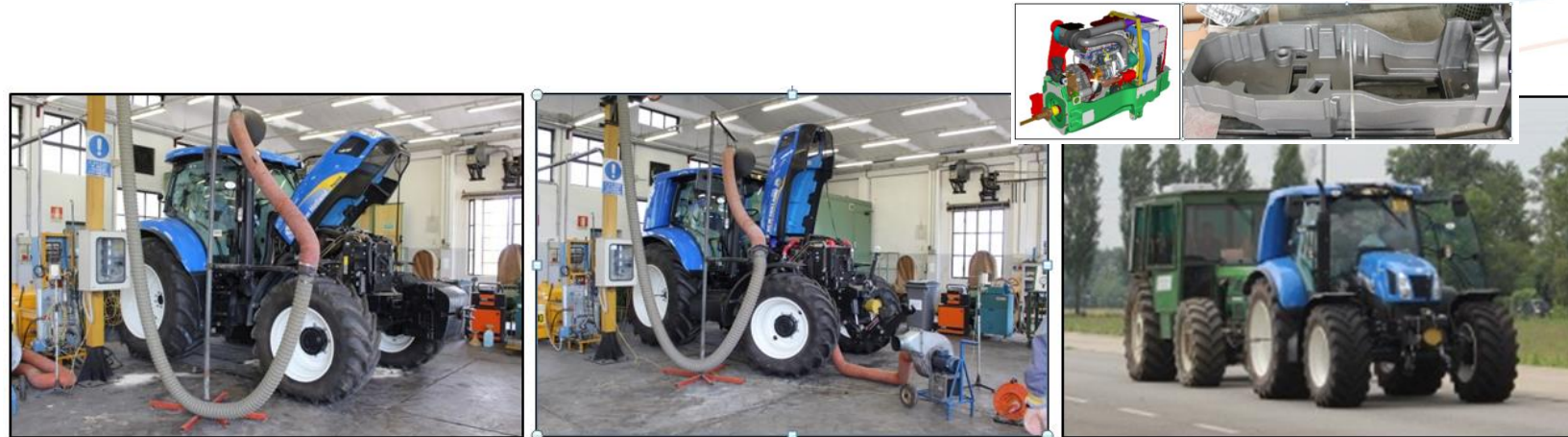

- prototype showed similar performances to diesel engine
- the main issue is autonomy, which is currently 40% of a comparable standard tractor

(Bisaglia et al., 2017)

SimAgri: a tractor driving simulator for precision agriculture

As part of the "Agridigit" program, the CREA set up a simulation platform (SimAgri) for precision agriculture strategies testing and application

Simulation of VRT
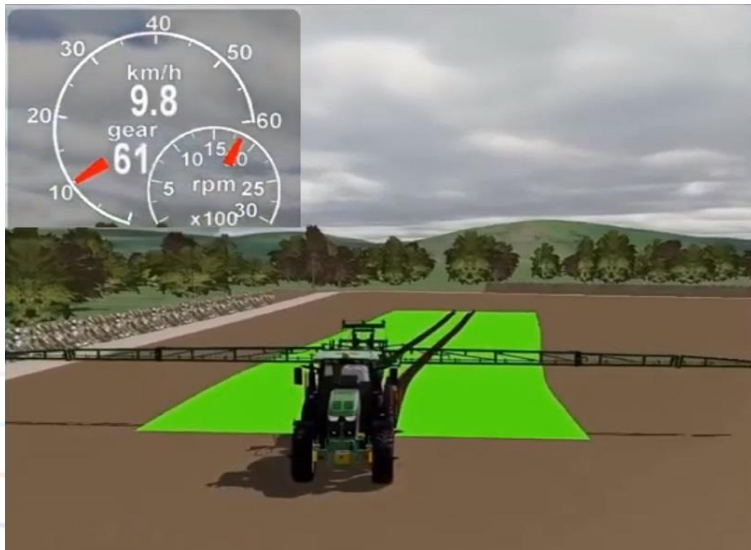
SimAgri reproduces the functionality of a tractor complete with some operating machines.
Its conception foresees a virtual/immersive reality "*driver in the loop*" system: the driver, immersed in the tractor and the working environment, checks the controls and receives the related feedback.
It presents realistic models to reconstruct events from real acquired scenarios.
The simulation areas concern:
* vehicle dynamics,
* global positioning system,
* semi automatic driving,
* management of precision agriculture operations (in particular VRT)

https://www.youtube.com/watch?v=cs3v_4hOEOE

Italian research structures and big sized farms made discrete experiences regarding **advanced testing** of optoelectronic sensors for AdP AND Digital Agriculture applications and their implementation

