Forests: Carbon sequestration, biomass energy, or both?

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Key Results

- More demand for wood increases net carbon sequestration in forests through investments, shifts in harvest ages, and shifts in harvesting patterns.
- Debate over carbon neutrality of wood-based biomass energy revolves around
  - Forest investments: Models that include forest investments are closer to carbon neutrality.
  - “Carbon debt”: Function of a single site.
  - System models important: Forested ecosystems and the markets that influence them (harvesting/planting/LU change) are a system.
- Emission taxes on biomass alone are inefficient, and lead to less forestland, less carbon in forests, and more carbon in the atmosphere. A carbon rental system would encourage more forests, more carbon in forests, and less carbon in the atmosphere.
  - Forest carbon mitigation and biomass energy are complements
  - IAMs likely have over-estimated the costs of AFOLU.

Methods – Global Timber Model

- Dynamic optimization model of global forest sector.
  - Timber Supply/Conservation: Sedjo and Lyon (1990); Sohngen et al. (1999).
  - Carbon/IAM/albedo: Sohngen and Mendelsohn (2003, 2007), Tavoni et al. (2007), Golub et al (2009,2012), Kindermann et al. (2008), Favero et al. (2018).
  - Biomass: Daigneault (2012), Favero and Mendelsohn (2014), Favero et al. (2017), Kim et al. (2018), Baker et al. (2019).
  - Climate impacts: Sohngen et al. (2001), Tian et al. (2016), Favero et al. (2018).

- Optimize harvests (age and quantity) and investments (area regenerated and $/ha), subject to
  - Demand for wood (scenario)
    - Assume 10-12% of global biomass sourced from forests.
  - Land constraints: rental function (cost of land) and maximum area defined by MC2 (Kim et al., 2017)
  - An investment cost function (decreasing returns to scale in investments)
  - 250-400 forest land classes globally, depending on version.
  - Data sources: country level inventories where available (US, Canada, Russia, Europe, China), and FAO (2015) otherwise.

What does the study do?

- Assesses effect of demand for biomass and carbon sequestration across RCPs, representing different levels of biomass demand and carbon prices.
- Compares a program that pays for timber and biomass energy without incentives for forest carbon, with a program (1) that also incentivizes carbon storage on the landscape and with a program (2) that taxes the carbon emissions from biomass energy and other harvesting activities.
- Evaluates interactions and effects on intensively managed plantations, moderately managed forests, and natural forests (unmanaged, although they can be accessed and converted to managed if timber prices become high enough, or to agriculture), as well as the resulting implications for forest and atmospheric carbon stocks.

Results

- Biomass energy policy would encourage a massive increase in forest area.

Small program: 0.1-0.2 Bha ~ 130 Gj energy (1-1.2 Gj/Mha)

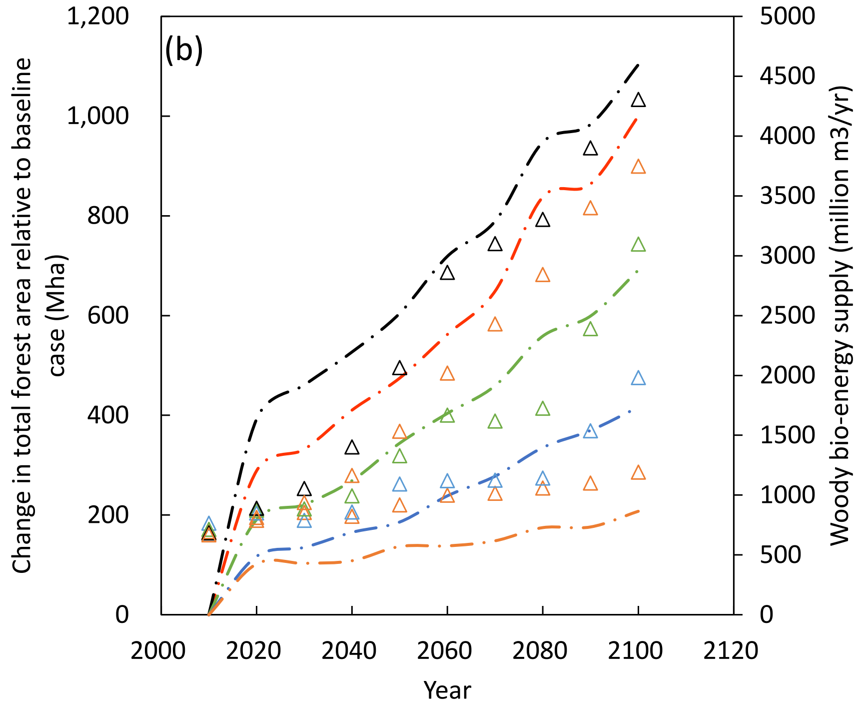
Large program: 0.8-1.0 Bha >500 Gj energy (2-2.5 Gj/Mha)

