Study combines drone, satellite data, and ground-based flux measurements to examine methane emissions from ruminants in Kenya.

The research is a pioneering effort to employ drones for methane (CH4) emission quantification from ruminants in sub-Saharan Africa. It is one of the first field studies to measure methane emissions from camels, a largely understudied source.

Methane emissions from livestock accounts for one-third of global anthropogenic methane emissions. Yet it remains poorly mapped in many regions—especially in Africa.

Using drones equipped with methane sensors, researchers flew over herds of cattle, goats, sheep, and camels—before and after grazing—to capture methane concentration data. A ground-based flux tower provided wind measurements.

The study was conducted at ILRI's Kapiti Research Station in Kenya, in a collaboration between the University of Oslo, ILRI, NIBIO, and the University of Milan. Initial test flights were carried out at NIBIOs research station Tjøtta in the north of Norway. The results may contribute to the development of more accurate livestock methane emission estimates, facilitating their use in climate models and national greenhouse gas inventories.

This is one of the first field studies to measure methane emissions from camels. Photo: Alouette van Hove/UIO

Flexible method for measuring greenhouse gas emissions in remote areas

"This study demonstrates that drones can effectively monitor emissions in remote or challenging environments, such as where traditional chamber methods are unavailable or impractical, for example with larger animals like camels", says Alouette van Hove, PhD candidate at the University of Oslo, and first author of the study. Her research aims to develop new methods for measuring and calculating emissions of greenhouse gases such as methane and CO_2, including those from agriculture, using unmanned aerial vehicles (drones) equipped with sensors.

"It's a flexible approach that allows researchers to travel to the animals' location and take measurements over several days and at various times, all without disturbing the animals" she adds.

Alouette van Hove, PhD candidate at the University of Oslo, during trials with drones at Kapiti Research farm in Kenya. Photo: Vibeke Lind/NIBIO.

The article, named "Inferring methane emissions from African livestock by fusing drone, tower and satellite data" is a part of CircAgric-GHG – A research project that will unravel mechanisms by which farming systems can enhance circularity, reduce GHG emissions, and provide ecosystem services at multiple scales.

Reliable method

The researchers applied a Bayesian inference method that integrates drone-based methane measurements and flux tower wind data with an atmospheric dispersion model. This probabilistic approach accounts for uncertainty in the data and integrates prior knowledge to produce more reliable emission estimates.

Three following approaches were compared:

- Bayesian inference (probabilistic, data-driven method)
- Mass balance method (based on inflow/outflow of methane in a specific area, data-driven)
- IPCC Tier 2 estimates (standardized values based on diet, activity, and animal type)

The researchers compared how consistent the different methods were, when compared to the IPCC estimates.

"We found that the Bayesian inference method consistently produced results that aligned with IPCC Tier 2 estimates, even for low-emission animals like goats and sheep, which indicates that the method is both reliable and robust under the conditions of the study, says van Hove.

In contrast, the mass balance method often overestimated emissions from the low-emission animals, suggesting potential limitations when applied to weaker sources.

Vibeke Lind, Research Scientist in NIBIO, and project leader of CircAgric-GHG, was responsible for calculating the IPCC Tier 2 methane emission estimates for the livestock monitored by the drones.

"The Tier 2 values incorporate detailed herd-specific or animal-specific data. In this case the data accounted for the local variations in Kenya and the livestock breed and feed qualities in the region. We used the method to estimate emissions from single animals, based on their weight, age, feed intake and feed quality", says Lind.

Test flights to fine tune the methodology were performed at NIBIOs research station Tjøtta. The drones measured methane and CO2 respectively at a height of about 20 metres above the barn, which houses between 60-70 cows. In addition, wind speed and wind direction were measured by suspending equipment in a so-called flux tower near the barn. If, for example, it is very windy, this must be calculated in, as the uncertainty in the measurements becomes greater. Photos: Vibeke Lind/NIBIO.

Drone photo of goats at a boma in Kapiti Research station. The researchers found that the Bayesian inference method consistently produced results that aligned with IPCC Tier 2 estimates, even for low-emission animals like goats and sheep. Photo: John Hulth.