AgriDigit

RGB ⬤ MULTISPECTRAL ⬤ HYPERSPECTRAL
THERMAL

Weed detection in baby-leaf crops through RGB sensor
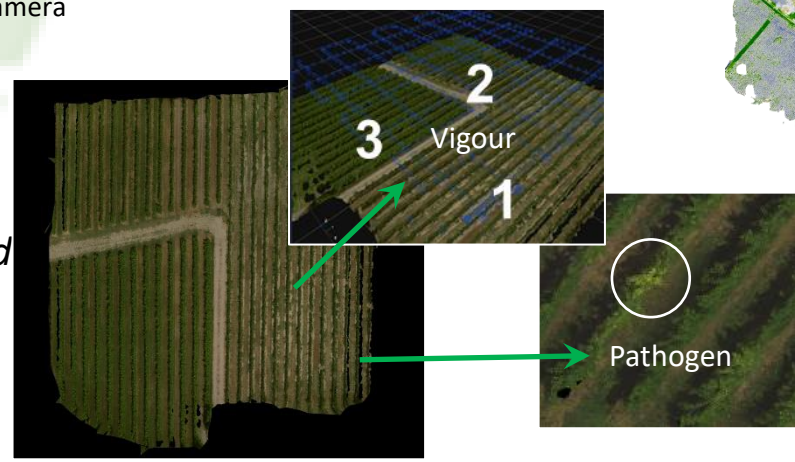
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Drone DJI™ SPARK™ RGB

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Sentera 6X high performance multispectral camera
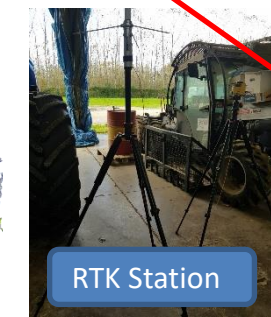
$$$$

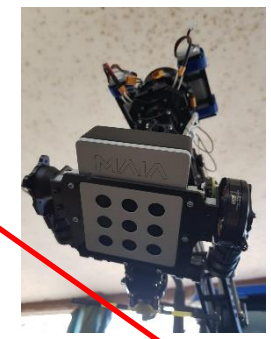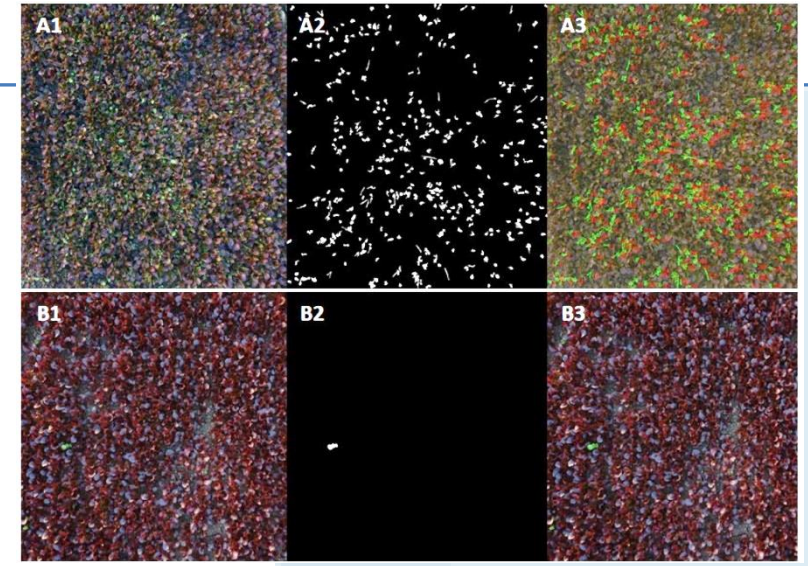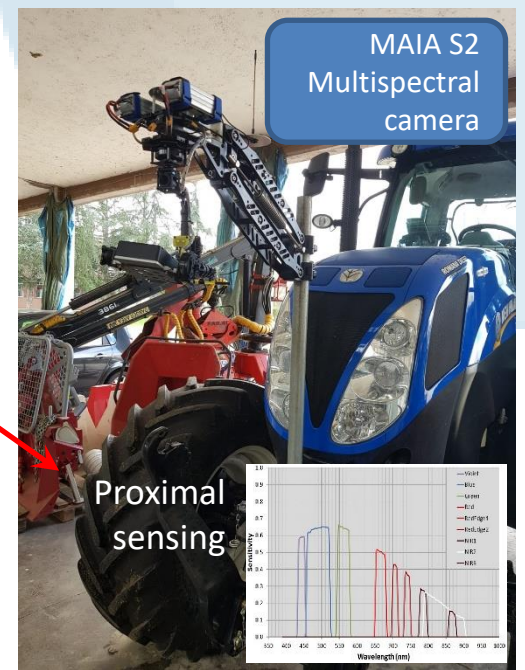Hyperspectral camera Senop HSC-2