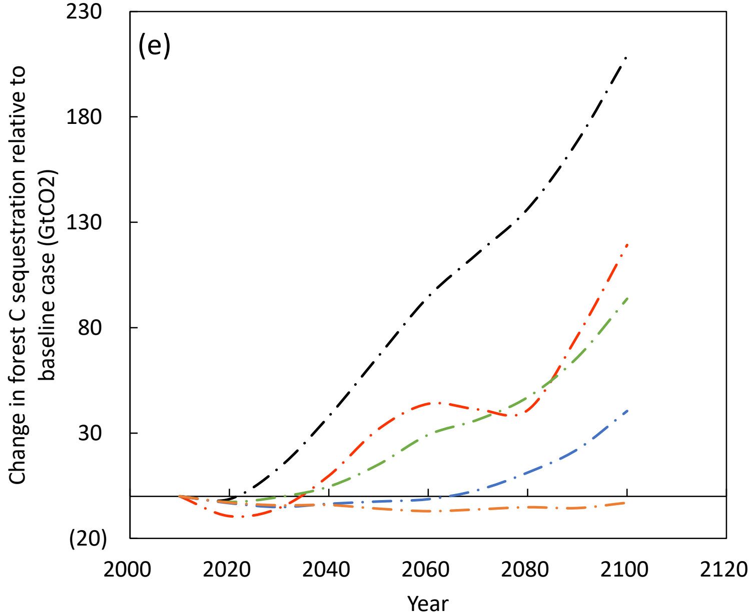
- Large potential increase in forest stock.

-33 Tg CO2/yr to **+2300** Tg CO2/yr

Slight decreases in carbon stocks under smaller program.

(note that a plus here is a reduction in carbon in the atmosphere)





What about valuing the standing carbon stock?

- Tons of carbon added to **and** lost from forests (net of product storage including potentially BECCS) are exchanged with the atmosphere and thus should be valued.
  - This means that standing forest stocks have carbon asset value that needs to be considered in policy.

- Two approaches to do this efficiently in the literature are equivalent.
  - Van Kooten et al. (1995): Subsidize growth and tax emissions, both with C price.
  - Sohngen and Mendelsohn (2003): Rent stock and pay for storage in markets.

- It is inefficient to tax emissions without also subsidizing the growth.

- It is inefficient to tax emissions if you rent the incremental stock gains.
  - Rent as you go systems should not be combined with an emission tax at harvest, but they can and should be combined with a payment for any net storage in timber products (houses, furniture, etc.) and any net storage in the ground (i.e., BECCS).

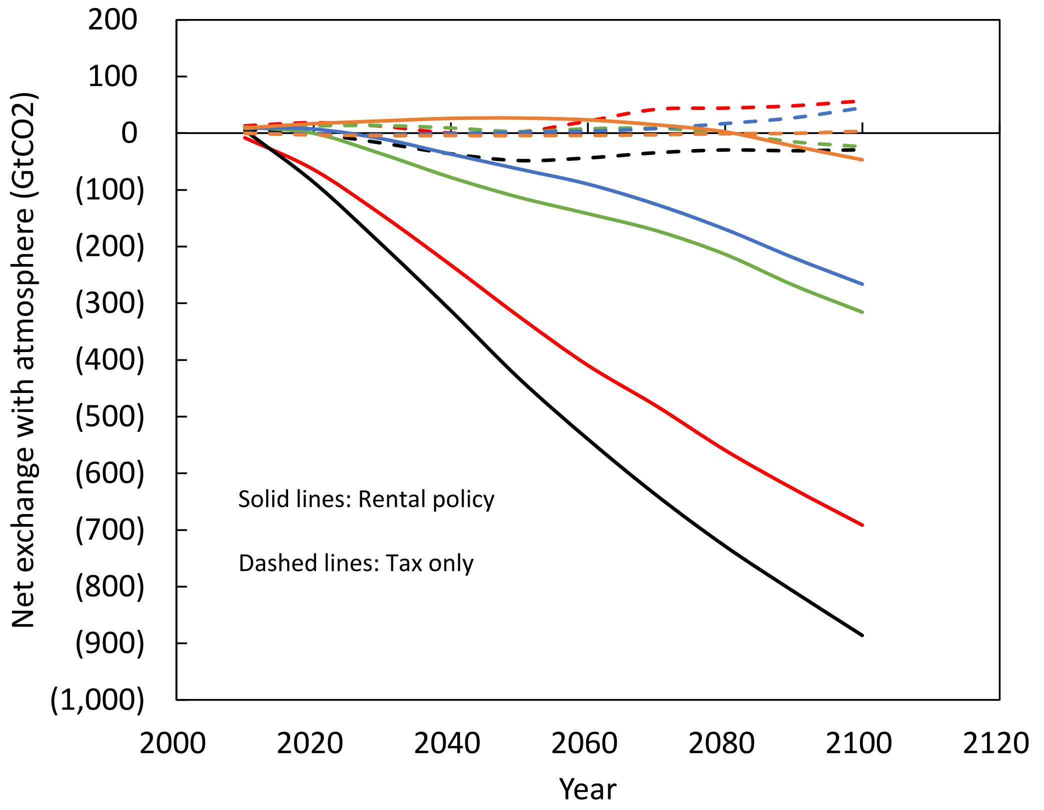
Carbon implications of policies that focus on forest stocks

