74th Annual Meeting of European Federation of Animal Science
EAAP 2023

26th Aug – 1st Sep 2023
Lyon, France

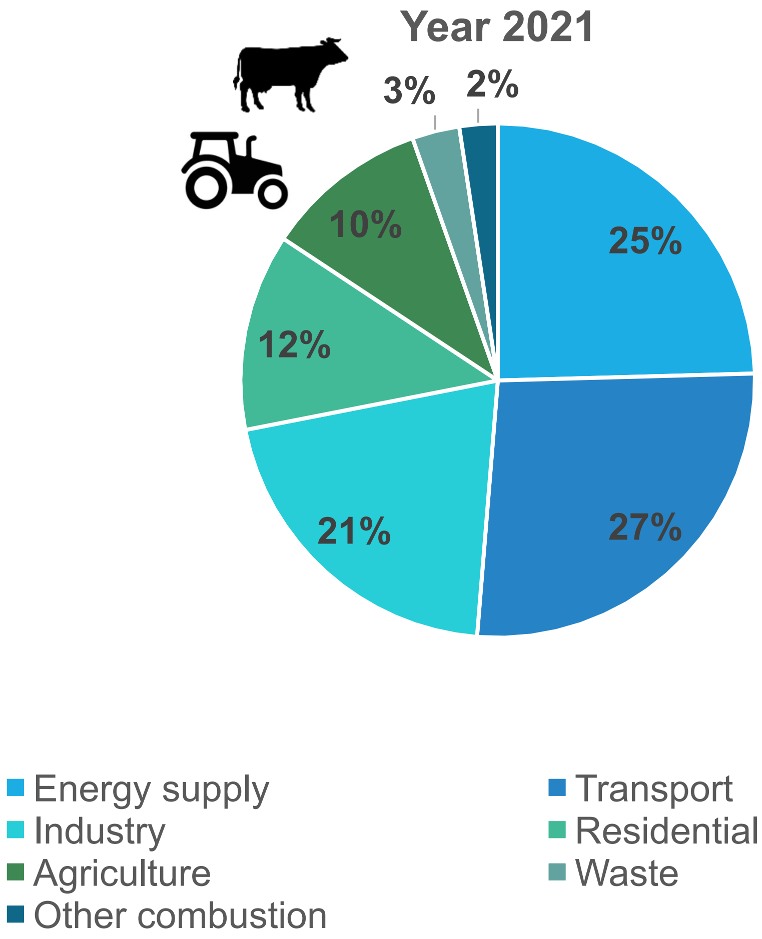
UAV-based approaches for gaseous emissions assessment in cattle farming

V. Becciolini[1], A. Mattia[1], M. Merlini[1], G. Rossi[1], F. Squillace[1], G. Coletti[2], U. Rossi[2] and M. Barbari[1]

[1] Department of Agriculture, Food, Environment and Forestry, University of Florence, Firenze, Italy

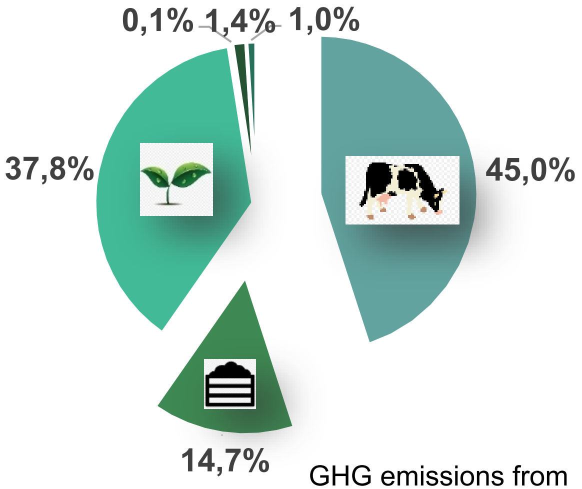
[2] Project & Design S.r.l.s., Firenze, Italy

GHG and NH_3 emissions from agriculture & livestock sector



GHG emissions in the EU
Source: EEA

	2021		2016		2011		2006	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
Agriculture	378,430.47	10.3%	386,350.86	9.5%	375,710.69	8.7%	386,079.74	8.0%



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

Agriculture contributes for 90% to NH_3 emissions in the EU
Source: EEA

UAV-based techniques for point-source emissions… from landfills and oil/gas plants to dairy farms?

