Achieving sustainable development in Eastern Africa: a portfolio-based integrated assessment modelling analysis among different Shared Socioeconomic Pathways

PARIS REINFORCE

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Introduction

We introduce a **two-level integration** of **integrated assessment modelling** and **portfolio analysis**, in order to simulate technological subsidisation and climate policies with implications for multiple **Sustainable Development Goals (SDGs)**, across different **socioeconomic trajectories** and considering different levels of **uncertainties**.

Materials and Methods

GCAM

In the **Global Change Assessment Model (GCAM)**, we simulated for Eastern Africa the following scenarios for 2020,2030,2040:

- Three **Shared Socioeconomic Pathways (SSPs)**:
  - SSP 2 ('Middle of the Road'), SSP 3 ('Regional Rivalry') and SSP 5 ('Fossil-fuelled Development')
- Six Technological Pathways:
  - Liquefied Petroleum Gas (LPG), photovoltaics (PV), Biogas, Ethanol, Charcoal and Fuelwood
- Two land policy pathways:
  - A baseline without options to increase sustainable forest output and
  - a land policy that assumes policy actions focused on increasing sustainable fuelwood supply.

First GCAM – PA link

The GCAM outputs translating into progress parameters relevant to different SDGs, are fed into a **portfolio analysis** (PA) model.

Portfolio Analysis

Indicators relevant to the three SDGs constitute the **evaluation criteria** of the PA:

1) Maximisation of GHG emission reductions
2) Maximisation of energy access tier change
3) Maximisation of avoided premature deaths

The alternative options are the six technological pathways.

The PA model is examined under **two different budget constraints**: a strict one with a low budget, and a higher one.

Uncertainty

Deterministic uncertainty: The resulting optimal portfolios are compared across the policy and SSP scenarios.

Stochastic uncertainty: Incorporated into the model by running a Monte Carlo simulation.

A **mean socioeconomic scenario** is also introduced and stress-tested against uncertainty (in terms of an '**SSP-robustness**' score).

Second link PA-GCAM

The portfolio analysis results are **fed back into GCAM**, to verify if the mean scenario ('midSSP') portfolios lead to more **robust solutions**.

Results

Comparison among SSPs

- Differences on the technological performances among the SSPs are mainly observed in SSP 5 for the years 2030 and 2040.
- In the baseline scenario:
  - SSP 2 can prove more progress-friendly in achieving the three SDGs in the short-term
  - In the medium- and long-term, SSP 3 leads to better results for the energy access and health criteria
- In the land policy scenario:
  - The energy access and premature mortality levels are higher for SSP 3
  - SSP 2 outperforms the other pathways in reducing GHG emissions
- SSP 5 features the lowest contribution to the optimisation objectives in both the baseline and the land policy scenario.

*Figure 1: Technology subsidy portfolios for a **"low" budget** that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the **baseline** scenario and per SSP in 2020, 2030 and 2040. Size of dots illustrates robustness against stochastic modelling parameters uncertainty.*

