Documentation of results submitted for the LUC4C model inter-comparison project (Phase-1)

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Note: Model technical description: see Meiyappan et al. (2014). The model has no specific name, and goes by the reference. If a model name is preferable, please let me know.

Basic Model Details:

Extent: Global
Spatial Resolution: 0.5 deg lat/lon (WGS84 datum, no projection).
Data type representation: Fractional land use within each land grid cell.
Land-cover types modeled: Cropland and Pastureland (only generic categories; corresponds to “c” and “p” in fig. 1 of LUC4C protocol document)
Model time-step: Annual

Modeling approach & Simulations for LUC4C:

In our spatial land use allocation model, the globe is split into 9 regions (see Fig. 1 of Meiyappan et al. (2014)) consistent with the regions used in the socioeconomic model PET (O’Neill et al., 2010). For future scenarios, the total aggregate demand for cropland and pastureland for each of the 9 regions and for each year between 2005 and 2100 (demands as projected by IAMs such as PET or GCAM) is given as input to the spatial land use allocation model. The model allocates the aggregate demand for each region to individual grid cells within that region. The model allocation is based on four factors: land use patterns in the previous time-step (temporal autocorrelation), land use patterns in the neighboring grid cells (spatial autocorrelation), land-use competition, and a set of grid-cell specific (and time-varying) biophysical (e.g. climate) and socioeconomic driving factors (e.g. population). Some biophysical factors such as soil and terrain conditions are kept static with time.

We first estimated the model parameters (e.g. importance of each driving factor in determining land use patterns, parameters that determine the importance spatial and temporal autocorrelation, etc.) using 106 years of historical data (1900-2005) for land use and its driving factors. Once we have estimated the model using historical data, the estimated model parameters are used for future scenarios as described in the above paragraph.

We know there are considerable uncertainties in spatial estimates of historical land use patterns. For example, the HYDE database is just one realization of what could have happened in the past. The other well-known Ramankutty and Foley (1999) estimates differ significantly from HYDE database (Meiyappan and Jain, 2012; Goldewijk and Ramankutty, 2004). To account for this uncertainty, we estimated two sets of model
parameters based on HYDE and Ramankutty’s reconstruction (but using the same set of historical driving factors for both estimates).

I have uploaded a total of 8 simulation results covering 4 scenarios (SSP3, SSP5, RCP4.5, and RCP8.5): two simulations for each scenario using the two sets of estimated model parameters (one based on HYDE, and the other based on Ramankutty’s reconstruction). Therefore, the differences in resulting spatial maps between the two simulations for a given scenario are attributable to uncertainties in our historical estimates of cropland and pastureland. All simulations cover the time period 2005-2100.

Further details on the 8 simulations submitted are summarized in the following table.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Simulation</th>
<th>Historical LU data used for estimating model parameters</th>
<th>Historical driving factors used for estimating model parameters</th>
<th>Source of future aggregate land demands for 9 world regions (IAM)</th>
<th>Future climate data used (Model-scenario)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP3</td>
<td>Sim1</td>
<td>RF*</td>
<td>Historical data as used in Meyappan et al. (2014).</td>
<td>GCAM</td>
<td>CCSM-RCP8.5*</td>
</tr>
<tr>
<td></td>
<td>Sim2</td>
<td>HYDE</td>
<td></td>
<td>GCAM</td>
<td>CCSM-RCP8.5</td>
</tr>
<tr>
<td>SSP5</td>
<td>Sim3</td>
<td>RF</td>
<td></td>
<td>GCAM</td>
<td>CCSM-RCP8.5</td>
</tr>
<tr>
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<td>Sim4</td>
<td>HYDE</td>
<td></td>
<td>GCAM</td>
<td>CCSM-RCP8.5</td>
</tr>
<tr>
<td>RCP4.5</td>
<td>Sim5</td>
<td>RF</td>
<td></td>
<td>GCAM</td>
<td>CCSM-RCP4.5</td>
</tr>
<tr>
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<td>Sim6</td>
<td>HYDE</td>
<td></td>
<td>GCAM</td>
<td>CCSM-RCP4.5</td>
</tr>
<tr>
<td>RCP8.5</td>
<td>Sim7</td>
<td>RF</td>
<td></td>
<td>MESSAGE</td>
<td>CCSM-RCP8.5</td>
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<tr>
<td></td>
<td>Sim8</td>
<td>HYDE</td>
<td></td>
<td>MESSAGE</td>
<td>CCSM-RCP8.5</td>
</tr>
</tbody>
</table>

# CCSM – Climate Community System Model (from NCAR).

For all future scenarios, only climate variables were kept transient for the future. The spatial patterns of socioeconomic variables (e.g. population) were assumed to be same as year 2005, because these estimates are not yet available (especially for SSPs).

