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OptiGob: A decision support tool for Agriculture, Forestry and Other Land Use transitions

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Summary

OptiGob is a Python-based tool designed to explore configurations of Ireland's agriculture, forestry, and other land use (AFOLU) sectors. The main purpose is to assist users in the assessment of environmental and economic impact pathways, based on different land use transition pathways under varying assumptions about agricultural, afforestation, emissions abatement, and carbon dioxide removal (CDR) strategies. OptiGOB combines data outputs from the GOBLIN Lite for agriculture and land use, from FERS-CBM for forestry, and from the LCAD2.0 for anaerobic digestion, to generate scenarios that respect biophysical constraints. OptiGob provides a flexible, customisable, tool for researchers, policymakers, and educators to explore environmental and economic trade-offs associated with land use transition pathways.

Statement of need

Ireland's agricultural landscape is dominated by grassland, supporting extensive dairy and suckler beef production. Investment in Ireland's bio-economy requires substantial changes to AFOLU sector. `OptiGob` allows users to manipulate critical AFOLU levers that determine transition pathways to explore their impacts. `OptiGob` utilises data from `GOBLIN Lite` (Duffy et al., 2022, 2024), FERS-CBM (Black et al., 2025; Kurz et al., 2008), and LCAD2.0 (Martinez-Acre, 2025) to calculate outputs from agriculture, forestry, and anaerobic digestion.

`OptiGob` estimates the net greenhouse gas (GHG) emissions from land use change and estimates available emissions and land budget for grass-based livestock (Dairy and Suckler cow) production. Pyomo (Bynum et al., 2021; Hart et al., 2011) is used to optimise livestock populations, while respecting area commitment (afforestation, anaerobic digestion, BECCS, protein crops) and emission (CO_2e in the case of Net-Zero, and CH_4, along with Net-Zero N_2O and CO_2 in the case of split gas targets) constraints.

The GOBLIN framework has been applied in recent studies of net-zero pathways for AFOLU (Bishop et al., 2024; Duffy et al., 2022; Henn et al., 2025). `OptiGob` builds upon this framework, offering insight into synergies and trade-offs with reduced overhead and complexity.

Model Overview

Figure 1 illustrates the architecture of the `OptiGob` model. User-defined parameters are provided via JSON or CSV input files and parsed by a data manager, which supplies values to the relevant sub-modules. The `OptiGob` class orchestrates the overall model flow, coordinating modules for emissions, land area, and economic outcomes. These call modules for forestry,

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livestock, bio-energy, other land uses, static agricultural (crops, sheep, pigs, poultry, and protein crops), and substitution effects.