Remote sensing

Best practices:
- *Vegetation indexes*
- *Weeds management*
- *Pathogens prediction and detection*
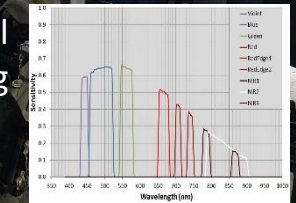
For site-specific semi- or fully-automated farm operations

Vigour

Pathogen

NDVI
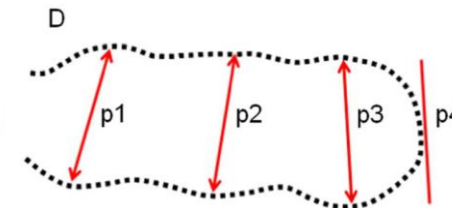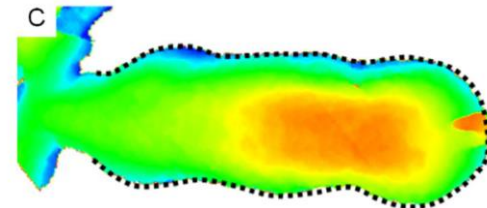
MAIA S2 Multispectral camera

Proximal sensing

RTK Station

Precision Agriculture – *Polarisengineeringsrl.it*

Precision livestock

Original papers

On-barn pig weight estimation based on body measurements by a Kinect v1 depth camera

Andrea Pezzuolo[a,*], Marcella Guarino[b], Luigi Sartori[a], Luciano A. González[c], Francesco Marinello[a]

[a] Department of Agroforesty and Landscape, University of Padua, Italy
[b] Department of Environmental Science and Policy, University of Milan, Italy
[c] Centre for Carbon Water and Food, School of Life and Environmental Sciences, Faculty of Agriculture and Environment, The University of Sydney, Camden, NSW, Australia

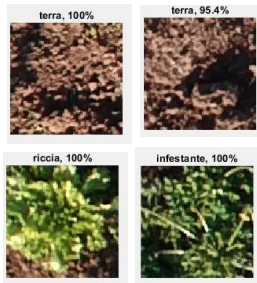2021 IEEE INTERNATIONAL WORKSHOP ON METROLOGY FOR AGRICULTURE AND FORESTRY

Anomaly detection in plant growth in a controlled environment using 3D scanning techniques and deep learning

Iva Xhimitiku, University of Padua, Italy. Federico Bianchi, Idea-Re Srl, Italy. Massimiliano Proietti, Idea-Re Srl, Italy. Tommaso Tocci, University of Perugia, Italy. Andrea Marini, Idea-Re Srl, Italy. Lorenzo Menculini, Idea-Re Srl, Italy. Loris Francesco Termite, K-Digitale Srl, Italy. Edvige Pucci, Idea-Re Srl, Italy. Alberto Garinei, Guglielmo Marconi University, Italy Marcello Marconi, Guglielmo Marconi University, Italy Gianluca Rossi, University of Perugia, Italy.