- Carbon rental policies increase forest stocks and reduce carbon stocks in the atmosphere.
  - With higher carbon prices, significantly lower atmospheric carbon.

- Tax policies that ignore the value of the standing stock at best lead to little change and at worst lead to emissions.

Net exchange with the atmosphere

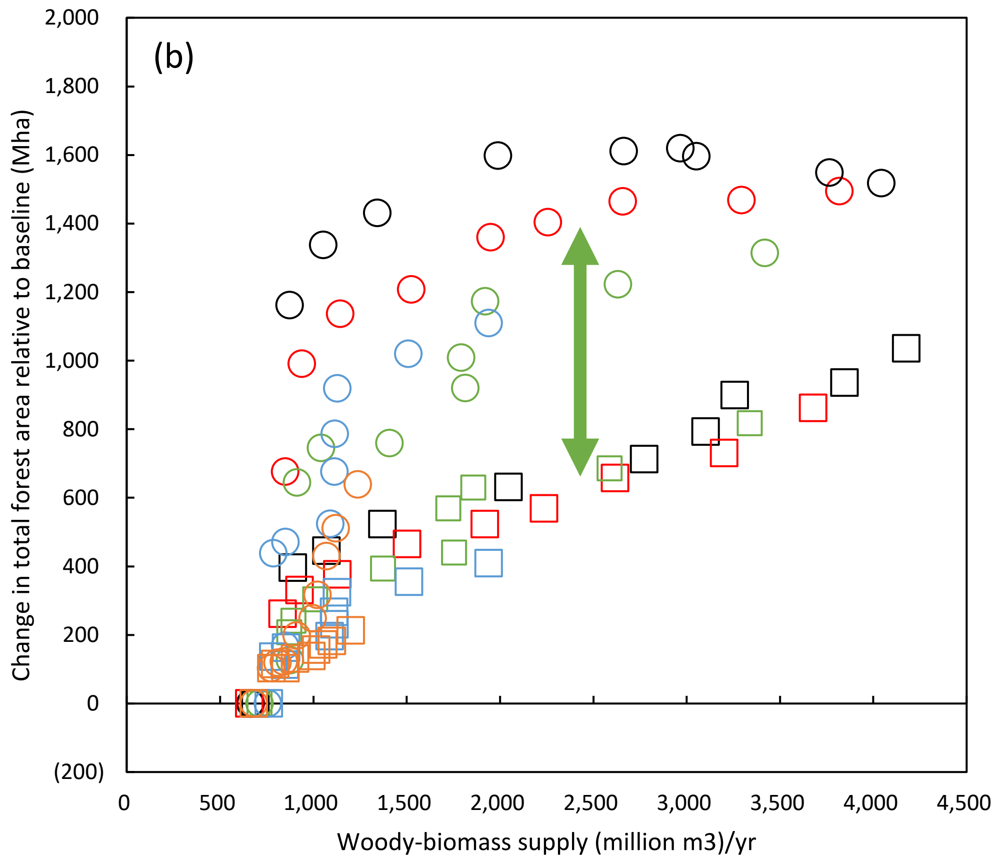
Negative is sequestration from atmosphere,
Positive is emission to atmosphere



