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High-resolution measurement-based methane quantification from beef cattle feedlots to improve agricultural GHG inventories

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Methane (CH_4) emissions from livestock production remain one of the largest and most uncertain components of national greenhouse gas inventories, largely because direct measurements at operational facilities are limited. This measurement gap constrains the accuracy of agricultural CH_4 estimates and the development of effective mitigation strategies. Strengthening the empirical basis for these inventories is therefore essential. Emerging close-range tools, such as uncrewed aerial vehicle (UAV) plume-sampling systems, can enhance monitoring, reporting, and verification (MRV) by providing high-resolution, facility-level observations.

To evaluate this approach, this study conducted a five-day field campaign at a commercial cattle feedlot in southern Alberta, Canada, housing approximately 28,000 cattle. UAV plume sampling was deployed alongside continuous CH_4 measurements from an open-path laser (OPL) to estimate CH_4 emission rate downwind of the facility. For both techniques, emission rates were derived using inverse dispersion modeling, for a direct comparison of performance and assessing the extent to which UAV-based sampling can complement established ground-based flux measurements.

Uncrewed aerial vehicle-derived CH_4 emission rates varied from 149 to 392 g head^{-1} day^{-1} (mean ± SE: 280 ± 22), in near-perfect agreement with OPL-derived emissions of 152-438 g head^{-1} day^{-1} (280 ± 22). Daily mean emissions differed by only 0.08% during overlapping sampling periods, and statistical distributions were highly consistent across methods. Hour-to-hour variability reflected transient atmospheric dynamics and associated changes in plume dispersion, rather than methodological bias. UAV flights also revealed spatial plume gradients not captured by the fixed OPL geometry, and consistent hourly emission estimates were found when UAV flights collected at least four usable plume samples per hour. Performance declined under very low-wind or highly turbulent conditions, clarifying key operational constraints for future deployments.

Overall, these findings demonstrate that UAV-based plume sampling can provide CH_4 emission estimates consistent with established ground-based systems, providing a validated pathway for quantifying emissions from commercial feedlots. The approach aligns with the Integrated Global Greenhouse Gas Information System (IG3IS) good-practice principles and provides empirical information that can improve IPCC Tier 2 emission factors for open-lot beef operations.