From geospatial data to accountability: satellite monitoring as enforcement catalyst of environmental regulations

KAYRROS

METHANE

Introduction

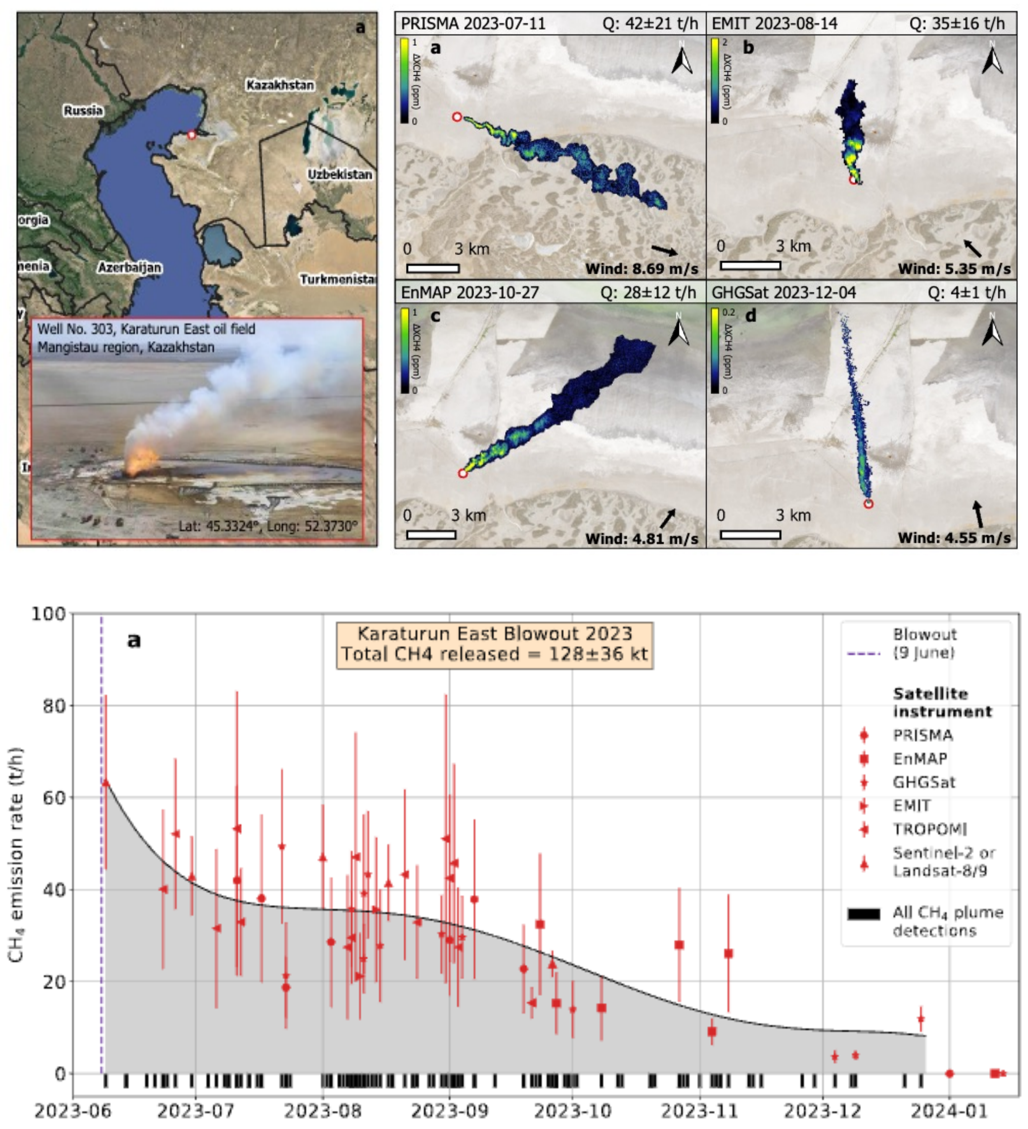
As the second most potent greenhouse gas, reducing methane emissions is paramount to achieving climate targets. However, there is still a substantial gap between reported and observed emissions. A recent study by Stanford University [1] confirmed the unique capability of Kayrros to monitor methane emissions using all available satellite sensors, reliably detecting plumes below 100 kg/hour. This unprecedented transparency is catalyzing new regulations aimed at curbing emissions, such as fines for excessive leaks in the U.S. and reduction targets covering imports in the EU. As satellite monitoring unequivocally exposes the environmental impacts of economic activities, it drives greater accountability from operators and paves the way for more effective methane mitigation policies backed by credible, independent emissions data.

