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Potential use of drones and ICT in livestock farming to deal with environmental sustainability

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Background

Globally, legislative actions, policy support, financial backing for research and businesses, and public opinion are increasingly aligned toward achieving environmental sustainability.

The livestock sector faces increasing pressure to **reduce nutrient losses** and **mitigate its environmental footprint**.

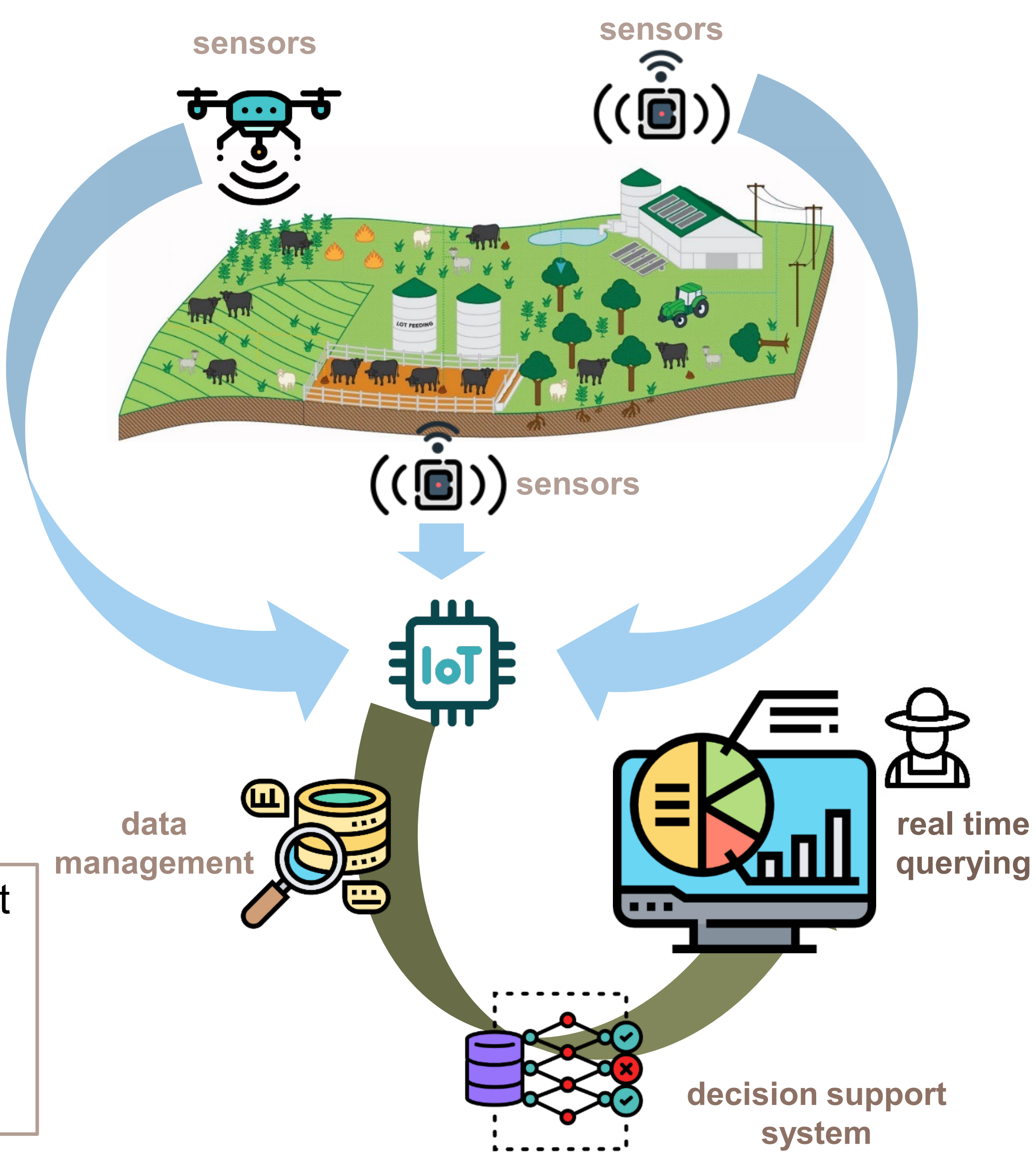
Modern challenges require innovative solutions that go beyond traditional farming methods and monitoring techniques.