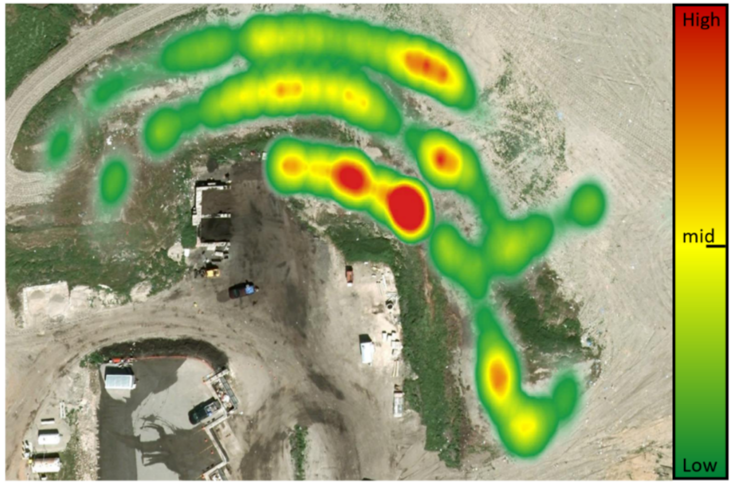
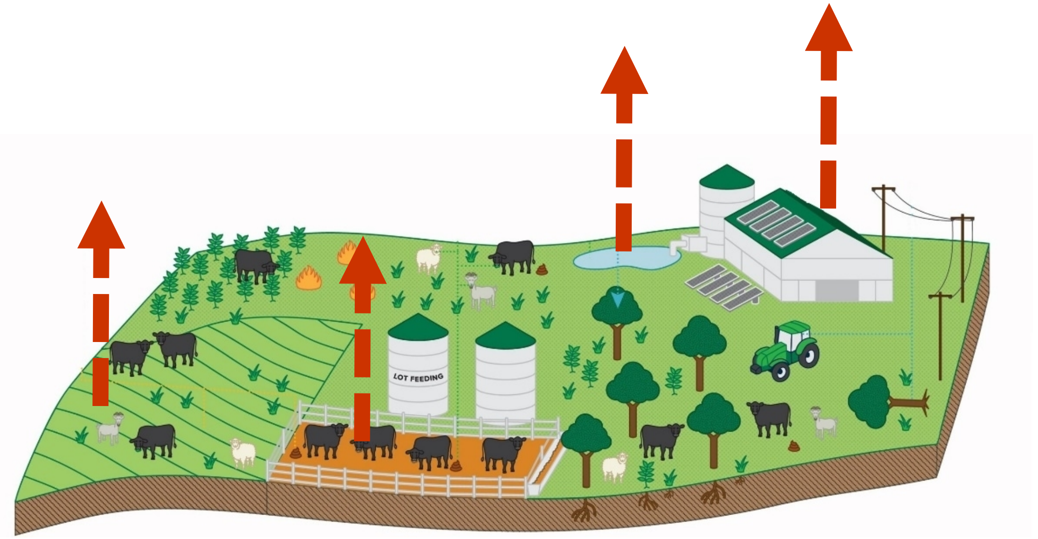


Photo credit: Emran et al. 2017. Low-altitude aerial methane concentration mapping. *Remote Sensing*.



