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EAAP 2022

4th – 9th Sep 2022
Porto, Portugal

Developing an in-flight network for gas and particulate emissions assessment in cattle dairy farms

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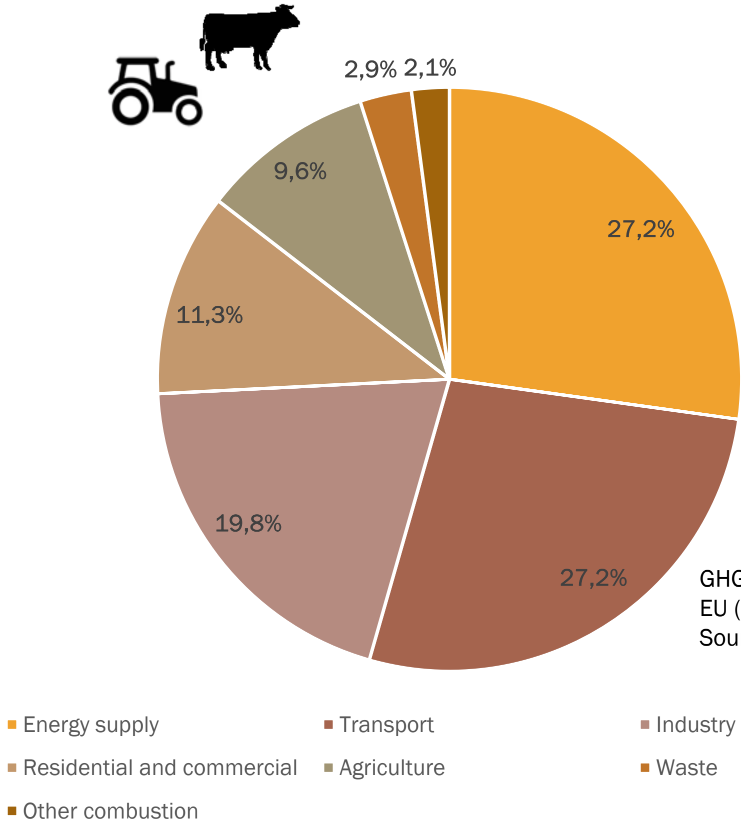
GHG emissions in agriculture & farming