To be clear about the relevance of RCP scenario climate used with respect to SSPs (as explained to me by Brian O’Neill, NCAR): the GCAM scenarios for the two SSPs were produced without considering climate impacts of any kind. They are "no climate" baselines.

The relation to RCP8.5 climate is straightforward for SSP5. The SSP5 baseline scenario produces forcing that is consistent with RCP8.5, so it is consistent to use RCP8.5 climate with SSP5 baseline for determining agricultural patterns.

An important caveat to note with respect to the SSP3 land use simulations uploaded: The SSP3 baseline produces something like 7 W/m² and is not consistent with RCP8.5
forcing. Nevertheless, for time being, I have used RCP8.5 climate to determine spatial land use patterns for SSP3 baseline scenario, which is an inconsistent assumption. Ideally, for full consistency, we should have introduced an extra step in which we first produce a high emissions variant of SSP3 that is consistent with the forcing in RCP8.5. This high emission SSP3 will have a somewhat higher GDP, CO2 emissions, and possibly some small change in land use relative to the GCAM SSP3 baseline (used currently). After this high emissions SSP3 baseline is created, we should have introduced RCP8.5 climate impacts on agriculture land use patterns as described above for SSP5. So, it is important to note that the cropland and pastureland areas for SSP3 (consistent with RCP8.5 forcing) would be lesser than the SSP3 baseline land demands (which I have used currently with RCP8.5 climate).

**Data organization and format:**

The files are organized as follows:

1. In the first level, there are 8 folders named as per simulation number (consistent with column 2 of above table). For example, Sim1 folder will contain all the results from Simulation 1 from the above table.
2. In the second level (i.e. within each of the 8 folders), there will be 4 sub-folders based on the year of data (corresponding to 2005, 2030, 2050, and 2100).
3. In the third level (i.e. within each year folder), there will be 9 ascii files. The 9 ascii files contain the downscaled land use results for the 9 aggregate world regions used by our land use allocation model. The ascii file names are self-explanatory. Each ascii file will contain the cropland and pastureland area of each land grid cell within the aggregate region.

**The ascii file format is as below:**

1. The ascii files submitted are in the native resolution of the outputs produced by the model.
2. There are 6 columns in each ascii files with several rows. Each row corresponds to a land grid cell within that aggregate region. The six columns give the grid cell attributes.
   a. First column - Unique grid number (you can disregard this).
   b. Second column – Centre point of the latitude of the grid cell
   c. Third column – Centre point of the longitude of the grid cell
   d. Fourth column – Grid cell area (all grid cells are 100% land)
   e. Fifth column – Cropland area
   f. Sixth column – Pastureland area

Note that fractional areas of cropland can be calculated as column 5 divided by column 4 (similarly column 6/column 4 for pasture). Column 4 – Column 5 – Column 6 gives the area of “Others” category (i.e. anything other than crop and pasture that occupies rest of the grid area. This could be forests, urban, barren land, etc.).
When you combine and plot the information from the 9 ascii files, you will get the global results. I have shown some projected land use patterns from the results submitted in the next section.

**Sample Plots:**
Note: 2005 is the starting year of all simulations. So, the cropland and pastureland maps for 2005 across all the 8 simulations will be identical.

I have included maps for 2005, 2030, 2050, and 2100 for all 8 simulations along with data submitted (in a separate folder in second level). Here, showing just 2005 and 2100 maps for comparison.

*All units in figures are in percentage of grid cell area.*
Sim 2 – SSP3 scenario, Model estimated using HYDE data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)

Sim 3 – SSP5 scenario, Model estimated using RF data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)

Sim 4 – SSP5 scenario, Model estimated using HYDE data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)
Sim 5 – RCP4.5 scenario, Model estimated using RF data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)

Sim 6 – RCP4.5 scenario, Model estimated using HYDE data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)

Sim 7 – RCP8.5 scenario, Model estimated using RF data
(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)
Sim 8 – RCP8.5 scenario, Model estimated using HYDE data

(a) PREDICTED MAP FOR CROPLAND (2100 A.D.)
Sim 1 – SSP3 scenario, Model estimated using RF data

(b) PREDICTED MAP FOR PASTURELAND (2005 A.D.)

Sim 2 – SSP3 scenario, Model estimated using HYDE data

(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)
Sim 3 – SSP5 scenario, Model estimated using RF data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)

Sim 4 – SSP5 scenario, Model estimated using HYDE data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)

Sim 5 – RCP4.5 scenario, Model estimated using RF data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)
Sim 6 – RCP4.5 scenario, Model estimated using HYDE data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)

Sim 7 – RCP8.5 scenario, Model estimated using RF data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)

Sim 8 – RCP8.5 scenario, Model estimated using HYDE data
(b) PREDICTED MAP FOR PASTURELAND (2100 A.D.)
Model Reference


References cited in text