Research Paper

A convolutional neural network approach to detecting fruit physiological disorders and maturity in 'Abbé Fétel' pears

Alessandro Bonora [a,*], Gianmarco Bortolotti [a], Kushtrim Bresilla [a,b], Luca Corelli Grappadelli [a], Luigi Manfrini [a]

[a] Department of Agricultural and Food Science, University of Bologna, Bologna, 40127, Italy
[b] Agrosystems Research, Wageningen University and Research, Wageningen, 16708PB, Netherlands

Fig. 2 — Example of superficial scald detection (polygon is ground truth, rectangle is Scald V2 detection).

Form *idea-re.eu/*

CREA
Consiglio per la ricerca in agricoltura
e l'analisi dell'economia agraria

EARLY DETECTION

Weed detection

Plant diseases

terra, 100%
terra, 95.4%
riccia, 100%
infestante, 100%
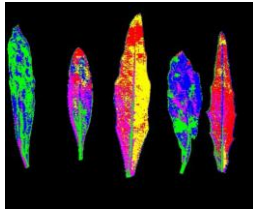
FOOD QUALITY EVALUATION

Cariossidi sane Cariossidi fusariate Cariossidi sane Cariossidi cariate

Cariossidi striminzite Cariossidi sane Semole da Cariossidi sane Cariossidi cariate
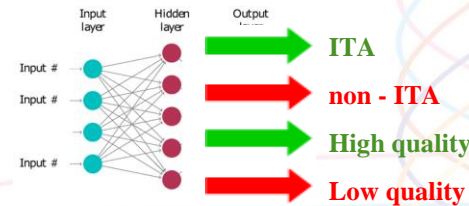
Original Segmented
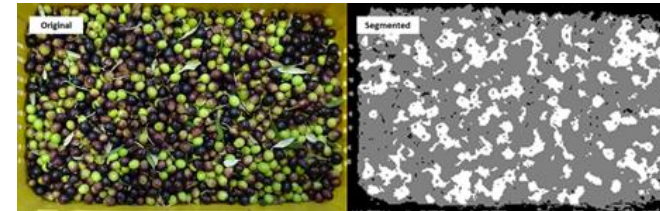
TECNOLOGY IMPROVEMENT

Production estimate from UAV

Animal Health

2, 29.6%
3, 99%
4, 74.5%
not classiable, 79.4%

Input layer Hidden layer Output layer
Input #
Input #
Input #

ITA
non - ITA
High quality
Low quality
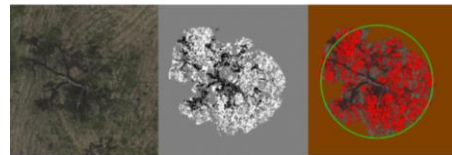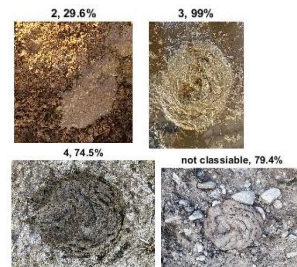
AgritechLab, CREA-IT (Ingegneria e Trasformazioni agroalimentari -Monterotondo (Italy)

RECENT PUBBLICATIONS

1. Navarro, A., Nicastro, N., Costa, C., Pentangelo, A., Cardarelli, M., Ortenzi, L., ... & Pane, C. (2022). **Sorting biotic and abiotic stresses on wild rocket by leaf-image hyperspectral data mining with an artificial intelligence model**. Plant methods, 18(1), 1-14.
2. Ortenzi, L., Violino, S., Pallottino, F., Figorilli, S., Vasta, S., Tocci, F., ... & Costa, C. (2021). **Early Estimation of Olive Production from Light Drone Orthophoto, through Canopy Radius**. Drones, 5(4), 118.
3. Ortenzi, L., Colle, G., Costa, C., & Moscovini, L. (2021, November). **Italian Speech Commands for Forestry applications**. In *2021 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor)* (pp. 401-405). IEEE.

