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

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Software

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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 agriculture, 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 the 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 et al., 2025) to calculate outputs from agriculture, forestry, and anaerobic digestion. This allows users to explore land use and livestock trade-offs, leveraging the outputs from the upstream models without the overhead of running upstream modelling chains. To the authors' knowledge, OptiGob represents the first attempt to do so in the Irish context.

A range of integrated modelling tools exist to explore AFOLU interactions under climate and land constraints, including optimisation-based land-sector models (e.g., FASOM-GHG (Beach et al., 2012)) and regional or global partial-equilibrium frameworks such as CAPRI (Leip et al., 2008), GLOBIOM (Havlík et al., 2010), and MAgPIE (Dietrich et al., 2019). These models typically operate at EU or global scales and solve equilibrium or dynamic land-allocation problems. OptiGob instead provides a lightweight, inventory-aligned optimisation layer tailored to rapid national policy exploration in Ireland.

OptiGob estimates the net greenhouse gas (GHG) emissions from land use change and 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 (Bioenergy with Carbon Capture and Storage), protein crops) and emission (CO_2e in the case of net-zero, or CH_4 alongside net-zero CO_2e for N_2O and CO_2 under a split gas target) 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, providing a single-interface tool for exploring synergies and trade-offs across sectors.

Model Overview

Figure 1 illustrates the architecture of the `OptiGob` model. User-defined parameters are provided via JSON or YAML 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. Arrows represent data flow and dependencies, showing how these modules query sector-specific modules for forestry, livestock, bio-energy, other land uses, static agricultural (crops, sheep, pigs, poultry, and protein crops), and substitution effects. Scenario data are read from a pre-generated `SQLite` database derived from `GOBLIN Lite`, `FERS-CBM`, and `LCAD2.0`.

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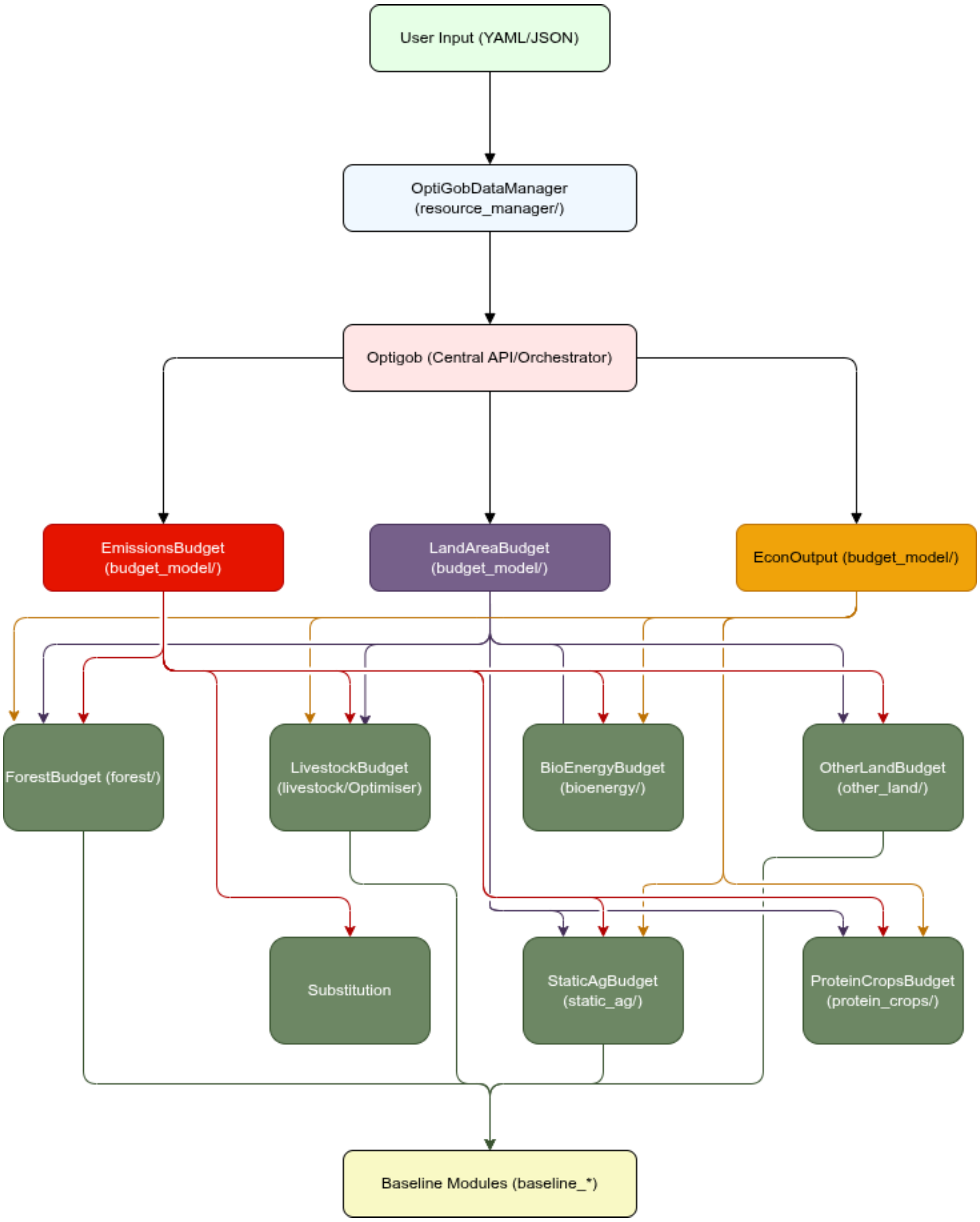

