Modeling a sustainable development pathway for climate action with REMIND-MAgPIE integrated assessment framework

- Miodrag Stevanović, Bjoern Soergel, Isabelle Weindl et al.
- (based on Soergel et al., 2021, Nature Climate Change, https://rdcu.be/csoFt)
- IEA-ETSAP webinar series, January 20, 2022

Soergel et al., 2021, Nature Climate Change, available here: https://rdcu.be/csoFt
Climate action and sustainable development

“...strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty”
Climate action and sustainable development

SDG 13: “Take urgent action to combat climate change and its impacts”
The world is not on track towards the targets

Projection for 2100 warming levels

Projection for 2030 poverty rates (pre-COVID)

Climate Action Tracker

-> 350 million people left in extreme poverty by 2030
(Soergel et al. 2021, Nature Communications)
Methodology

REMIND-MAgPIE
Integrate Assessment Modeling (IAM) Framework
Methodology: REMIND

REMIND (REgional Model on INvestments and Development):

- Modular, multiregional model with a detailed representation of the energy sector in the context of long-term macroeconomic developments.

- Intertemporal optimization with optimal aggregate macroeconomic technology-specific and energy investments (2005 - 2100), fully accounting for interregional trade in goods, energy carriers, and emissions allowances.

- Primary energy carriers:
  - Exhaustible: coal, oil, gas and uranium.
  - Renewable: hydro, wind, solar, geothermal, and biomass.

- > 50 technologies for conversion into final energy.
Methodology: REMIND

REMIND (REgional Model on INvestments and Development):

- **Greenhouse gas (GHG) emissions:**
  - long-lived GHGs
    - CO\(_2\) (fuel combustion and industrial processes)
    - CH\(_4\) (fossil fuel extraction and residential energy use)
    - N\(_2\)O (energy supply based on sources)
  - short-lived GHGs
    - CO
    - NO\(_x\)
    - volatile organic compounds – VOCs
- aerosols
  - SO\(_2\)
  - black carbon – BC
  - and organic carbon – OC
- Fluorinated gases (F-gases) and emissions from land-use change are included exogenously (endogenously) with different trajectories depending on the SSP and climate target.
- Analysis of **technology options** and **policy proposals** for climate change mitigation.
Methodology: MAgPIE

MAgPIE (Model of Agricultural Production and its Impact on the Environment):

- **Socio-economic model** of land-use and agricultural sector with **spatially explicit** and **dynamic** features
- Balance **biophysical** and **economic** side:
  - Bringing together biophysical (crop yields, terrestrial carbon stocks, nutrients, water) and economic (costs, prices, demand, policies) aspects
- Global agricultural & landuse **cost minimization**
  - Cost minimization of consecutive times slices with a length of 5-20 years until 2100
- **Optimal** land-use, trade and investment patterns
- Subject to agricultural **demand**
- Optimized agricultural **production** systems
- **Crop**, livestock and processed products
- **4 spatial** layers:
  - Global | 5-20 world regions | 2000 spatial clusters | 0.5°x0.5° grid
- Agricultural and land-use change **emissions**
- Climate change **mitigation** policy

Dietrich et al., Geosci. Model Dev., 2018
Methodology: MAgPIE

MAgPIE with Climate Change Impacts:

- Subject to bio-chemo-physical spatially explicit constraints
- Biophysical input on a geographic grid level (0.5°x0.5°)

- Climate models (GCMs):
  - temperature, precipitation…
- Vegetation-hydrology model LPJmL:
  - crop yields, available water and carbon fluxes
- Global land data: LUH, FAO
  - cropland, pasture, forest, natural vegetation area

- Potential yields of 16 crops
  - Irrigated & rainfed
- Water availability
- Terrestrial carbon content

Dietrich et al., Geosci. Model Dev., 2018
Energy and land-use system are interlinked.

