Bioenergy and Climate Mitigation: Lessons from GCAM Modeling and Research

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Outline

- Bioenergy Use in Energy System Carbon Mitigation
  - Large scale bioenergy: build-up and where is it used in the energy system
- Modeling Terrestrial Carbon Emissions from Land Use Change
  - Modeling emissions from direct and indirect drivers for specific bioenergy sources
- Analyzing Policies to Address Bioenergy and Land Use Change
  - UN protected lands
  - GCAM study of various policies to balance bioenergy and land use
- Current Efforts and Going Forward

Bioenergy Use in Energy System Carbon Mitigation

Bioenergy Resources Modeled in GCAM

- Bioenergy Crops: Lignocellulosic sources such as perennial grasses and woody crops
  - Yields specific to each GCAM land region.
  - These crops compete for land with forest and other agriculture.
- Agricultural and Forestry Lignocellulosic Residues:
  - Secondary output from production of food, forest, and other crops.
- Organic Municipal Solid Waste (MSW)
  - Supply potential linked to regional economic activity (Greg 2009).
  - Smaller but not insignificant.
- Conventional or first-generation biofuel sources such as corn, sugars, oil crops that are also grown as part of food production.

- Much of the focus in long-term analysis of bioenergy and climate mitigation has been on large scale production of bioenergy crops and residues, with amounts reaching 200 EJ per year or more globally by the end of the century.

Large Scale Bioenergy: Upgrading to a transportable, tradable market commodity

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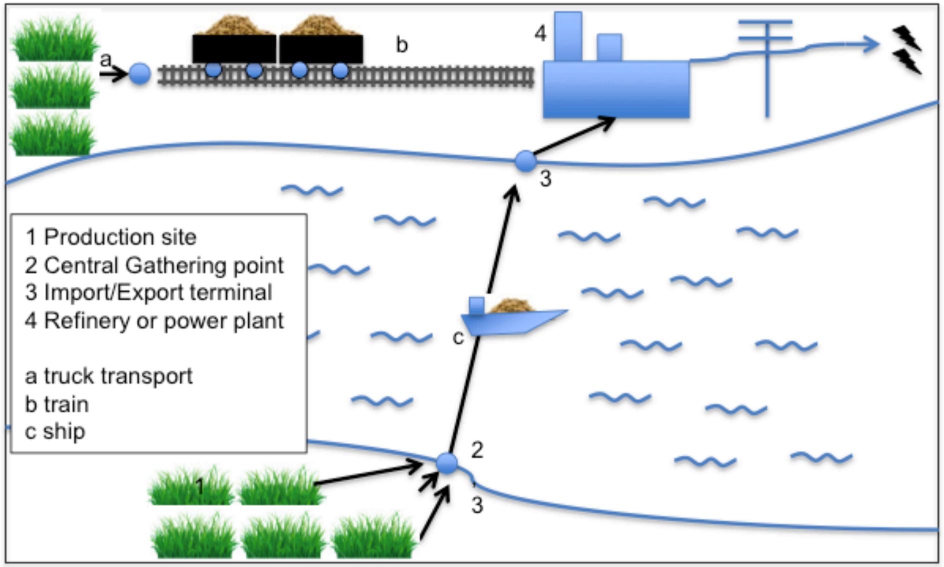
Incorporating Costs of Collection and Processing of Lignocellulosic Bioenergy

- Cost to transport to local collection facility and pelletize
- Pelletizing or otherwise bundling to increase the energy density of the fuel and facilitate transportation
- Cost of International transport
- Upgrading and transport costs are high relative to today's bioenergy value but changes in a future where bioenergy has higher value



Logisitics based on Hamelink et al 2005

GCAM study in Luckow et al, 2010

Where is Bioenergy Used in Mitigation?

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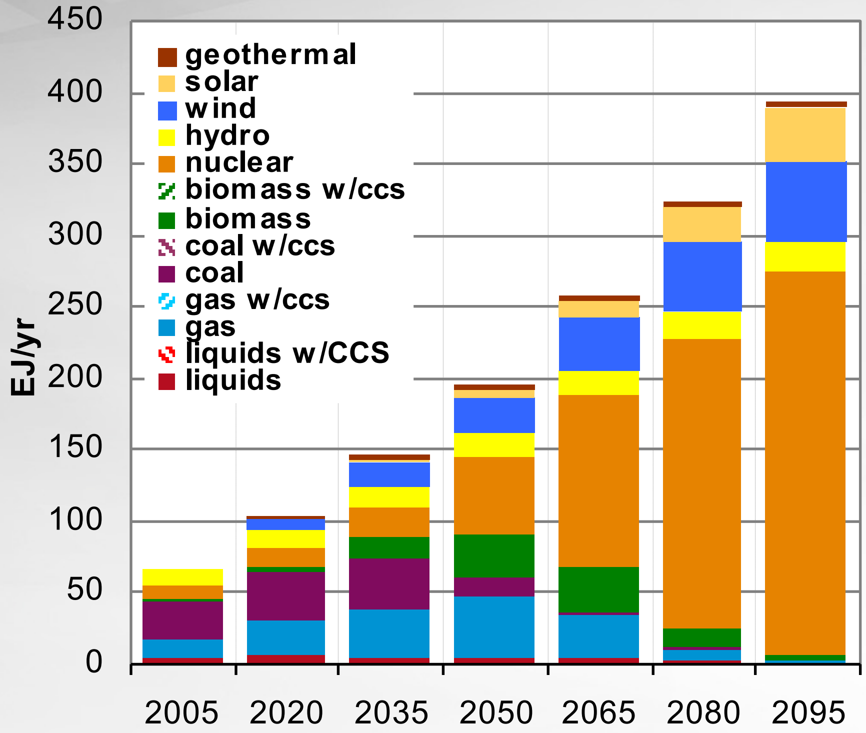
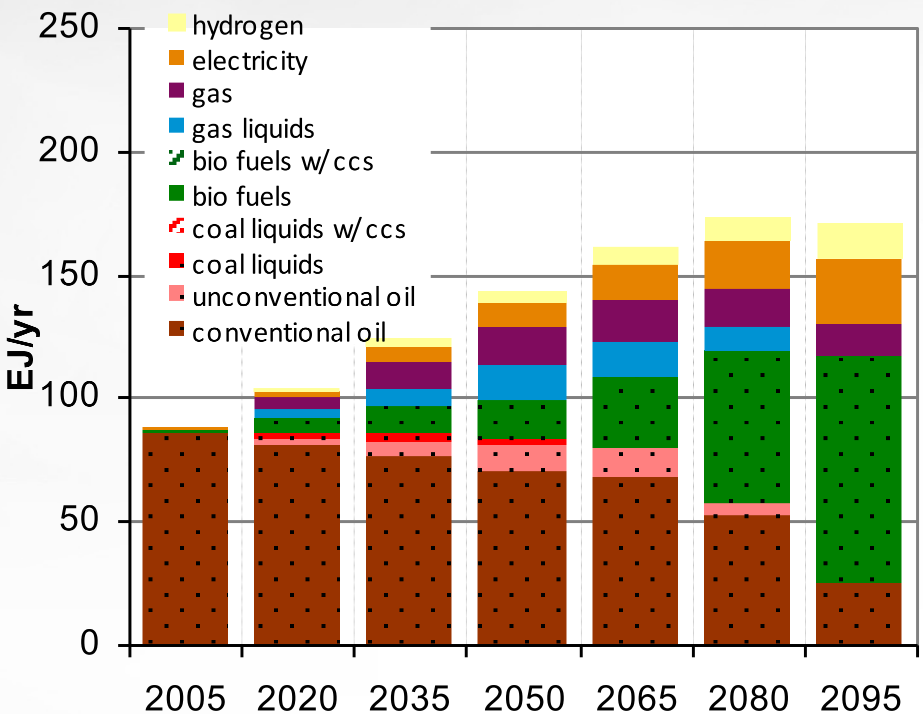
450ppm CO_2 Scenario when CCS *is not* available





