BIOMASS ENERGY HARVESTING EFFECTS ON CARBON FLUXES

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Irreversible climate change due to carbon dioxide emissions

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Contributed by Susan Solomon, December 16, 2008 (sent for review November 12, 2008)

The severity of damaging human-induced climate change depends not only on the magnitude of the change but also on the potential for irreversibility. This paper shows that the climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop. Following cessation of emissions, removal of atmospheric carbon dioxide decreases radiative forcing, but is largely compensated by slower loss of heat to the ocean, so that atmospheric temperatures do not drop significantly for at least 1,000 years. Among illustrative irreversible impacts that should be expected if atmospheric carbon dioxide concentrations increase from current levels near 385 parts per million by volume (ppmv) to a peak of 450–600 ppmv over the coming century are irreversible dry-season rainfall reductions in several regions comparable to those of the "dust bowl" era and inexorable sea level rise. Thermal expansion of the warming ocean provides a conservative lower limit to irreversible global average sea level rise of at least 0.4–1.0 m if 21st century CO_2 concentrations exceed 600 ppmv and 0.6–1.9 m for peak CO_2 concentrations exceeding ~1,000 ppmv. Additional contributions from glaciers and ice sheet contributions to future sea level rise are uncertain but may equal or exceed several meters over the next millennium or longer.

dangerous interference | precipitation | sea level rise | warming

Over the 20th century, the atmospheric concentrations of key greenhouse gases increased due to human activities. The stated objective (Article 2) of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent "dangerous anthropogenic interference with the climate system." Many studies have focused on projections of possible 21st century dangers (1–3). However, the principles (Article 3) of the UNFCCC specifically emphasize "threats of serious or irreversible damage," underscoring the importance of the longer term. While some irreversible climate changes such as ice sheet collapse are possible but highly uncertain (1, 4), others can now be identified with greater confidence, and examples among the latter are presented in this paper. It is not generally appreciated that the atmospheric temperature increases caused by rising carbon dioxide concentrations are not expected to decrease significantly even if carbon emissions were to completely cease (5–7) (see Fig. 1). Future carbon dioxide emissions in the 21st century will hence lead to adverse climate changes on both short and long time scales that would be essentially irreversible (where irreversible is defined here as a time scale exceeding the end of the millennium in year 3000; note that we do not consider geo-engineering measures that might be able to remove gases already in the atmosphere or to introduce active cooling to counteract warming). For the same reason, the physical climate changes that are due to anthropogenic carbon dioxide already in the atmosphere today are expected to be largely irreversible. Such climate changes will lead to a range of damaging impacts in different regions and sectors, some of which occur promptly in association with warming, while others build up under sustained warming because of the time lags of the processes involved. Here we illustrate 2 such aspects of the irreversibly altered world that should be expected. These aspects are among reasons for concern but are not comprehensive; other possible climate impacts include Arctic sea ice retreat, increases in heavy rainfall and flooding, permafrost melt, loss of glaciers and snowpack with attendant changes in water supply, increased intensity of hurricanes, etc. A complete climate impacts review is presented elsewhere (8) and is beyond the scope of this paper. We focus on illustrative adverse and irreversible climate impacts for which 3 criteria are met: (*i*) observed changes are already occurring and there is evidence for anthropogenic contributions to these changes, (*ii*) the phenomenon is based upon physical principles thought to be well understood, and (*iii*) projections are available and are broadly robust across models.

Advances in modeling have led not only to improvements in complex Atmosphere–Ocean General Circulation Models (AOGCMs) for projecting 21st century climate, but also to the implementation of Earth System Models of Intermediate Complexity (EMICs) for millennial time scales. These 2 types of models are used in this paper to show how different peak carbon dioxide concentrations that could be attained in the 21st century are expected to lead to substantial and irreversible decreases in dry-season rainfall in a number of already-dry subtropical areas and lower limits to eventual sea level rise of the order of meters, implying unavoidable inundation of many small islands and low-lying coastal areas.

Results

Longevity of an Atmospheric CO_2 Perturbation. As has long been known, the removal of carbon dioxide from the atmosphere involves multiple processes including rapid exchange with the land biosphere and the surface layer of the ocean through air–sea exchange and much slower penetration to the ocean interior that is dependent upon the buffering effect of ocean chemistry along with vertical transport (9–12). On the time scale of a millennium addressed here, the CO_2 equilibrates largely between the atmosphere and the ocean and, depending on associated increases in acidity and in ocean warming (i.e., an increase in the Revelle or "buffer" factor, see below), typically ~20% of the added tonnes of CO_2 remain in the atmosphere while ~80% are mixed into the ocean. Carbon isotope studies provide important observational constraints on these processes and time constants. On multimillenium and longer time scales, geochemical and geological

Author contributions: S.S., G.-K.P., R.K., and P.F. designed research; S.S., G.-K.P., and R.K. performed research; G.-K.P. and R.K. analyzed data; and S.S., G.-K.P., R.K., and P.F. wrote the paper.

The authors declare no conflict of interest.

Freely available online through the PNAS open access option.

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This article contains supporting information online at www.pnas.org/cgi/content/full/0812721106/DCSupplemental.

Wood energy: pros and cons

Pros: Local, renewable, support local economies and forestry, incentive for good forestry

Cons: Potential net greenhouse gas emissions, impacts on wildlife habitats

Question: How to we maximize benefits while minimizing risks?

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Economics of integrated harvests with biomass for energy in non-industrial forests in the northeastern US forest