EU

- 55% by 2030

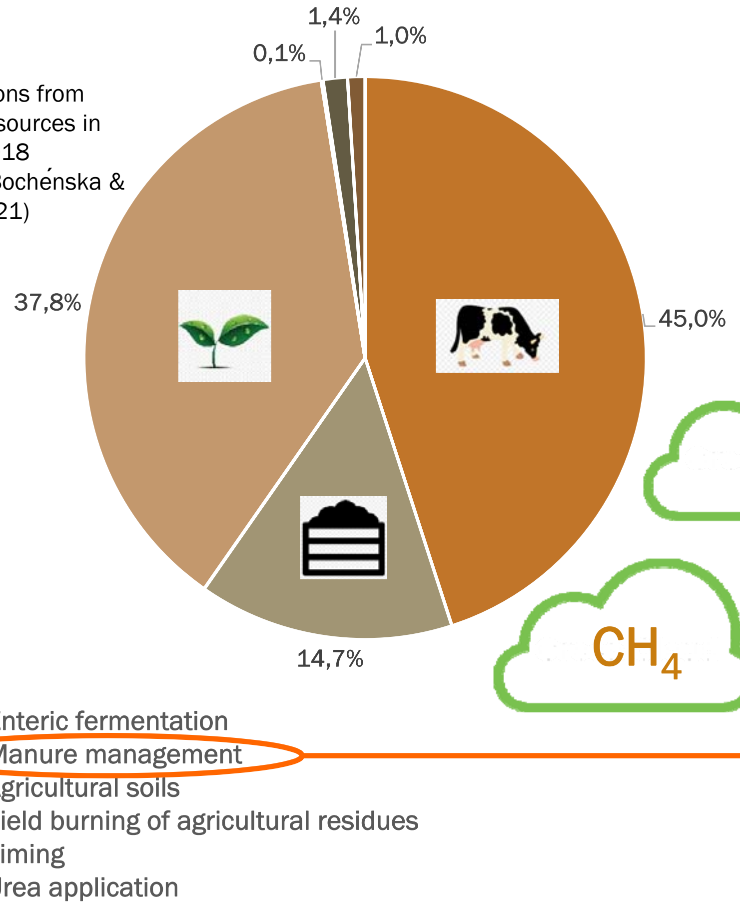
European Green Deal

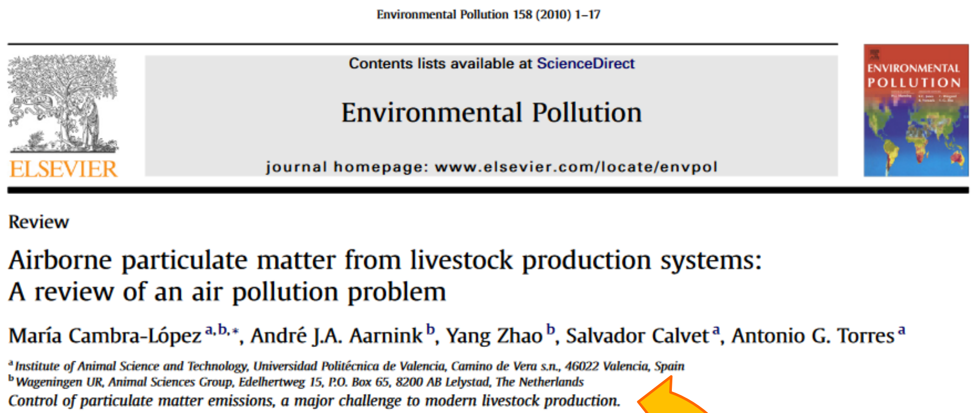


GHG emissions in the EU (2018)
Source: EEA

Agriculture and livestock

GHG emissions from agricultural sources in the EU in 2018 (Mielcarek-Bocheńska & Rzeznik, 2021)




Environmental Pollution 158 (2010) 1–17

Contents lists available at ScienceDirect

Environmental Pollution

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

ELSEVIER

Review

Airborne particulate matter from livestock production systems: A review of an air pollution problem

María Cambra-López [a,b,*], André J.A. Aarnink [b], Yang Zhao [b], Salvador Calvet [a], Antonio G. Torres [a]

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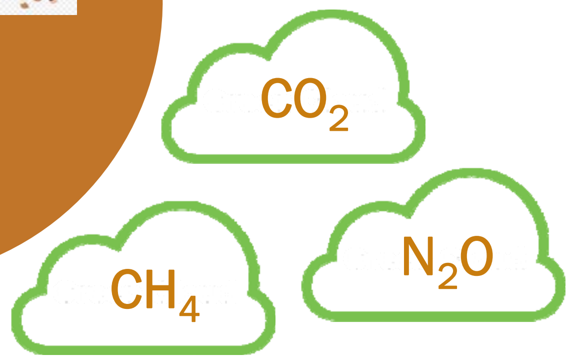
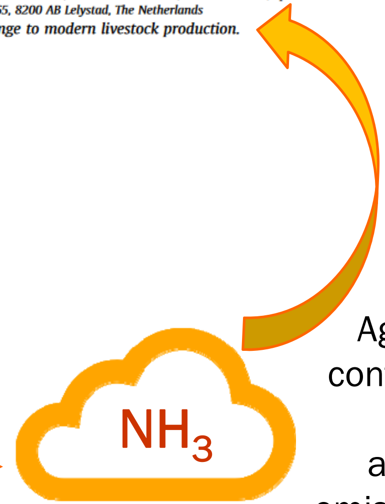
Control of particulate matter emissions, a major challenge to modern livestock production.



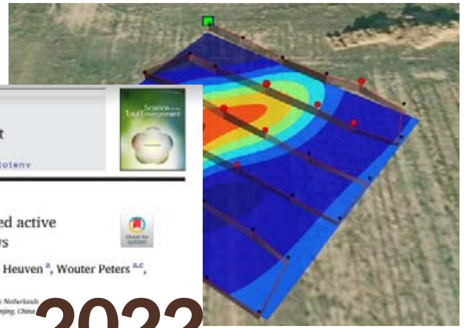


Agriculture contributes for 90% to ammonia emissions in the EU

Source: EEA

Aim of the research

- Gas-sensitive UAVs: cost-effective technology for flexible and rapid assessment of pollutants emissions.
- Perspectives: gas concentration mapping, gas source localization, gas flux quantification.

