Global Soil Respiration Insights Through Machine Learning: Projections and Future Climate Change Implications

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Global soil carbon stock contains more than twice the amount of carbon found in Earth's atmosphere. Soil respiration (Rs) is the emission of carbon dioxide (CO2) from soil microorganisms and plant roots into the atmosphere, representing the second-largest terrestrial carbon flux on Earth. This process is sensitive to climate change but varies spatially. Traditional Rs measurements are conducted over small land areas (<1m2) using surface chambers or underground CO2 sensors. Upscaling to global levels and predicting future vulnerability requires an understanding between Rs and its controlling factors. The relationship between Rs and soil properties, climate factors, and vegetation attributes was investigated by adopting a data-driven machine learning (ML) model. This study leveraged the georeferenced soil respiration database (SRDB v5.0), the latest compilation of Rs data worldwide, and a cluster of predictor variables derived from Google Earth Engine at each corresponding spatial location. A soil respiration prediction model was created with an R-squared value of 0.55 and a root mean squared error of 1.7 gC m-2 using eighteen predictor variables. Key findings identified soil respiration's novel dependence on pH, cation exchange capacity, and surface solar radiation. With the filtered predictor variables, the ML model was applied globally to identify regional Rs hotspots and assess vulnerability under three future scenarios: failed Paris Climate Agreement goals, fluctuating precipitation, and reforestation. This study advances our understanding of Earth's soil carbon dynamics, improves the accuracy of Rs predictions, and provides insights to inform climate change mitigation strategies and guide policymaking and conservation efforts.