Land-use climate feedbacks in an Integrated Earth System Model (iESM): GCAM Human Activities Scenario Development

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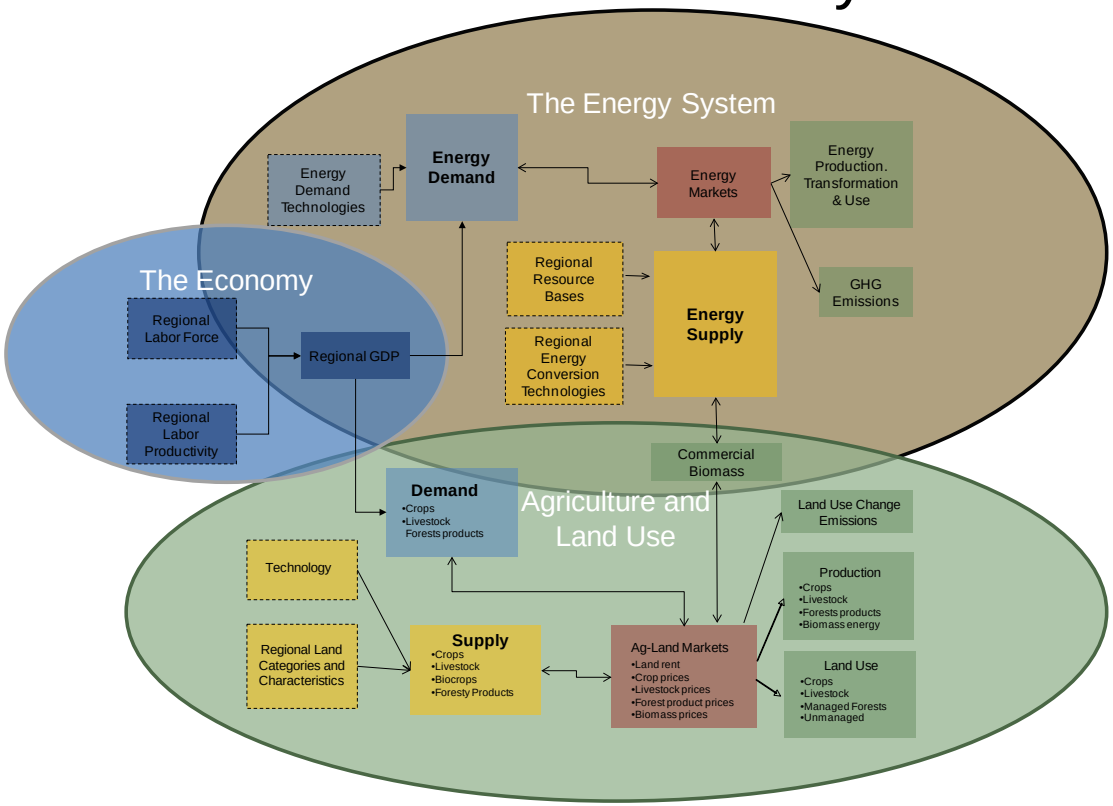
THE GLOBAL CHANGE ASSESSMENT MODEL (GCAM)