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Evaluating the use of an Unmanned Aerial Vehicle (UAV)-based active AirCore system to quantify methane emissions from dairy cows

Katarina Vinković [a], Truls Andersen [a], Marcel de Vries [a], Bert Kers [a], Steven van Heuven [a], Wouter Peters [a,c], Arjan Hensen [d], Pim van den Bulk [d], Huilin Chen [a,b,*]

HIGHLIGHTS

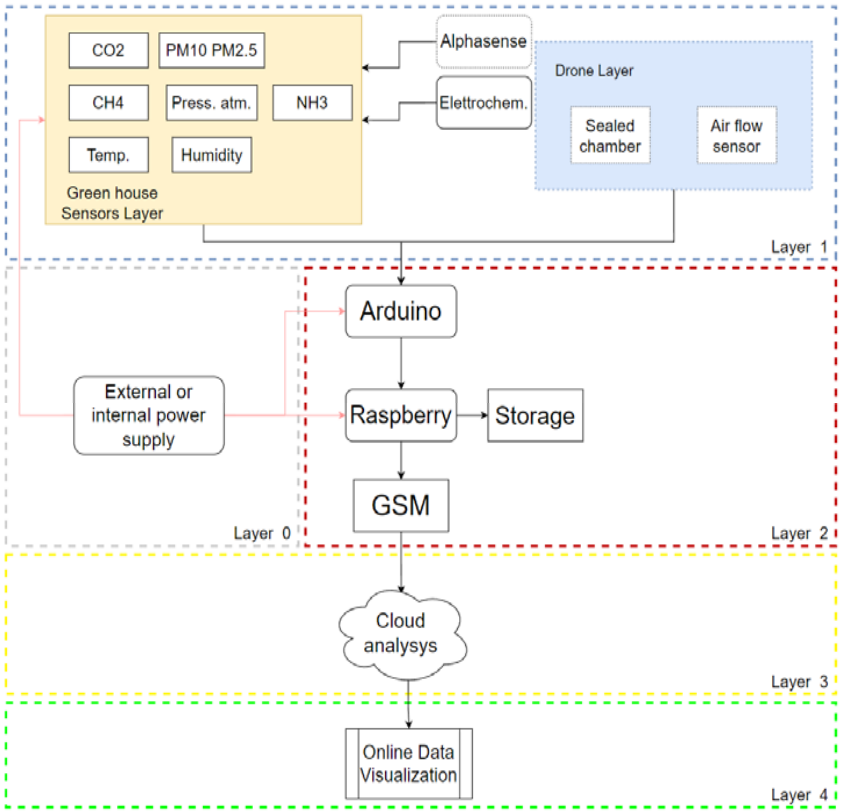
GRAPHICAL ABSTRACT

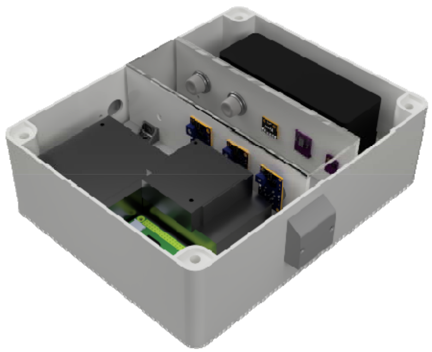
2022

www.cccfarming.eu

- Develop a rapid and real-time system for emission monitoring of livestock buildings, manure and feed stores.
- Assess the feasibility of ground and in-flight measurements at the farm level.