Figure 1: OptiGob Architecture.

`OptiGob` explores Ireland's AFOLU sector under alternative assumptions regarding productivity, emissions abatement, land use change, and carbon dioxide removal (CDR).

The workflow first 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} (100-year Global Warming Potential) net-zero target or a split-gas CH_4 target, is used to optimise allowable cattle production via `Pyomo`, subject to land and emissions constraints. 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.

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 is applied. 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.

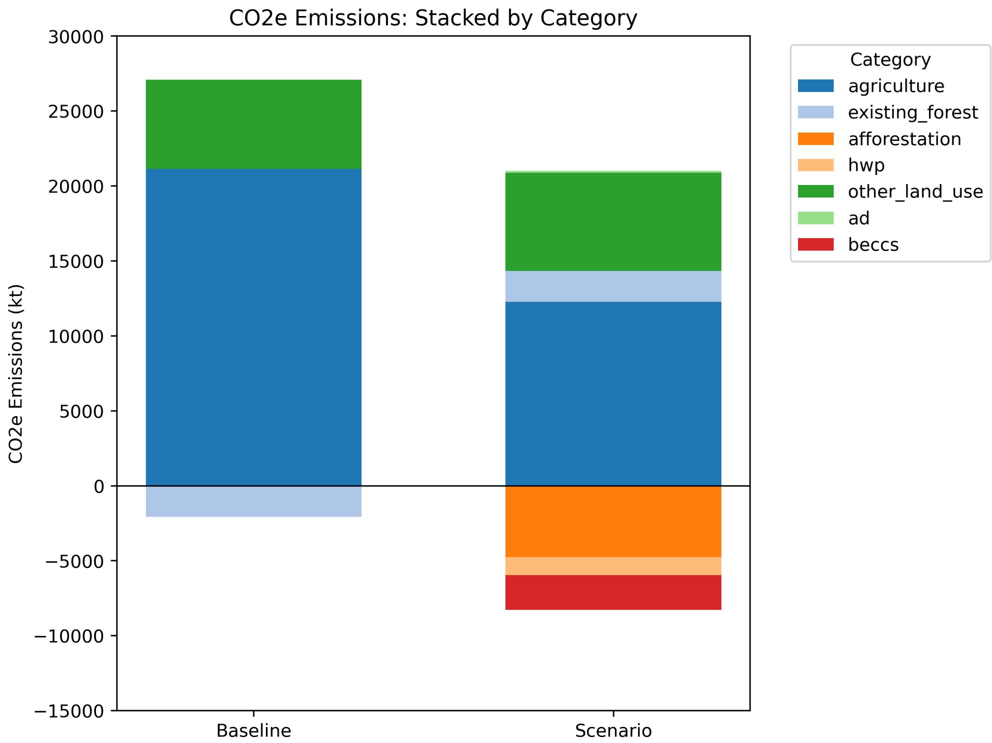

Figure 2: Emissions and Removals from Agriculture, Existing Forest (Managed Forest), Afforestation, Harvested Wood Products (HWP), Other Land Use (Wetlands and Organic Soils), AD (Anaerobic Digestion) and BECCS (CO_2e).