Q: Where are emissions coming from? How much? **What are the spots to focus on?**

Q: Where are emissions coming from? How much? **What are the processes to focus on? How far can gases be spread?**

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Exponential growth of applied research in UAV-based atmospheric chemical sensing

In 2021 and 2022
68 scientific papers were published on the topic

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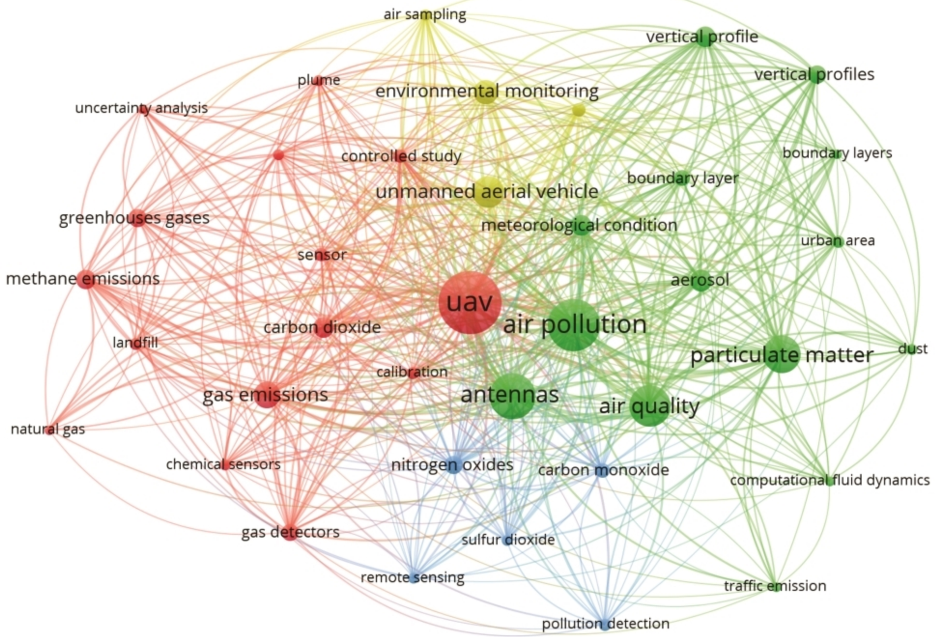
Number of scientific papers published in the previous 9 years

Bedin et al. 2023. State of the art and future perspectives of atmospheric chemical sensing using Unmanned Aerial Vehicles: a bibliometric analysis. *Sensors*. In press.



…questions?

1. Can technologies and methods for gaseous hotspots mapping and emission estimation from point sources be transposed to livestock farms?
2. What type of equipment is required?
3. Can low-cost technologies be employed for this purpose?
4. What methods can be applied to map and estimate gaseous emissions?
5. How can a protocol be built and validated?

1. Can technologies and methods for gaseous hotspots mapping and emission estimation from point sources be transposed to livestock farms?

Uncertainties in emission data

- GHG assessment from livestock farming
- Mitigation practices efficacy assessment

Decision support system

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Evaluate the potential use of drones equipped with sensors to identify hotspots of CH_4 and CO_2 emissions at farm scale linked to a real-time kinematic positioning system

Study a rapid top-down approach to derive emission fluxes in dairy farms

Emission fluxes → Atmospheric sampling + Atmospheric dispersion models

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2. What type of equipment is required?

Platforms		
	Ground-based	• Heavy and accurate instrumentation • Sampling void between ground and high altitudes
	Aircrafts and UAVs	• High geospatial coverage • Payload and energetic limits (small aircrafts)

Weight	Payload limit	Max air speed	Wing type	Propeller type
100 g to 20 kg			• Fixed-wing • Rotary-wing	• (Liquid fuel) • Batteries

2. What type of equipment is required?

Wind measurement

Ground-based	• Easier data processing • Can introduce measurement uncertainty
Onboard UAVs	• Coupled gas-wind measurement • Wind field of the UAV can interfere

