Topic 11: Feedbacks to climate change

11.1: Biogeochemical feedbacks cont.

Climate Change Ecology
Geography 404
Jeff Hicke

Topic 11: Feedbacks to climate change

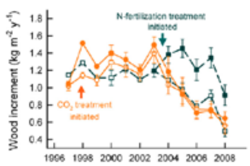
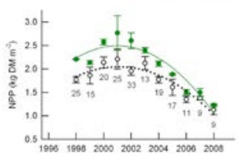


Fig. 2. Growth response to nitrogen addition. Responses in the N fertilizer experiment (dashed lines) are compared with responses in the FACE experiment (solid lines). Elevated CO_2 (solid circles) caused a significant increase in wood increment in the first year after treatment initiation (1998), but the response diminished in subsequent years and in later years was not statistically different from FACE controls (open circles). N fertilization (shaded squares) caused an immediate and sustained increase in wood increment compared with unfertilized plots (open squares) ($P < 0.001$).



Norby et al., PNAS, 2010

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Global ecosystem modeling results with C only vs. with C and N

Table 3. Summary of Carbon Fluxes for the C-N and Carbon-Only Simulations, Showing Means With Interannual Standard Deviations in Parentheses[a]

Experiment	GPP	NPP	AR	HR	Fire	NEE[b]
			Years 2076–2100			
CN+co2	118.8 (1.4)	49.9 (0.8)	68.9 (0.8)	45.8 (0.7)	1.3 (0.1)	−2.81 (0.6)
CN+ndep	109.0 (1.2)	44.9 (0.7)	64.0 (0.7)	43.1 (0.5)	1.2 (0.1)	−0.70 (0.6)
CN+co2ndep	127.9 (2.2)	54.5 (1.1)	73.4 (1.2)	49.0 (1.0)	1.5 (0.1)	−4.08 (0.6)
C+co2	256.5 (5.9)	120.3 (3.2)	136.2 (2.9)	105.7 (2.6)	4.0 (0.3)	−10.65 (2.0)
C_L+co2	220.5 (4.8)	99.4 (2.6)	121.2 (2.4)	87.5 (2.2)	2.6 (0.2)	−9.21 (1.6)

[a]Values are given for the final 25 a of the control experiments, and over the periods 1976–2000 and 2076–2100 for the transient experiments. AR is autotrophic respiration. HR is heterotrophic respiration. NEE is net ecosystem exchange of carbon. NPP is net primary production. GPP is gross primary production. Units are PgC a^{-1}.
[b]Positive upward (carbon release from land).

Thornton et al., GBC, 2007

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Forest net C fluxes (inventory, field observations)

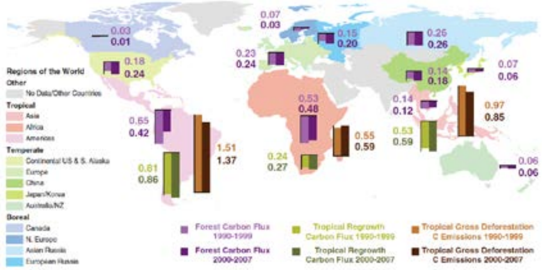

Fig. 1. Carbon sinks and sources (Pg C year^{-1}) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestation emissions.

Pan et al., Science, 2011

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Changes in Disturbance in Response to Climate Change

Fire

Global C emissions from fires

Where are there intense fires? Where are there intense, frequent fires?

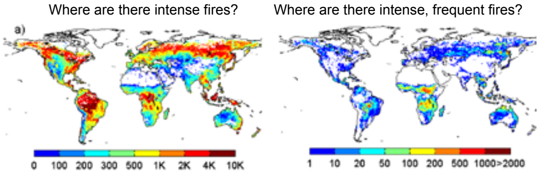

Fig. 5. (a) Fire emissions per m² of burned area (g C m^{-2} year^{-1}). Fig. 6. Mean annual fire emissions (g C m^{-2} year^{-1}) averaged over 1997–2004.

van der Werf et al., 2006

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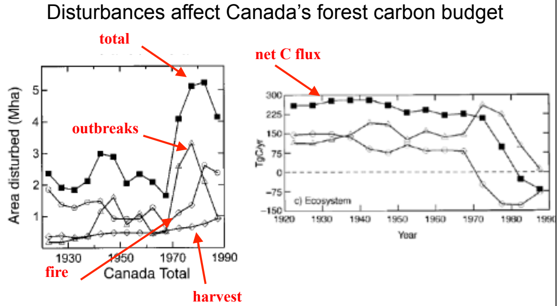
Disturbances affect Canada's forest carbon budget



