Climate change and mitigation in agriculture and forestry: An integrated assessment of impacts on poverty

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in collaboration with M. Gusti,...
Introduction

- Agriculture plays a key role in developing countries
  - Source of food in food insecure regions with limited market access
    - 70% of population of low income countries living in rural area
  - Source of income and economic growth
    - 60% of African labor force working in the agricultural sector

- Agriculture particularly exposed to climate change

- At the same time, large expectations for mitigation from the land use sectors
  - Direct non-CO₂ emissions reduction
  - Avoided CO₂ emissions and carbon sequestration
  - Biomass for energy
Outline

1. Socio-economic scenarios
2. Modeling approach
3. Climate change impacts: Scenarios and Results
4. Climate change mitigation: Scenarios and Results
5. Climate change impacts *versus* mitigation
6. Discussion
Scenarios: Shared Socio-economic Pathways

SSP4
- Fast growth in rich regions
- Slow growth in developing regions
- Inequality remains high
- Economies isolated
- Limited adaptive capacity

SSP5
- Rapid economic growth
- High energy demand
- Investment in human capital
- Slower population growth
- Globalized economy
Implications for crop yield development

World

World CRP17

GDP per cap (1000 USD)

Index

1960 2000 2040 2080

1000 500 200 100 50 20 10 5

SSP0 SSP1 SSP2 SSP3 SSP4 SSP5

t DM / ha

1960 2000 2040 2080

3.0 2.5 2.0 1.5 1.0 0.5 0.0

HIST; SSP0 SSP1 SSP2 SSP3 SSP4 SSP5
Different patterns of food demand

World

Food consumption (kcal/cap/day)

GDP_SSP4_Diet_SSP2

GDP_SSP5_Diet_SSP5

Legend:
- SUGAR
- ROOTS
- Pulses
- OSDVOL
- CEREALS
- PTEGGS
- MILK
- MGMEAT
- RMMEAT
GLOBIOM

- Global scale model based detailed spatial resolution (>200k cells)
- Partial equilibrium
  - Agricultural, wood and bioenergy markets
  - 30 world regions
  - Bilateral trade flows based on spatial equilibrium approach
- Bottom-up approach
  - Explicit description of production technologies a la Leontief
  - Technologies specified by production system and grid cell
- Linear programming approach
  - Maximization of consumer + producer (incl. trade costs) surplus
  - Non linear expansion costs
  - Optimization constraints
- Base year: 2000
- Time step: 10 years, time horizon: 2030/2050 but also 2100
Population, GDP, consumer preferences

Demand
- Food
- Fibers
- Energy
- Industry

MARKET & TRADE: EU + WORLD \(\rightarrow\) PRICES

Production
- EPIC
  - Crop model
  - Worldwide: 18 crops (FAO + SPAM)
  - Management systems: low/high input & irrigated
  - EU28: 9 additional crops, crop rotations.
  - Management options: fertilizer, irrigation & tillage

- RUMINANT
  - Digestibility model
  - 7 animals (FAO + Gridded livestock)
  - Conversion technologies
  - First generation biofuels
  - Second generation biofuels
  - Biomass power plants
  - 8 different systems
  - Feed intake
  - Animal production
  - GHG emissions

- BIOENERGY
  - Processing
  - MJ biofuel
  - MJ bioelectric
  - Coproducts

- G4M
  - Global Forest model
  - Harvestable wood
  - Harvesting costs

Land use
- Cropland
- Grassland
- Short rotation plantations
- Managed forest
- Natural forest
- Other natural land

Gridded representation of world land use
Climate change scenarios

![CMIP5 models, RCP scenarios graph]

- Historical (42)
- RCP 2.6 (26)
- RCP 4.5 (32)
- RCP 6.0 (17)
- RCP 8.5 (30)

Global surface warming (°C) vs. Year (1900-2100)
Climate change impacts modeling chain

- 2 Representative Concentration Pathways (RCP)
  - Strong climate change: RCP 8.5 (radiative forcing 8.5 W/m²)
  - Contained climate change: RCP 2.6 (radiative forcing 2.6 W/m²)

- 5 General Circulation Models
  - HadGEM2-ES, IPSL-CM5A-LR, GFDL-ESM2M,
    MIROC-ESM-CHEM, NorESM1-M

- 1 Global Gridded Crop Model: EPIC
CC impacts on crop yields - Global

[% variation t dm]

World 2050

World 2080

Yield change

Climate models
- HadGEM2-ES
- IPSL-CM5A-LR
- GFDL-ESM2M
- MIROC-ESM-CHEM
- NorESM1-M

RCP 2.6  RCP 8.5  no CO₂

RCP 2.6  RCP 8.5  no CO₂
Propagation of CC shocks through global markets
Price impact

World SSP4 2050

LatinAmericaCarib SSP4 2050

SubSaharanAfr SSP4 2050

SouthAsia SSP4 2050

Average price change

RCP 2.6 RCP 8.5

Climate models
- HadGEM2–ES
- IPSL–CM5A–LR
- GFDL–ESM2M
- MIROC–ESM–CHEM
- NorESM1–M

World SSP5 2050

LatinAmericaCarib SSP5 2050

SubSaharanAfr SSP5 2050

SouthAsia SSP5 2050

Average price change

RCP 2.6 RCP 8.5
Food consumption per capita change

World SSP 4 2050
Latin America Carib SSP 4 2050
Sub-Saharan Afr SSP 4 2050
South Asia SSP 4 2050

World SSP 5 2050
Latin America Carib SSP 5 2050
Sub-Saharan Afr SSP 5 2050
South Asia SSP 5 2050

Climate models:
- HadGEM2-ES
- IPSL-CM5A-LR
- GFDL-ESM2M
- MIROC-ESM-CHEM
- NorESM1-M
Climate change mitigation scenarios