Flux quantification requires accurate wind speed and direction

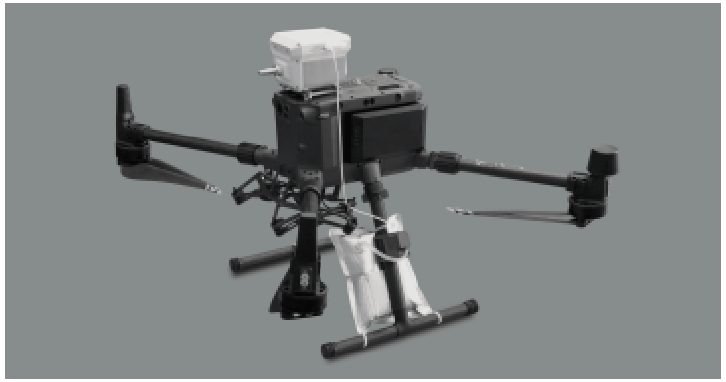
Type of anemometer

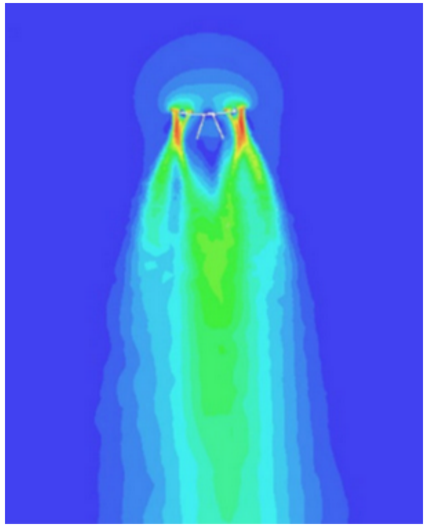
- Cup anemometer
- 2D ultrasonic anemometer
- 3D ultrasonic anemometer

2. What type of equipment is required?

Gas measurement approaches

Air samples collected onboard the UAV	• High performance instrumentation • Discretized gas measurements (low spatial resolution)
Air sampled through tubing connected to the UAV	• High performance instrumentation • Caution due to lag-time • Tethering causes logistic issues and reduced range of motion
Air sampled live onboard the UAV	• Requires lightweight instruments (lower accuracy) • Continuous gas measurements (high spatial resolution) • Payload may decrease flight autonomy • Downwash affects air sampling





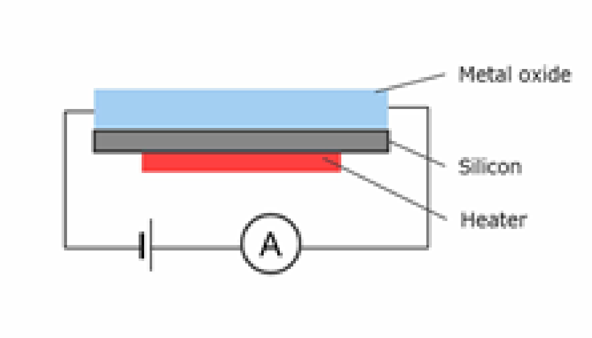
2. What type of equipment is required?

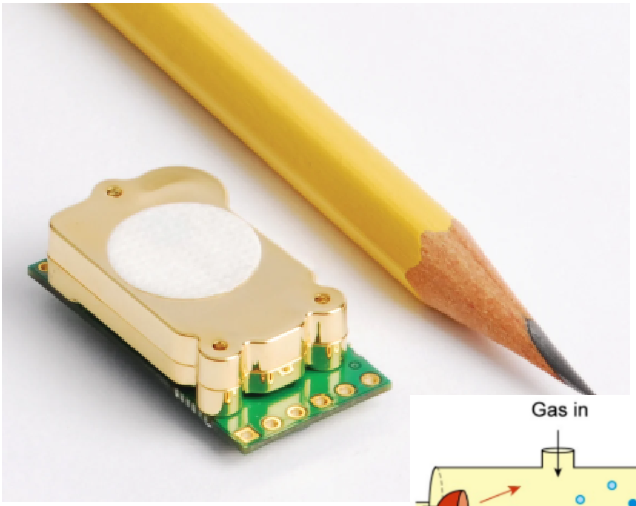
Gas sensors

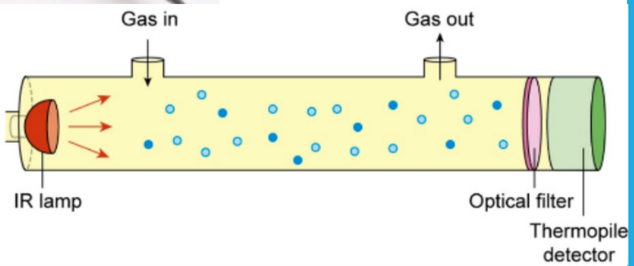
Electrochemical sensors	• NH_3 • Limited cost (hundreds €) + Low power consumption • Cross-sensitivity, drift, limited lifetime
Non-dispersive infrared sensors (NDIR)	• CO_2 • Limited cost (hundreds €) + Higher lifetime • Accuracy (ppm) affected by T, P_{atm} + Higher power consumption
Laser absorption spectroscopy sensors	Tunable diode laser absorption spectrometers (**TDLAS**) Off-axis integrated cavity output spectrometers (**OA-ICO**) Cavity Ring-Down Spectrometers (**CRDS**)