Bioenergies – topic examples

a) CC: CO₂ capture via Chemical Looping Gasification (SEG)
b) CS CO₂ storage
c) Flexible Power to Gas 10 €/MWh H₂+CO
d) CU: CO₂ conversion and use: 33 €/MWh methanol and 100 €/MWh electricity

ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development

ENEA works on experimental activities for the production of green hydrogen from biomass gasification, with capture of CO_2 by solid sorbents. The process for the energy exploitation of captured carbon dioxide will be optimized through the use of highly innovative reactors in which CO_2 is dissociated into carbon monoxide (CO) and oxygen (O_2) by means of an ionized gas (cold plasma).
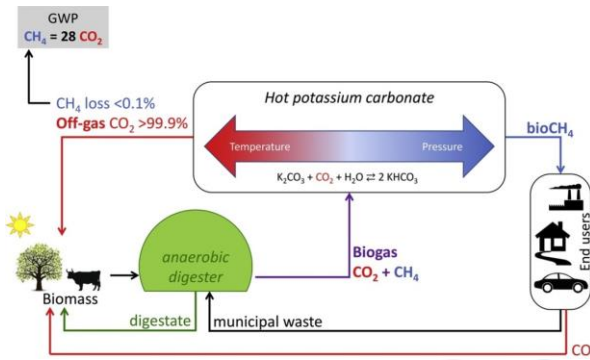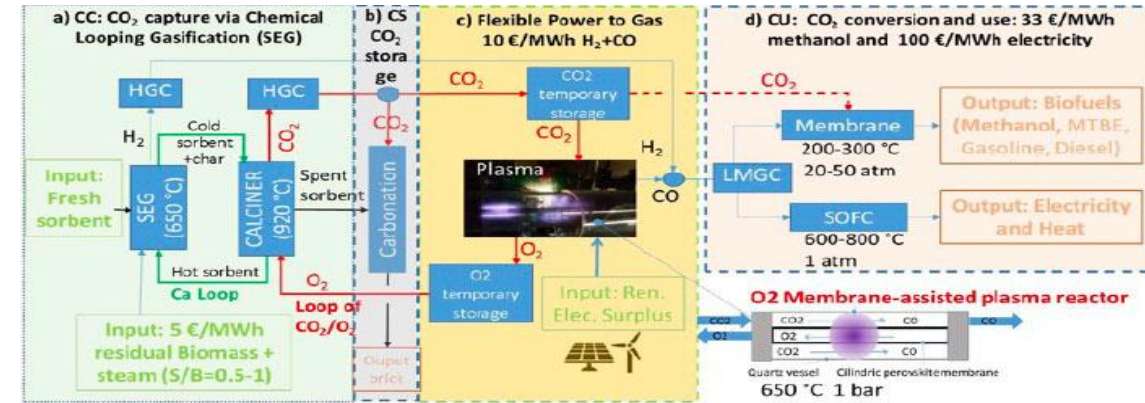