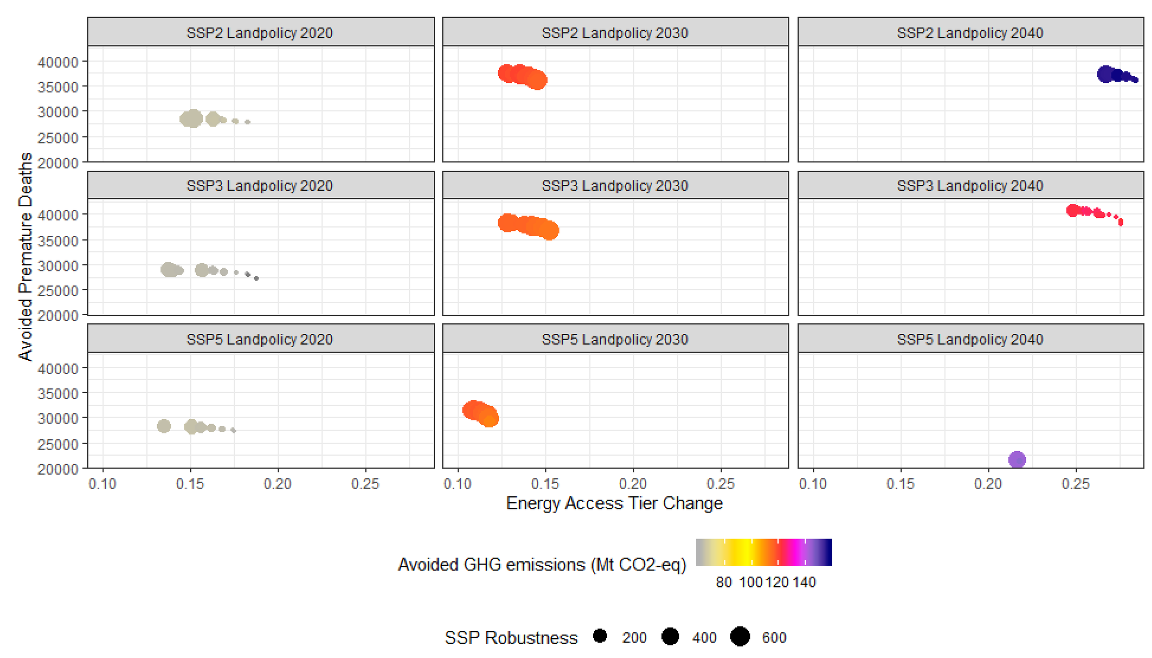

Figure 2: Technology subsidy portfolios for a "low" budget that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the land policy scenario and per SSP in 2020, 2030 and 2040. Size of dots illustrates robustness against stochastic modelling parameters uncertainty.

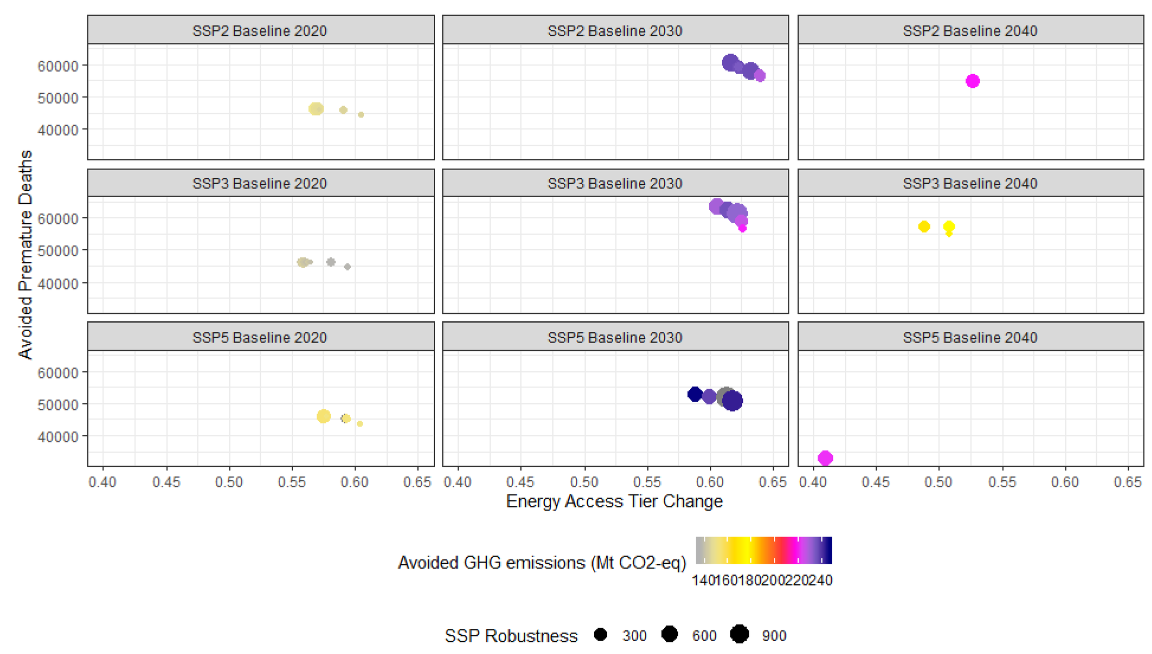

Figure 3: Technology subsidy portfolios for a "high" budget that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the baseline scenario and per SSP in 2020, 2030 and 2040. Size of dots illustrates robustness against stochastic modelling parameters uncertainty.