Sensor choice depends on the target gas species (CO_2, CH_4, NH_3)

Concentration is determined by measuring target gas absorption peaks



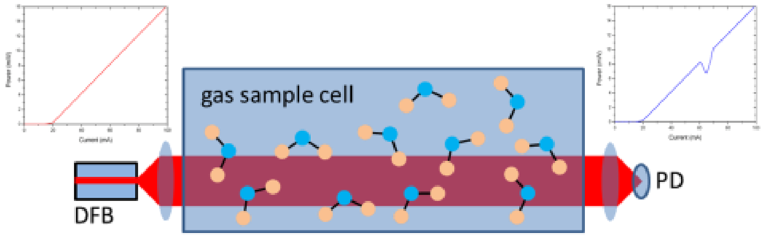




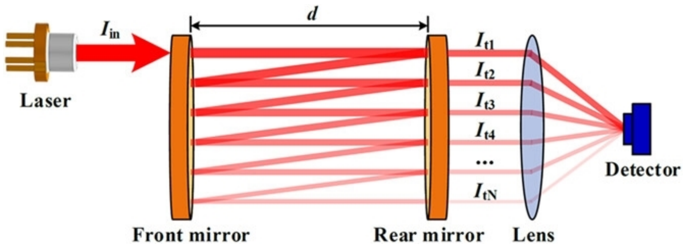
2. What type of equipment is required?

Gas sensors

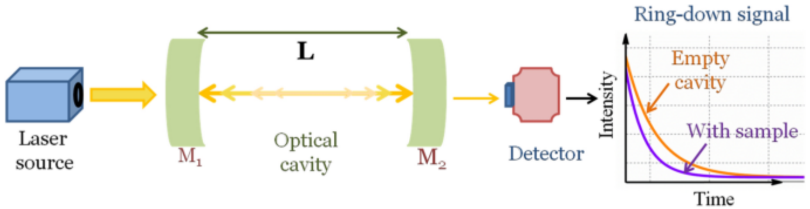
Laser absorption spectroscopy sensors	Tunable diode laser absorption spectrometers (**TDLAS**)	Off-axis integrated cavity output spectrometers (**OA-ICO**)	Cavity Ring-Down Spectrometers (**CRDS**)



- CO_2, CH_4, NH_3
- High cost (~ 6k €)
- High accuracy (ppm) + Available for UAVs



- CO_2, CH_4, NH_3
- Higher cost
- Higher precision (ppb)



- CO_2,CH_4, NH_3 …
- Higher cost + Expertise required
- Higher precision (ppb) + prototype for UAVs