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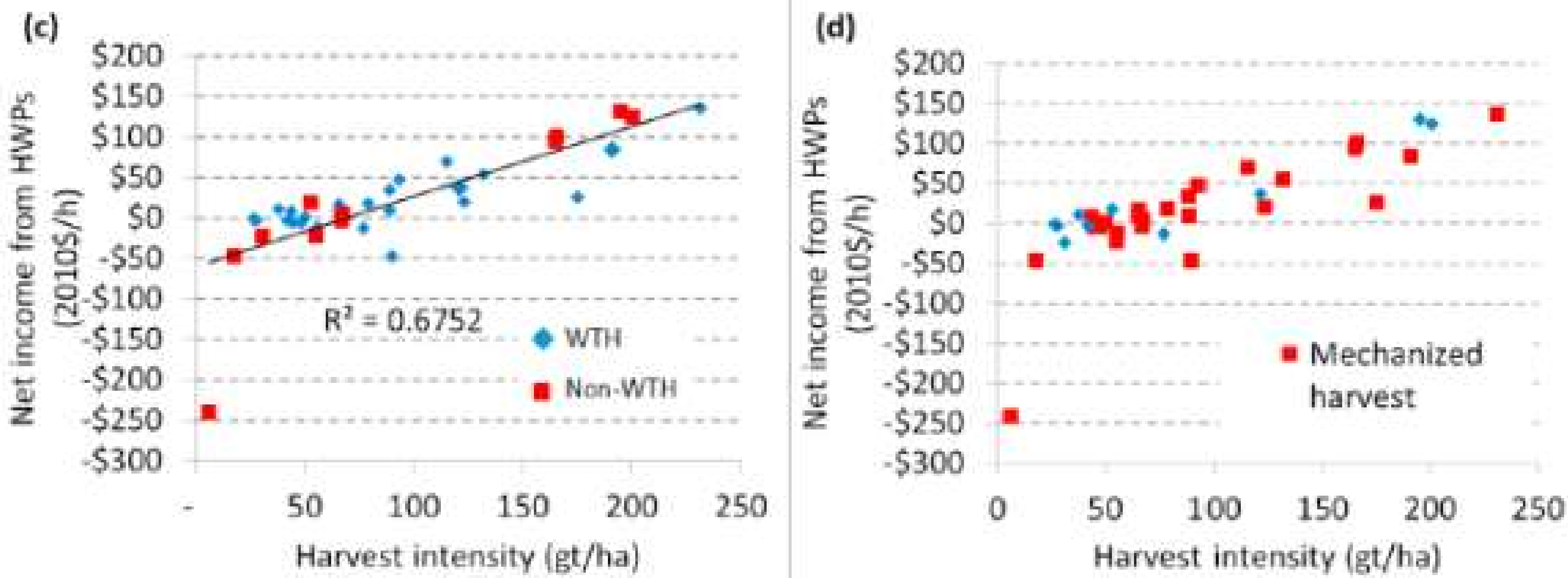
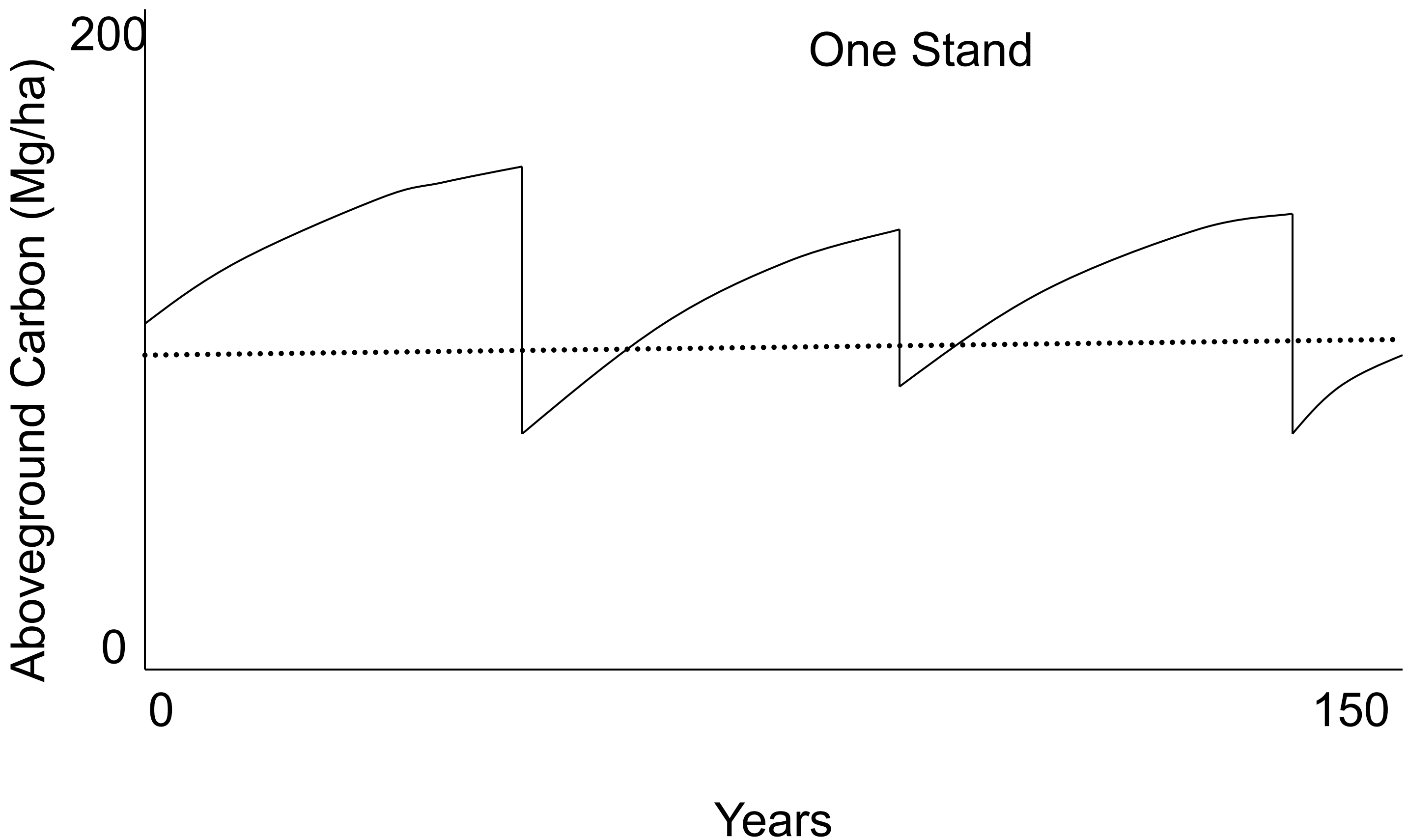
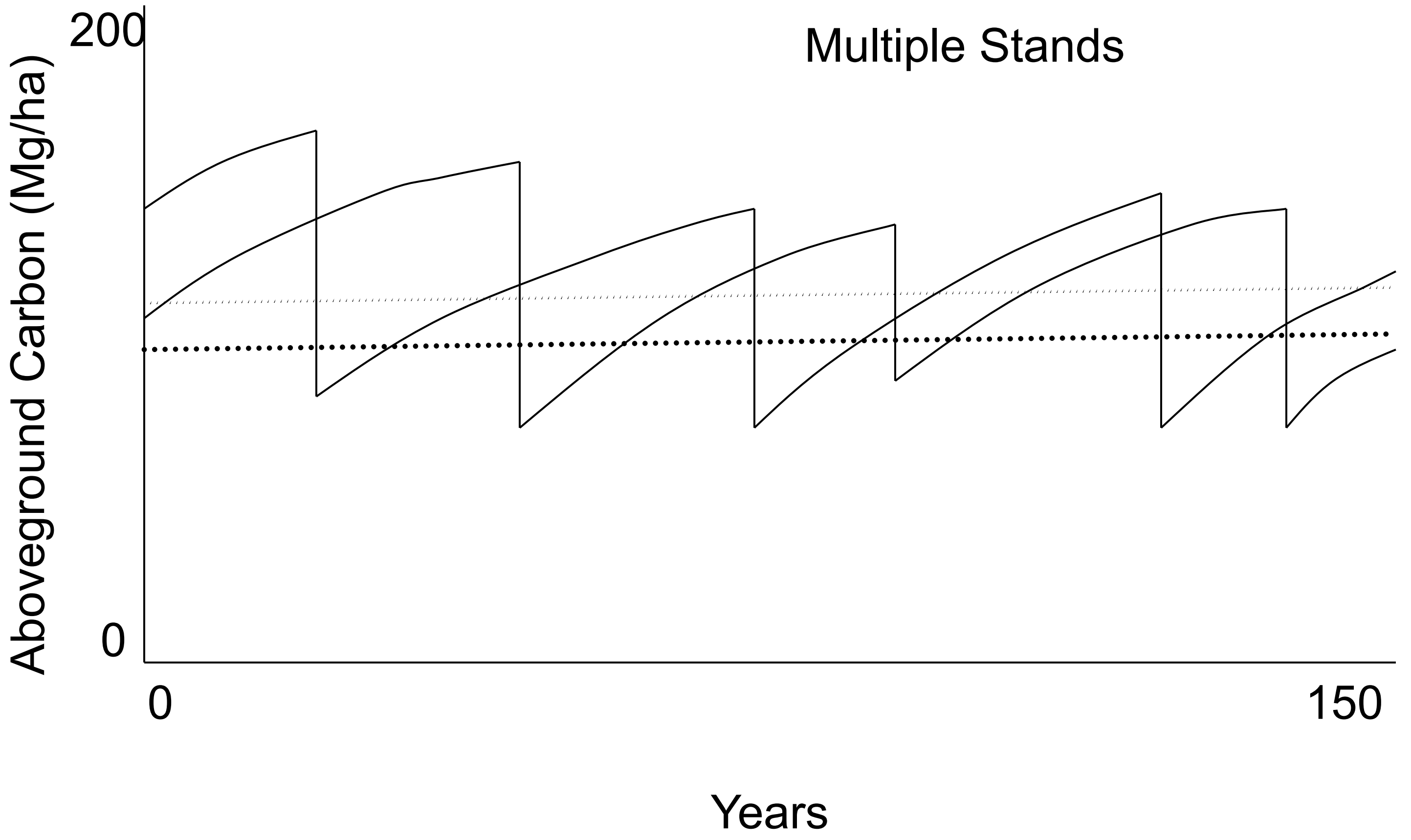