Note, these estimates treat biomass burned as an emission. Changing this assumption to account for adoption of BECCS in the future would further decrease atmospheric stocks

Forestland implications

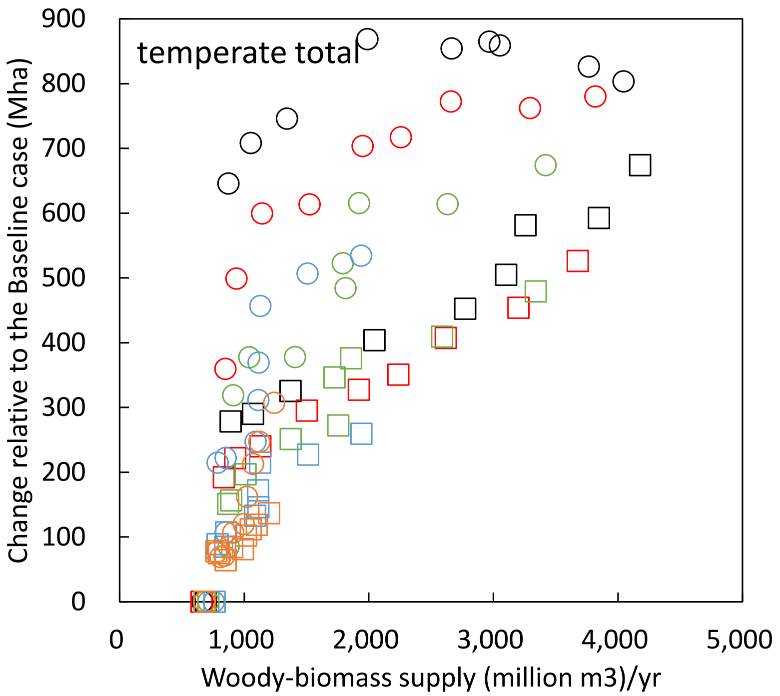
- All approaches lead to an increase in forestland area globally
- Assuming carbon neutrality (only biomass expansion policy) and the tax policy lead to about the same effect on total land
- The rental policy leads to about 75% more land in forests.

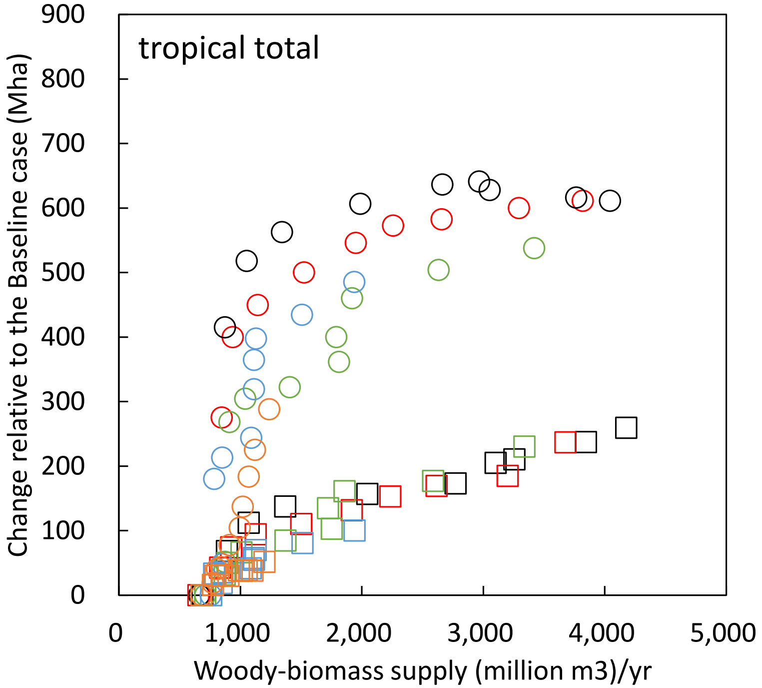


Forestland implications.

- The largest increases in forest area occur in the temperate zone, but 90% of these increases occur in forests that receive some sort of management.

- Large increases in total forest area also occur in the tropics, but the rental policy encourages a significantly larger expansion in tropical natural forests through avoided deforestation and Afforestation/Reforestation.