Environmental monitoring and assessment <u>is integrated into farm management</u>

ICT tools have the potential to transform raw data into actionable insights, helping farmers adopt more sustainable practices

Drones equipped with advanced sensors offer a groundbreaking way to monitor environmental conditions in real-time

A comprehensive decision support system can guide farm management decisions, ensuring both productivity, welfare and sustainability

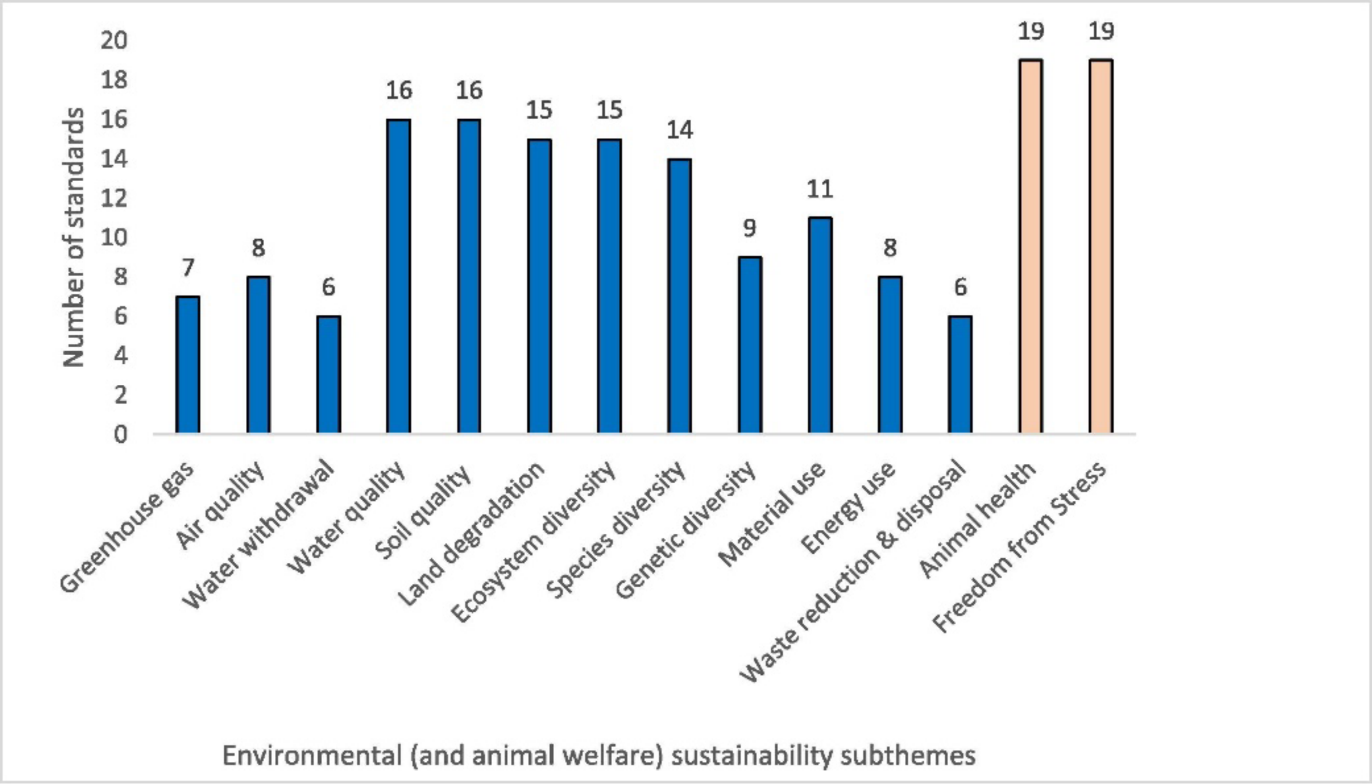


Background

Animal Welfare and Health Certification Schemes (27 in EU)

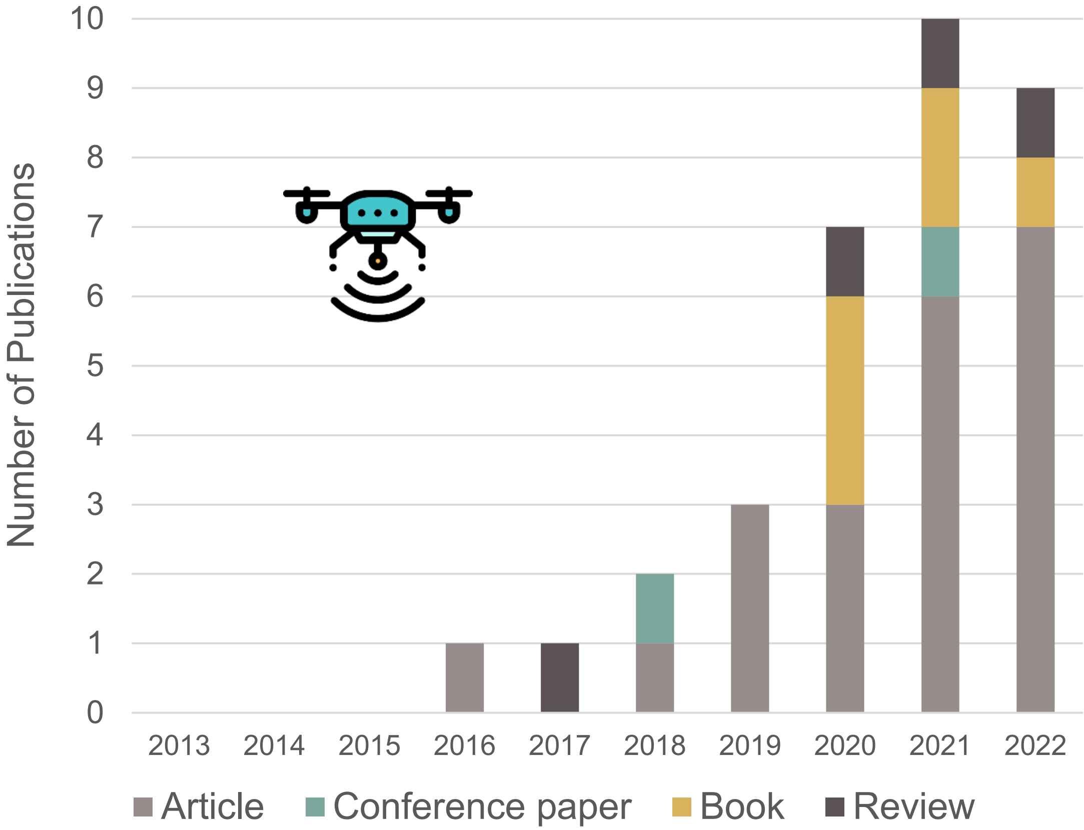
Climate Certification Schemes (9 in EU)