GCAM is an integrated assessment model

GCAM human Earth systems

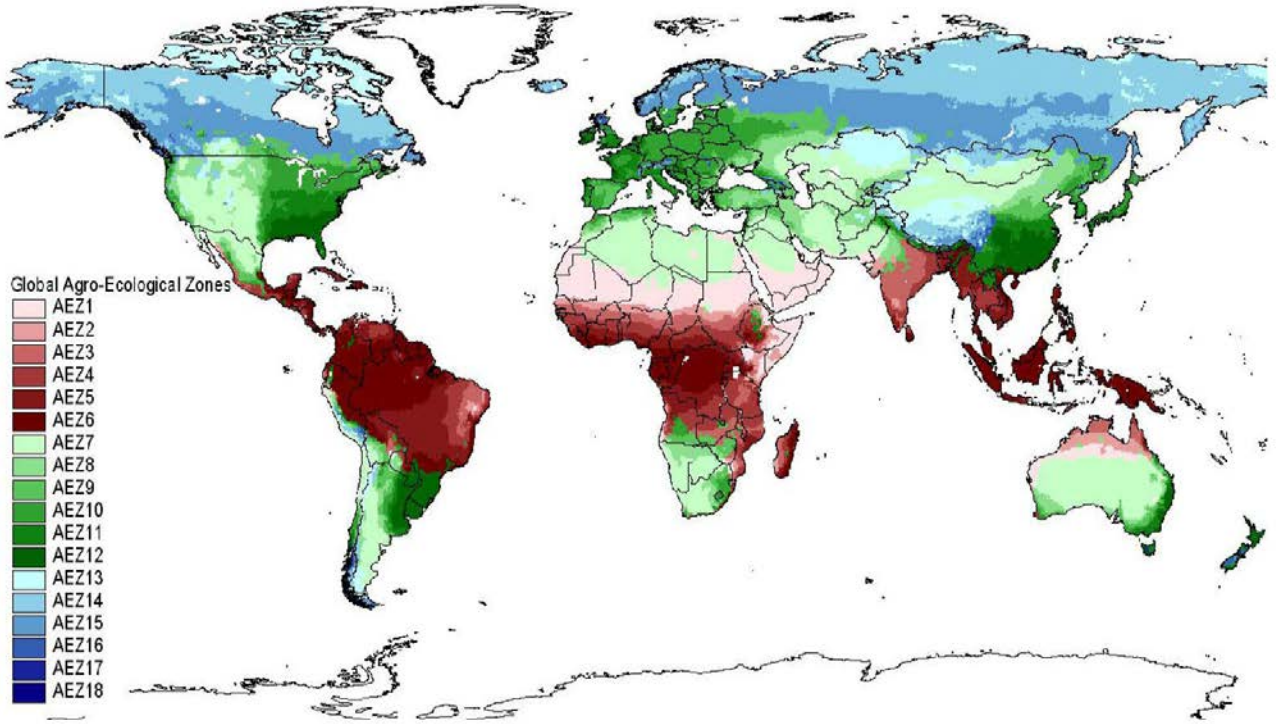


GCAM has 14 Geo-Political Regions

- **Open source model.**
- **Research model.**
- **The GCAM human Earth systems model has Economic, Energy and Land-use systems.**
- Physical and Technological detail in Energy and Ag/Land.
- Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonaceous aerosols, reactive gases, sulfur dioxide.
- **Runs through 2100+ in 5-year time-steps (though time step is variable).**

