A Novel Approach to Measuring the Impact of Thawing Permafrost on Carbon Emissions Using Remote Sensing

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Since the late 1970s, the Arctic has experienced a temperature rise more than three times the global average, leading to accelerated thawing of permafrost. This thawing initiates thermokarst formation, which significantly impacts local Indigenous communities and wildlife habitats. Additionally, thermokarst processes release greenhouse gases (GHGs) such as CO2 and CH4, a major yet underrepresented factor in current climate models and carbon budgets. As the permafrost thaw accelerates, the corresponding rise in carbon emissions could have serious implications for climate change projections. However, monitoring these changes across vast Arctic regions remains a challenge due to the lack of cost-effective methods. This research explores the integration of optical and Synthetic Aperture Radar (SAR) remote sensing data, analyzed using machine learning, to develop a cost-effective and scalable approach for monitoring thermokarst expansion and estimating the associated rise in carbon emissions. The study aims to detect and map thermokarst affected areas, assess changes over time, and quantify the carbon emissions linked to these changes. A supervised classification model achieved a high accuracy of 98.07% in mapping thermokarst landscapes. The analysis showed a significant increase in both thermokarst lake area (23%) and thermokarst terrain area (16%) between 2023 and 2024, resulting in a total increase of 343 Mg in carbon emissions from the study area within this period. The findings highlight the effectiveness of remote sensing and machine learning in long-term monitoring of thermokarst landscapes, providing a reliable, inexpensive tool for evaluating carbon emissions in the Arctic.

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