Source: Farm certification schemes for sustainable agriculture - https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2022)699633



McGarr-O'Brien et al.. (2023). Characterising sustainability certification standards in dairy production. Animal, 17(7), 100863.

Background



Publications per year searching for *drones for chemical sensing* in Scopus, <u>limited to agricultural, biological, and environmental sciences</u>

UAV-based atmospheric chemical sensing

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

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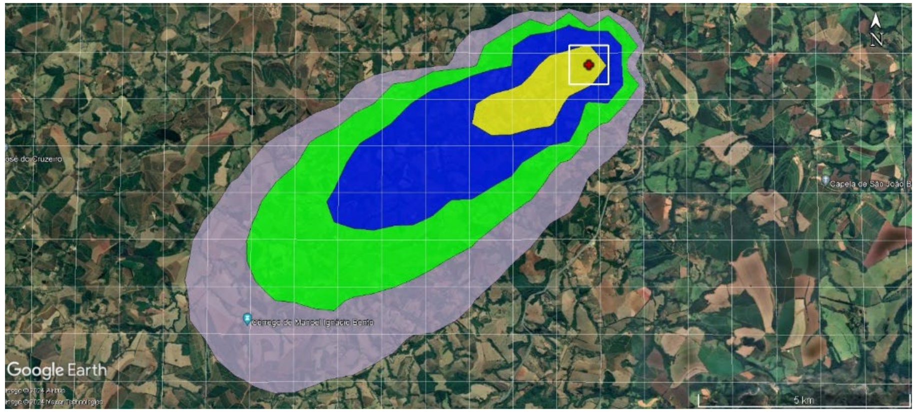
Number of scientific papers published in the previous 9 years

Aim of the research



Indoor monitoring

- Air pollutants
- Environmental parameters

- Animal Welfare
- Animal health
- Pollutant Emissions

Outdoor monitoring

- Air pollutants
- Environmental parameters

- Pollutant Emissions
- Pollutant Dispersion

Equipment

CO_2

NDIR sensor (ppm)

- Limited cost (hundreds €) + Higher lifetime
- Accuracy (ppm) affected by T, Patm + Higher power consumption

NH_3

Electrochemical sensor (ppm)

- Limited cost (hundreds €) + Low power consumption
- Cross-sensitivity, drift, limited lifetime

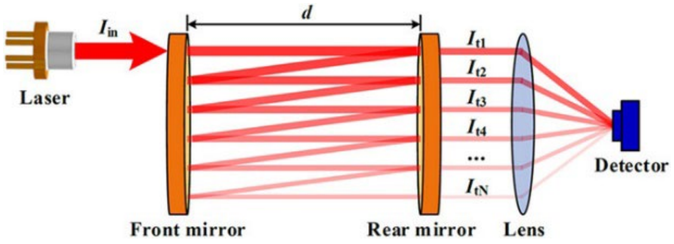
PM

Optical sensor ($\mu g \cdot m^{-3}$)

T RH P

(°C; %; hPa)

Data processing, transmission, storage

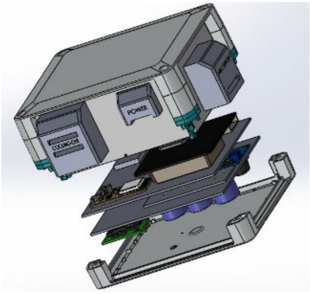


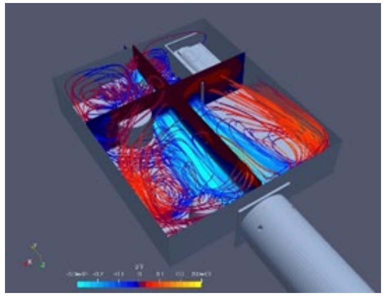
CH_4

TDLAS sensor (ppm)