GCAM Results: when CCS is not available, biomass is more valuable for reducing emissions in transportation fuels than electric power, which has other low or no-carbon technology options in this scenario.

Where is Bioenergy Used in Mitigation?

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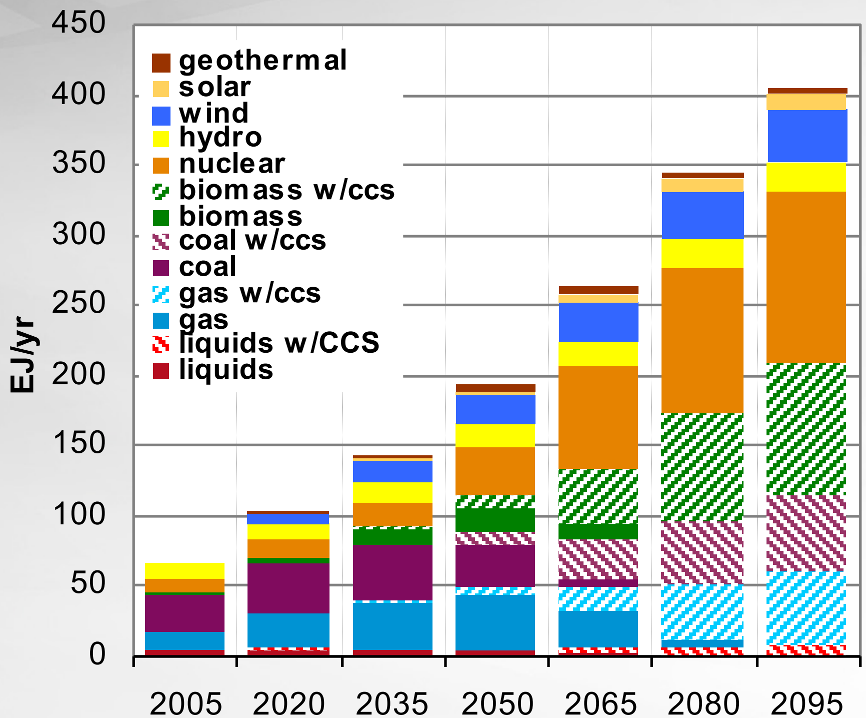
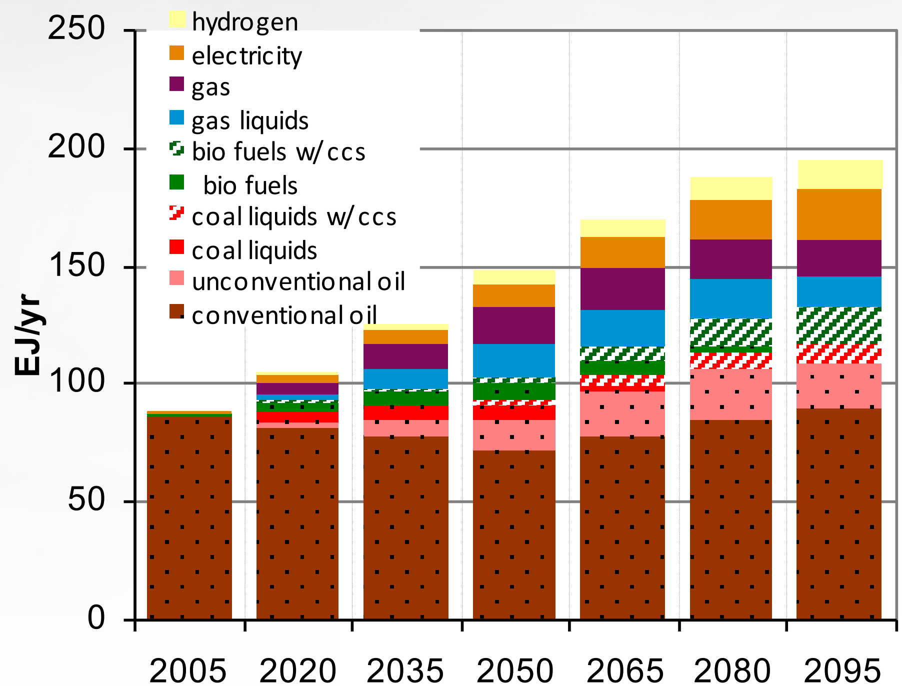
450ppm CO_2 Scenario when CCS *is* available

Global Electricity



Global Transportation Fuels



With CCS, biomass is concentrated in electric power, with bio+CCS contributing net negative emissions. This allows headroom for continued use of some fossil fuels in transportation. Biomass still has a large role there, with CCS in the fuel processing.

Modeling Terrestrial Carbon Emissions from Land Use Change

Bioenergy and Land Use Change (LUC)Emissions

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- GCAM has always computed terrestrial carbon emissions from land use change for bioenergy, as it does with all land use activities.
  - In scenarios where we value terrestrial carbon (Wise et al 2009 *Science*), LUC carbon factored into the economic land use decisions.

- Objective of some recent studies: Use GCAM to isolate and quantify the LUC carbon emissions of specific biomass sources/crops.
  - Bioenergy Carbon Intensities are being considered for policy.
  - Growing body of literature to which we can compare GCAM studies.

- These are total emissions and include direct and indirect emissions.
  - **Direct emissions**: net LUC emissions in the place where the bioenergy is grown. (May be positive or negative.)
  - **Indirect emissions**: LUC emissions from expansion of land elsewhere to replace crops (e.g., food) supplanted by growing the bioenergy crop.
    - Requires an integrated, global model of agriculture and land use.