GCAM 3.0 Agriculture & Land Use Model

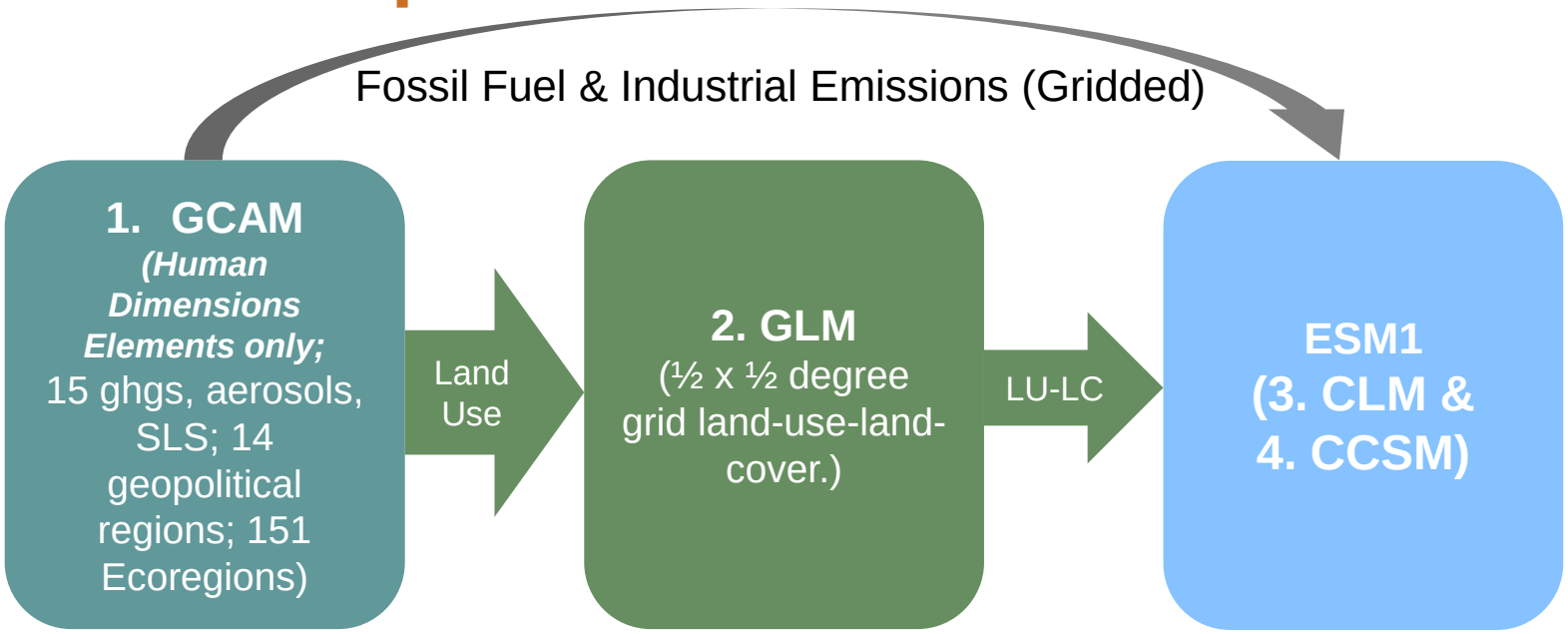
- In GCAM 3.0 core version, the world's land is divided into ***151*** regions based on agro-ecosystem zones (AEZs) and our 14 geopolitical regions
  - Key for iESM in modeling effect of climate impacts on human land use activities



Source: Ramankutty; GTAP

IESM EXPERIMENT 0

The iESM Experiment 0



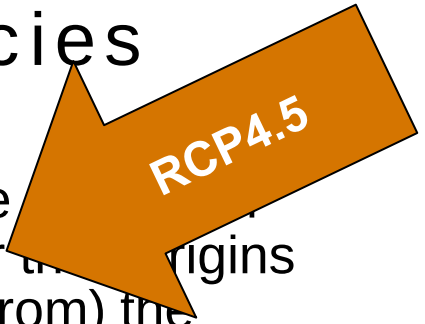
- **Experiment 0:** Compare RCP 4.5 (and its assumed economically efficient emissions mitigation) with an alternative 4.5 Wm^{-2} scenario that *does not* include a terrestrial mitigation instrument.
  - Further experiments will progressively include more interactive model integration with impacts fed back into GCAM altering its modeling of human activities and economics

iESM Experiment 0 uses the RCP4.5…

	Description	*Publication – IA Model*
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO_2 eq) by 2100.	(Riahi et al., 2007) **MESSAGE**
RCP6	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO_2 eq) at stabilization after 2100	(Fujino et al., 2006; Hijioka et al., 2008) **AIM**
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 (~650 ppm CO_2 eq) at stabilization after 2100	(Clarke et al., 2007; Smith and Wigley, 2006; Wise et al., 2009) **GCAM**
RCP3-PD^2	Peak in radiative forcing at ~ 3 W/m^2 (~490 ppm CO_2 eq) before 2100 and then decline (the selected pathway declines to 2.6 W/m^2 by 2100).	(Van Vuuren et al., 2007a; van Vuuren et al., 2006) **IMAGE**

…with two different land use policies

Two alternative land use policies



1. Universal carbon tax (UCT)—in this regime [illegible] emissions are valued equally regardless of either [illegible]rigins or the activity that introduces it to (or removes it from) the atmosphere.

   This is a strictly efficient policy where the CO_2 implications of all activities in the energy and agriculture systems are considered equally.

2. Fossil fuel and industrial carbon tax (FFICT)—in this regime only fossil fuel and industrial carbon emissions are valued. Bioenergy is treated as having no net carbon. Terrestrial carbon emissions are valued at **zero**.