CNR-IIA - National Research Council Institute of Atmospheric Pollution Research

The CNR-IIA works for optimising the cleaning and upgrading of biogas to biomethane (for example, an upgrading system based on the use of zeolites has been developed in collaboration with CREA-IT). Have carried out numerous studies also to optimize the processes for assessment of CH4 emissions from biomethane purification
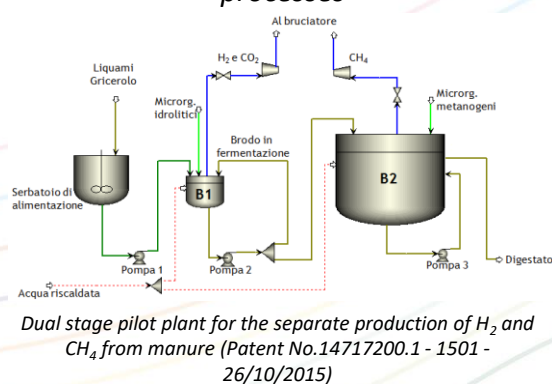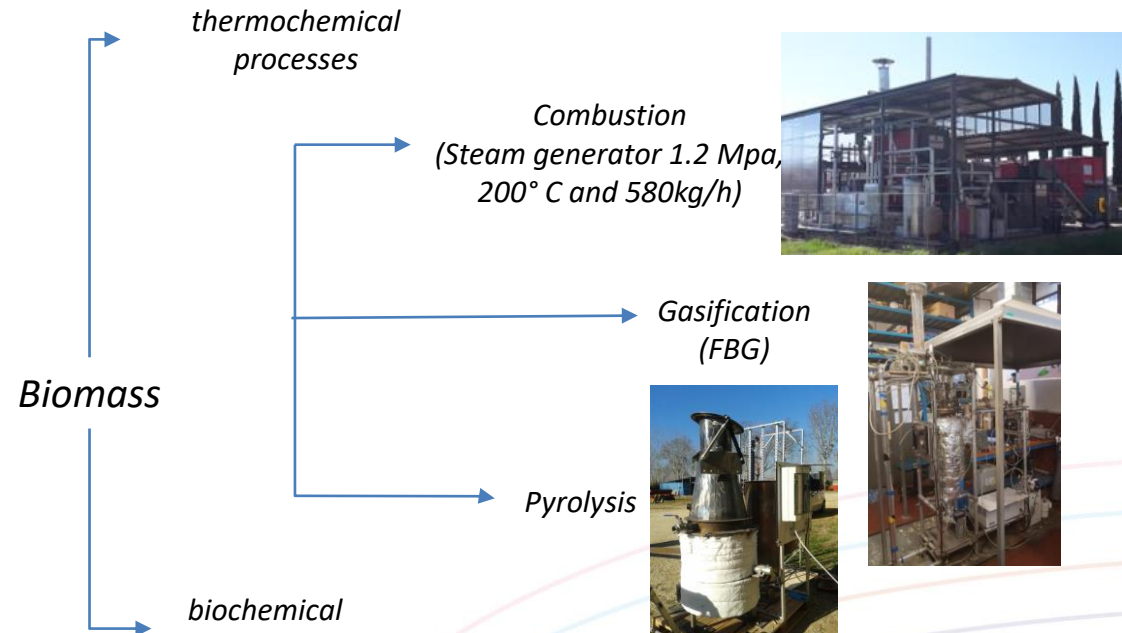
DIMA - Department of Mechanical and Aerospace Engineering

DIMA in collaboration with the University of Novi Sad (Faculty of Sciences) conducting research on Terrestrial Microbial Fuel Cells (TMFCs), a type of BES (Bio-Electrochemical Systems) that can both generate electricity and mitigate greenhouse gas emissions and bioremediate soil and sediment from pollution. The study aimed at evaluating MFCs' ability to generate electricity and, simultaneously, enhance Polycyclic Aromatic Hydrocarbons (PAHs) degradation in historically contaminated sediments.
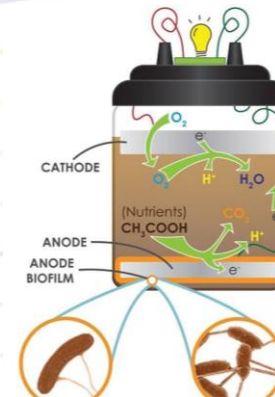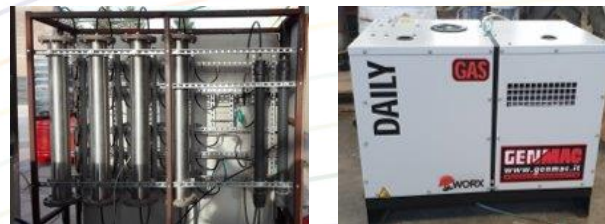

DIMA also works on the optimization of technologies for the CCU (Carbon Capture Utilization) through thermochemical cycles that involve a metal oxides (MxOy) flowing through two or more reactors for CO2/H2O splitting into CO/H2, with conversion rates of about 35%

Biomass energy production and emission monitoring – facilities at CREA

Energy conversion processes of biomass

Biomass

thermochemical processes

Combustion (Steam generator 1.2 Mpa, 200° C and 580kg/h)

Gasification (FBG)

Pyrolysis

biochemical processes

biogas and biomethane

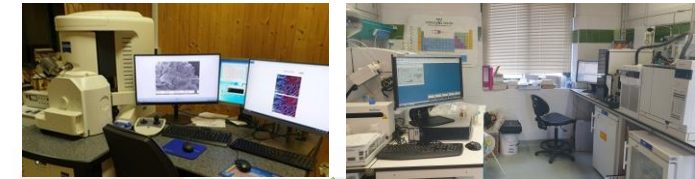*Dual stage pilot plant for the separate production of H_2 and CH_4 from manure (Patent No.14717200.1 - 1501 - 26/10/2015)*