Detecting, quantifying, attributing

Kayrros' approach harnesses the capabilities of remote sensing, machine learning, and atmospheric physics to pinpoint methane hot spots and quantify their environmental impact, leveraging several constellations with hyperspectral or multispectral capabilities.
First, high-resolution maps of methane concentration are computed by analyzing satellite observations of atmospheric absorption and comparing them against a reference methane absorption spectrum derived from physics-based atmospheric modeling.
Potential methane plumes are then identified, either through manual delineation or an automated deep-learning approach that can reliably detect plume signatures.
Each detected plume is attributed to its likely source by tracing back to the most upwind pixel within the plume boundaries.
Finally, the plume's spatial extent is combined with analyzed wind data to derive a quantitative estimate of the emission rate from the identified source.

From measures to action

In July 2023, Kayrros detected multiple major methane super-emitters in Kazakhstan and attributed the event to a natural gas well blowout. After Bloomberg News published the findings, the operator initially claimed the observed gas plume was water vapor rather than methane, despite confirming an exploitation accident had occurred.



In response, a consortium of researchers from various institutions joined forces to comprehensively analyze all available satellite imagery. Their investigation demonstrated that the leak persisted for 205 days, ultimately releasing 128±36 kilotons of methane into the atmosphere - the largest documented methane emission from an infrastructure accident to date. As a result of violating environmental regulations, the operator was fined $774,000 by a Kazakhstani environmental agency. This case highlights the critical role of remote sensing technologies in identifying, quantifying, and mitigating major environmental incidents and supporting regulators and civil society in taking corporations accountable for the environmental arm associated with their operations.

Illustration: Localization of the natural gas well and examples of methane plumes observed with different satellites over a few months after the exploitation accidents. Total emissions have been estimated using 48 hyperspectral and multispectral images. All visuals from Guanter and al 2024 [1].

They use our data

Kayrros works with UNEP's International Methane Emission Observatory (IMEO) as a key data provider for the Methane Alert and Response System (MARS). Our data also contributes to the International Energy Agency's Methane Tracker annual report.

UN environment programme

iea International Energy Agency

References

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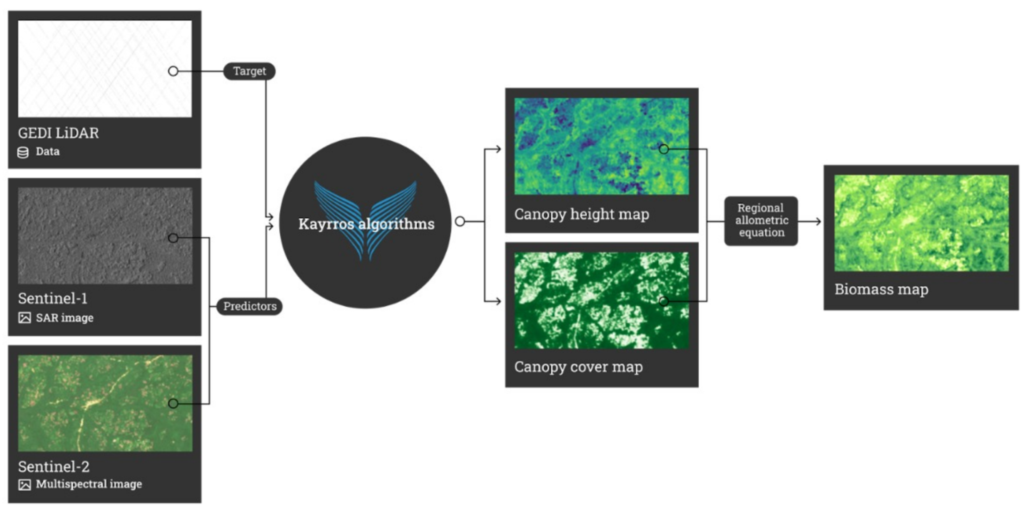
FORESTS

Introduction

Forest degradation represents one of the most environmentally destructive crimes, wreaking havoc on carbon emissions, biodiversity, water resources, and local communities' livelihoods. For European nations, robust deforestation monitoring capabilities are critical to align consumption practices with climate commitments. In regions grappling with rampant deforestation, accurate and timely forest mapping is paramount for designing and enforcing regulations that carry profound implications not just for the climate crisis, but also for regional security and sustainable development agendas.

Qualifying forest changes

Kayrros forest monitoring technology relies on Sentinel-2 and Sentinel-1 images, combined with the Global Ecosystem Dynamics Investigation (GEDI) as a training dataset. Leveraging an adapted U-Net model from Milesi (2022), we perform pixel-wise regression to predict canopy height and fractional canopy cover. To derive above-ground biomass, we utilize GEDI's L4A product, which maps functional plant types to regionally-calibrated allometric equations based on field plot data. A root-to-shoot ratio is then applied per pixel to estimate the total biomass content across our 10x10m resolution maps.