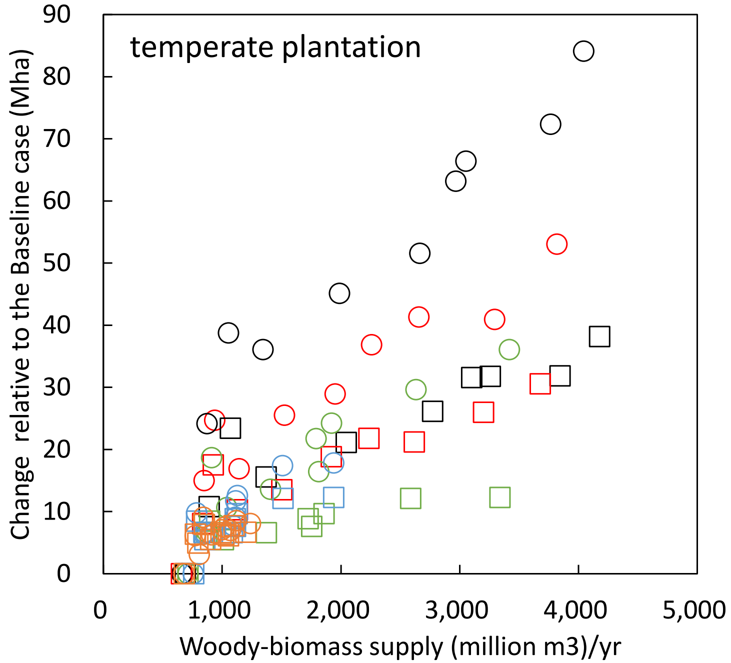


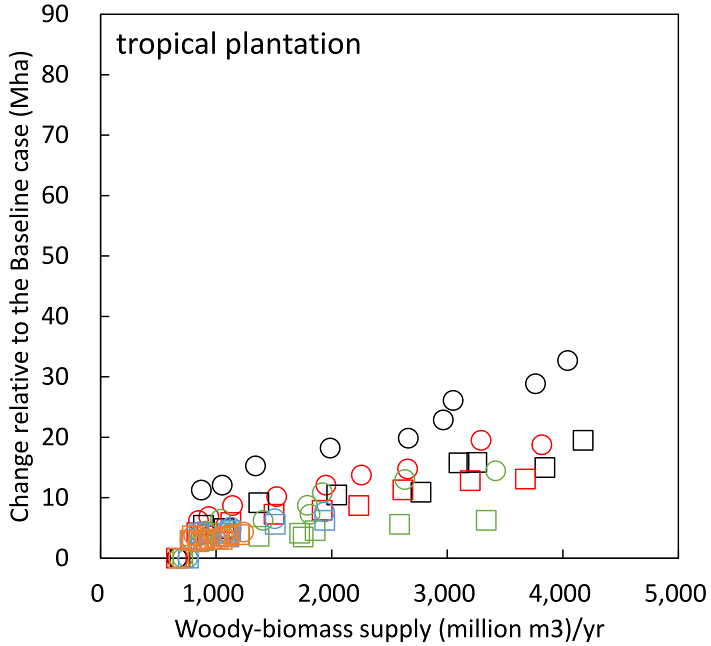


Plantation implications

- Intensively managed plantations play an important role, yet they are only a modest proportion of total land area expansion:
  - 4% of total land area increase in rental scenarios
  - 5% in tax scenarios.