Modeling LUC Emissions from Bioenergy Crops in USA AEZ 7 and AEZ 10

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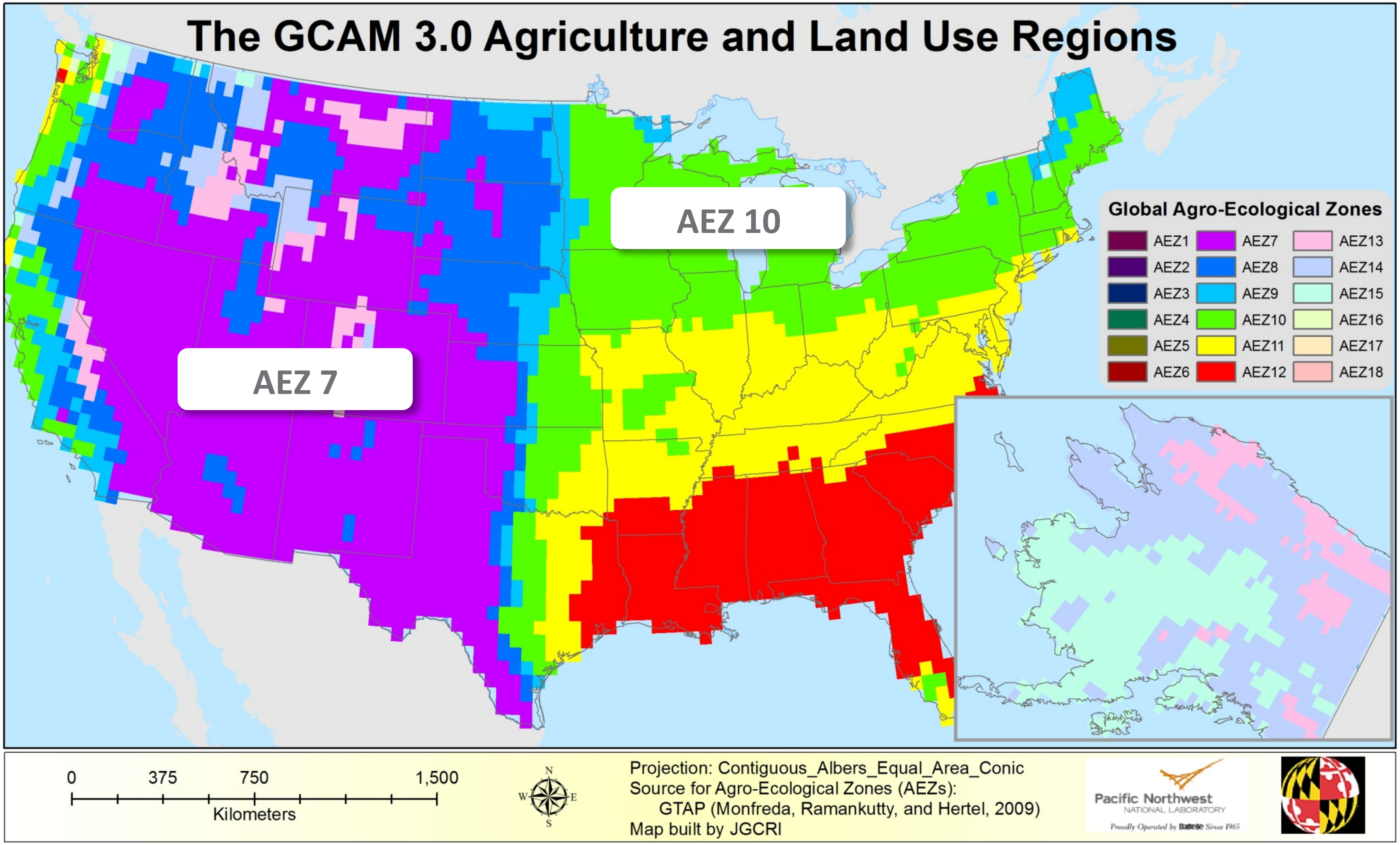
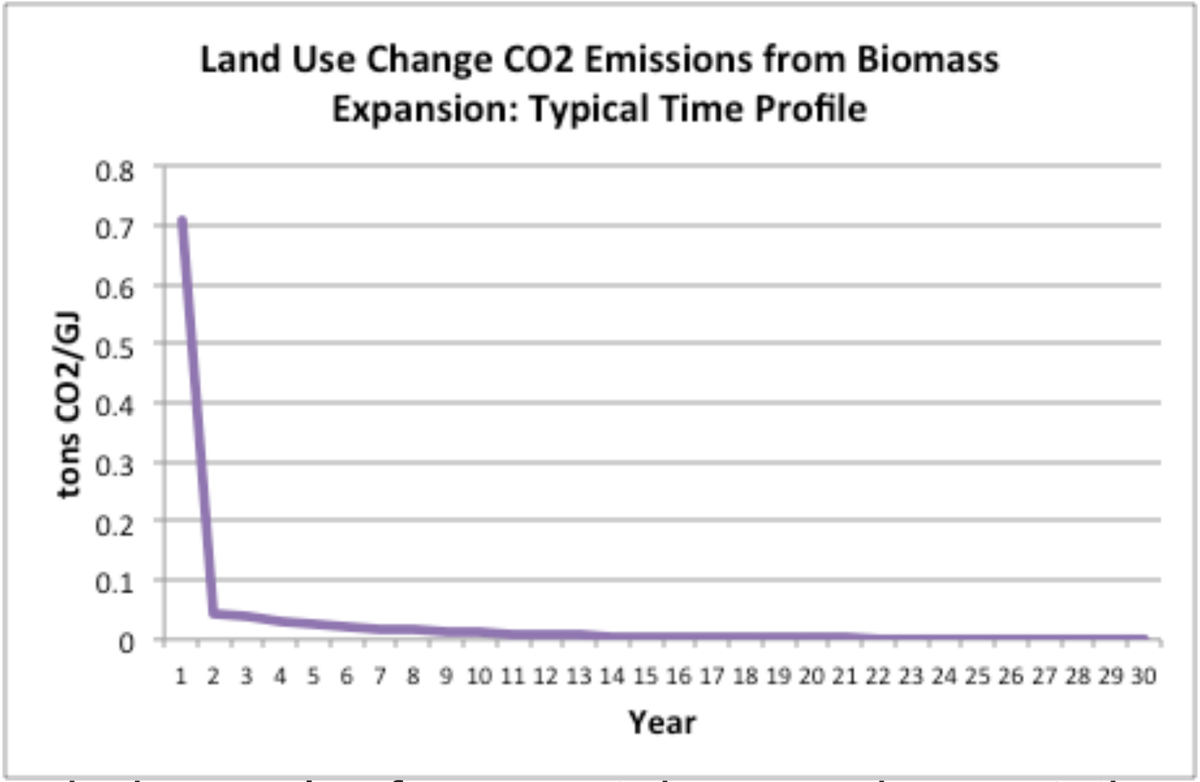


Time Profile of LUC Carbon Emissions from Expansion of Bioenergy Production



- Initial emissions pulse from a net decrease in vegetative carbon followed by long tail of lagged changes in soil carbon.
- Discounting may become necessary to compare initial positive emissions from LUC with an annual stream of emissions reductions from the energy system (straight 30-year average is common).