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

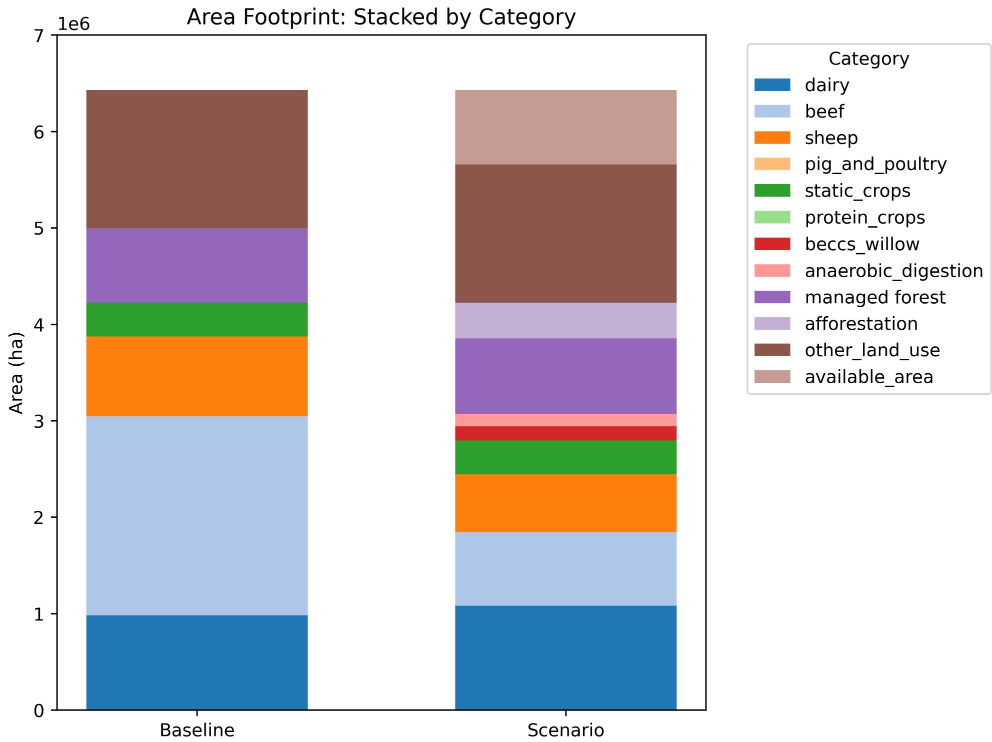

Figure 3: Total area footprint from Dairy, Suckler Beef, Sheep, Pigs & Poultry, Crops, Protein Crops, BECCS (Willow), AD (Anaerobic Digestion), Existing Forest (Managed Forest), Afforestation, Other Land Use (Wetlands and Organic Soils), and Available Area (Spared area not in use).

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.

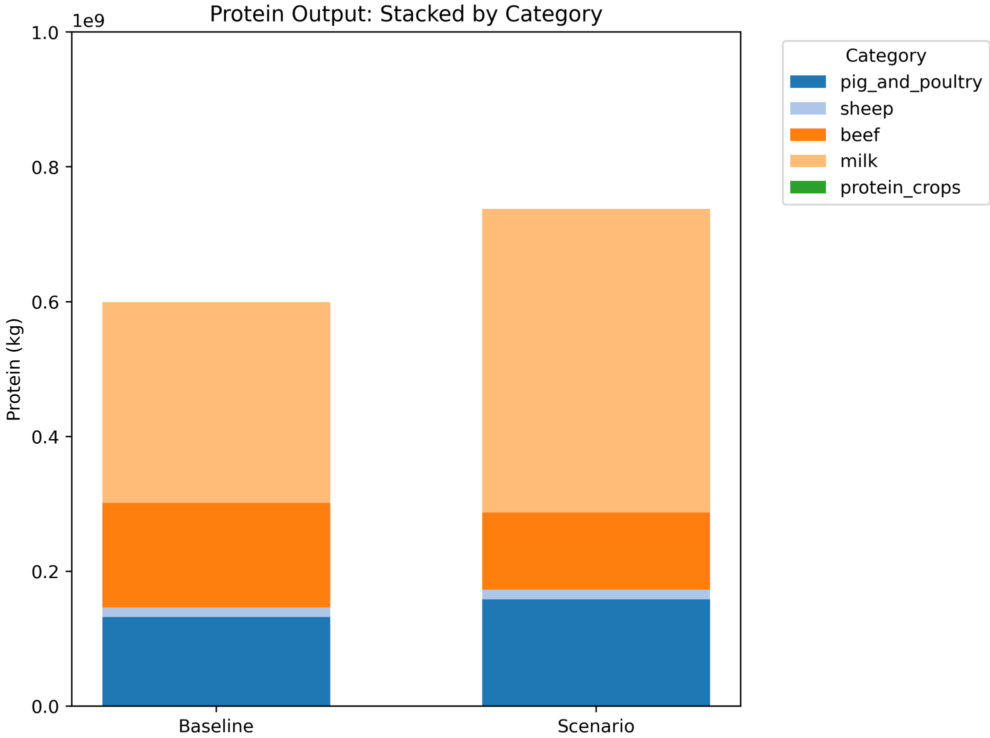

Figure 4: Protein output from Milk, Beef, Pigs & Poultry, Sheep and Protein Crops.

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