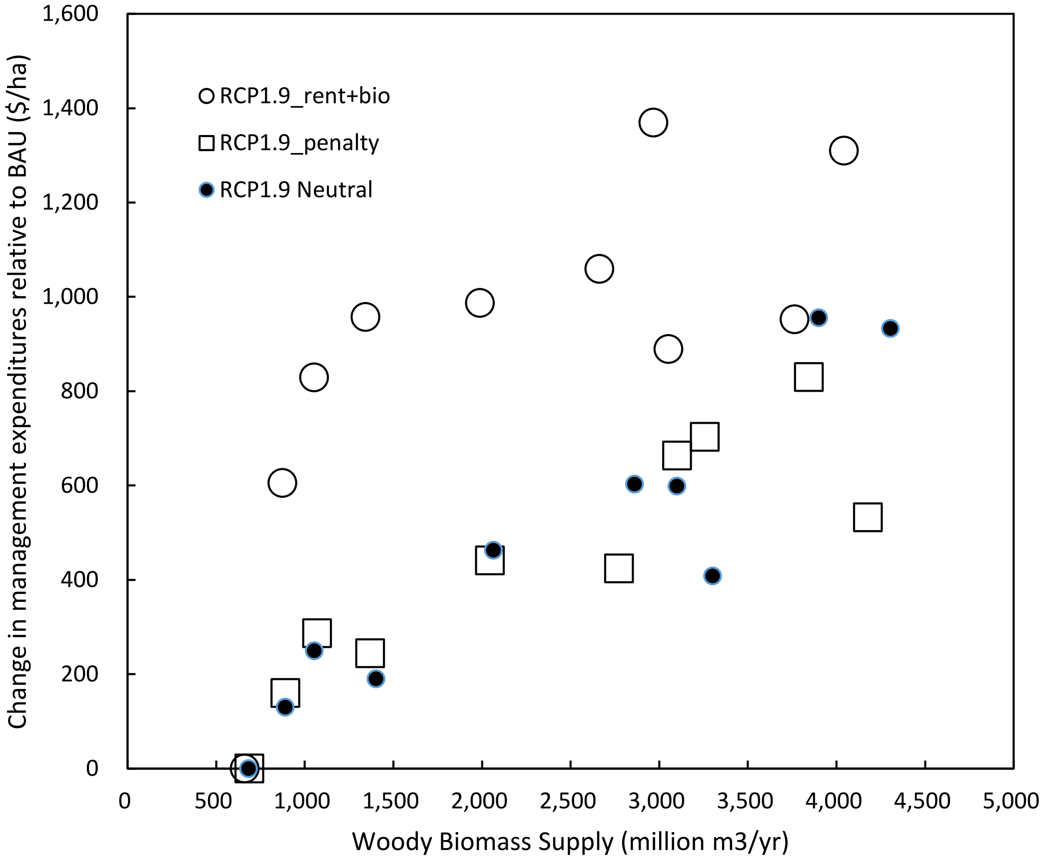
- They play a larger role in the temperate zone, due to proximity to markets (costs), growth assumptions, and opportunity costs.
  - Small role in boreal countries (not shown)





Forest Management implications – Managed Forests

- Management in managed forests increases substantially in all cases.
- Increases in management expenditures is similar for tax case and biomass only policy/neutral case.
- For high biomass/carbon price cases, management expenditures increase by about 70% more in the carbon rental scenario compared to other two.
- For the low biomass/carbon price cases, management expenditures increase more modestly, 10-20% more, in carbon rental scenario compared to other two.



Forest management implications - rotations

- Rotations in managed forests tend to increase with biomass policy, as longer rotations in many places that are managed economically lead to greater timber supply.
  - Some places with Annual Allowable Cut constraints may already be near maximum supply, so have limited ability to change rotations.
  - Combined with management/silvicultural changes could lead to changes in AAC on regulated forests through the Allowable Cut Effect (ACE).

- Average rotation length in some regions may decline if type shifts lead to forests with shorter rotations.

Broader implications

- Biomass and AFOLU (A/R, forest management, and avoided deforestation) are complements
  - Favero et al. (2017); Baker et al. (2019)
  - Policies to encourage one will lower the costs of the other.

- One can pay for A/R, Reduced Impact Logging, and Avoided Deforestation now, and transition those areas to biomass projects in the future efficiently.
  - Use rental payments, if appropriate include other constraints that help meet SDG goals, etc.

Broader implications

- IAMs may overestimate costs of AFOLU activities
  - if they don't value forest stock changes
  - if they do not account for forest management.
- Range of sequestration and avoided deforestation in Roe et al. (2019)
  - AFOLU 2050: -0.9 to -7.8
- Range in Favero et al. (2020)

	Rent		Tax	
	2050	2090	2050	2090
	Gt CO2/yr			
RCP 6.0	-0.8	-3.6	0.0	-0.4
RCP 4.5	-3.6	-6.4	-0.2	-1.8
RCP 3.4	-4.8	-7.9	-1.9	-3.9
RCP 2.6	-10.5	-9.9	-1.2	-2.5
RCP 1.9	-13.9	-11.5	-3.1	-3.7

Range of 1.5C – 2.0C Scenarios

Conclusions

- Expansion in biomass energy leads to an increase in forest stocks and an increase in forest management. The size of the increases determines carbon neutrality.
  - Need system models to evaluate carbon neutrality.
- Policies that value the full exchange of carbon between forests and the atmosphere are efficient, and lead to large reductions in atmospheric carbon in strong policy scenarios (e.g., RCP 1.9).
  - Carbon rental policies are most efficient and should not be combined with taxes on emissions.
- A/R, RIL, AD, etc. and biomass are complements, lowering marginal costs.
- Other goals of sustainable development need to be evaluated.