- Resolution:
  - Flexible, default: 12 regions
  - Large countries as regions
  - Small countries grouped

Climate policy setting:
- Policy starts after 2020
- Staged accession: convergence to global carbon price in 2050
A sustainable development pathway for climate action within the UN 2030 Agenda

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Ambitious climate policies, as well as economic development, education, technological progress and less resource-intensive lifestyles, are crucial elements for progress towards the UN Sustainable Development Goals (SDGs). However, using an integrated modelling framework covering 56 indicators or proxies across all 17 SDGs, we show that they are insufficient to reach the targets. An additional sustainable development package, including international climate finance, progressive redistribution of carbon pricing revenues, sufficient and healthy nutrition and improved access to modern energy, enables a more comprehensive sustainable development pathway. We quantify climate and SDG outcomes, showing that these interventions substantially...
Modelling toolbox + indicators

- SSP scenarios as basis
- energy-economy-land-climate modelling framework REMIND-MAgPIE as workhorse
- additional downstream models for SDG indicators
  - Ocean (SDG 14)
  - Air pollution & health (SDG 3,11)
  - Inequality & Poverty (SDG 1,10)
  - Political institutions & violent conflict (SDG 16)

Goal: quantify indicators or meaningful proxies for all 17 SDGs

Soergel et al., Nature Climate Change
A sustainable development pathway (SDP)

Current trends and policy actions extrapolated (SSP2-NDC)

Soergel et al., Nature Climate Change
A sustainable development pathway (SDP)

Current trends and policy actions extrapolated (SSP2-NDC)

Intervention A
(Development)

Intervention B
(Resource efficiency)

New trends towards sustainable development (SSP1-NDC)

Soergel et al., Nature Climate Change
A sustainable development pathway (SDP)

Current trends and policy actions extrapolated (SSP2-NDC)

Intervention A (Development)

Intervention B (Resource efficiency)

Intervention C (Climate change mitigation)

Policies enacted to reach Paris climate goal (SSP1-1.5C)

New trends towards sustainable development (SSP1-NDC)

Soergel et al., Nature Climate Change
A sustainable development pathway (SDP)

Current trends and policy actions extrapolated (SSP2-NDC)

Intervention A (Development)

Intervention B (Resource efficiency)

Intervention C (Climate change mitigation)

Policies enacted to reach Paris climate goal (SSP1-1.5C)

New trends towards sustainable development (SSP1-NDC)

Intervention D (Food & energy)

Intervention E (Global equity)

Intervention F (Equality & poverty alleviation)

Holistic SD policy approach (SDP-1.5C)

Soergel et al., Nature Climate Change
Interventions towards sustainable development

- transition to zero hunger and healthy diets (EAT-Lancet) by 2050
- meet energy demand for decent living standards in developing regions
- reduce energy consumption in high-income regions
- additional energy and land system sustainability policies
Interventions towards sustainable development

**Intervention D (Food & energy)**

- transition to zero hunger and healthy diets (EAT-Lancet) by 2050
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**Intervention E (Global equity)**

- international redistribution of part of the carbon pricing revenues (‘climate & development finance’)
Interventions towards sustainable development

- **Intervention D (Food & energy)**
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  - meet energy demand for decent living standards in developing regions
  - reduce energy consumption in high-income regions
  - additional energy and land system sustainability policies

- **Intervention E (Global equity)**
  - international redistribution of part of the carbon pricing revenues (‘climate & development finance’)

- **Intervention F (Equality & poverty alleviation)**
  - national redistribution of carbon pricing revenues (+ int’l transfers) as climate dividend
Results: Comprehensive coverage of the SDG space
Redistribution policies funded from carbon pricing revenues reduce inequality and poverty.

Climate policy trade-off is more than compensated.
Effects of the different interventions: food

- Transition to healthy and sustainable nutrition (EAT-Lancet)
- Prevalence of underweight is substantially reduced (zero by 2050)
- Effect of climate policy on food prices is fully compensated.

Soergel et al., Nature Climate Change
Effects of the different interventions: land

Planetary boundaries in 2050

Large co-benefits of healthy and sustainable nutrition for multiple planetary boundaries.