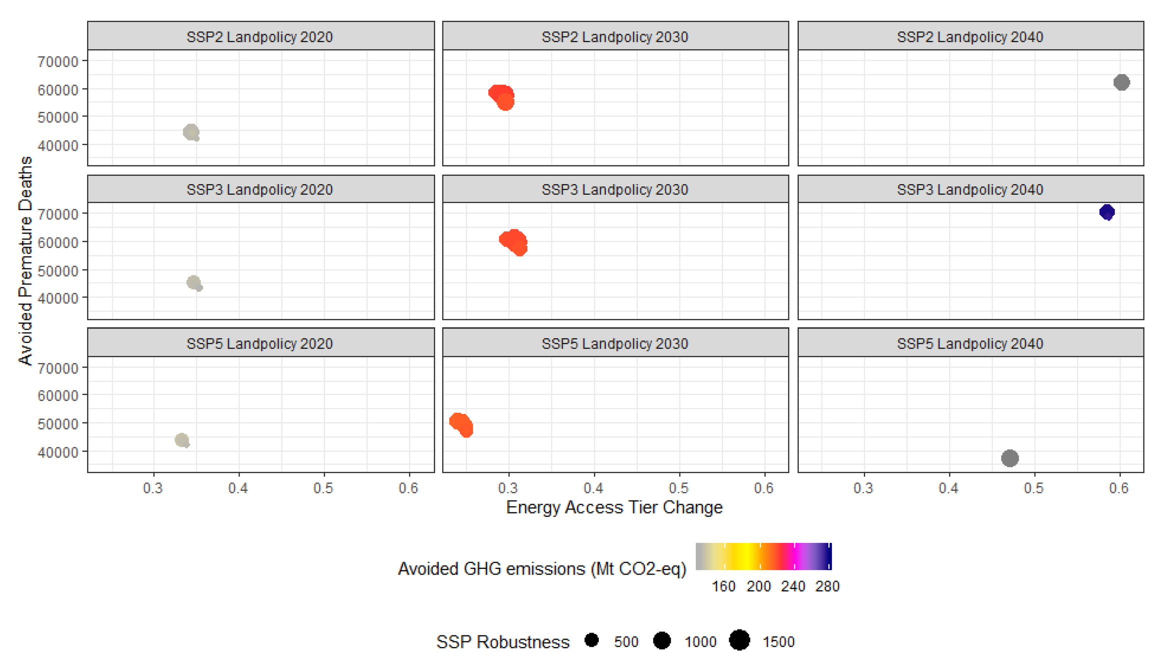

Figure 4: Technology subsidy portfolios for a "high" budget that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the land policy scenario and per SSP in 2020, 2030 and 2040. Size of dots illustrates robustness against stochastic modelling parameters uncertainty.