CLOSED CHAMBER

Or

OPEN PATH

3. Can low-cost technologies be employed for this purpose?

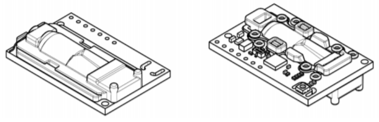
CO_2

CH_4 NH_3

PM 2.5 PM 10

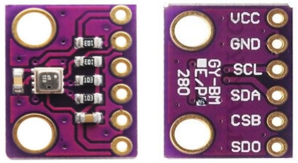
T RH P

NDIR sensor



Electrochemical sensors

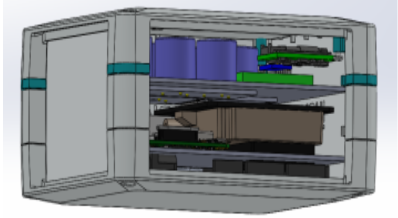
Optical sensor



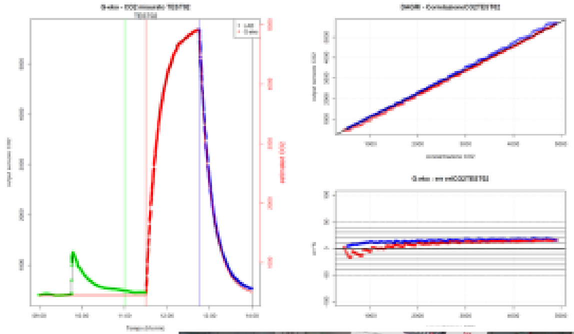
Data processing, transmission, storage

CSV

Weight: ~ 0.7 kg



BUT!



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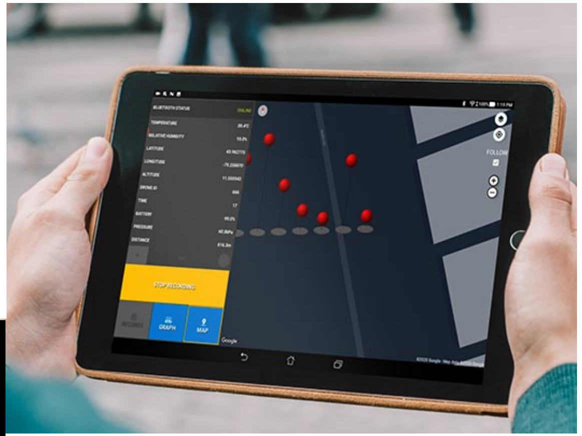
3. Can low-cost technologies be employed for this purpose?

…as an alternative

Ready to use commercial solutions



BUT!

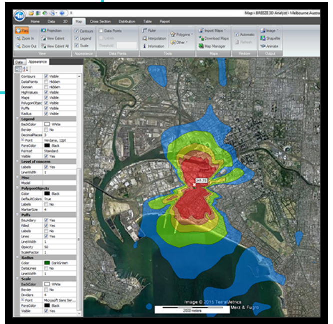
- Cost (from 20k €)
- Sensor calibration under standard conditions
- Sensor lifetime
- Are dispersion models suitable? Accurate evaluation is required

4. What methods can be applied to map and estimate gaseous emissions?

Flux quantification approaches (short range dispersion)	Method	Characteristics
	Mass balance modelling	• Requires a constant wind field between upwind and downwind measurements
	Gaussian plume inversion modelling	• Gaussian statistics are used to infer gaseous fluxes downwind a point source • Requires large amounts of time averaging
	Lagrangian stochastic modelling	• Simulate the path of particles as they travel with the local wind field • Computational time may be high • Multiple simultaneous measurements are required when multiple sources are present

The methods require upwind (i.e. background) and downwind gas concentration measurements

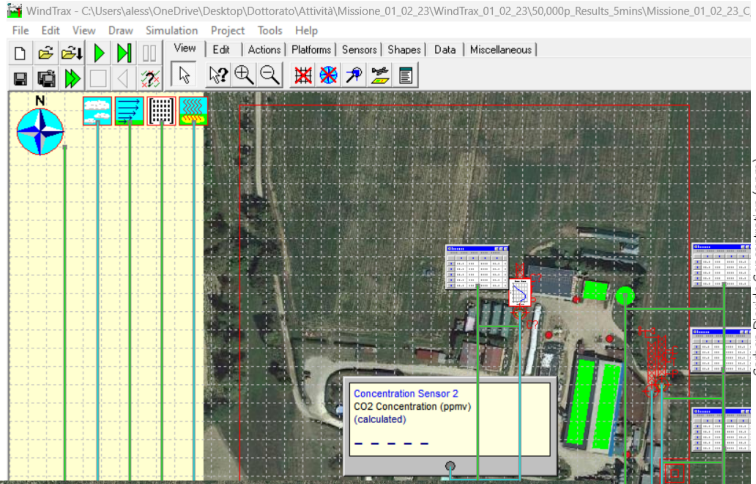
Modelling expertise is required
OR
Specific **software environments** that incorporate dispersion models