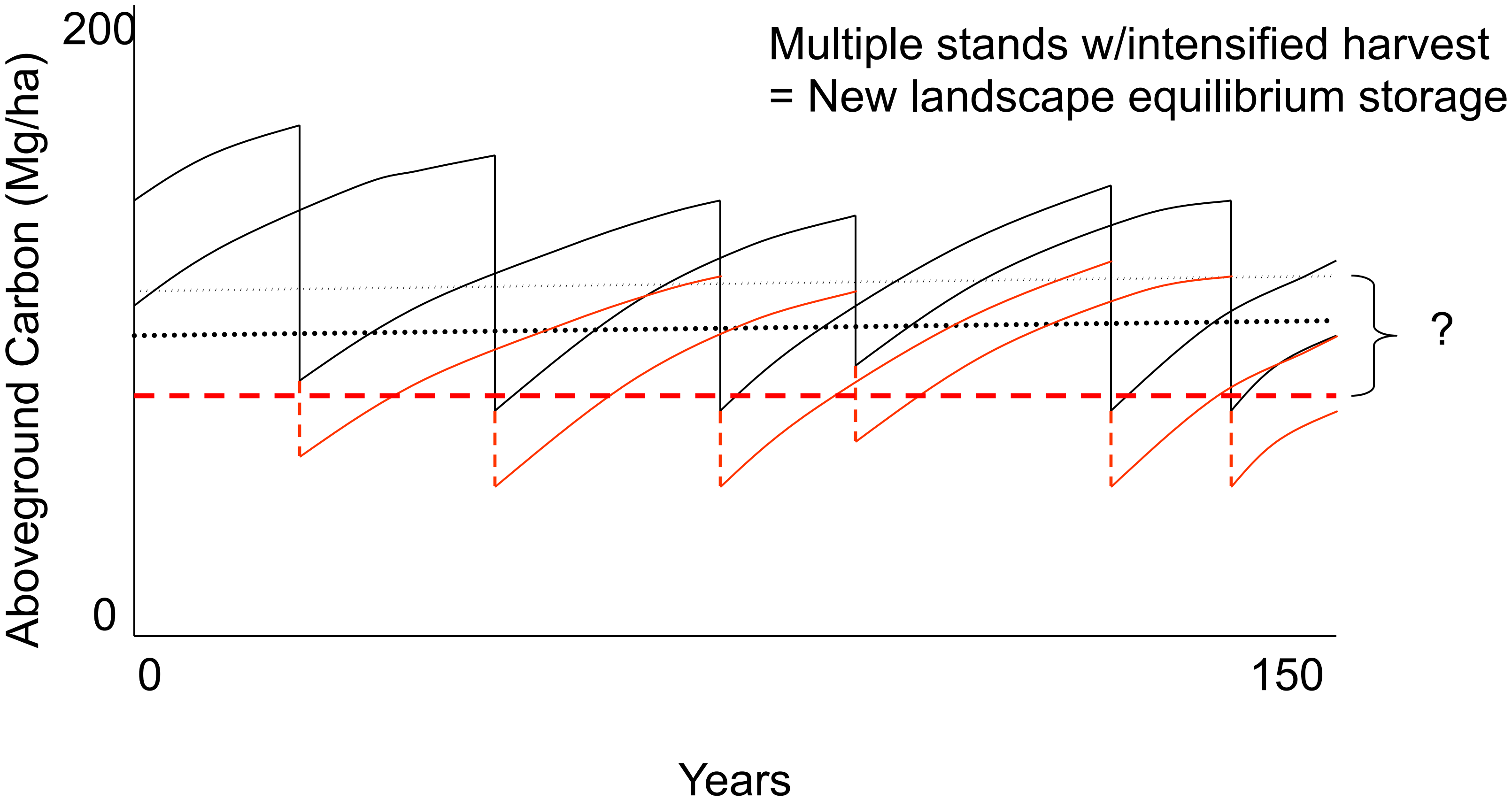
Landscape Scale Carbon Storage: Working Hypothesis



