Including albedo affects in IAM scenarios

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What are the Questions?

- How do we design a set of experiments that are interesting and relevant to three different research communities (IAM, IAV, Climate)?
  
  Effects of land use and land use change on climate.

- How do we improve upon the CMIP5 process?
  
  Including albedo in IAM’s definition of radiative forcing.
EFFECTS OF LAND USE AND LAND USE CHANGE ON CLIMATE
We run two scenarios: RCP 4.5 (UCT) and Rep 4.5 (FFICT).

We hold total CO$_2$ and non-CO$_2$ GHG emissions fixed and run the two scenarios that limit year 2095 radiative forcing to 4.5 Wm$^{-2}$.

In **RCP 4.5 (UCT)** we use the original RCP 4.5 land use.

In **Rep 4.5 (FFICT)** we use the alternative land use—the ONLY thing that is different between the two.

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**Quantifying the effect of land cover on temperature: Results using GCAM & CESM**

Calvin et al. In review
Quantifying the effect of land cover on temperature: Results using GCAM & CESM

- Large change—1Wm\(^{-2}\) change in climate forcing from the alternative (Rep 4.5, FFICT) land-use policy assumption.

- Change is almost immediate
  - Time scale of the change from direct physical effects is a decade—in addition to changes in the atmospheric composition of GHGs.
  - Well within a decadal (up to 40-year) time horizon.

**Comparison between Rep 4.5 and RCP 4.5**

Rep 4.5 is shown to be cooler, with rapid transition under Rep 4.5
The SSPs provide a wide range of land cover estimates within a single model (GCAM) without climate policy.
Reaching a climate target (e.g., RCP4.5) requires climate policy, the specification of which will effect land cover.

<table>
<thead>
<tr>
<th>NAME</th>
<th>SSP</th>
<th>RF</th>
<th>ACCESSION</th>
<th>LAND POLICY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP1_AFFOREST</td>
<td>SSP1</td>
<td>4.5 W/m(^2)</td>
<td>Immediate</td>
<td>LUC emissions priced at same level as energy-related emissions.</td>
</tr>
<tr>
<td>SSP3_AFFOREST</td>
<td>SSP3</td>
<td>4.5 W/m(^2)</td>
<td>Immediate</td>
<td>LUC emissions priced at same level as energy-related emissions.</td>
</tr>
<tr>
<td>SSP3_DELAY</td>
<td>SSP3</td>
<td>4.5 W/m(^2)</td>
<td>Delay</td>
<td>LUC emissions priced at same level as energy-related emissions when participating.</td>
</tr>
<tr>
<td>SSP3_REDD</td>
<td>SSP3</td>
<td>4.5 W/m(^2)</td>
<td>Immediate</td>
<td>LUC emissions unpriced. Forestland cannot be converted to bioenergy.</td>
</tr>
<tr>
<td>SSP3_DEFOREST</td>
<td>SSP3</td>
<td>4.5 W/m(^2)</td>
<td>Immediate</td>
<td>LUC emissions unpriced. All land is available for bioenergy production.</td>
</tr>
</tbody>
</table>
Layering different mitigation policies to reach RCP4.5 leads to a wider range of land cover scenarios within one model (GCAM).
These scenarios could differ both globally and regionally.
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2095 Forest Cover in SSP3_DEFOREST
(Fraction of Region)
We could choose scenarios with the same atmosphere, but different land cover to explore economics, science, and impacts.

- IAM community may be interested in cost of mitigation and energy system dynamics under different land-based mitigation options.

- Climate modeling community may be interested in effect on temperature and precipitation under different land cover scenarios.

- IAV community may be interested in effect on ecosystem productivity and disturbances under different land cover scenarios.
INCLUDING ALBEDO IN IAM’S DEFINITION RADIATIVE FORCING.
Incorporating albedo into GCAM

- **Albedo factors:**
  - We use CESM to compute the radiative forcing due to land conversion from woody vegetation (forests and/or shrublands) to non-woody vegetation (grassland and/or cropland).
  - We then compute change in top-of-atmosphere radiative flux change that would result from conversion of woody vegetation to non-woody vegetation using an offline radiative transfer model.

- **Land conversion:**
  - At each timestep, for each region, we compute the amount of land that is converted from woody vegetation to non-woody vegetation in GCAM.

- **Albedo:**
  - The change in albedo is computed by multiplying the albedo factors and the amount of land converted for each region, and then summing over the regions.
  - This change in albedo is passed into MAGICC.
Albedo Forcing Factors by GCAM Region
Incorporating these factors into GCAM results in different albedo across even reference scenarios.
The variation across RCP4.5 replications is as much as 0.35 W/m².
Including albedo in our RCP replications *could* ensure that global climate is more similar across scenarios.

- In this way, we would increase consistency across RCP replications at a global level.

- However, quantifying regional climate is probably still outside the realm of IAMs and would need climate model experiments.
Revisiting the GCAM-CESM land cover experiments: Regional Temperature

Regional & Local changes are much larger than the global changes.

- Cooling in high latitudes
- Warming in other regions.

Comparison between Rep 4.5 and RCP 4.5 (difference RCP 4.5 less Rep 4.5). Rep 4.5 is shown to be cooler, but with significant regional differences and some regions warmer under Rep 4.5.
Revisiting the GCAM-CESM land cover experiments: Regional Precipitation

Comparison between Rep 4.5 and RCP 4.5 (difference RCP 4.5 less Rep 4.5). We observe significant regional differences and some regions wetter and some dryer under Rep 4.5 as compared to RCP 4.5.
What are the Questions?

- How do we design a set of experiments that are interesting and relevant to three different research communities (IAM, IAV, Climate)?
  
  Option: Choose a set of scenarios that isolate the effects of land use and land use change on climate.

- How do we improve upon the CMIP5 process?
  
  Option: Adjust the definition of radiative forcing in the IAMs to include albedo, increasing consistency across RCP replications.
DISCUSSION
The SSPs: Underlying Assumptions

POPULATION

GDP per CAPITA

- SSP1
- SSP2
- SSP3
- SSP4
- SSP5
## GCAM DRAFT SSP Input Assumptions

### New SSP Pop & GDP

<table>
<thead>
<tr>
<th>SSP5 Development First</th>
<th>SSP4 Inequality</th>
<th>SSP3 Fragmentation</th>
<th>SSP2 Middle of the Road</th>
<th>SSP1 Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7 (4th)</td>
<td>11.8 (2nd)</td>
<td>14.1 (1st)</td>
<td>9.8 (3rd)</td>
<td>7.2 (5th)</td>
</tr>
<tr>
<td>1,205 (1st)</td>
<td>461 (4th)</td>
<td>355 (5th)</td>
<td>684 (3rd)</td>
<td>770 (2nd)</td>
</tr>
</tbody>
</table>

### Energy Service Demands
- **Low**
- **Medium**
- **High**

### End-Use Technology
- **High**
- **Medium**
- **Low**
- **Low / High**

### Nuclear / CCS
- **Low**
- **Medium**
- **Medium**
- **Mixed**

### Renewable Technology
- **High**
- **Medium**
- **Low**
- **High**

### Fossil Fuel Extraction
- **Low**
- **Medium**
- **High**
- **Medium**

### Crop Yield Improvement
- **High**
- **Medium**
- **Low**
- **Low / Medium**

### Notes
- **2100 Population [billion] (IIASA)**
- **2100 GDP [trillion 2005 USD, PPP] (OECD)**

### Technology
In delayed accession scenario, Former Soviet Union and Middle East Never Join the global carbon market.