Global Mean Warming

Default baseline

450 ppm

Source: Kriegler et al. 2014
Scenarios: Mitigation

- Based on EMF 27 scenarios set up (Kriegler et al. 2014)
  - Technology assumptions

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FullTech</td>
<td>all modeled technologies included, reference energy intensity improvements</td>
</tr>
<tr>
<td>LowEl</td>
<td>low energy intensity: 20-30% lower final energy demand in 2050 and 35-45% in 2100 compared to the reference case</td>
</tr>
<tr>
<td>NoCCS</td>
<td>carbon capture and storage excluded from technology portfolio in all sectors</td>
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<tr>
<td>NucOff</td>
<td>phase out of nuclear energy with no new nuclear power plants built beyond those under construction; existing plants operated until end of their technical lifetime</td>
</tr>
<tr>
<td>LimSW</td>
<td>share of electricity production from intermittent solar and wind technologies (wind, solar PV and CSP) limited to 20%</td>
</tr>
<tr>
<td>LimBio</td>
<td>global primary bio-energy supply – including purpose grown crops, residues and municipal solid waste, but excluding traditional biomass – limited to 100 EJ/yr</td>
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<tr>
<td>Conv</td>
<td>Combined LimSW &amp; LimBio</td>
</tr>
<tr>
<td>EERE</td>
<td>Combined LowEl &amp; NoCCS &amp; NucOff</td>
</tr>
<tr>
<td>LimTech</td>
<td>Combined NoCCS &amp; NucOff &amp; LimSW &amp; LimBio</td>
</tr>
</tbody>
</table>

- Policy dimension: Baseline, 450 CO₂eq, 550 CO₂eq
**Scenarios: Mitigation**

- CC & Poverty scenarios: Drivers from MESSAGE (McCollum et al. 2014)

![Graph showing carbon price and bioenergy demand trends](attachment:image.png)

- Applied to SSP4 and SSP5 until 2100, here focus on 2050
Scenarios: Mitigation

- **CC & Poverty scenarios**

<table>
<thead>
<tr>
<th></th>
<th>Policy scenario</th>
<th>Bioenergy demand</th>
<th>Carbon price</th>
<th>Carbon sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>REFL</td>
<td>Base FullTech</td>
<td>Base FullTech</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>FULL</td>
<td>450 Fulltech</td>
<td>450 Fulltech</td>
<td>450 Fulltech</td>
<td>AFOLU</td>
</tr>
<tr>
<td>LOWE</td>
<td>450 LowEI</td>
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</tr>
<tr>
<td>FAGR</td>
<td>450 Fulltech</td>
<td>Base Fulltech</td>
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<td>Agri Non-CO2</td>
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<tr>
<td>FLUC</td>
<td>450 Fulltech</td>
<td>Base Fulltech</td>
<td>450 Fulltech</td>
<td>LUC CO2</td>
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<tr>
<td>FBIO</td>
<td>450 FullTech</td>
<td>450 FullTech</td>
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</tbody>
</table>

- Applied to SSP4 and SSP5 until 2100, here focus on 2050
AFOLU emissions [MtCO2eq]

- AFOLU emissions globally to be reduced by 61% to today (mostly LUC)
- 47% of reduction coming from LAM and 23% from AFR
Biomass supply for bioenergy multiplied by 4 in FULL compared to REFL

- 16% to come from LAM and 27% from AFR
- Potential source of new income
Crop production [tDM]

- Increase by 84% globally, 122% in SAS and 155% in MEA and 241% in AFR
- Increase lower by 6% in MEA and 16% in SAS under FULL
- Increase lower by 34% in MEA and 22% in SAS under LIMB
Livestock production to increase by 81% globally, 205% in SAS and 227% in AFR

- Bovine meat, small ruminant meat, and small ruminant milk production -20%
- Poultry production -4%
Globally, intensive systems share increase from 33% to 40% in FULL and LIMB.

In AFR, intensive systems represent 36% under FULL compared to 26% in REFL.
- Industrial round wood production would increase by 76% between 2000 and 2050.
- Little effect of mitigation policies globally (+/-5%).
  - Complementary with bioenergy in LAM and competing in SSA.
Sectorial revenue and CO2 tax [billion USD2000]

- Total revenue net tax +21% in FULL and 6% only in LIMB
- LAM: +31% – agriculture and forest carbon sequestration
- AFR: +31% – biomass for bioenergy
Total abatement calorie cost (TACC)

Source: Havlík et al. 2014
Impact versus mitigation: Crop prices

World SSP4 2050

World SSP5 2050
Impact versus mitigation: Food supply

World SSP4 2050

World SSP5 2050

Food consumption change (kcal/c/d)

Scenarios climate change

- HadGEM2-ES
- IPSL-CM5A-LR
- GFDL-ESM2M
- MIROC-ESM-CHEM
- NorESM1-M

Scenarios mitigation

- FULL
- LOWE
- LIMB
- FAGR
- FLUC
- FBIO

RCP 2.6  RCP 8.5  Mitigation

RCP 2.6  RCP 8.5  no CO2  Mitigation
Discussion

- Climate change impacts low income countries more than some other regions due environmental context, and vulnerability to change in food prices

- Mitigation presents opportunities for land use sectors
  - New demands (biomass)
  - Payments for carbon sequestration
  - Higher prices (producers)

- Mitigation presents also challenges
  - Higher production cost
  - Restructuring of the sectors
  - Higher prices (consumers)

- Sectors and regions affected very differently
  - Forestry tends to benefit and agriculture to loose
  - Developed regions marginally affected and least developed most affected

- If mitigation not implemented carefully, potentially worse effects than climate change itself, at least in medium term
Thank you!

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