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

CSV



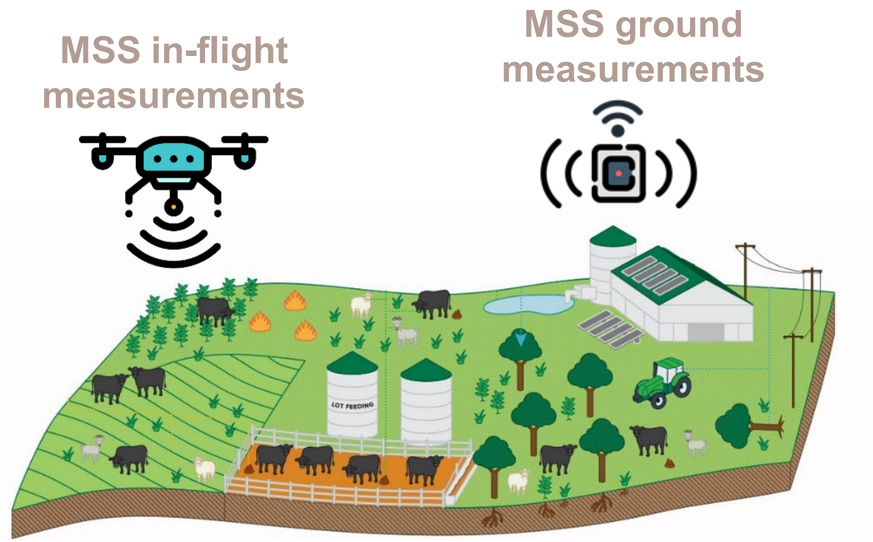


Multi-sensor system (MSS)
Weight = 0.7 kg

Equipment

Quadrotor UAV
RTK
(max payload 2.7 kg)

2D Sonic anemometer:
Wind speed ($m \cdot s^{-1}$)
Wind direction (° from North)



GNSS receiver

Map the localization of extended area sources (i.e., housings, storages), MSS ground measurements, ground control points

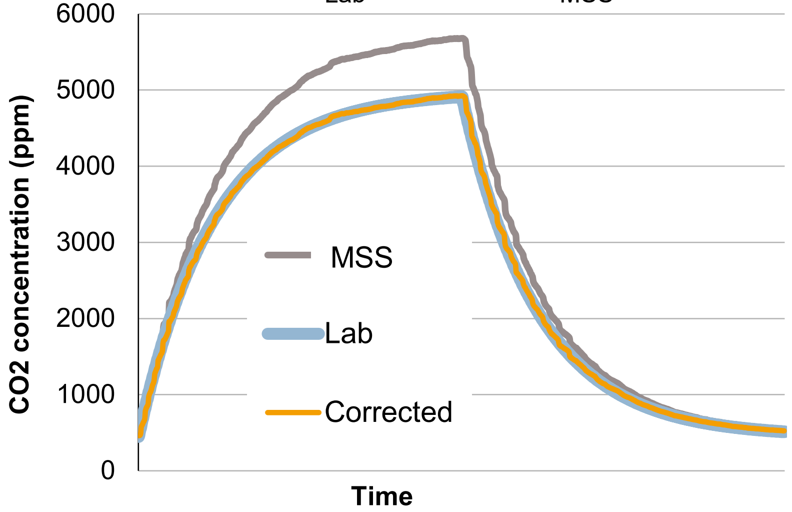
Results - study and validation of the system

Characterization of sensors in a controlled environment

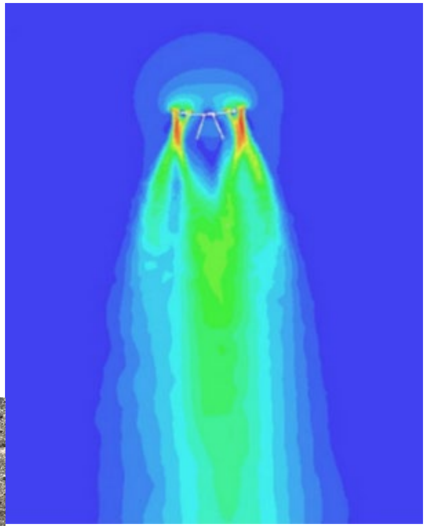
Mean Percentage Error (%) before and after fitting a correction equation

Sensor	MPE uncorrected data	MPE corrected data
CO_2	12.1%	1.7%
CH_4	52.0%	10.2%
SO_2	62.5%	6.9%

$$C_{Lab} = 0.855 \cdot C_{MSS} + 67.517$$

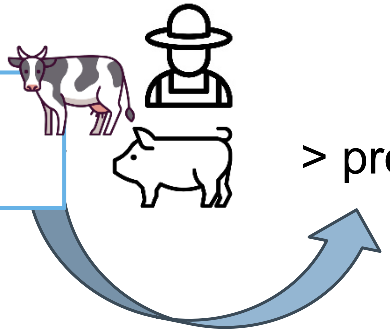


Fluid dynamic assessment of downwash flow field for quadrotor UAVs



Results – indoor monitoring insights

Aim: Ensure health and welfare of animals and workers



> productivity

Thresholds: National and international regulations
Certification schemes

Noise

Ventilation

Lighting

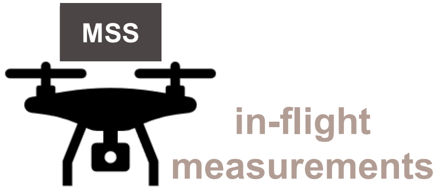
Air quality (PM, NH_3, CO_2)