Landscape Scale GHG Emissions: Working Hypothesis



Landscape Scale GHG Emissions: Working Hypothesis



GLOBAL CHANGE BIOLOGY BIOENERGY

GCB Bioenergy (2015), doi: 10.1111/gcbb.12245

A global meta-analysis of forest bioenergy greenhouse gas emission accounting studies

THOMAS BUCHHOLZ[1,2], MATTHEW D. HURTEAU[3], JOHN GUNN[4] and DAVID SAAH[1,5]

Baselines are Key!!!!

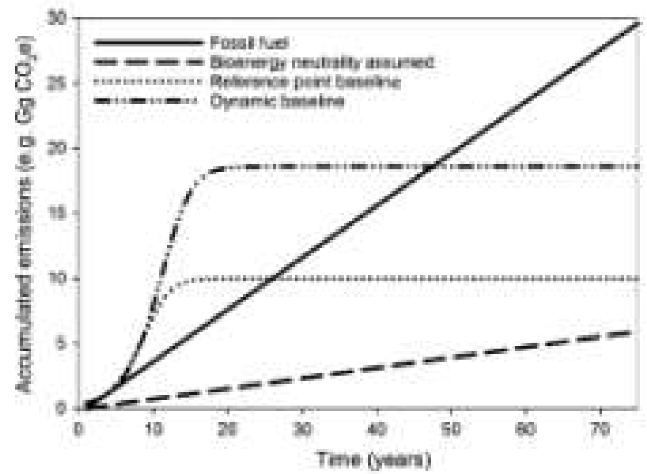
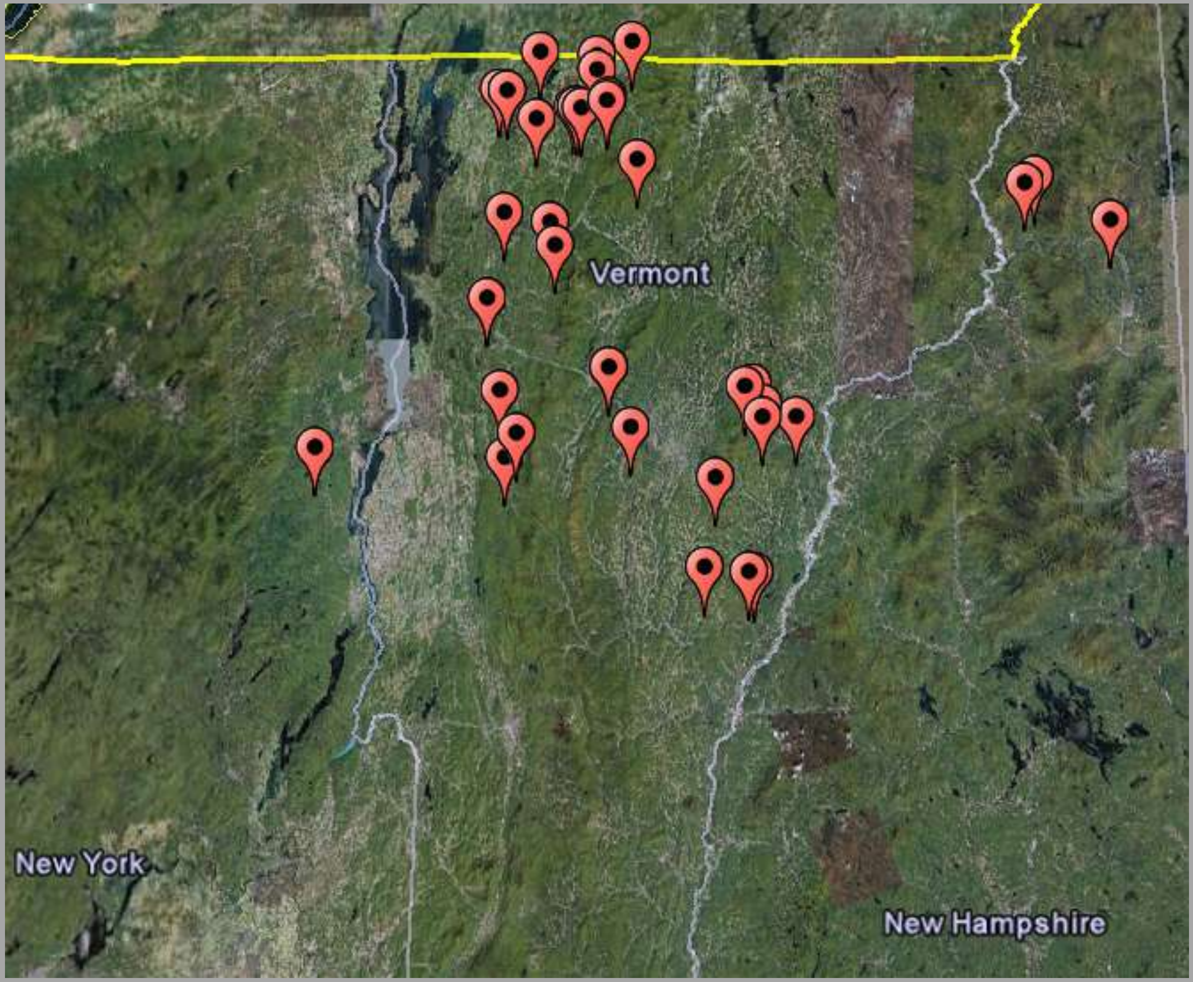