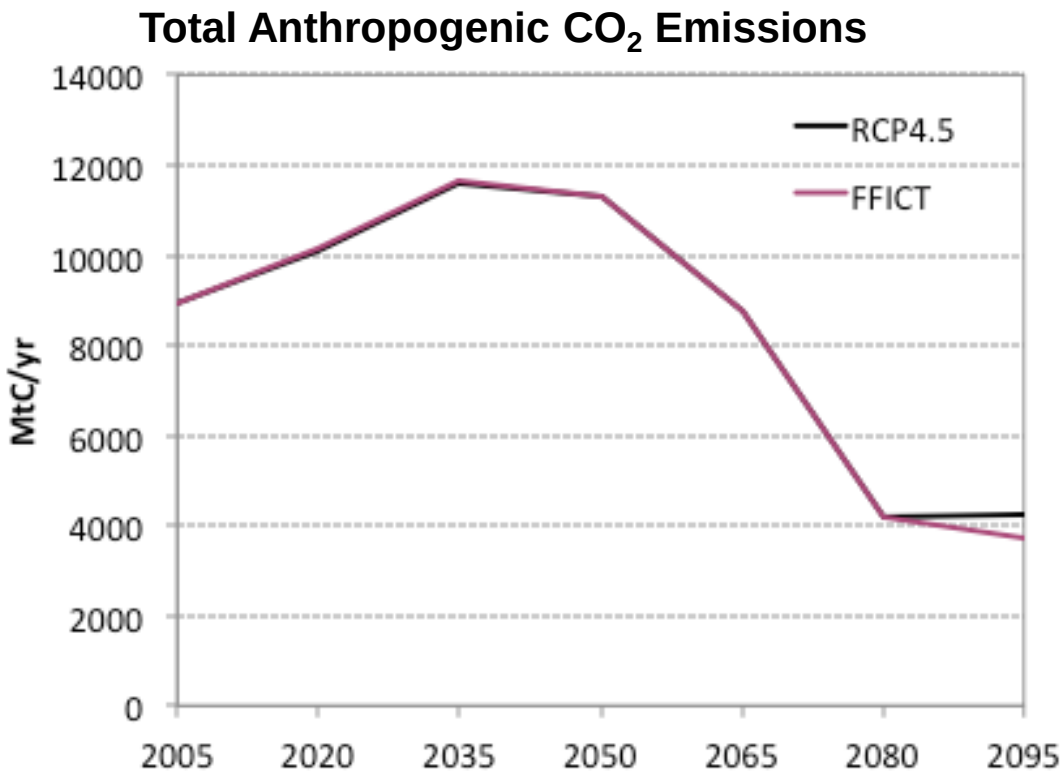
   In other words, the FFICT has includes no consideration of terrestrial mitigation instruments, although the effects of changes in terrestrial system are a major factor in CO_2 emissions..

GCAM provides CESM with land cover patterns and emissions/concentrations from its modeling of human activities

- GCAM provides CESM with:
  - Land cover by grid cell (with some help from GLM)
  - CO_2 and other gas emissions/concentrations results
    - Gridded pollutant (e.g., BC, OC, SO_2) and ozone precursor emissions (e.g., CH_4)
    - Global emissions for other GHGs (CO_2, N_2O)