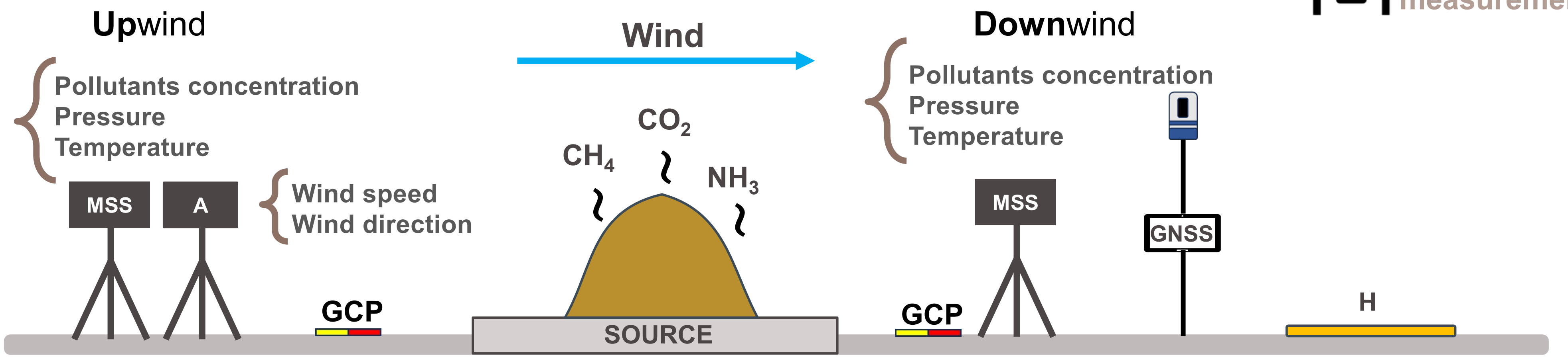
Methods: Real-time monitoring
Specific thresholds for each area

Results – outdoor monitoring insights

Emission fluxes and dispersion

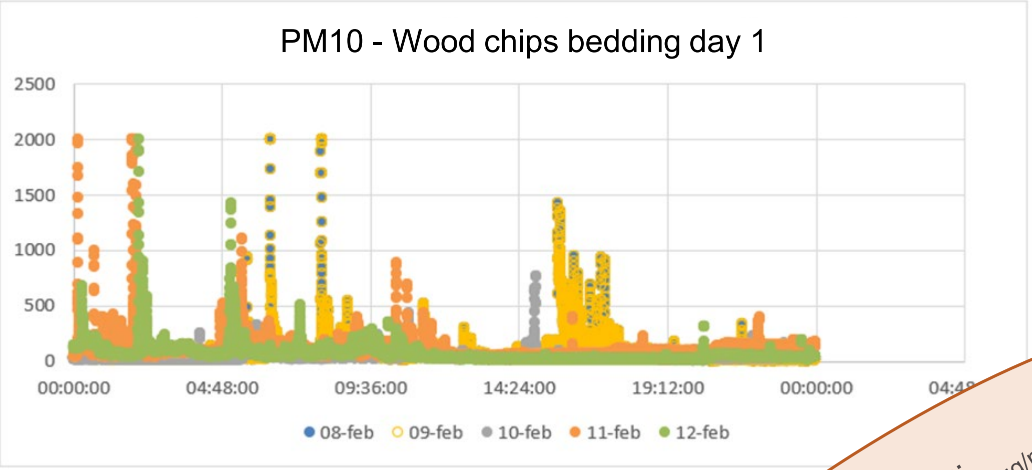
Atmospheric sampling + Atmospheric dispersion modeling

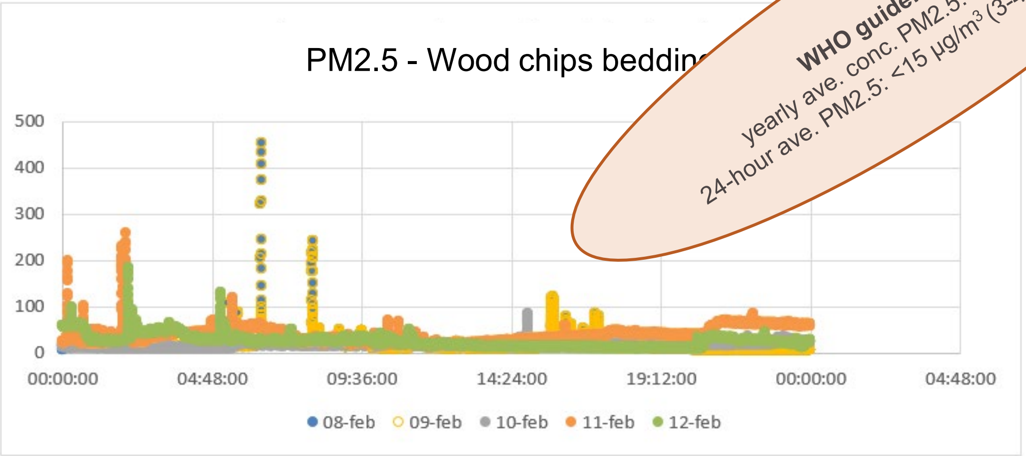




Results – indoor monitoring experiences

Indoor air quality monitoring in a horse stable using different bedding materials

