Using Whole Farm Modelling to Inform Land Use Planning for Greenhouse Gas Emissions Mitigation and Offsetting

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The agriculture sector contributes approximately 12% of global greenhouse gas (GHG) emissions, although the specific amount at regional or farm levels depends on soil, climate, and management practices. Mitigation approaches associated with alternative land use and management practices are constrained by limited information on activity data and the accurate quantification of GHG emissions/removals, and nutrient losses at a farm/landscape level. Given the continuing uncertainties associated with labour-intensive field measurements and monitoring, modelling is one of the best approaches to address these challenges. Most of the existing whole farm/landscape models have limitations in the methodologies that are required for a systems-based quantification of GHG emissions and nutrient losses, covering extensive areas and/or long-time scales. To explore this further, we tested the Whole Farm Canadian Model 'HOLOS' on a 45-ha farm consisting of 2/3 pasture and 1/3 silage with 176 livestock units. The model estimated the overall GHG balance/budget at a farm scale and found that the response of GHG emissions to soil variables depended on the ratio functions used. The primary drivers of GHG emissions were N fertilizer and temperature, and a 30% reduction in these variables decreased the total on-farm GHG emissions by 9% and 18%, respectively. The majority of the 865 Mg CO_2-equivalent emissions came from enteric-CH_4 (51%), direct-N_2O emissions (22%), and manure-CH_4 (17%). We also assessed different land use combinations and found that a reduction in dairy cattle by 10-20% decreased emissions by 10-20%. When combined with silage production, the land use that showed the highest carbon sink, the emissions decreased by 86-90%. Arable land with or without forestry also showed lower emissions compared to pasture or pasture and silage with 100% dairy cattle (837-845 Mg CO_2-equivalent). These results suggest that shifting from a single land use to a mixed farming system. consisting of arable, pasture, silage, and forestry has the potential for reducing on-farm GHG emissions. However, to achieve carbon neutrality, a reduction in livestock and inorganic fertilizers application combined with more afforestation, would be necessary.

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