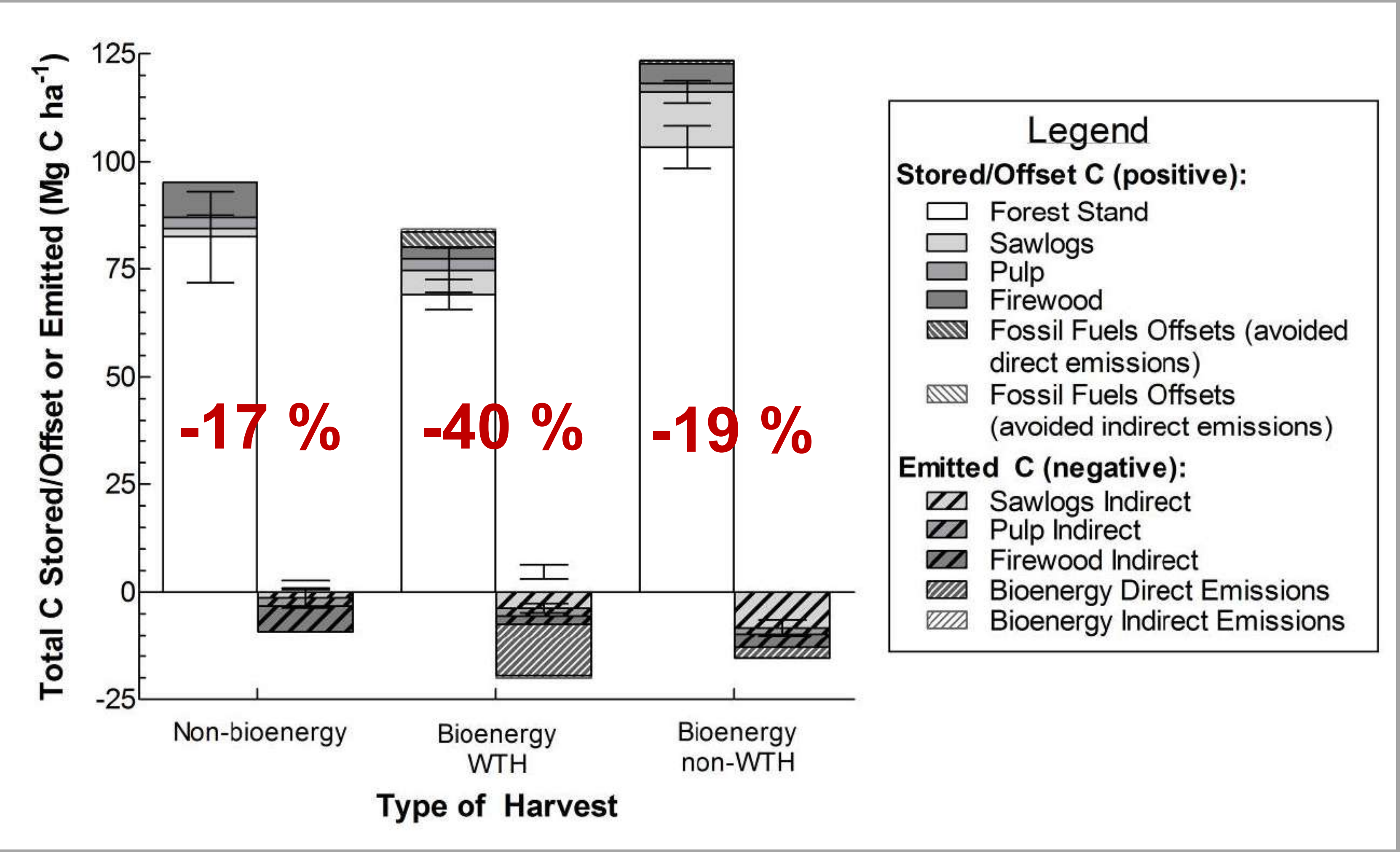
Fig. 2 Baseline choices influence carbon payback when comparing bioenergy alternatives with fossil-fuel emissions. In this hypothetical case, the reference point baseline assumes a scenario where forest carbon stocks briefly decrease followed by a recovery compared to a reference point in time. The dynamic baseline assumes a project scenario where forest stocks decrease compared to business as usual and require a longer time span to recover.

METHODS:

- 35 Sites
- Site matching criteria
- Paired reference at each location
- Harvested within last 3 years
- Range of harvesting intensities and product mixes



Net C Flux Post-Harvest



From: Mika and Keeton 2012.
Global Change Biology: Bioenergy

Simulation modeling in FVS:

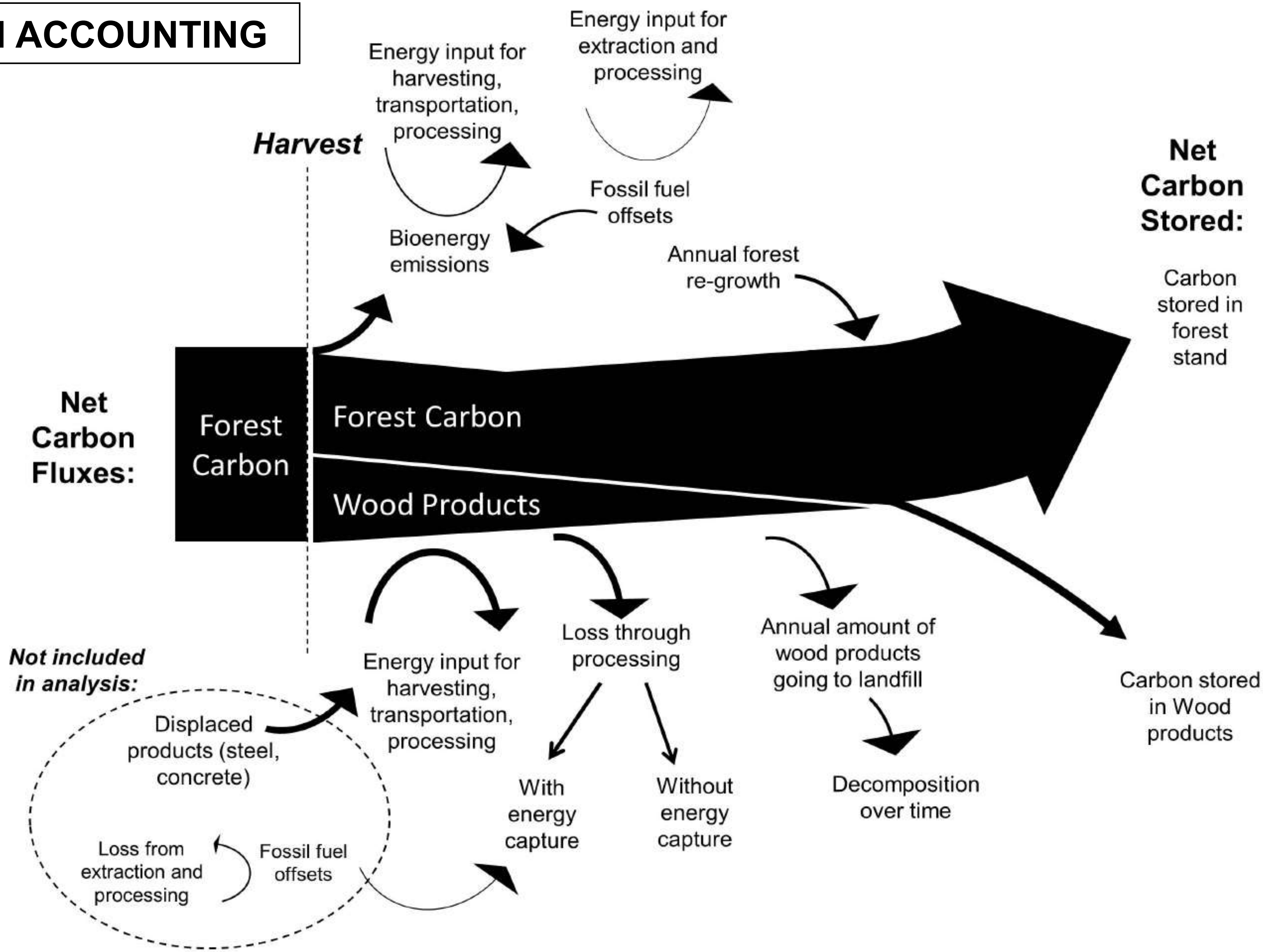
Data:

- 362 FIA plots from New York, Vermont, New Hampshire and Maine
- Randomly selected from 3,306 sites meeting criteria
- Representative of age class and stocking distributions for the Northeast

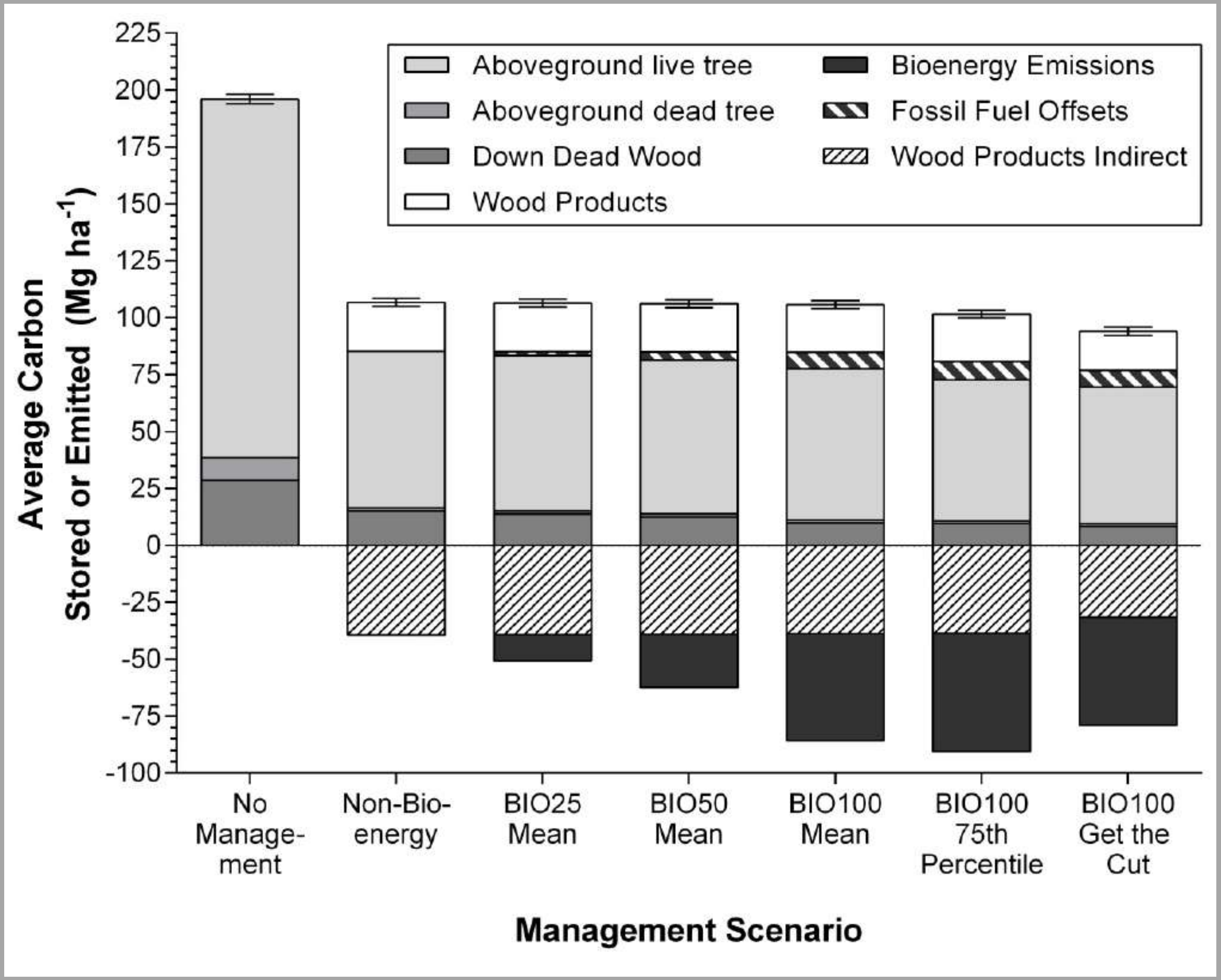
Scenarios and scheduling:

- Bioenergy intensification from Mika and Keeton (2012)
  - Mean and 75 percentile
- Silvicultural scenarios proportionate to use
  - Selection harvest
  - Shelterwood
  - Clearcut/patch cut
- Bioenergy scenarios applied to 25%, 50%, and 100% of landscape
- Minimum residual stocking threshold for some scenarios.
- Stands randomly selected for “cutting” when they attain harvestable stocking levels
- Regeneration inputs from Nunery and Keeton (2010)