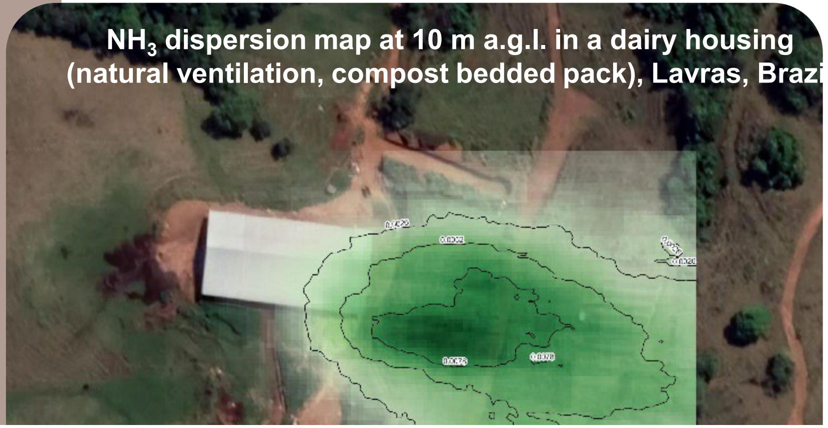


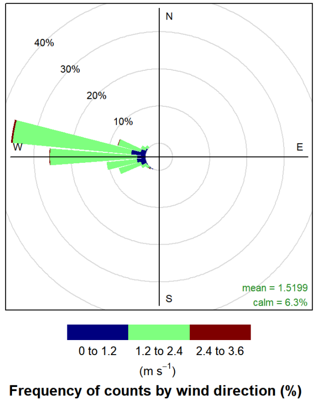


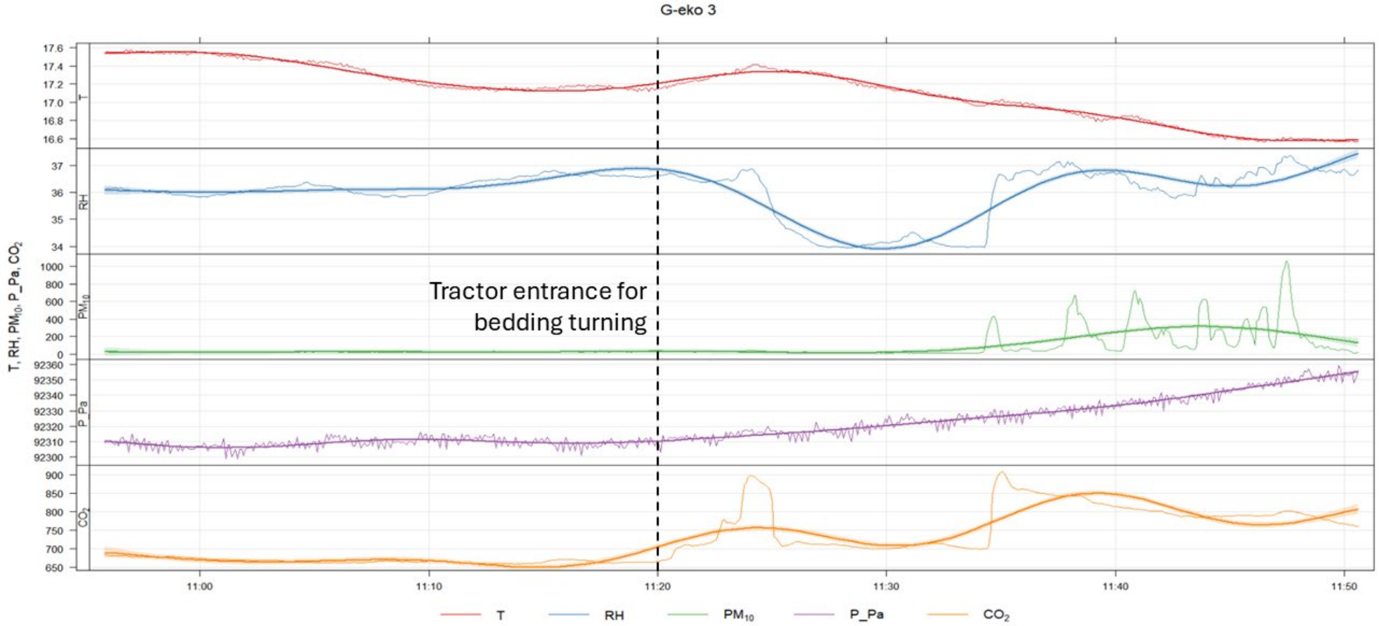
WHO guidelines:
yearly ave. conc. PM2.5: <5 μg/m^3
24-hour ave. PM2.5: <15 μg/m^3 (3-4 days/year)