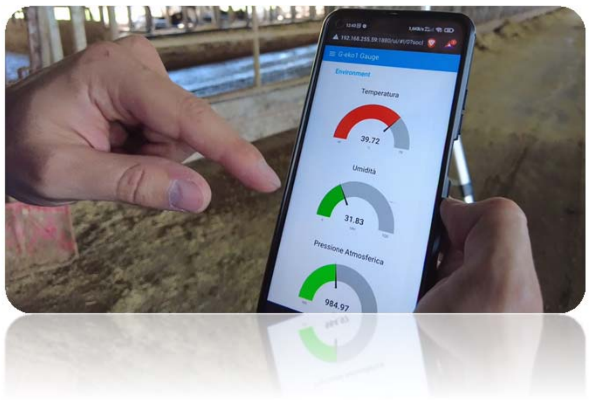
System design – prototype #1



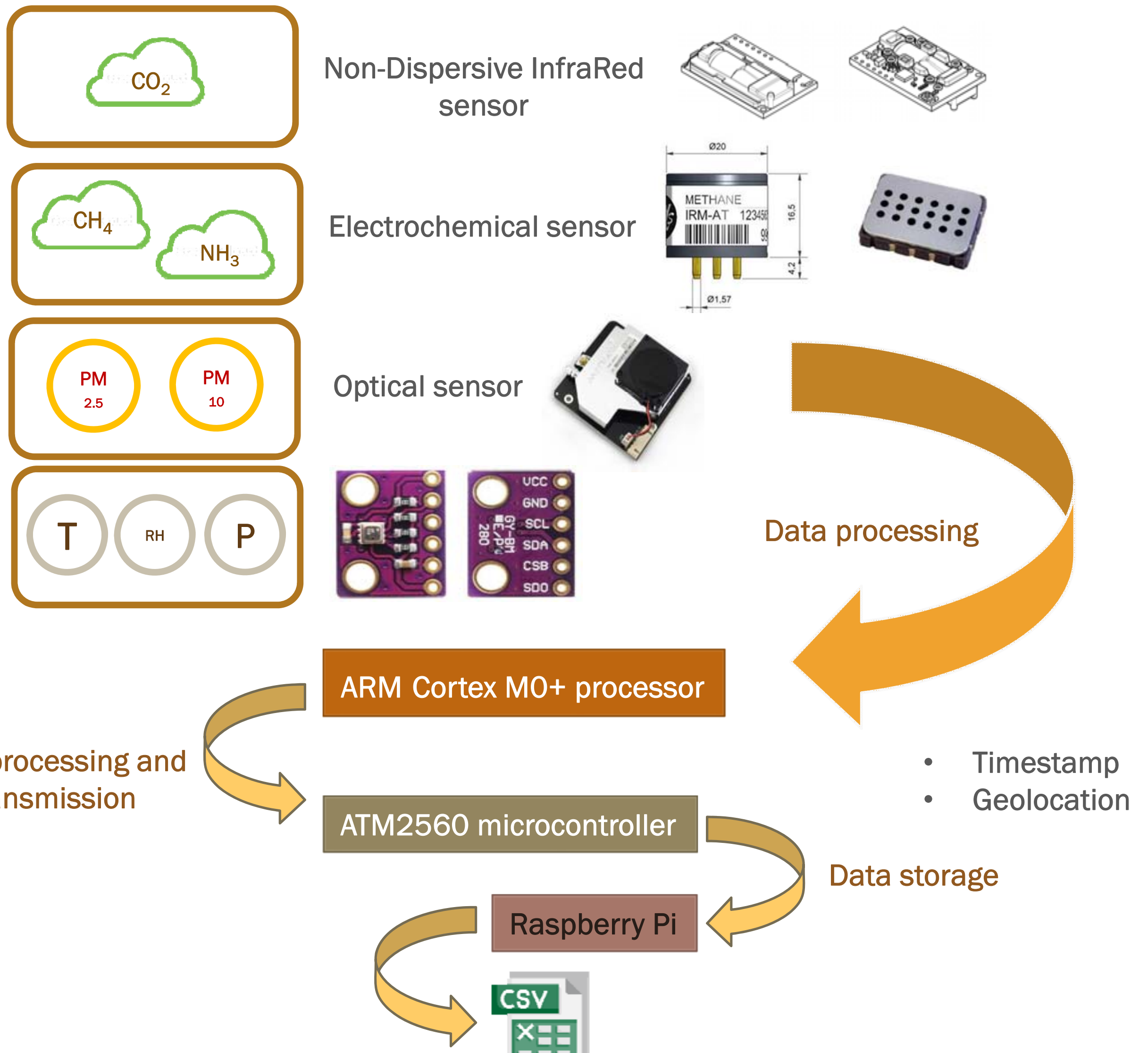


- Weight: ~ 1.5 kg

- UAV: 3DR Solo (1.5 kg)



Prototype #1 -



CO_2
Non-Dispersive InfraRed sensor
CH_4
NH_3
Electrochemical sensor
METHANE
IRM-AT
PM 2.5
PM 10
Optical sensor
T
RH
P
VCC
GND
SCL
SDA
CSB
SDO
Data processing
ARM Cortex M0+ processor
Data processing and transmission
ATM2560 microcontroller
Timestamp
Geolocation
Data storage
Raspberry Pi
CSV

Field tests

- 2 field tests in a commercial dairy farm (450 Holstein cows)
- March 2021, July 2021
- Ground measurements: 5 locations (1 inside and 4 around the building)