GCAM Results: LUC from an Incremental amount of Switchgrass in AEZ 7 and 10

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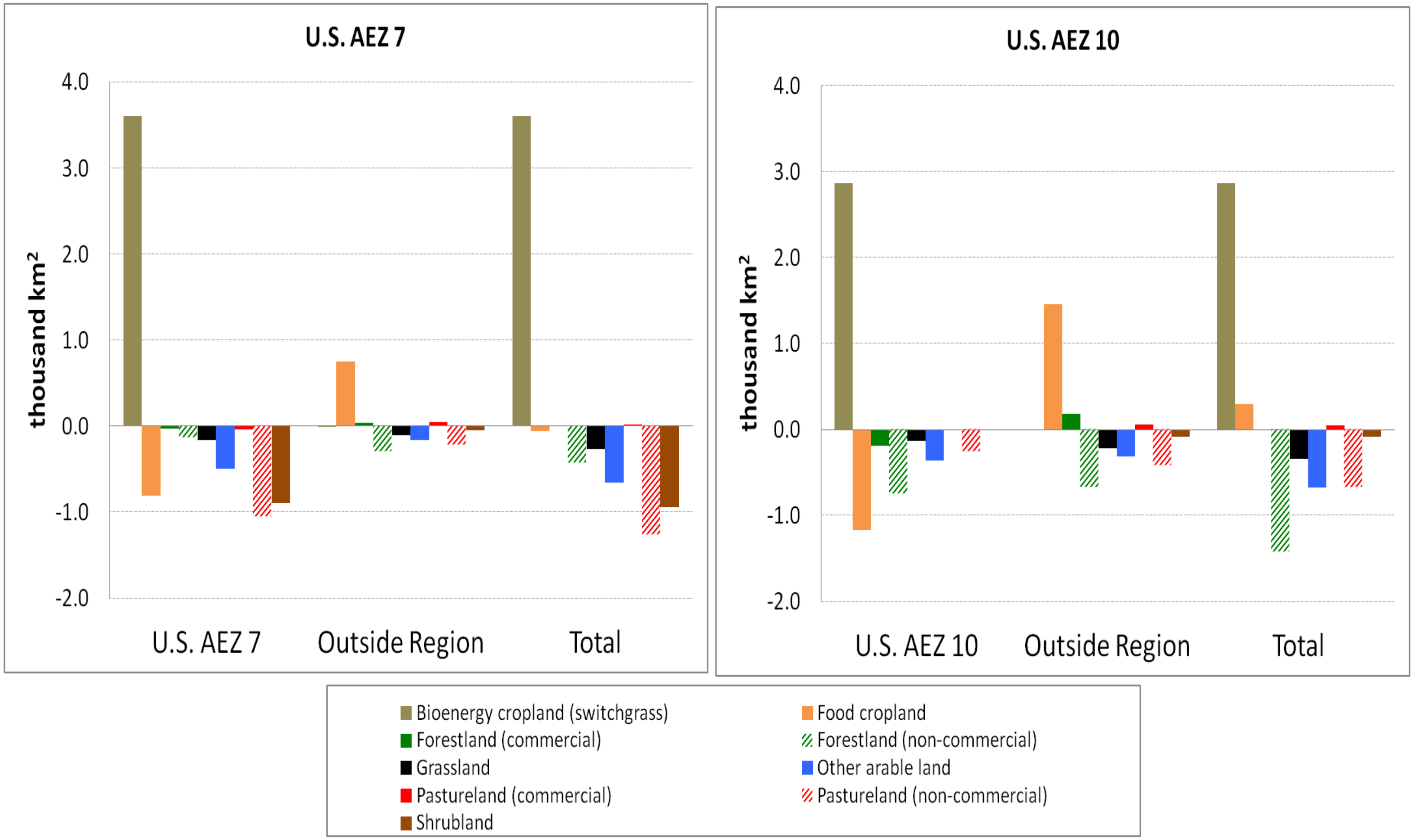
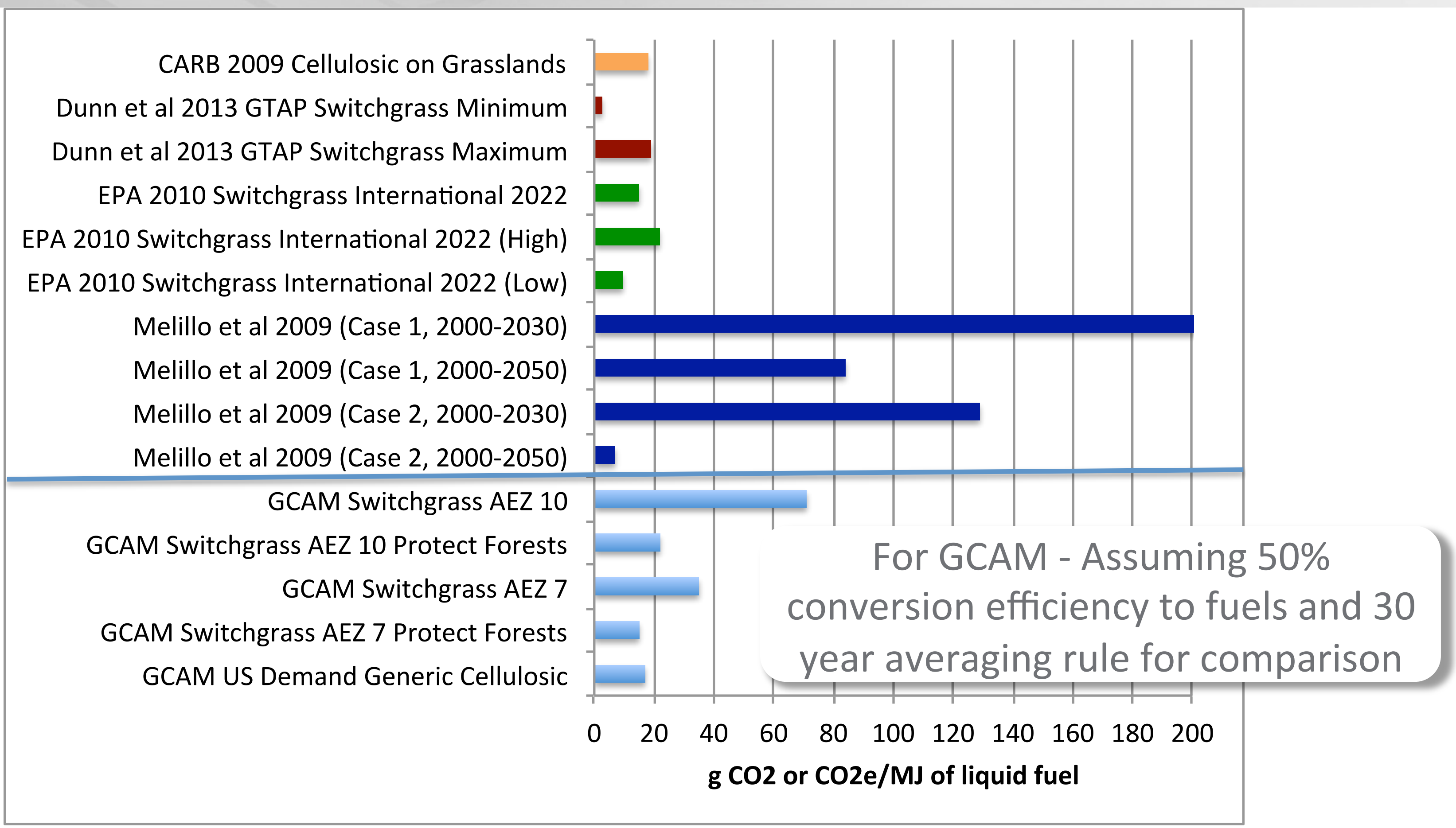