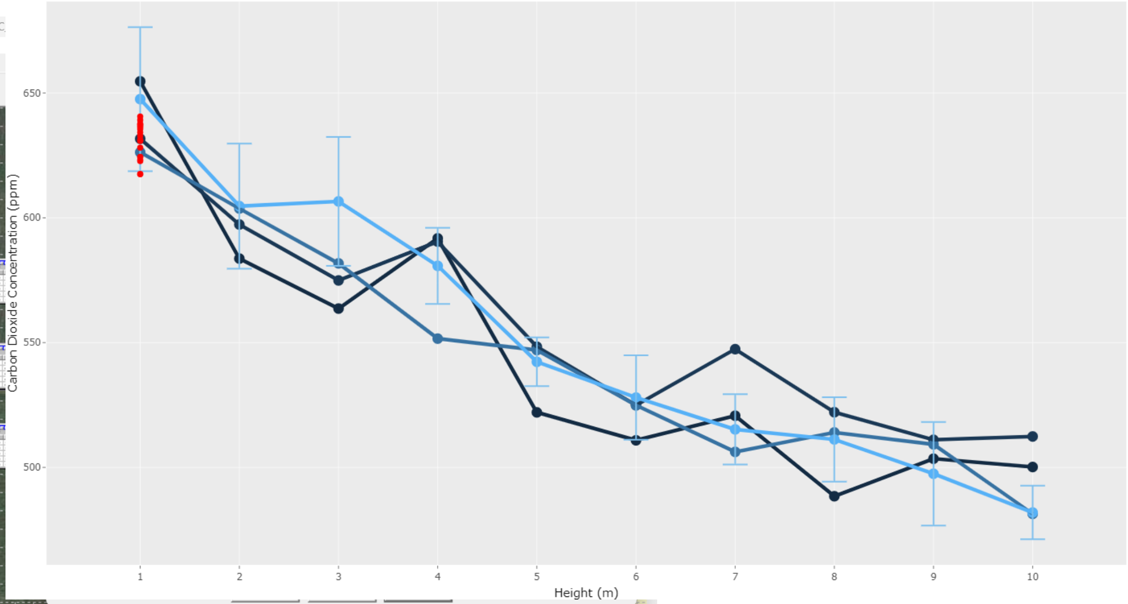


5. How can a protocol be built and validated?

1. Selection of sensors and flux quantification method (model)
2. Sensor validation under laboratory conditions (mandatory for electrochemical and NDIR sensors)
3. Based on the chosen model, plan field tests to meet requirements and assumptions with **controlled gas sources**
4. Address sampling issues, assess the magnitude of errors, validate measurements, refine the protocol
5. Validate measurements in uncontrolled field conditions

1. Can technologies and methods for gaseous hotspots mapping and emission estimation from point sources be transposed to livestock farms?






IV Convegno AISSA#under40

Campus di Fisciano, 12-13 luglio 2023

Corso di Agraria-DIFARMA - Università degli Studi di Salerno

Deducing emission rates from gas concentrations in a dairy cattle farm through a backward Lagrangian stochastic method-based model

Alessio Mattia [1], Marco Merlini [1], Rafael Pinheiro Amantea [1], Gabriele Coletti [2], Federico Squillace [1], Giuseppe Rossi [1], Matteo Barbari [1], Valentina Becciolini [1].

[1] Department of Agriculture, Food, Environment, and Forestry (DAGRI) University of Florence, Florence, 50144, Piazzale delle Cascine, 18

[2] Project & Design s.r.l.s., Florence, 50142, Italy

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DAGRI DEPARTMENT OF AGRICULTURE, FOOD, ENVIRONMENT AND FORESTRY

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… Concluding

- UAV-suited technologies for GHG emission assessment are still in their infancy

- **Opportunities**
  Rapid and real-time assessment of emission fluxes
  Identification of critical processes
  Development of decision support systems for farmers
- **Limitations**
  Sensing technologies (accuracy, limits of detection, size/weight)
  Costs
  Dispersion models
  Expertise

Thank you for your attention!

Valentina Becciolini, PhD

valentina.becciolini@unifi.it