20 minutes in each location

1 record every 22 seconds

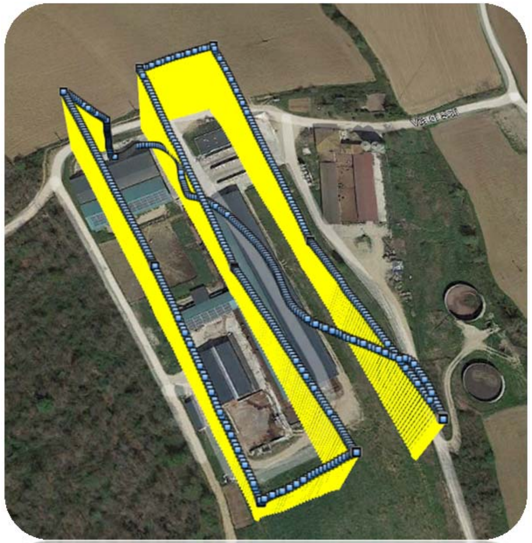
Geolocalization by GPS-GNSS receiver

NH_3

CH_4

CO_2

Field tests



In-flight measurements

Field test #1 (March 2021): 7 minutes non-stop flight -> "dynamic" measurements

1 record every 3 seconds

Field test #2 (July 2021): 2 consecutive flights (24 minutes total) -> "static" measurements (UAV stopped at predefined waypoints)

1 record every 3 seconds

Results

Field test #1

	Sensor (Ave ± SD)	Gas Chromatography
Inside	15.88 ± 12.02 ppm	525.34 ppm
Outside	6.92 ± 4.08 ppm	448.38 ppm

New sensor

Field test #2

	Sensor (Ave ± SD)	Gas Chromatography
Inside	467.81 ± 15.38 ppm	608.80 ppm
Outside	426.20 ± 22.31 ppm	486.01 ppm

Min: 0 ppm; Max: 40000 ppm; Average ± SD: 3187.49 ± 7440.68 ppm

Results

CH_4

Field test #1

	Sensor (Ave ± SD)	Gas Chromatography
Inside	4.49 ± 3.26 ppm	8.50 ppm
Outside	2.52 ± 1.50 ppm	3.24 ppm

Min: 0.75 ppm; Max: 4.44 ppm; Average ± SD: 2.48 ± 0.87 ppm

Testing other sensors

Field test #2

Min: 0.12 ppm; Max: 26.8 ppm; Average ± SD: 5.24 ± 5.77 ppm

Results

NH_3

Field test #1

	Sensor (Ave ± SD)	Dräger tube
Inside	0.27 ± 0.04 ppm	0.83 ppm
Outside	0.42 ± 0.10 ppm	0.04 ppm

Testing other sensors

Field test #2

Min: 0.47 ppm; Max: 1.10 ppm; Average ± SD: 0.99 ± 0.21 ppm

Results

PM 2.5 PM 10

Field test #1

	PM 2.5 Sensor (Ave ± SD)	PM 10 Sensor (Ave ± SD)
Inside	1.65 ± 0.27 μg m^{-3}	4.45 ± 3.83 μg m^{-3}
Outside	2.82 ± 0.87 μg m^{-3}	5.03 ± 1.87 μg m^{-3}

Min: 4.60 ppm; Max: 327.60 ppm; Average ± SD: 153.16 ± 126.83 ppm

Min: 7.56 ppm; Max: 327.48 ppm; Average ± SD: 123.50 ± 100.07 ppm

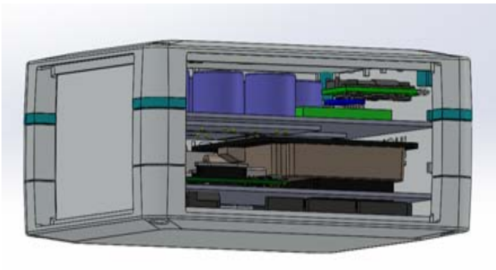
Field test #2

	PM 2.5 Sensor (Ave ± SD)	PM 10 Sensor (Ave ± SD)
Inside	6.43 ± 1.99 μg m^{-3}	17.38 ± 20.32 μg m^{-3}
Outside	5.10 ± 0.89 μg m^{-3}	10.30 ± 8.61 μg m^{-3}