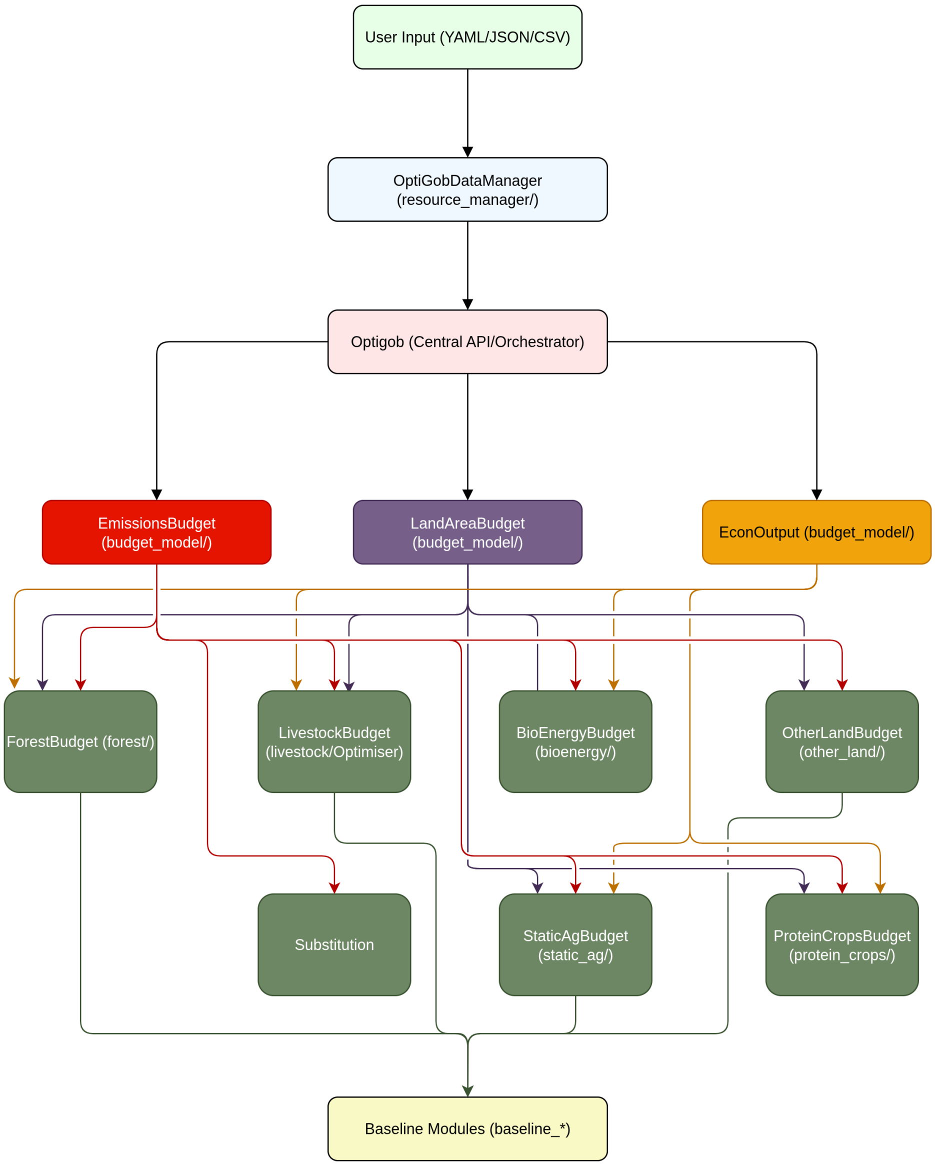

Figure 1: OptiGob Architecture.

OptiGob explores Ireland's AFOLU sector under alternative assumptions regarding productivity, emissions abatement, land use change, and carbon dioxide removal (CDR). Key inputs include: the dairy-to-beef cow ratio, abatement level, agricultural productivity, afforestation and harvest intensity, wetland and organic soil restoration, bio-methane deployment, protein crop and willow area, and BECCS (Bioenergy with Carbon Capture and Storage).

The workflow estimates CDR from forestry, harvested wood products, and BECCS to 2050. Fixed emissions from land use, crop production, pigs, poultry, and anaerobic digestion are then subtracted. The remaining emissions budget, defined by a GWP_{100} net-zero target or a split-gas CH_4 target, is used to optimise allowable cattle production via Pyomo (Bynum et al., 2021; Hart et al., 2011), subject to land and emissions constraints.

Three levels of agricultural abatement are included: baseline (no additional measures), MACC-level (full implementation of measures in the Teagasc 2023 MACC (Lanigan et al., 2023)), and “frontier” (a high ambition pathway including grass-clover swards, methane inhibitors, anaerobic digestion, and manure management technologies).

Agricultural productivity is selectable at three tiers. More ambitious scenarios assume higher milk yields and shorter beef finishing times by 2050. National herd structure is user-defined by the ratio of dairy to suckler beef cows. `OptiGOB` allows expansion of protein crop areas (e.g., field beans and peas).

Example Output

An illustrative example is provided for a 2050 climate neutrality target year, using a 2020 baseline and a split-gas approach. The CH_4 emissions are reduced by 30% relative to the baseline, while CO_2 and N_2O are balanced under GWP_{100}.

Parameter selection reflects the ‘frontier’ (strong productivity increase) abatement path. The 10:1 dairy-to-beef ratio reflects a dairy-dominated pathway. A higher afforestation rate (16 kha/per year), with a composition of 70:30 conifer to broadleaf split. BECCS and bio-energy (anaerobic digestion and willow) are also included. Wetland restoration is assumed to be 90% of exploited peatland, and 50% of organic soils under grass rewetted. Pig and Poultry output has also been increased by 20%.

Figure 2 shows the emissions and removals by category for the baseline and transition scenario.