Kurz and Apps, EA, 1999

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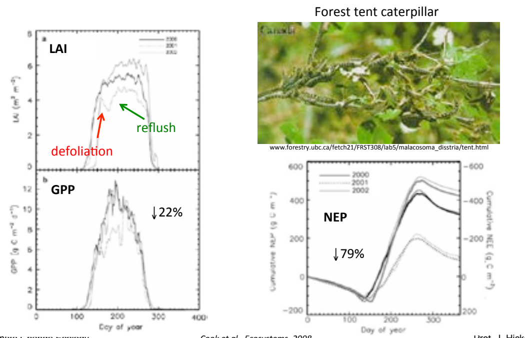
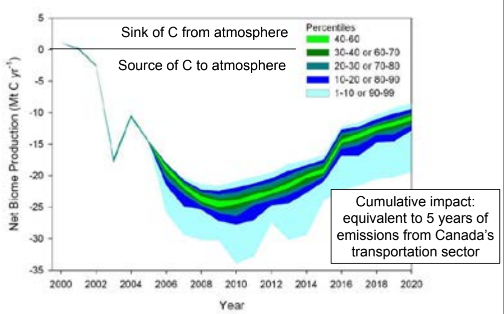
Effects of defoliation derived from EF towers



Climate Change Ecology — *Cook et al., Ecosystems, 2008* — Prof. J. Hicke

Carbon Impacts of MPB in Western Canada

13 million ha affected in 2007



Source: Kurz et al. 2008, Nature — *Slide courtesy W. Kurz, CFS*

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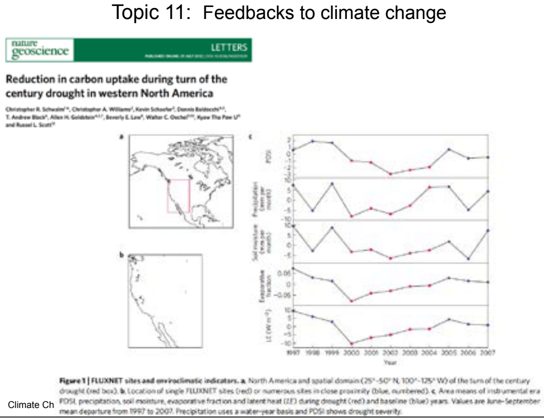

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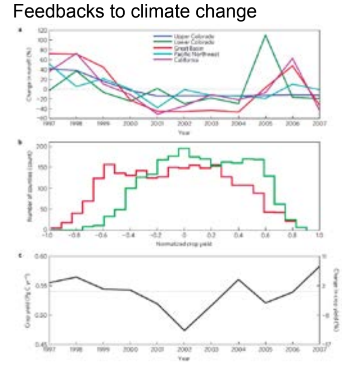
Effects on runoff and crop yield



Schwalm et al., 2012

Figure 2 | Basin runoff and crop productivity in the western conterminous United States from 1997 to 2007. a, Annual changes in basin runoff the 11-year mean. Upper Colorado, Lower Colorado, Great Basin, Pacific Northwest, and California basins. **b,** Detrended normalized crop product county (n = 2328 counties in the western United States) during drought (red) and non-drought (green) conditions. Drought peak is shifted towa values (two-sampled two-tailed t-test; p < 0.001). **c,** Total detrended crop productivity and per cent change (solid line) relative to the 11-year me line).

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Flux tower measurements of C, latent heat, sensible heat

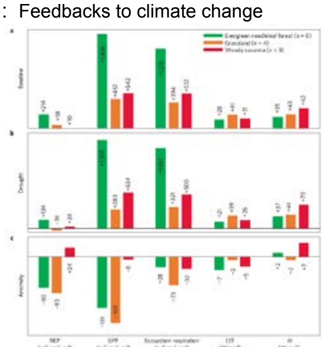

Figure 3 | Carbon and energy fluxes observed at FLUXNET from 1997 to 2007. NEP, GPP, ecosystem respiration, LE and H. Values are grouped by land cover and were derived using 15 flux tower locations and 84 site years. **a,** Baseline. **b,** Drought. **c,** Anomaly. Note different scales for carbon and energy fluxes.