Min: 2.00 ppm; Max: 249.30 ppm; Average ± SD: 96.41 ± 70.47 ppm

Min: 3.30 ppm; Max: 715.70 ppm; Average ± SD: 206.81 ± 197.43 ppm

Prototype #2



Weight: ~ 0.7 kg

120 x 100 x 67 mm

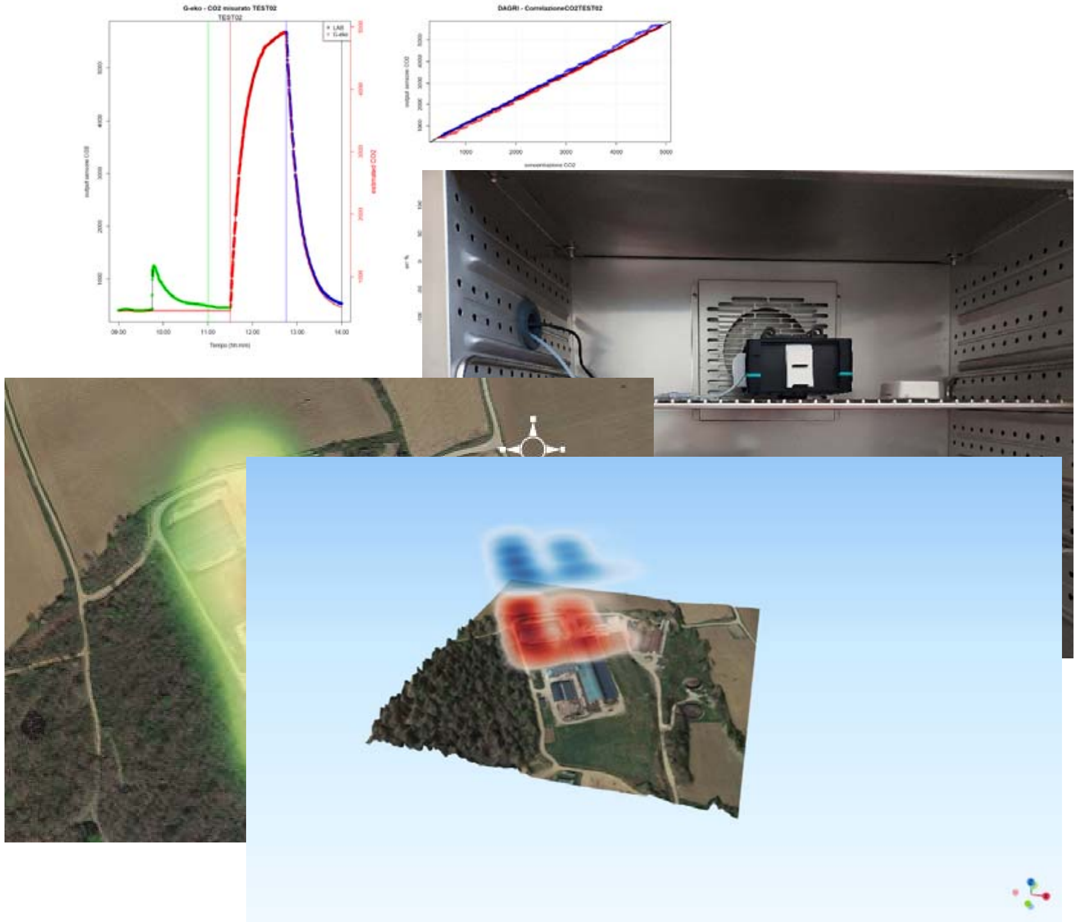
Ground measurements

In-flight measurements

ESP32

In progress tasks & results

- **Sensor validation:** sensors tested and calibrated in a specialized laboratory under standard conditions (20°C, 30% RH) and in a UNIFI laboratory under field conditions (5 treatments).
- **Gas concentration mapping (GCM):** implementing a measurement protocol to obtain reliable GCM from livestock farm facilities.
- Study of a measurement protocol for in-flight measures



Conclusions

Implementing a UAV-based low-cost air quality monitoring system for livestock farms is feasible

Further technical adjustments are needed to reduce size of the measurement units, improve accuracy of measures

Low-cost sensors provided reliable measurements when compared with traditional techniques

Currently, the availability of performing and accurate low-cost sensors on the market could be the major limitation

Measurements collected with the UAV unit yielded values that were consistent with those measured by the ground unit, suggesting that in-flight gas and particulate assessment is a promising technique

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Thank you!