Upgrading system with zeolites and ferric oxide for CO2 and H2S removal

Internal combustion engine (ICE)

Emission monitoring:
- *Metals*
- *Macro pollutants: CO, CO2, PM, NO_x, SO_2, TOC*
- *Micro pollutants: VOC, PAH, PCB, PCDD/F*

Syngas analysis:
- *Metals*
- *Tar*
- *Composition (CH_4, H_2, CO_2, CO, ecc.)*

*Biogas and Biomethane Analysis:*
- *Metals*
- *Siloxanes, VOC*
- *Composition (CH_4, H_2, CO_2, CO, etc.)*

The agrophotovoltaic aims to produce green energy using solar radiation, a process that must take place in harmony with the environment and the crops present. CREA-IT is developing integration solutions between solar energy and biomass energy, such as the use of panels to produce energy to power conversion or abatement systems (such as the ceramic filter, for thermal cracking, feed for the abatement of contaminants in the gasification system) or also for the production of Hydrogen

$2H_2O \rightarrow O_2 + 2H_2$
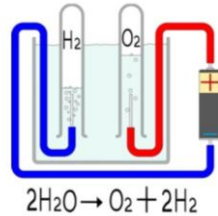
- Biomass Steam Generator (Steam Reforming)

- Installations for gasification or pyrolysis

- Biogas production systems and biomethane upgrading

- Electrolysis to produce H_2

CREA-IT is conducting research for the production of syngas with reduced CO2 content and high H2 content thanks to CLH (Chemical-Looping Hydrogenation). This CCU (Carbon Capture Utilization) technology converts CO2 and H2O(v) to H2 and CO using metal catalysts (such as Fe).

$CO + H_2$

Fe
T ≈ 800°C

$CO_2 + H_2O_{vap}$
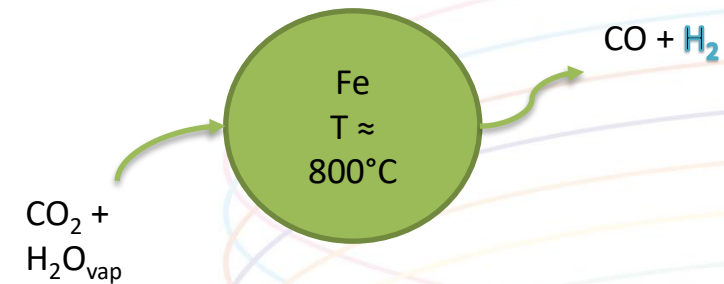
CREA-IT also works on optimising BioH2 production. For example, with processes of gasification and conversion or steam reforming of biomethane.

H_2O H_2O Pure H_2

$BioCH_4$ → Reforming 900°C → H_2 / CO → Shifting 400°C → H_2 / CO_2 → Cleaning → CO_2
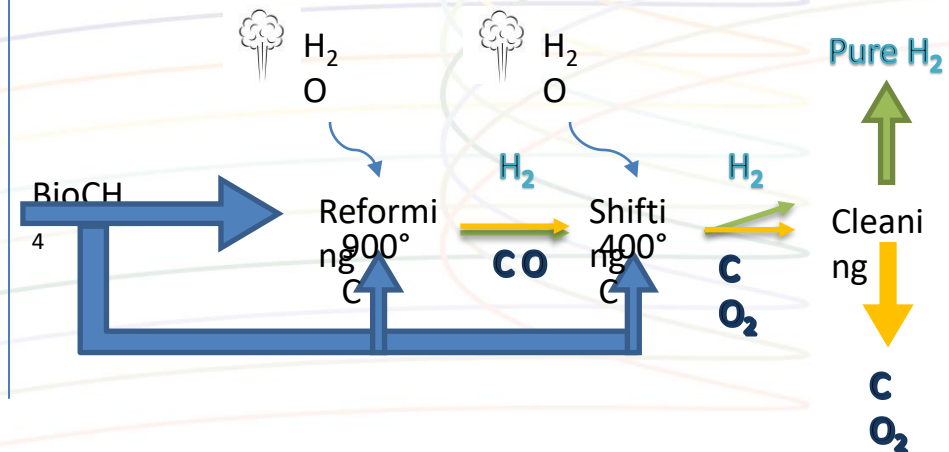
Grazie per l'attenzione

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