MODASYS: An Integrated Framework for Farm-Level GHG Mitigation, Carbon Sequestration, and Economic Optimisation

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In a 30-ha dairy farm, enteric methane dominated the emissions, cattle numbers were the strongest lever for lowering total carbon footprint, and diversified crop-livestock systems offered stronger profit margins than specialised or monoculture systems.

Challenge and objective

Carbon-neutral agriculture by 2050 requires farm-scale decisions that reduce greenhouse gas emissions (GHGs) while sustaining productivity and income.

OBJECTIVE Create a decision-support model that simulates GHG mitigation, carbon sequestration and economic performance across farm systems.

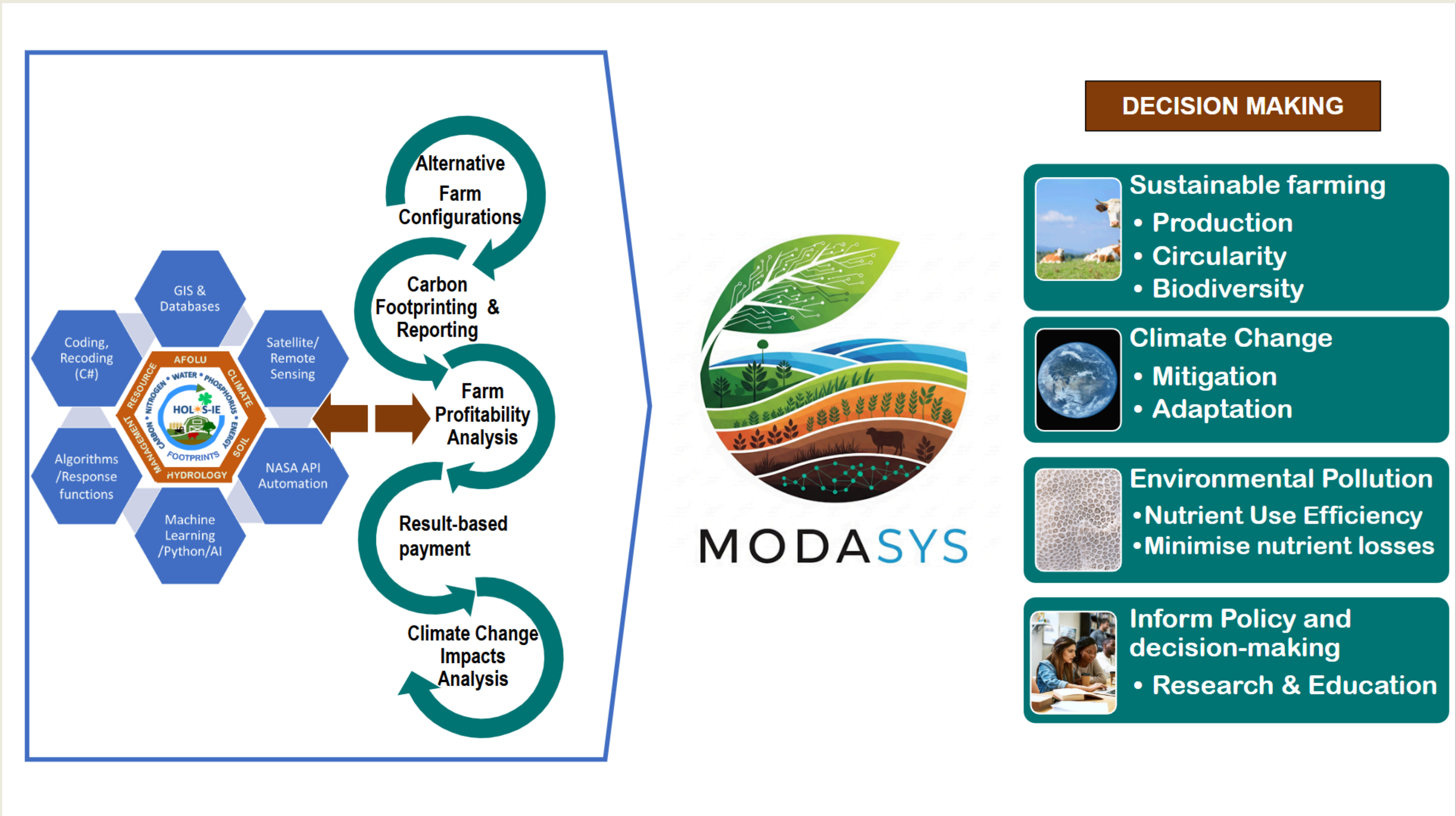
CORE QUESTION Which land-use and livestock configurations reduce GHG emissions, enhance carbon sequestration and economic benefit without undermining farm productivity?

GHG mitigation | Carbon sequestration | Profit margin

Decision-support principle

Balance climate mitigation with sustained productivity using scenario-based, data-driven evidence.

MODASYS Framework



Scenario Testing

30 ha	9	VSR
TEST FARM	LAND-USE CASES	KEY LIVESTOCK

- Single farm boundary used for scenario comparison
- From monoculture wheat and grass silage to grazing systems with or without agroforestry
- Stocking rates were varied to evaluate the effects of dairy production intensity and the associated trade-offs between productivity and environmental performance.

Scenario spectrum

Wheat · Grass · Mixed · Dairy · Silvopasture

Key GHG findings: Source Contribution Ranges

Share of total GHG emissions across the nine modelled scenarios

Enteric CH_4 Livestock the dominant source — 71-84%

Direct N_2O Highest in arable/grassland without dairy — 2-41%

Indirect N_2O Lower under agroforestry — 6-18%

Manure CH_4 Decreased with agroforestry — 1-8%

Main driver	Agroforestry effect	Mitigation lever
Enteric CH_4 made up 71-84% of emissions.	Lower manure CH_4 and indirect N_2O in agroforestry scenarios.	Reducing dairy numbers lowered footprint more strongly than agroforestry alone.

Result snapshot

71-84%
DOMINANT SOURCE
Enteric methane share of total GHG emissions

2-41%
DIRECT EMISSIONS
Direct N_2O range; highest in arable and grassland systems without dairy

6-18%
INDIRECT EMISSIONS
Indirect N_2O range; lower under agroforestry scenarios

Interpretation: enteric CH_4 is the major emission source; land-use diversification could improve system resilience and co-benefits.

Economic optimisation

Mixed farming systems combining crops and livestock significantly outperformed specialised or monoculture systems in profit margins.

- Diversification mitigates risks across production streams.
- Mitigation pathways should be tested against income, not only CO_2e.
- The model links environmental footprints to farm business outcomes.

Management implications

Prioritise livestock CH_4
Enteric CH_4 dominates emissions, so herd size, productivity and feed strategies deserve first attention.

Use agroforestry strategically
Silvopasture could reduce GHG emissions and enhance biomass carbon, but offsetting potential for intensive dairy system is small.

Optimise whole systems
The optimal pathway is to balance emission reductions with sustained farm profitability.

Model refinement and next steps

Current model strength

- Simulates farm-level GHG emissions.
- Represents biomass carbon impacts.
- Connects environmental and economic outcomes.

Known refinement needed

Improved algorithms for to predict SOC density trends to strengthen long-term sequestration estimates.

Planned additions

Biodiversity | Circular bioeconomy | Sustainability indices

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