Results – outdoor monitoring experiences

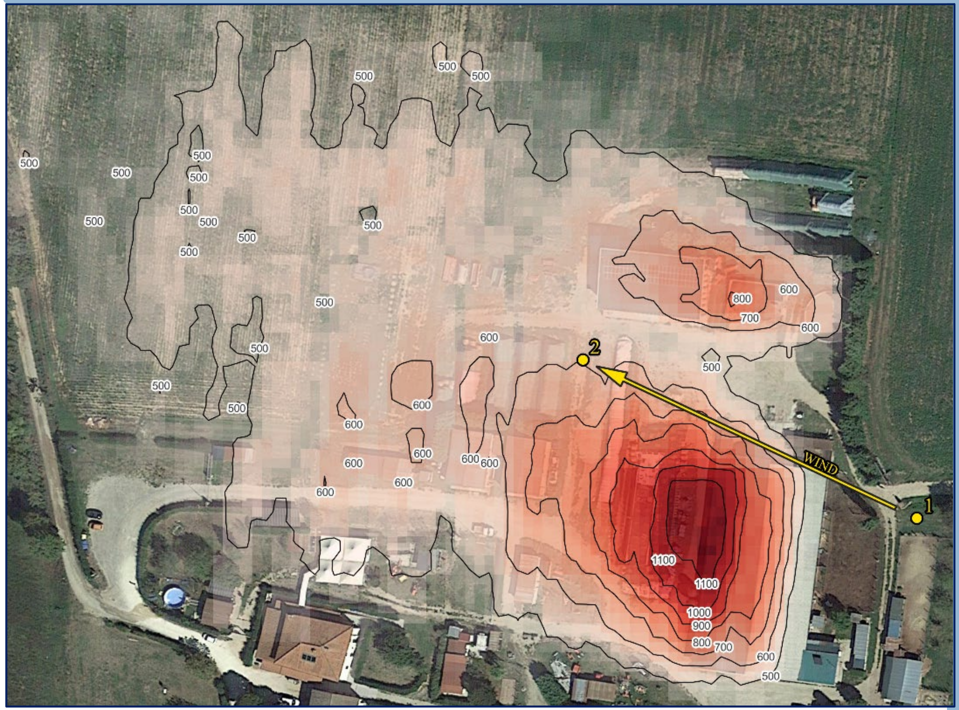
Short-range atmospheric dispersion of gases from dairy housings







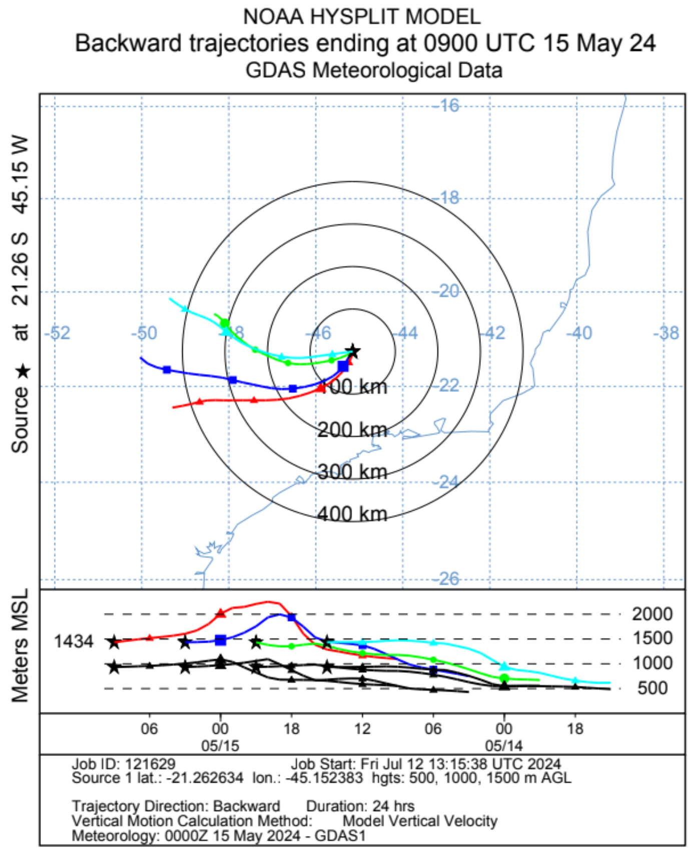
CO_2 concentrations (ppm) by WindTrax (Lagrangian stochastic modelling) in QGIS