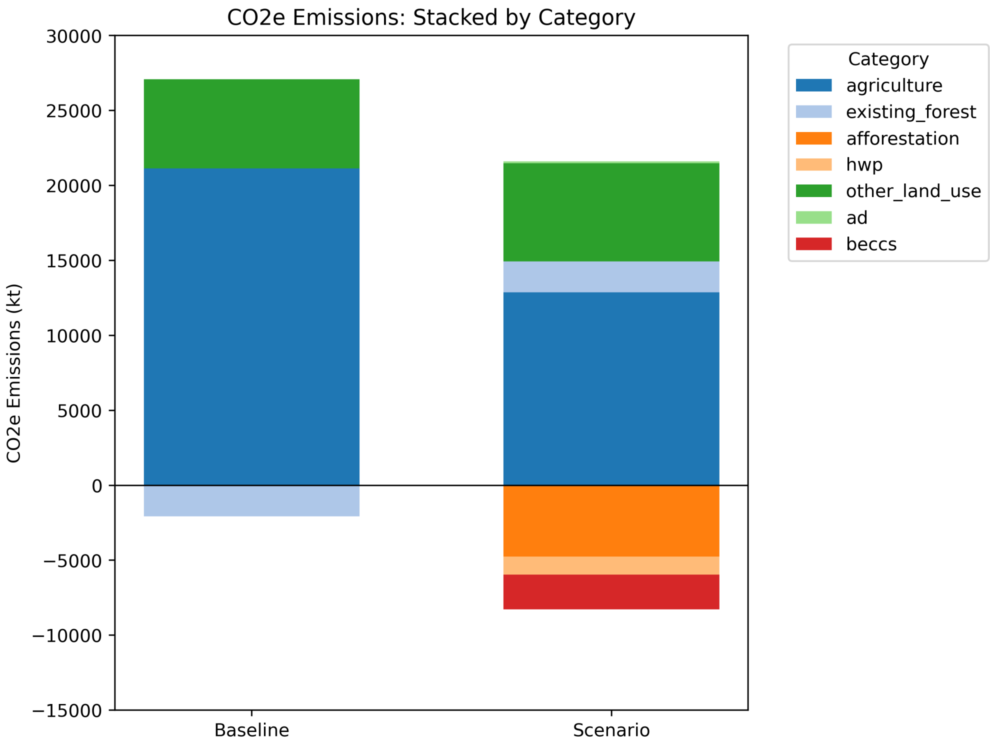

Figure 2: Emissions and Removals from Agriculture, Existing Forest (Managed Forest), Afforestation, Harvested Wood Products (HWP), Other Land Use (Wetlands and Organic Soils), AD (Anaerobic Digestion) and BECCS (CO_2e).

Figure 3 shows total area breakdown by category for the baseline and transition scenario.

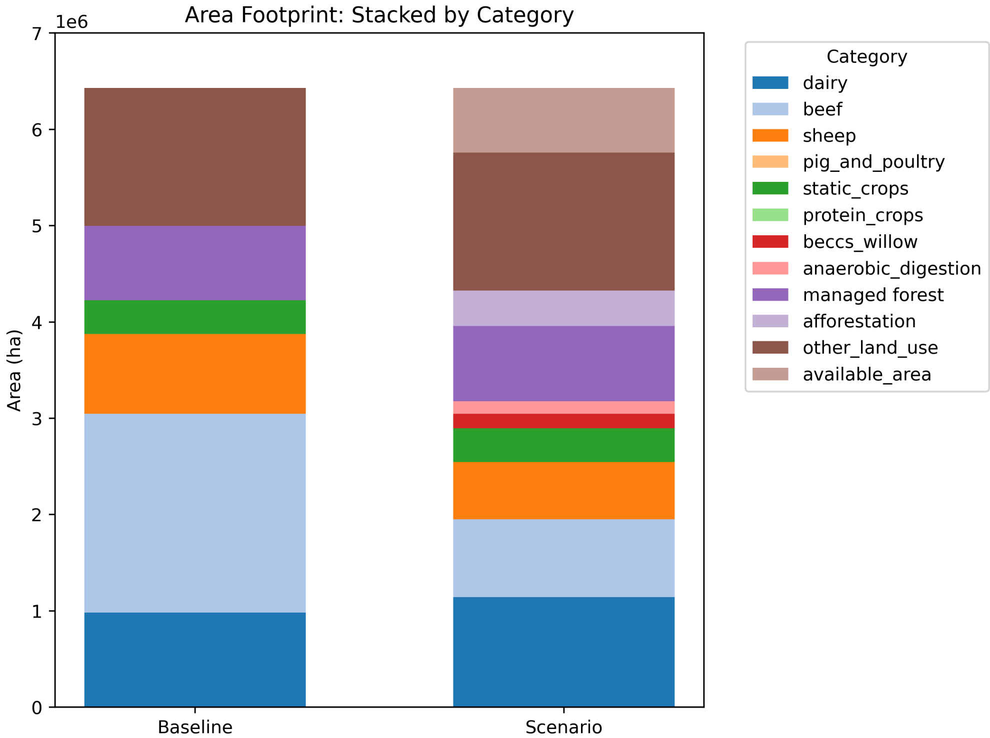

Figure 3: Total area footprint from Dairy, Suckler Beef, Sheep, Pigs & Poultry, Crops, Protein Crops, BECCS (Willow), AD (Anaerobic Digestion), Exiting Forest (Managed Forest), Afforestation, Other Land Use (Wetlands and Organic Soils), and Available Area (Spared area not in use).