- Higher bioenergy crop yield, but AEZ 10 emissions > AEZ 7
  - Higher mix of forest displaced in AEZ 10, pasture and shrubland in AEZ 7.
  - More indirect emissions from cropland displaced in AEZ 10.

GCAM LUC Carbon emissions in context to literature



- GCAM AEZ 7 and 10 results generally higher than GTAP studies.
- But when we remove non-commercial forests from the economic land allocation ("Protect Forests"), GCAM results are closer to the GTAP, CARB, and EPA studies.

Some Sources of Differences among Studies

- How does the study or economic modeling approach determine the mix of land use directly displaced by bioenergy?
  - Is or how is non-commercial land included in the economic choice?
- Net direct emissions (+ or -) on the land on which bioenergy is grown.
  - Differences in carbon intensity assumptions for different uses of land.
- How are indirect and/or international LUC modeled?
  - Different approaches to modeling agricultural trade can have a big impact
- Yield changes from Intensification and extensification.
- Are emissions marginal or averaged (either over crops or over time)?
- Consideration of time profile of emissions (averaging, discounting).

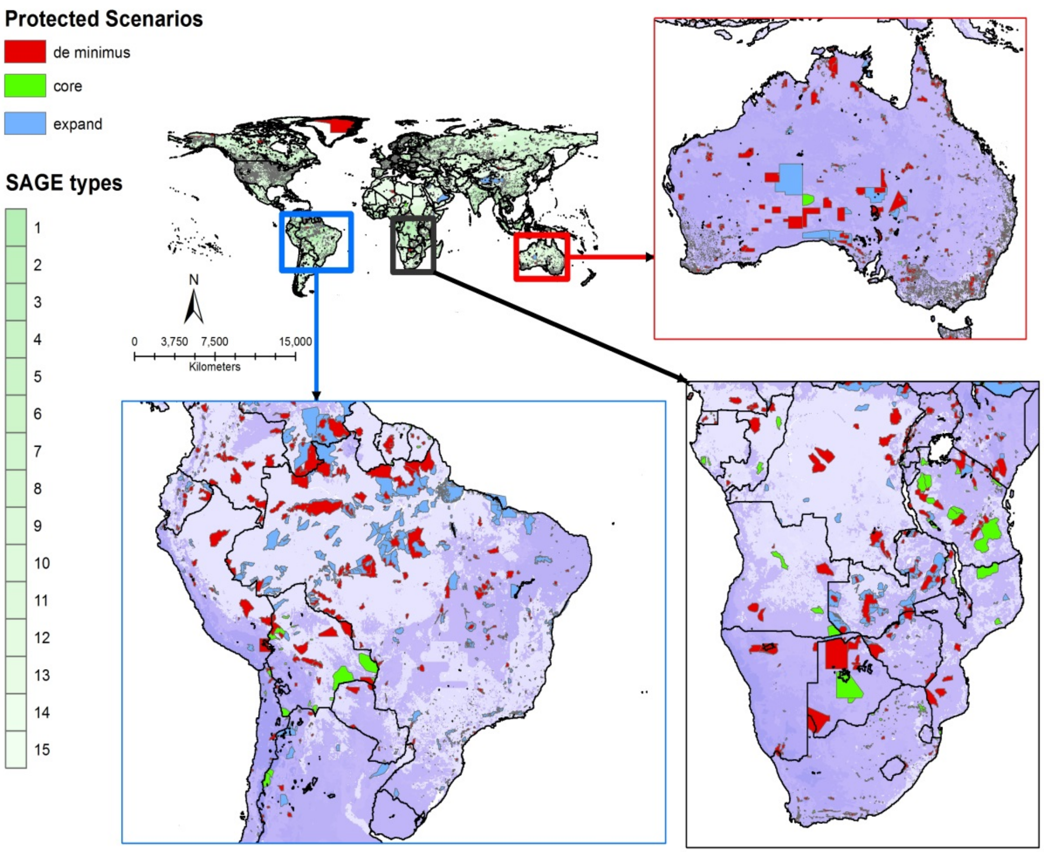
Analyzing Policies to Address Bioenergy and Land Use Change

Types of Bioenergy and Land Policies

- Protecting non-commercial Forests and other Lands.
- Valuing all Terrestrial Carbon.
- Tax or Penalty on Bioenergy based on an assumed carbon intensity
  - Much like treatment of fossil fuels.

UN Protected Lands and Bioenergy

- GCAM modeling shows that a large biomass expansion would not encroach on UN protected lands (<10% of total land area).
- The research also indicates that much more land would need to be protected to limit land use change emissions from a large-scale ramp-up of bioenergy.
- These lands are critical for any number of reasons, but they do not appear to be a factor in global bioenergy



UN Environment Programme World Conservation Monitoring Centre's World Database on Protected Areas

Valuing Terrestrial Carbon

- One of the clearest results from the Science paper (Wise et al 2009) was that a policy that valued carbon in energy but not in land could lead to runaway clearing of land for bioenergy.

- But another result was that, in a policy where the carbon in land could be valued equally with the carbon in the energy system – bioenergy could still be an major component of climate mitigation

- When terrestrial carbon is valued - Provides incentive for maintaining or even expanding forested and other unmanaged lands for their terrestrial carbon value.

- Bioenergy would be grown only where the value of the energy provided and the carbon mitigated in the energy system exceeds the carbon value (and any product) of using that land for of other purposes.