Soergel et al., Nature Climate Change
● SDP scenario improves substantially over reference scenario across nearly all SDGs.
● Nonetheless: many targets are difficult to meet by 2030.
● Further progress until 2050 can close most of the gaps.

Soergel et al., Nature Climate Change
Regional SDG achievement and gaps (SDP 2030)

Soergel et al., Nature Climate Change
Conclusions

- development, resource efficiency and moderate lifestyle change + climate policies are insufficient to meet SDGs

- additional SD interventions required:
  - global cooperation: “climate & development” scheme
  - national redistributive policies funded from carbon pricing revenues (“policy linking”)
  - food & energy -> co-benefits of healthy diets for climate, land, water, nitrogen cycle, biodiversity

- => Substantial improvements towards nearly all SDGs

- comprehensive coverage of SDG space

- SDG achievement gaps remain in 2030, but can largely be closed by 2050
Thank you!

- REMIND: https://github.com/remindmodel/remind
- MAgPIE: https://github.com/magpiemodel/magpie
Back-up
REMIND-MAgPIE SDG coverage

scenario design:  
endogenous dynamics:  
post-processing:  
partial coverage:  
external models:  
from SSPs:  

IAM-related

non-IAM

in total: around 65 SDG indicators, all 17 SDGs covered at least partially
Interventions in the land and food system

**Current trends SSP2-NDC**
- Population
- GDP
- Trade
- Food demand: driven by SSP1 inputs and using functional forms aligned to the SSP1 storyline

**Intervention A (Development)**
- Population
- GDP
- Trade
- Food demand: driven by SSP1 inputs and using functional forms aligned to the SSP1 storyline

**Intervention B (Resource efficiency)**
- Increase in SNUPE
- More efficient AWMS
- More efficient LPS
- Phase-out of 1st-gen. bioenergy
- EFP

**Intervention C (Climate change mitigation)**
- peak budget: 900 Gt CO2 from 2011.
- Regionally differentiated price

**Intervention D (Food & energy)**
- transition to EAT-Lancet diet and zero mal-nourishment by 2050; food waste reductions to a maximum of 50% the current levels in high income regions
- Strong increase in SNUPE (75% by 2050; 80% by 2100)
- Increase in irrigation efficiency (on top of EFP)
- Protection of biodiversity hotspots
- Afforestation only in the tropics; maximum 500 Mha
- Maximum 100 EJ/yr 2nd-gen. bioenergy

**Intervention E (Global equity)**

**Intervention F (Equality & poverty alleviation)**

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SNUPE: soil nitrogen uptake efficiency
AWMS: animal waste management systems
LPS: livestock production systems
EFP: Environmental flow protection

Soergel et al., Nature Climate Change
Land-use & energy systems

SDP: Transition to sustainable diets lead to rapid reduction of agricultural emissions

- slightly (100 Gt) higher 1.5C-compatible CO\textsubscript{2} budget

- higher, SDG compatible energy demands in low-income regions, ambitious reductions in high-income regions

(Soergel et al. in prep. - please do not cite or share)
Global cooperation & equity, inequality & poverty

- SDP-1.5C: Carbon prices roughly halved compared to SSP1-1.5C

- Differentiated carbon prices & international climate finance: low policy costs for developing regions

- Redistribution of carbon pricing revenues reduces inequality and poverty

(Soergel et al. in prep. - please do not cite or share)
The role of the land and food for climate mitigation

SDG 13

- Agricultural CH4 and N2O emissions are reduced rapidly in the SDP scenario, allowing it to reach the 1.5°C target with a 100 Gt higher CO2 budget.
- Reduced demand pressure in the SDP allows for regrowth of natural vegetation and afforestation and turns the land-use system from a carbon source into a carbon sink.
- Sustainable food and energy systems reduce the need for carbon-dioxide removal techniques like BECCS (bioenergy with carbon capture and storage).

Soergel et al., Nature Climate Change