Figure 4 shows the total protein output by category for the baseline and transition scenario. Given the variability in composition of non-protein crops, and the relatively small contribution to the overall protein value, static crops have not been included.

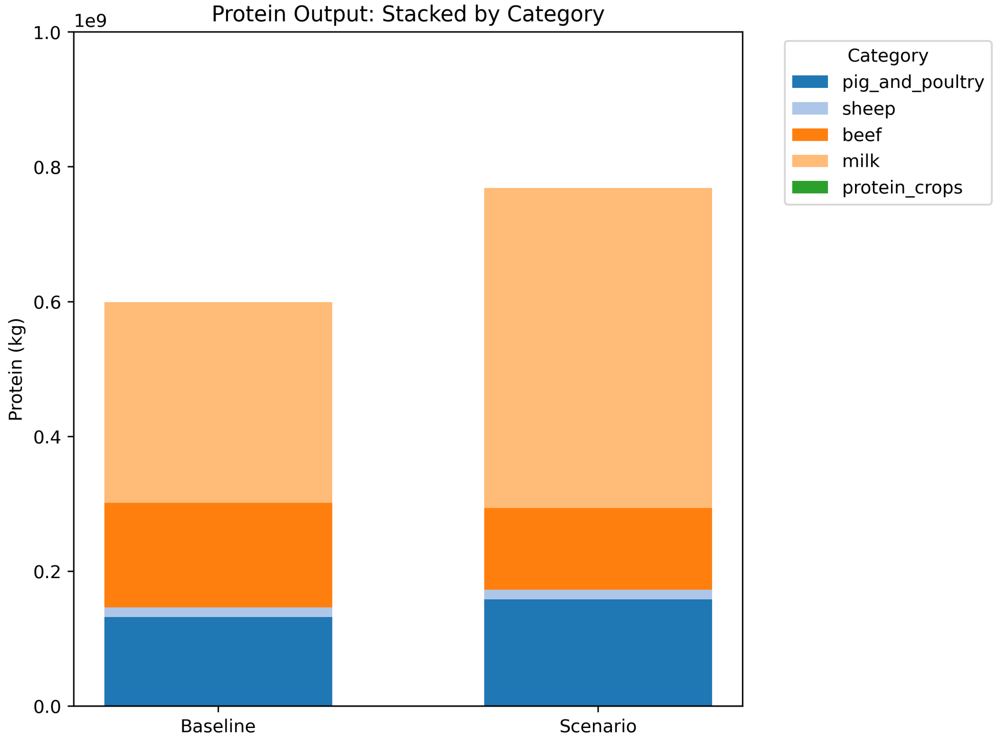

Figure 4: Protein output from Milk, Beef, Pigs & Poultry, Sheep and Protein Crops.

Functionality

`OptiGob` centres on exploring how different land-use and agricultural choices shape Ireland's AFOLU outcomes. Users define scenarios through structured CSV or JSON input files, selecting parameters such as mitigation ambition, productivity levels, afforestation rates, wetland restoration, bioenergy deployment, and livestock restructuring. `OptiGob` calculates resulting emissions, removals, and land requirements under the selected assumptions, using linear optimisation to maximise allowable cattle production while meeting ratio, emission and land area constraints. The model supports both GWP_{100} net-zero and split-gas targets. However, while the model optimises livestock populations (dairy and suckler beef) to meet constraints, it does not guarantee that net-zero or split-gas targets are achieved. Rather, it reports whether a given scenario is compliant.

Limitations

`OptiGob` does not ensure that user-defined pathways achieve climate neutrality; rather, users must verify whether targets are met. Within the default database, some inputs (e.g., wetland restoration, forestry on organic soils) are restricted to predefined combinations. By default, target years are capped at 2050 due to the available animal data. Users can extend this by supplying their own customised database. Emissions and productivity assumptions reflect nationally representative data and technical pathways, but do not capture uncertainty in adoption or emerging technologies. Finally, the model operates at national scale only, without spatial detail or economic feedbacks.

Acknowledgements

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