The carbon price on land is the only policy that incentives afforestation

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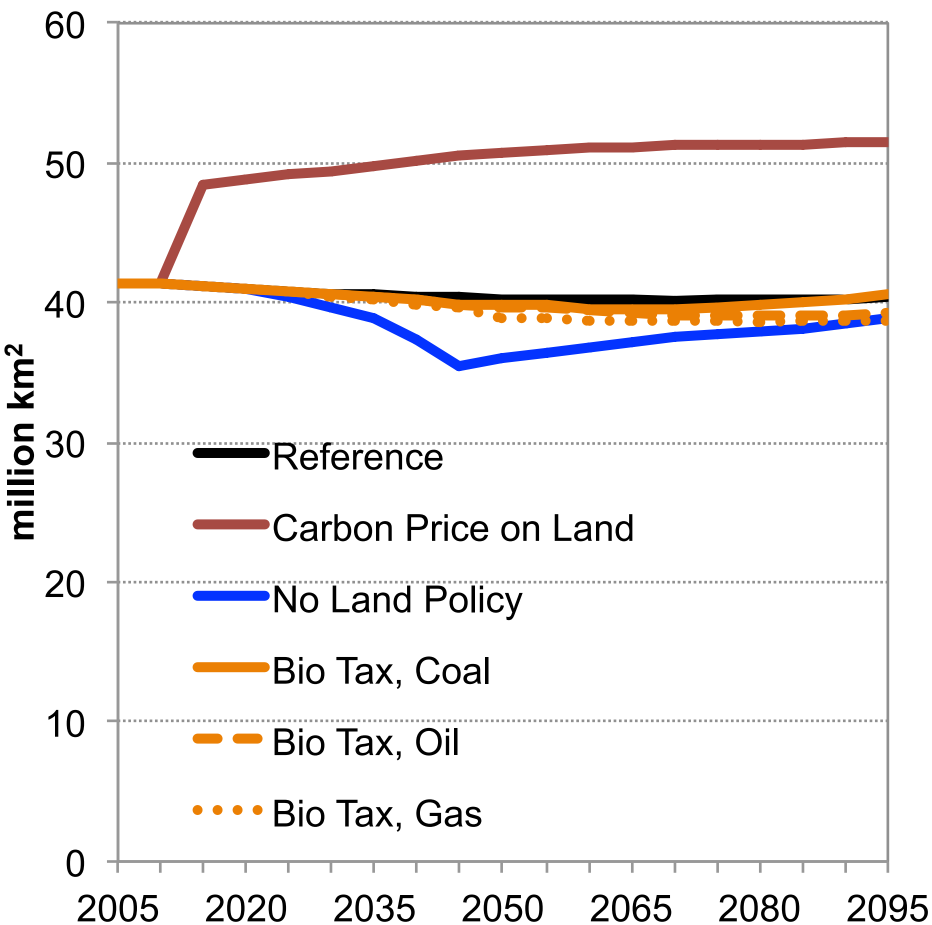
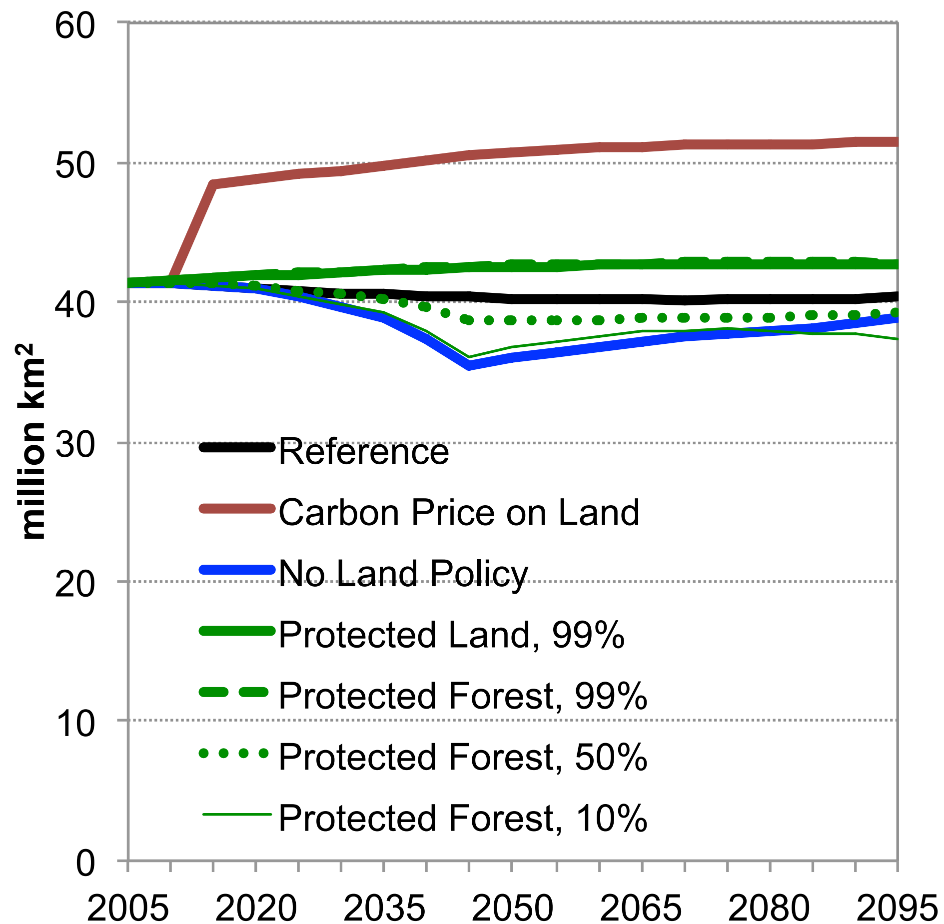
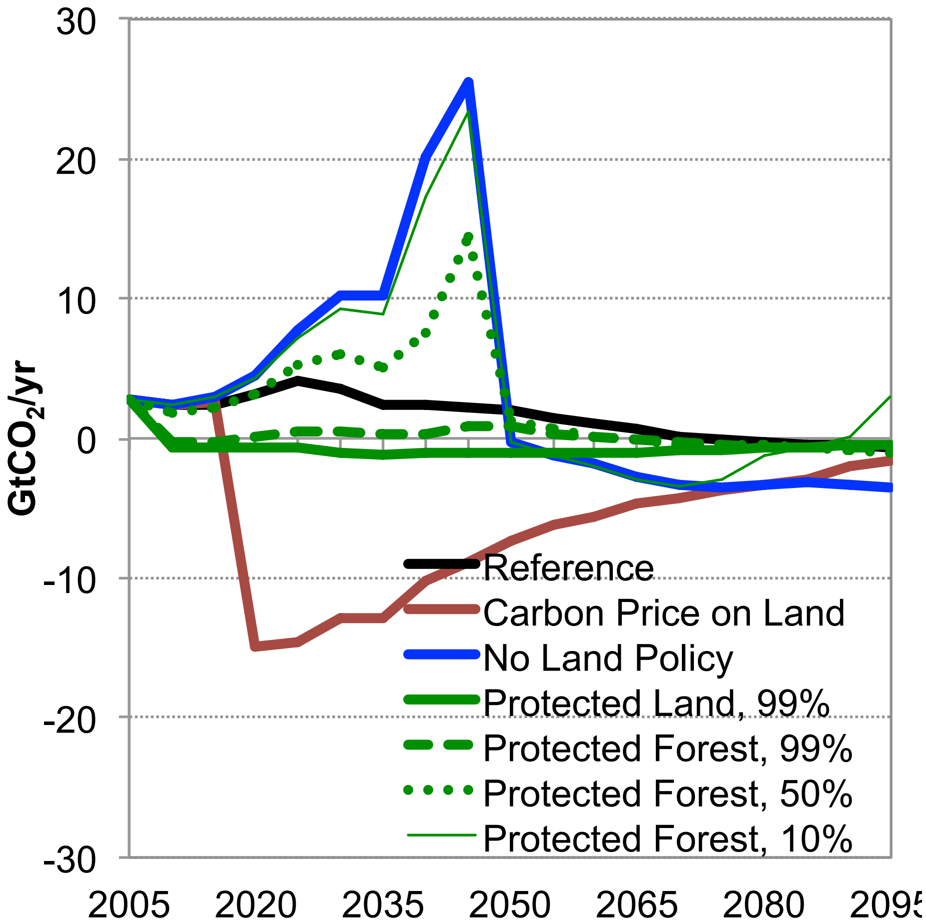
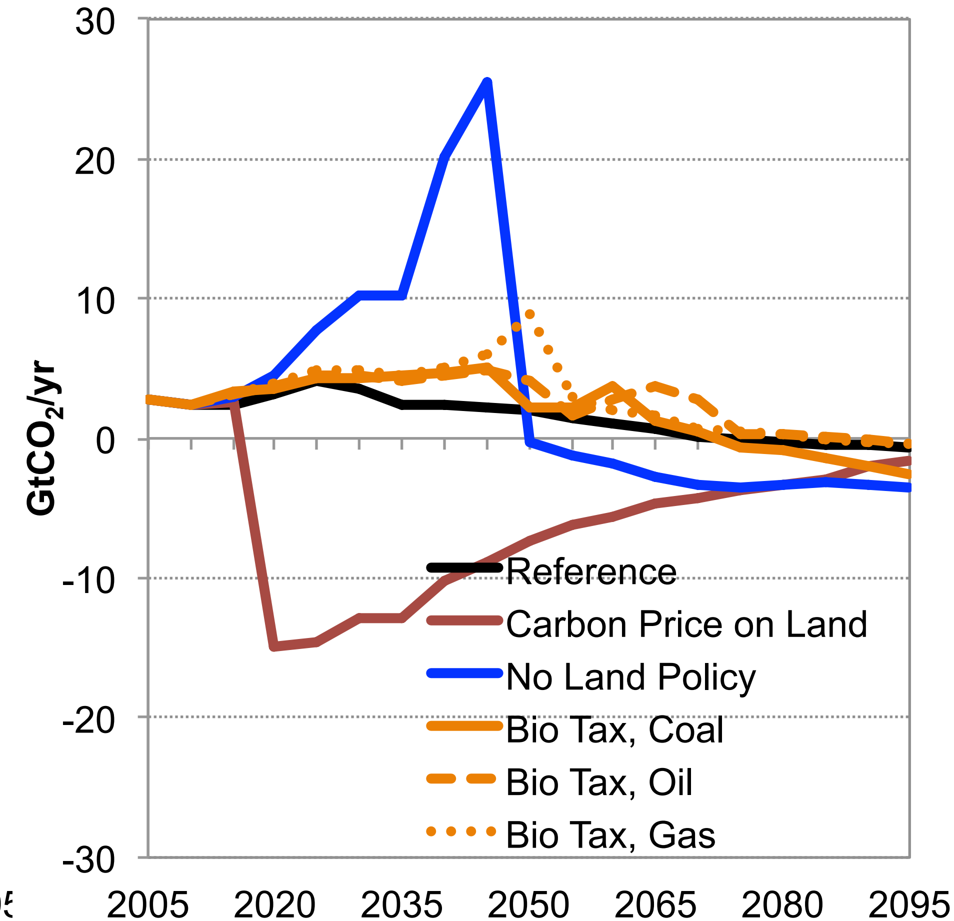