4176 A. van Hove et al.: Inferring methane emissions from African livestock by fusing drone, tower, and satellite data

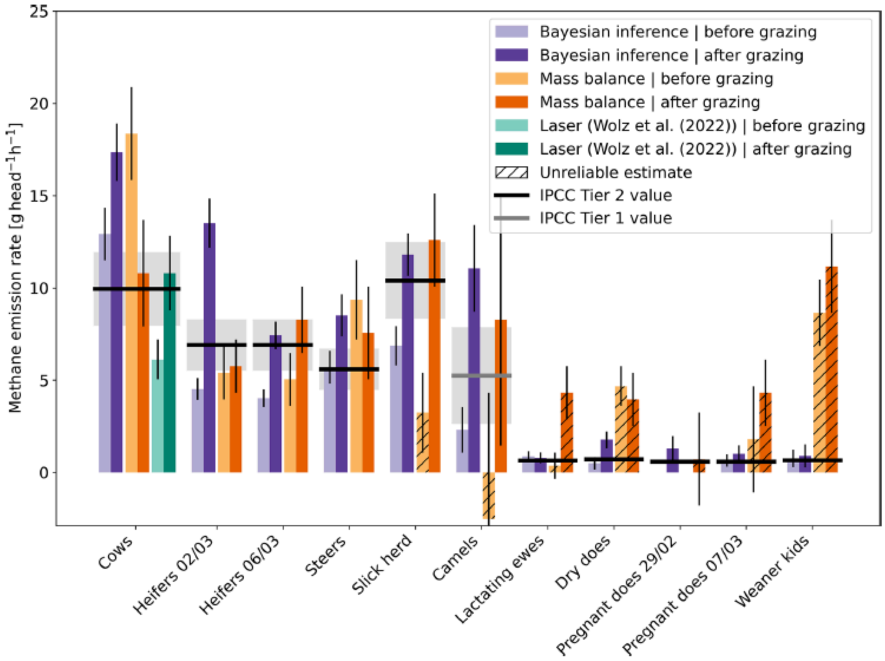

Figure 5. Methane emission rate estimates from the Bayesian inference method using concentration observations and mean wind speed, mean wind direction, and diffusivity data derived from Monin–Obukhov similarity theory (observation case c), the mass balance approach, a laser spectrometry study by Wolz et al. (2022), and IPCC emission factors converted from daily to hourly emission rates. Error bars represent one standard deviation uncertainty. The uncertainty range of IPCC values, depicted by gray shading, is $\pm 20\,\%$ for Tier 2 values and $\pm 30\,\%$ to $\pm 50\,\%$ for Tier 1 values (Paustian et al., 2006); this figure uses $\pm 50\,\%$ for the IPCC Tier 1 value. Unreliable mass balance estimates due to a low signal-to-noise ratio are indicated by hatched lines.

Integration of satellite data

Another innovation is the integration of hyperspectral satellite data. Researchers from the University of Milan used hyperspectral imagery from the Italian Space Agency satellite mission PRISMA acquired over the Kapiti farm at same time as the drone study was carried out. The goal was to see if hyperspectral satellite sensors could detect landscape features associated to herd location and potential methane emissions at Kapiti.

Usually, satellite imagery is applied to spot larger emission sources, like gas leaks from a factory. Therefore, the researchers where excited to investigate whether the satellites were able to detect spatial anomalies linked directly or indirectly to animal emissions. And it turned out; the satellite images did detect anomalies exactly at the locations of the herds.

However, further research is needed to investigate whether these anomalies were caused by elevated methane levels or by other factors, such as changes in vegetation or soil moisture.

“While this was an exploratory assessment, the encouraging results suggest a potential for multi-scale assessment of point emissions sources at landscape scale, combining drones and last-generation spaceborne hyperspectral sensors” says Associate Professor, Francesco Pietro Fava, at the University of Milan.