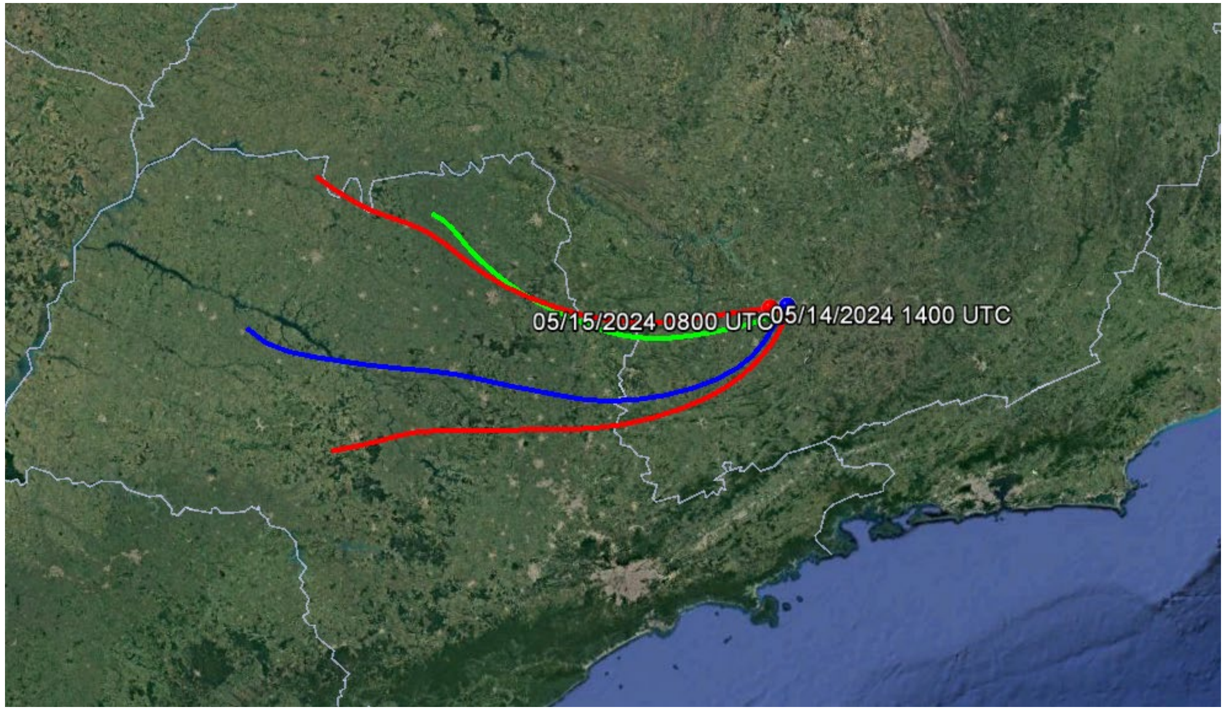


Wind speed: 1.14 m · s^{-1}
Emission rate: 0.29 g · m^{-2} s^{-1}
Temperature: ~ 10 °C
Pressure: ~ 995.60 hPa

In progress – outdoor monitoring experiences

Trajectory analysis of air masses (HYSPLIT model)





Publications

Papers

Becciolini, V., Merlini, M., Massera, E., Marin, D. B., Rossi, G., Barbari, M. (2024). Performance of a Multi-Sensor System for Ground and Aerial Sampling of Pollutants in Livestock Farms. In Conference of the Italian Society of Agricultural Engineering. Cham: Springer International Publishing.

Marin, D. B., Becciolini, V., Santana, L. S., Rossi, G., Barbari, M. (2023). State of the Art and Future Perspectives of Atmospheric Chemical Sensing Using Unmanned Aerial Vehicles: A Bibliometric Analysis. *Sensors*, *23*(20), 8384.

Becciolini, V., Conti, L., Rossi, G., Marin, D. B., Merlini, M., Coletti, G., Rossi, U., Barbari, M. (2022). Real-time measurements of gaseous and particulate emissions from livestock buildings and manure stores with novel UAV-based system. In Conference of the Italian Society of Agricultural Engineering (pp. 1049-1056). Cham: Springer International Publishing.

Becciolini, V., Conti, L., Rossi, G., Merlini, M., Coletti, G., Rossi, U., Barbari, M. (2022). A UAV-based system for greenhouse gases and particulate measurement in livestock farms. In Precision livestock farming '22 (pp. 450-456). European Conference on Precision Livestock Farming.

Conferences

Becciolini, V., Merlini, M., Amantea, R., Verdi, L., Squillace, F., Rossi, G., Barbari, M. (2024). Assessment of Carbon Dioxide Measurements from a Prototype Multipollutant Sensor System under Different Environmental Regimes. The 6th CIGR International Conference 2024, May 19 - 23, 2024, Jeju, Korea.

Mattia, A., Merlini, M., Amantea, R. P., Coletti, G., Squillace, F., Rossi, G., Barbari, M., Becciolini, V. (2023). Deducing emission rates from gas concentrations in a livestock farm through a backward Lagrangian stochastic method-based model. IV Convegno AISSA#UNDER40, Fisciano 12-13 luglio 2023. p.120.

Becciolini, V., Merlini, M., Coletti, G., Conti, L., Marin, D. B., Mattia, A., Rossi, G., Rossi, U., Barbari, M. (2022). Mapping atmospheric concentration of gas and particulate matter in livestock farms using drone-based measurements. In The XX CIGR World Congress 2022 (pp. 1-2). CIGR.

Thank you for your attention!

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