All with a Global 3.7 W/m2 mitigation policy

A large portion of land needs to be protected to limit LUC emissions





Taxes on bioenergy reduce LUC emissions, but do so simply by reducing bioenergy.

Summary of Bioenergy and Land Policy Measures (Calvin et al 2014, EMF 27 Study)

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- Placing a carbon price on the terrestrial system:
  - Is the only scenario that increases forest cover
  - Decreases land-use change emissions
  - Increases the price of food, which leads to reduced meat consumption
- Protecting land:
  - Limits deforestation
  - Requires a large percentage to be protected to have an impact
  - Moderates land-use change emissions
  - Can also increase the price of food (depending on demand growth and degree of protection)
- Taxing bioenergy:
  - Decreases deforestation
  - Moderates land-use change emissions
  - Limits or eliminates bioenergy as a mitigation option (increases carbon price)
  - Blunt - Difficult to exempt residues that have no LUC emissions.

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Going Forward

Development Frontier: current and future efforts

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- Bioenergy water consumption and irrigation.
  - Part of long-term water modeling development effort
  - Early results developing bioenergy crop water coefficients and modeling a future scenario of bioenergy demand
- Bio Jet Fuels: new project with EERE BETO
  - GCAM modeling of air transportation demands
  - Integrated analysis of fuel resources and impact on energy system
- Agricultural Trade – develop model capability to better integrate modeling of regional markets with modeling of global markets.
  - More capability in modeling regional and global impacts of nearer-term regional policies such as US Biofuels standards

Developing consistent water and irrigation coefficients for agriculture and bioenergy requires reconciling large data sets