CARBON ACCOUNTING

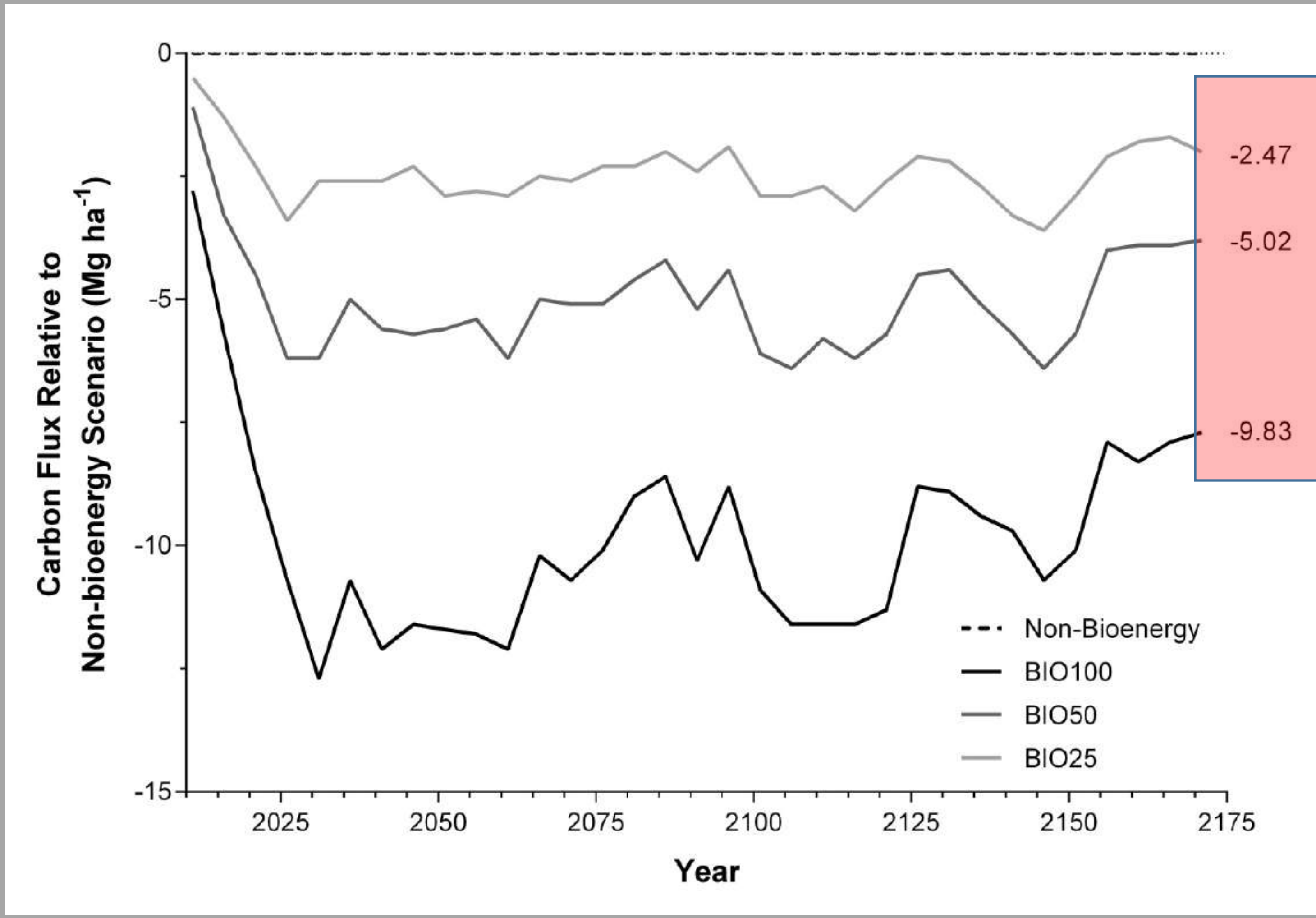


Average fluxes projected over 160 years in NE-FVS



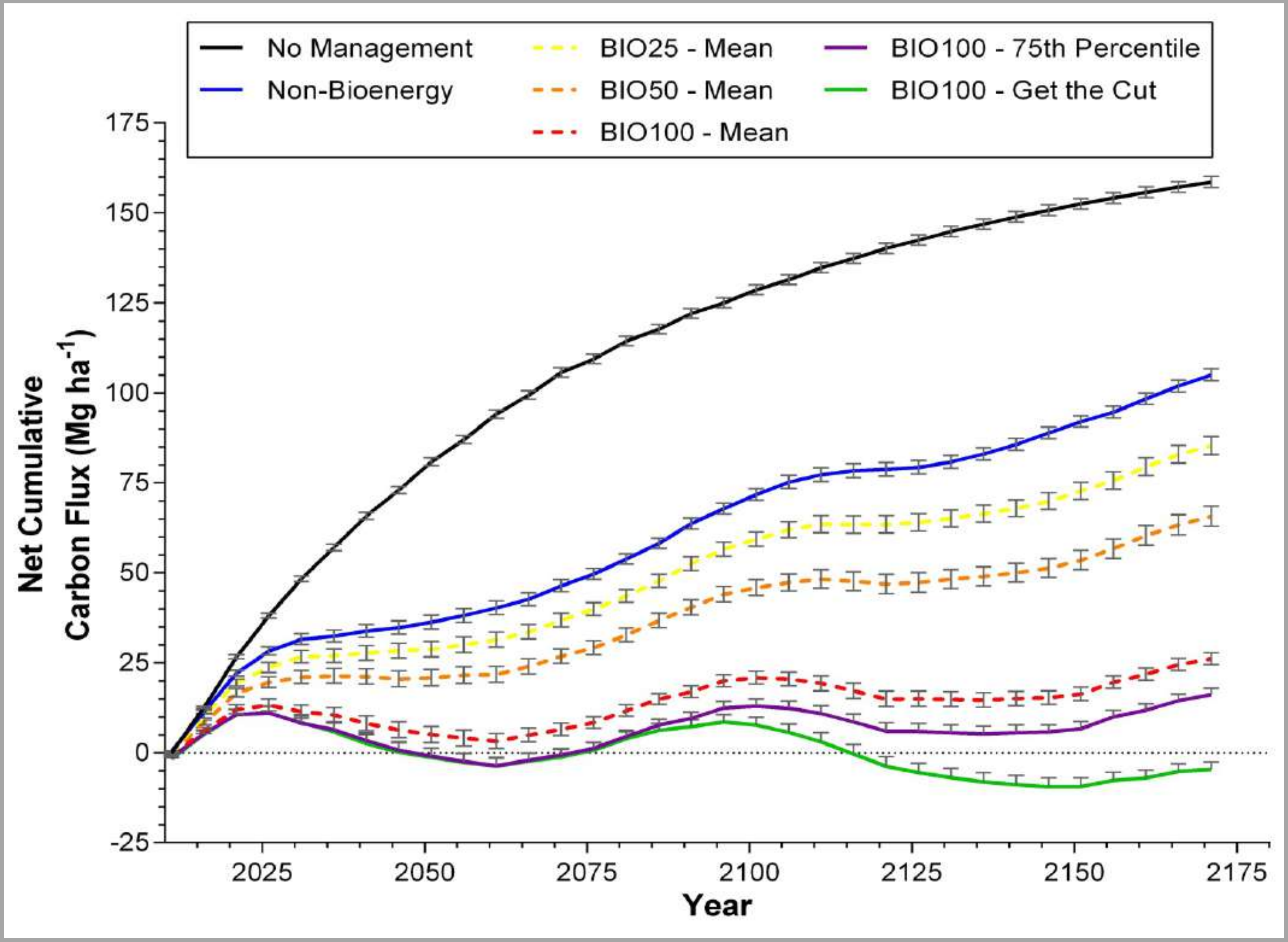
From: Mika and Keeton 2012.
In prep.