Mean socioeconomic scenario

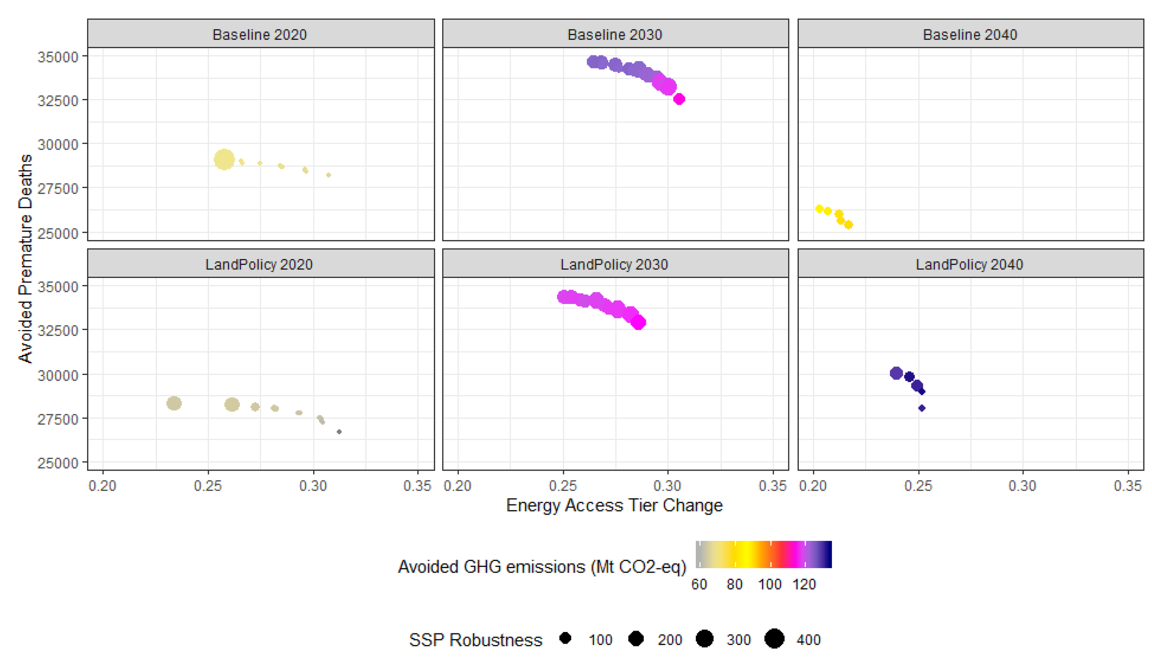

Figure 5: Technology subsidy portfolios for a "low" budget that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the baseline and land policy scenarios in 2020, 2030 and 2040. Size of dots illustrates robustness against SSP uncertainty.

- The behaviour of the optimal solutions across the different timescales and policy scenarios shows homogeneity with the analysis provided for the different SSPs.
- The technologies participate in optimal portfolios as follows:

Table 1: Total impact and contributions per technology for robust Pareto optimal subsidy portfolios in the 'midSSP' model.

Technology	SC	Energy Access	GHG Emissions	Mortality	SC	Energy Access	GHG Emissions	Mortality
LPG	2020 BL Low	23%	33%	18%	2020 LP Low	21%	33%	17%
PV		20%	8%	4%		24%	8%	5%
Biogas		52%	51%	75%		50%	51%	73%
Charcoal		1%	2%	2%		1%	2%	4%
Fuelwood		0%	0%	0%		0%	0%	0%
Ethanol		3%	5%	2%		3%	5%	2%
LPG	2030 BL Low	12%	13%	9%	2030 LP Low	20%	19%	14%
PV		17%	8%	5%		13%	6%	3%
Biogas		63%	72%	80%		64%	69%	78%
Charcoal		1%	1%	2%		3%	4%	4%
Fuelwood		0%	0%	0%		0%	0%	0%
Ethanol		7%	7%	5%		0%	2%	1%
LPG	2040 BL Low	31%	32%	24%	2040 LP Low	37%	37%	29%
PV		21%	18%	9%		16%	14%	7%
Biogas		48%	50%	67%		47%	49%	63%
Charcoal		0%	0%	0%		0%	0%	0%
Fuelwood		0%	0%	0%		0%	0%	0%
Ethanol								

Confirmation of SSP robustness

We select two optimal portfolios for each of the six Pareto curves of Figure 5, one with a higher robustness score and one with a lower robustness score.

We re-iterate these portfolios in the GCAM model to test whether the ranges of SDGs performances between the SSPs are smaller in case of a more robust portfolio.

In the majority of the scenarios we can confirm a smaller output range between SSPs, if a portfolio with a higher robustness score is chosen.

The range in outcomes **decreases by up to 16%** for the baseline scenario in 2020.

Table 2: Decrease in GCAM output ranges between SSPs for each of the three SDGs and policy scenarios in the "low" budget case when selecting a portfolio of higher robustness score.

Decrease in output ranges between SSPs

Scenario	GHG Emissions	Mortality	Energy Access
Baseline 2020	-1%	-4%	-16%
Baseline 2030	-4%	1%	-1%
Baseline 2040	2%	-1%	-11%
Landpolicy 2020	-2%	-4%	-14%
Landpolicy 2030	-4%	4%	0%
Landpolicy 2040	-5%	0%	-14%

Notes

- Results for 2020, 2030 and 2040 come from the same scenarios in GCAM, just at another time step. Therefore, subsidies applied in 2020 might somewhat affect the outcomes in 2030, for example in the case of subsidising PV systems which have a lifespan of 30 years (although costs and thus subsidies are annualised).
- We also see a temporal correlation effect with forest resources: by subsidising technologies that avoid the use of fuelwood or by applying a land policy in 2030, the available "unsustainable fuelwood" resources in 2040 increase, as this is seen an exhaustible stock—everything not consumed in one year, is available to consume at a later year.
- This is specifically the reason why the results in the baseline case are worse in 2040: as fuelwood is getting scarce, consumers will switch to other (and usually cleaner) alternatives, even without subsidies. Therefore, the impact of subsidies is lower, as they essentially represent a "waste" of money on subsidising for example LPG, while many households would have been using LPG anyway (but now it is simply cheaper for them).

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