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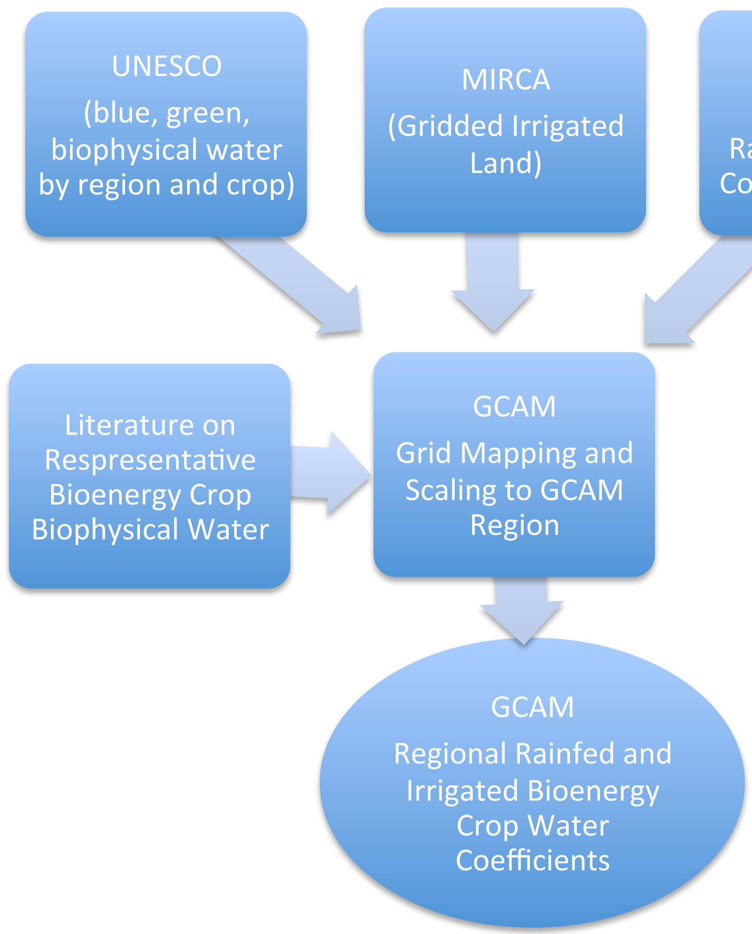

Early GCAM Results for Agricultural Water Consumption and Irrigation

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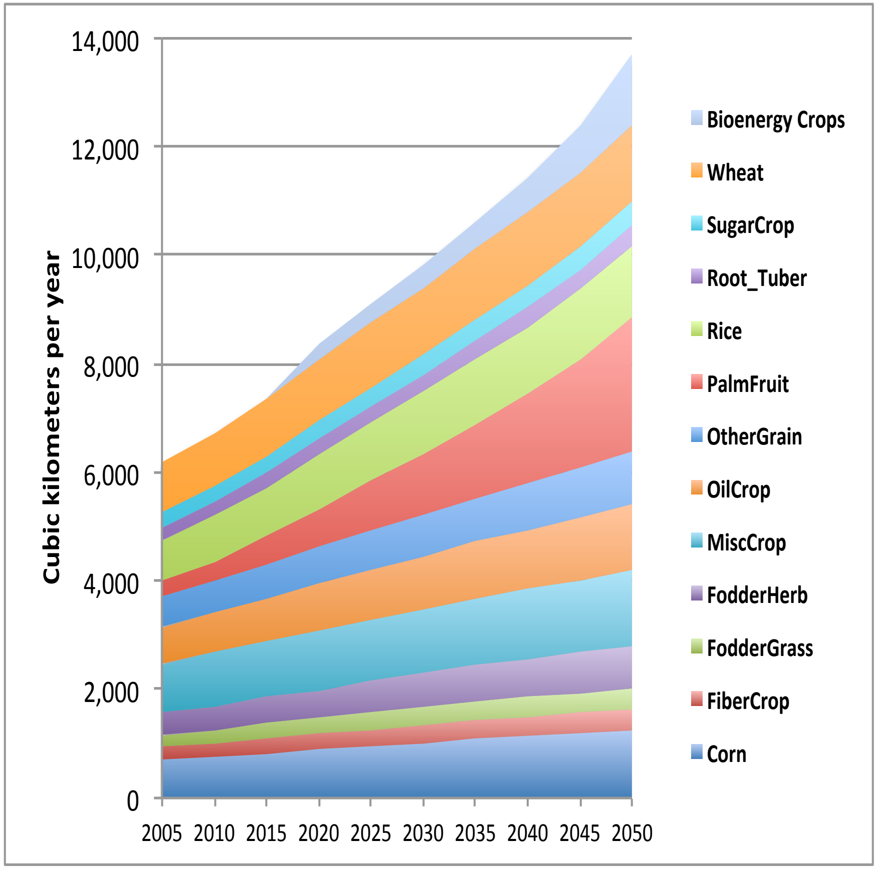
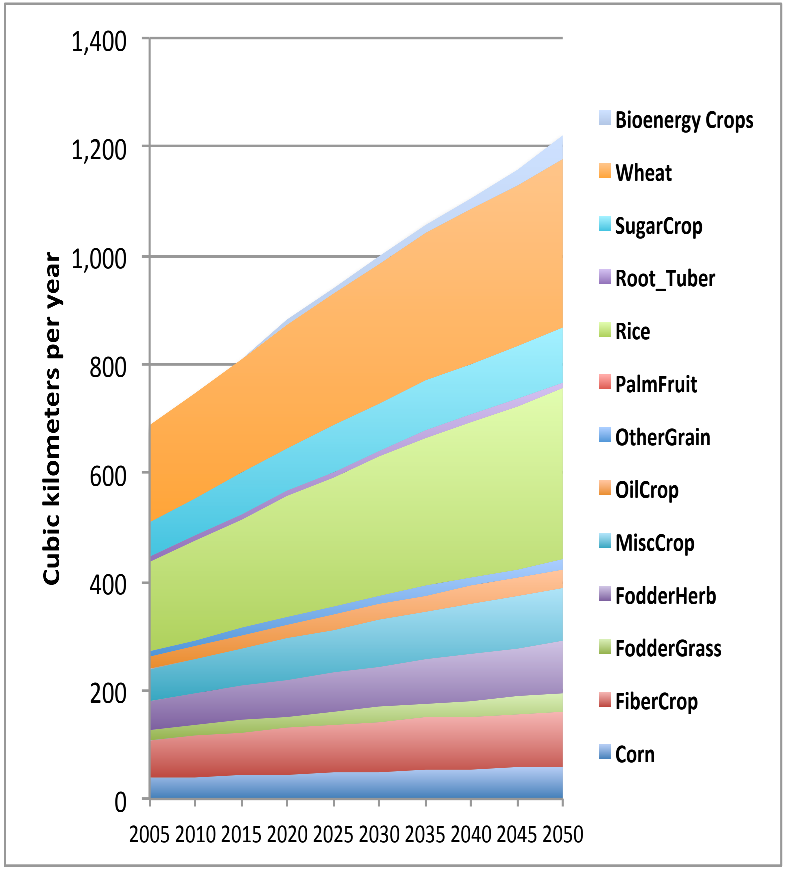
Global Biophysical Water Consumption



Global Blue Water (Irrigation)



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