Greenhouse Gas Emission Dynamics from Agricultural Soils in Malaysia from 1990 to 2021

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Abstract

Agricultural soils are among the major sources of greenhouse gas (GHG) emissions for agriculture sector in Malaysia, mainly through nitrous oxide (N_2O) emissions resulting from nitrogen inputs to managed soils and carbon dioxide (CO_2) emissions from urea application and agricultural liming. This study presents the temporal dynamics of GHG emissions from agricultural soils in Malaysia from 1990 to 2021 based on the national GHG inventory prepared in accordance with the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, using the Tier 1 methodology and the best available national activity data. In 2021, total GHG emissions from Malaysia's agriculture sector amounted to 7,310.04 Gg CO_2 eq., with emissions from agricultural soils contributing approximately 44.7% of the sector's total emissions. Direct N_2O emissions from managed soils were the second largest emission source within the agriculture sector after rice cultivation, accounting for 2,201.35 Gg CO_2 eq. (30.11%). This was followed by indirect N_2O emissions from managed soils (542.71 Gg CO_2 eq.; 7.42%), CO_2 emissions from urea application (394.47 Gg CO_2 eq.; 5.40%), and CO_2 emissions from liming (17.18 Gg CO_2 eq.; 0.24%). The time series analysis shows that emissions from agricultural soils fluctuated throughout the study period, peaking in 2008 before exhibiting interannual variations that largely reflected changes in fertilizer consumption, cultivated area, and agricultural production. Direct and indirect N_2O emissions exhibited the greatest temporal variability, primarily driven by changes in nitrogen inputs from synthetic fertilizers, crop residues, and managed organic soils. Meanwhile, emissions from urea application followed national urea consumption trends, whereas emissions from liming remained relatively low throughout the reporting period, reflecting the relatively low application of agricultural limestone in Malaysia. Continuous improvements in activity data collection, stakeholder engagement, expert judgement, and inventory compilation have enhanced the transparency, consistency, completeness, and accuracy of Malaysia's national GHG inventory. The findings provide valuable insights into the temporal dynamics of agricultural soil emissions and support future inventory improvements and evidence-based mitigation planning under the Enhanced Transparency Framework (ETF).

Keywords: agricultural soils, greenhouse gas inventory, nitrous oxide, time series, Enhanced Transparency Framework

Abstract for your presentation at WGIA23: about 400 words (one page)

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