Our canopy height and cover products have been rigorously validated against airborne lidar acquisitions spanning diverse biomes, achieving mean absolute percentage errors as low as 15.5% for trees over 5m in the Amazon rainforest, and 24.5% in dry, open forests.

Illustration: Overview of the deep learning process used by Kayrros to measure above-ground biomass over large areas using 10m resolution satellite data.

Scaling up conservation efforts

For countries with vast forested areas facing deforestation pressures, the 10-meter resolution is crucial for identifying small-scale deforestation and forest degradation hotspots, which are frequently linked to illegal logging activities, and are typically hard to measure in remote and isolated regions. Precise biomass measurements enable a comprehensive assessment of environmental impacts from forest clearing, allowing conservation efforts to prioritize areas with high-density biomass where the carbon emissions would be most severe. Moreover, deforestation detection can serve as evidence for other environmental crimes such as illegal gold mining, which not only causes deforestation but also significant soil disturbance and long-term water pollution from the mercury used in artisanal mining methods.

From the European Union's standpoint, the overarching goal is to reduce environmental crimes indirectly driven by the import and consumption of goods linked to deforestation and ecosystem degradation. In this context, regulators require a global view of forest stocks and dynamics, with regular updates to accurately measure the efficiency of implemented policies and regulations. Remote sensing provided independent monitoring tools to validate the evidence provided by importers during mandated due diligence processes. Accurate canopy height data can be essential for better distinguishing natural forests from forest plantations (e.g., timber, rubber, palm oil, agroforestry systems) in the context of the European Union's regulation on deforestation-free products.

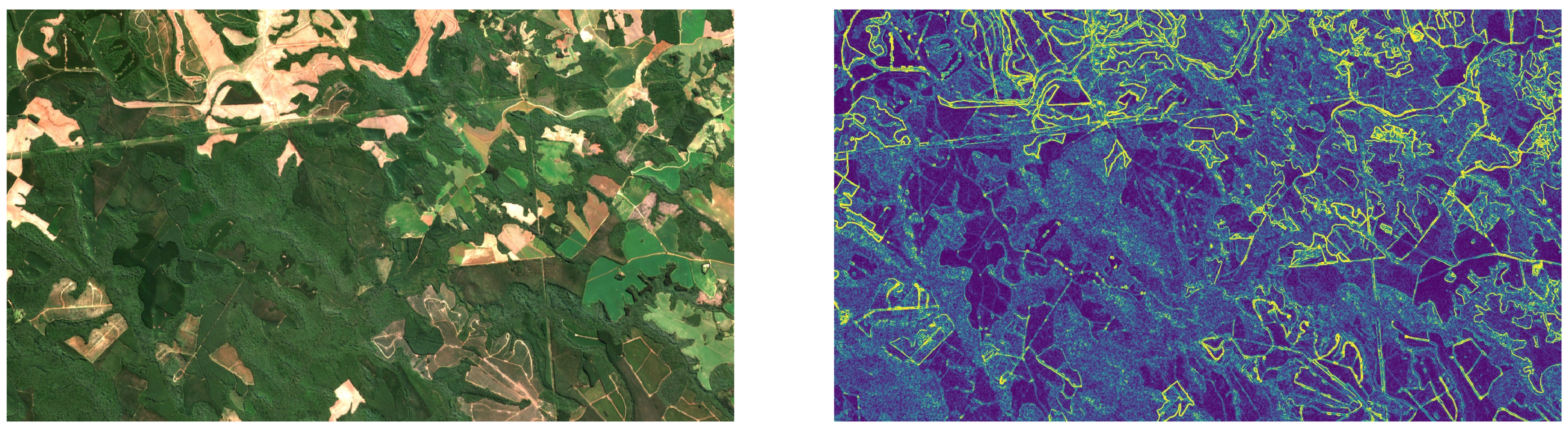


Illustration: 2020 Sentinel-2 composite image over a timber-producing region in Brazil (left) and Kayrros 10-m resolution height map over the same area (right). Parcels of forests with constant heights (dark violet patches on the right image) are considered as plantations.

References

[1] Schwartz, M., Ciais, P., Ottlé, C., De Truchis, A., Vegac, C., Fayad, I., Brandt, M., Fensholt, R., Baghdadi, N., Morneau, F., Morin, D., Guyon, D., Dayau, S., Wigneron, J.P., : High-resolution canopy height map in the Landes forest (France) based on GEDI, Sentinel-1, and Sentinel-2 data with a deep learning approach, https://doi.org/10.48550/arXiv.2212.10265, 2022.

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