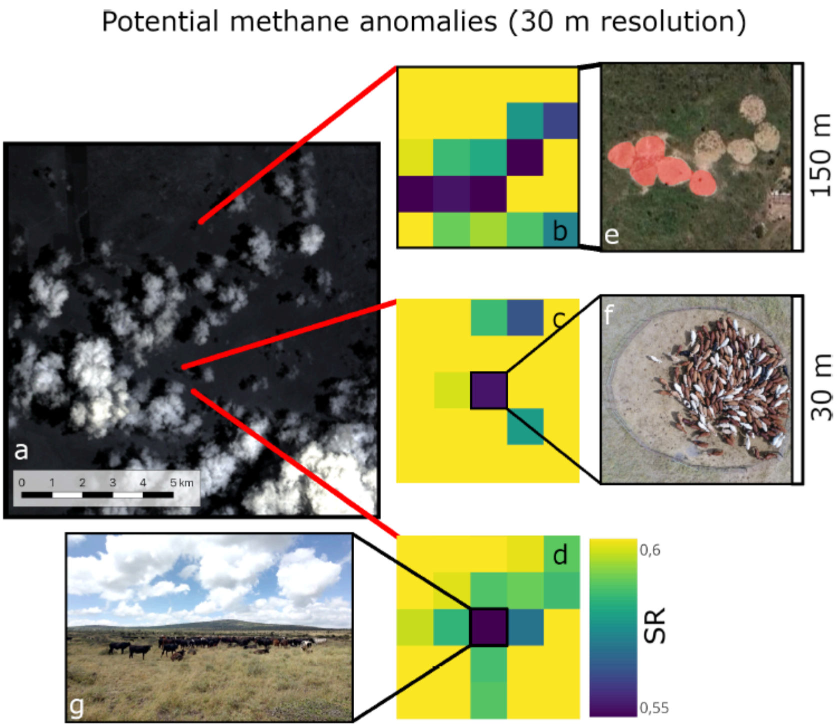

Figure 6. (**a**) PRISMA true color image of Kapiti from 6 March 2024 08:00 Coordinated Universal Time (UTC) + 3 h, corresponding to East Africa Time. (**b**) to (**d**) The simple ratio (SR) radiance index of 2300/2100 nm with 30 m resolution for three distinct sites: (**e**) five adjacent bomas (shaded red) housing 583 cows at the time of the satellite overpass but empty in this picture, (**f**) a single boma at the drone field site with 206 heifers, and (**g**) a free-grazing herd of 148 heifers. (**e**) includes ©Google Satellite Imagery (2021). PRISMA product derived from L1 6 March 2024©Italian Space Agency (ASI) (2024). All rights reserved.

Shows potential for identifying emission sources and estimating volumes

The method presented in the study may be compared to what is happening when zooming in on a map from a far distance, to identify the detail in a single pixel.

“Satellites help identify emission sources, while drones provide an overview of emission concentrations and daily variations, such as before and after feeding”, says Lind.

To further zoom into the details, it’s possible to measure emissions from individual animals. Lind explains that this may be done using methods such as respiration chambers, the SF6 tracer gas technique, or face masks.

“Although drones are promising, they require certified operators and data experts, making them currently inaccessible for most farmers. Still, this technology shows potential for identifying emission sources and estimating volumes”,
Lind concludes.

Vibeke Lind, Research Scientist in NIBIO, project leader of CircAgric-GHG, and guest researcher at ILRI. Lind has been following the researchers from UIO from their initial test phase at NIBIO Tjøtta in Sandnessjøen, where she spends most of her time, till the study was carried out at Kapiti Research station in Kenya. Lind's expertise is, among others, to measure emissions from single animals. She believes the drone technology shows potential for identifying emission sources and estimating volumes. In this study she was responsible for calculating the IPCC Tier 2 methane emission estimates for the livestock monitored by the drones. Photo: NIBIO.

What's Next?

Accurate, localized measurements are essential for developing effective mitigation strategies. This research could inform debates on feed subsidies, grazing practices, and emission reduction policies—especially in regions where data is scarce. The study also lays the groundwork for expanding methane mapping to other sources, such as wetlands, landfills, and thawing permafrost. Adaptations of the framework will be needed to handle multiple, diffuse sources and overlapping emission plumes, improving its relevance for complex landscapes.

As Alouette van Hove notes,

“It’s exciting to work on something that can actually be changed. Measuring methane from cows is not just a technical challenge—it’s a way to support better decisions for climate and agriculture.”

She is now working on optimizing drone flight paths using machine learning, enabling drones to autonomously detect and estimate methane sources in environments where their locations are unknown — “like smelling where the cows are,” as van Hove puts it. This could further improve efficiency and accuracy in future monitoring campaigns.

Alouette van Hove, PhD student at University of Oslo, Norway, visited ILRIs Kapiti Research station in Kenya in February 2024, together with

John Hulth, head engineer at the department of geosciences. The researchers measured emissions from herds of ruminants (camels, goats, cows and sheep that digest plant-based food in a specialized stomach, resulting in methane production as a by-product). Photo: Vibeke Lind/NIBIO.

Read the research article here (https://bg.copernicus.org/articles/22/4163/2025/)

FACTs: What the Research Reveals

- Methane emissions increase after feeding, confirming known patterns of enteric fermentation.
- Bayesian inference estimates of weak sources were more accurate than those from the traditional mass balance method. The method also performed better under variable wind conditions.
- Drone-based methods are flexible, allowing measurements across species, landscapes, and timeframes.
- Satellite data may help locate emission hotspots, guiding future drone missions.

By; Anette Tjomsland Spilling

Published; 01.10.2025.

News archive (https://www.circagric.org/news/)