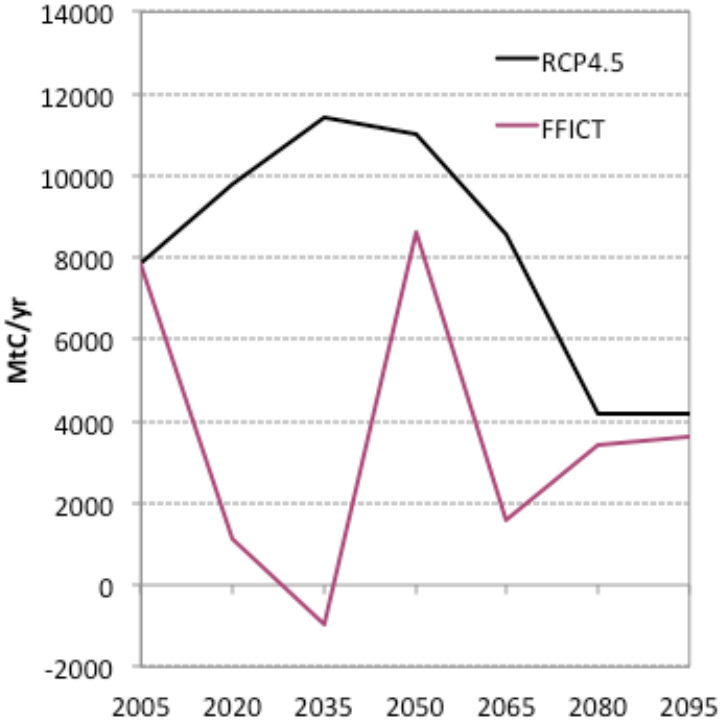
- For iESM Experiment 0, we are holding CO_2 emissions/concentrations between the two scenarios constant - but the land cover will be very different in the second scenario in the absence of the terrestrial mitigation instrument.
  - That is, the second scenario does not include terrestrial mitigation instrument, so it will achieve this CO_2 emissions path in a different manner with different results for energy and land cover.

We constrained total anthropogenic CO_2 emissions in the FFICT to the RCP4.5 levels.

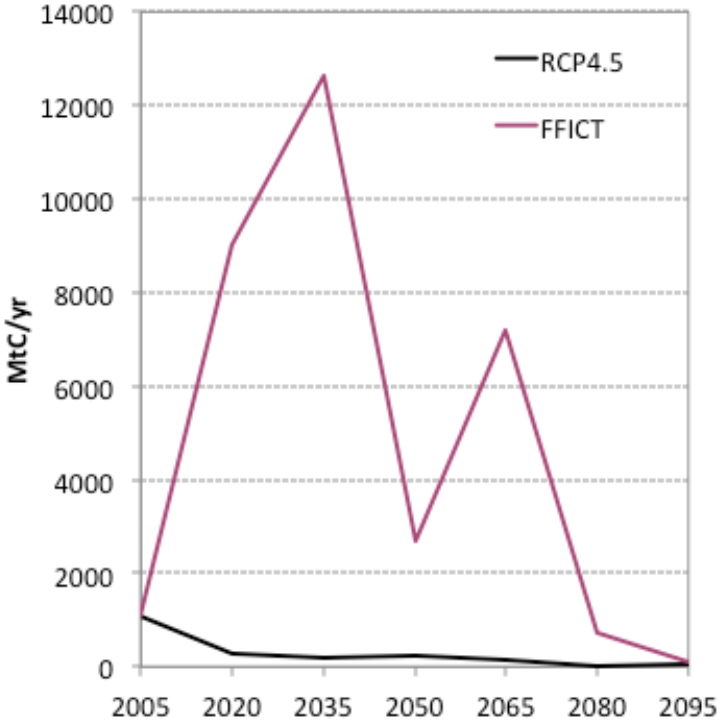


Land policy affects the fraction of total anthropogenic CO_2 emissions that come from fossil fuel and industry…