Projected net carbon flux compared to baseline (non-bioenergy harvesting)



From: Mika and Keeton 2012.
In prep.

Net carbon flux projected over 160 years in NE-FVS (N = 362)

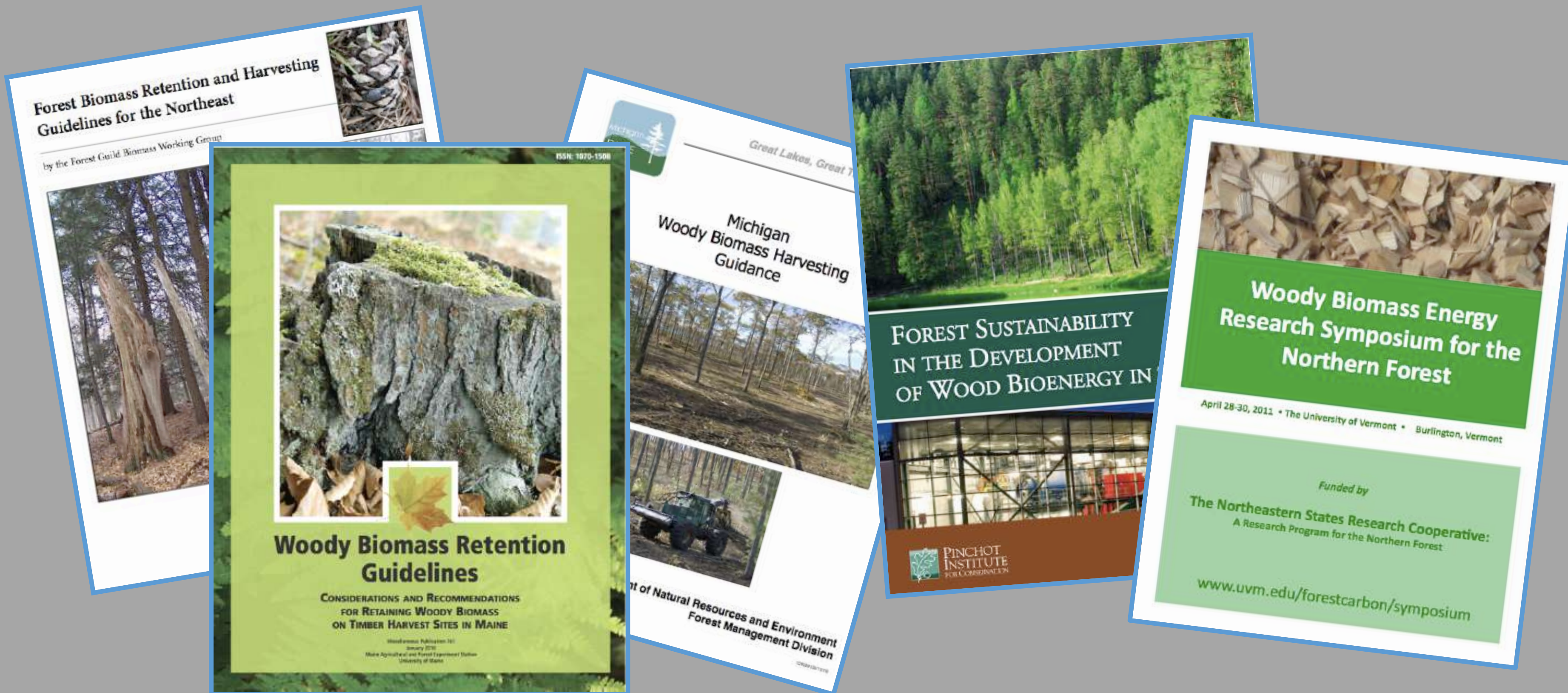


How do we minimize CO2 emissions?

- Harvesting guidelines to maintain in-situ stocking
- Silvicultural systems w/structural retention
- Reserves to offset emissions from intensive harvesting
- High efficiency energy conversion technologies
- Go small scale, go local!
- Emphasize use for thermal energy not electricity
- For industrial scale energy production emphasize combined heat and power
- Emphasize substitution for coal over natural gas

Role of Harvesting Guidelines

30 % of operators already meeting the Forest Guild's retention guidelines (Littlefield and Keeton 2012)



Slide courtesy of Caitlin Littlefield

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Act174WorkingGroup

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Biomass Energy Development Working Group
Final Report
January 17, 2012

Pursuant to No. 37 of the Acts of the 2009 Session

Biomass Energy Development Working Group Members

s	Rep. John Malcolm
	Sen. Ginny Lyons
e	Dep. Sec. Chris Recchia
ee	George Nagle
rce center	Adam Sherman
dustry	Rocky Bunnell, Paul Cate
nvironmental organizations	Jamey Fidel, Robert Turner
Two representatives of an industry or utility that produces electricity or heat from biomass	Chris Brooks, Bill Kropelin
A representative of the Vermont woodlands association	Sam Miller
A representative of a university or college with a focus on biomass	Bill Keeton
A representative of the consulting foresters association	Ben Machin (2009–2010); currently vacant
A representative of the forest guild	Ehrhard Frost

Utility Industries

Publications

The second meeting was held on Thursday, August 25, 2016 (Agenda)

The first meeting was held on Friday, August 5, 2016 (Agenda) Presentation re: Overview of current PSB processes and points of citizen participation.

For more information please contact Andrea McHugh, PSB staff, andrea.mchugh@vermont.gov.

Public Hearing

The **Citizen Participation in PSB Proceedings Working Group (established by Act 174)** convened a public hearing on:

Tuesday, October 11, 2016, in Room 11 of the Statehouse in Montpelier, Vermont.

Links