Fossil Fuel & Industrial CO_2 Emissions

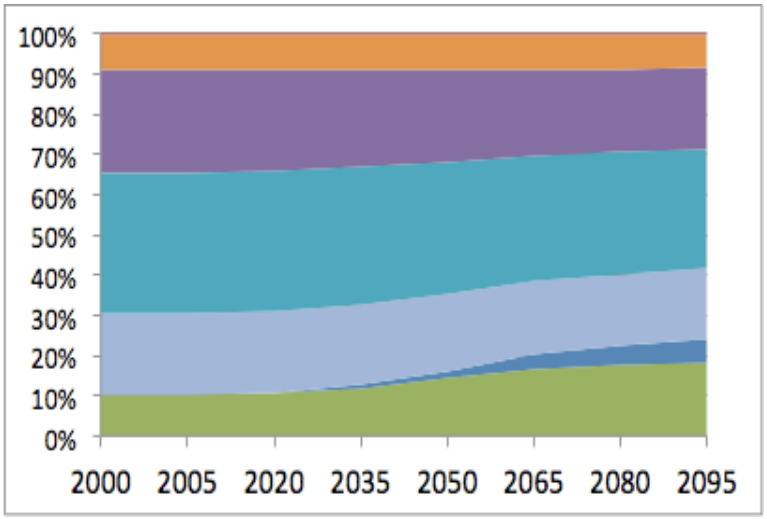


Land-Use Change CO_2 Emissions

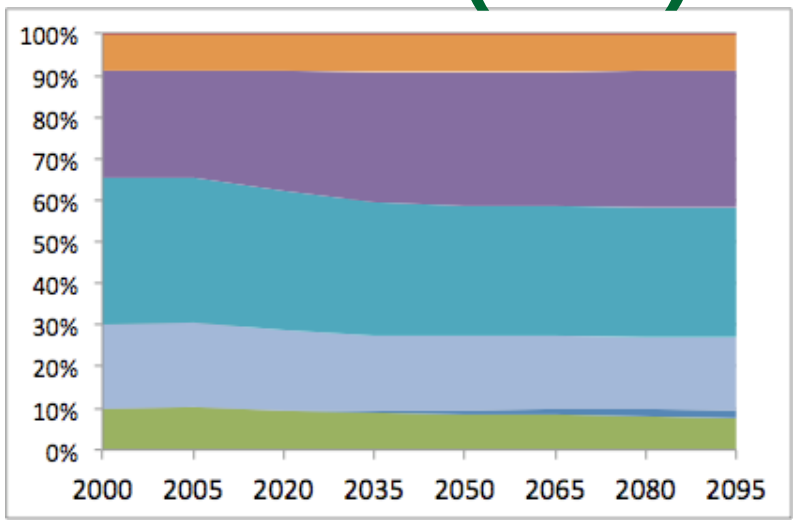


…and the land allocation in the future (global results shown here).

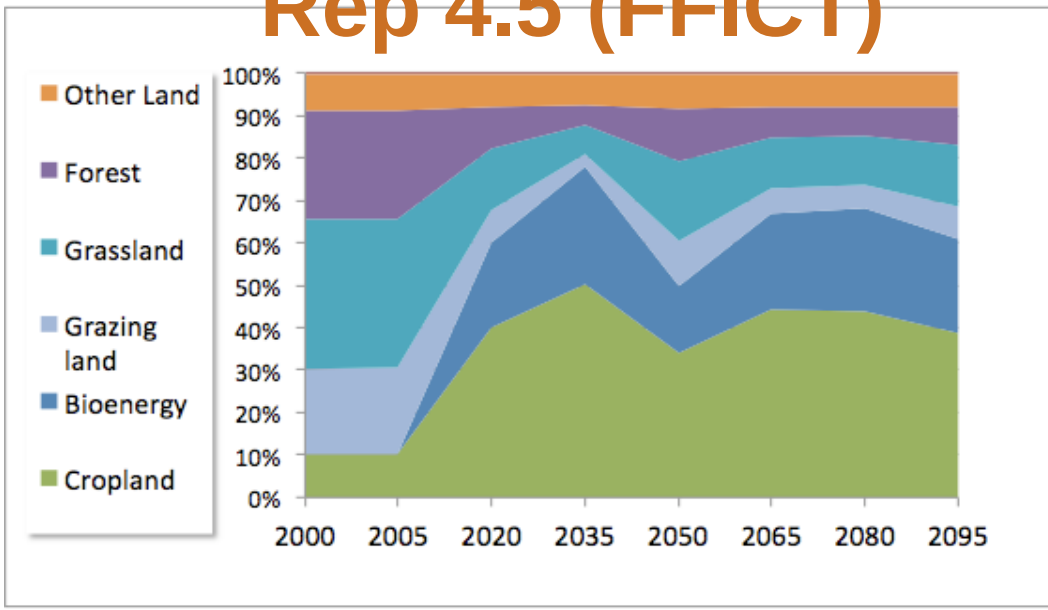
Baseline or No Target



RCP4.5 (UCT)



Rep 4.5 (FFICT)



GCAM land results downscaled from the GCAM regions through GLM to ESM

- Andrew Jones will present the climate implication results, as part of the iESM project, later in this session.

- DISCUSSION