Schwalm et al., 2012

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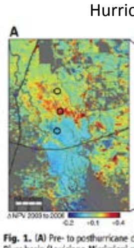
Hurricane Katrina's effects on forest C stocks



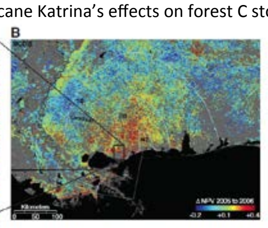


Fig. 1. (**A**) Pre- to posthurricane change in the NPV fraction (ΔNPV) on a Landsat 5 subset for the Pearl River basin (Louisiana-Mississippi state line) provided a quantitative measure of disturbance intensity. By using this map, we established forest inventory plots (white markers) across the disturbance gradient. Open black markers represent (top) moderately resistant, infrequently flooded, bottomland hardwood forest; (middle) minimally resistant, frequently flooded, bottomland hardwood forest; and (bottom) highly resistant, flooded, cypress-tupelo swamp forest. (**B**) MODIS-derived ΔNPV from 2005–2006 provided regional estimates of tree mortality and biomass loss across the entire impact region. Isotachs (white lines) represent tropical storm (TS), category 1 (H1), and category 2 (H2) wind fields (9).

- Mortality and damage to 320 million large trees
- 105 Tg C
- 50-140% of net annual C sink in US forests

Chambers et al., 2007

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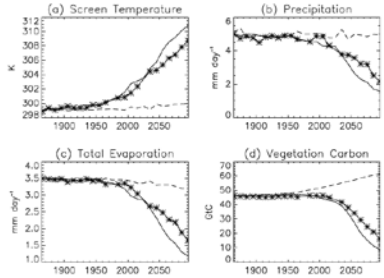

Model predictions of Amazon dieoff in response to future climate change

Fig. 7. Evolution of climate and biomass over the Amazon box, from three separate HadCM3LC simulations with dynamic vegetation. (a) Screen temperature, (b) precipitation, (c) evaporation, (d) vegetation carbon. The continuous line represents the fully coupled climate-carbon cycle run, the dashed line is from the run without climate effects on the carbon cycle, and the stars are from a run with prescribed IS92a CO_2 concentrations. The related CO_2 scenarios are shown in Fig. 1

Cox et al., 2004

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Model predictions of Amazon dieoff in response to future climate change

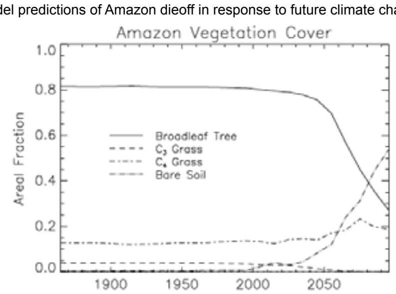

Fig. 6. Evolution of the vegetation cover in the Amazon box from the coupled climate-carbon cycle simulation

Cox et al., 2004

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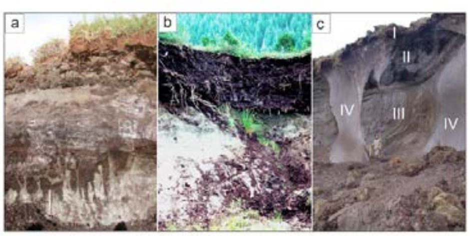

Figure 3. Near-surface SOC pools and deeper organic C pools in peatlands and frozen sediment-paleosoil horizons in North American high latitudes. (a) Strongly cryoturbated soil exposed on a thermokarst lake bluff in a tundra lowland on the Seward Peninsula, Alaska (hammer for scale) (photo: G.G.). (b) About 3 m thick peat exposed at a bluff, Diana Lake in Prince Rupert area, British Columbia, Canada (photo: D. Vitt). (c) Deep carbon-rich permafrost sediments exposed in a thaw slump on the Colville River, Alaska North Slope (person for scale). I, modern peaty soil; II, perennially frozen, ice-rich silt with peat horizons and organic-rich soils; III, perennially frozen, ice-rich sand with peat balls and sedge tussocks; IV, syngenetic ice wedge (photo: G.G.).

Grosse et al., JGR, 2011

Distribution of permafrost in the Arctic

Schurr et al., BioScience, 2008

Figure 1. Latitudinal zonation of permafrost. Source: Brown and colleagues (1998).

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Model predictions of permafrost loss

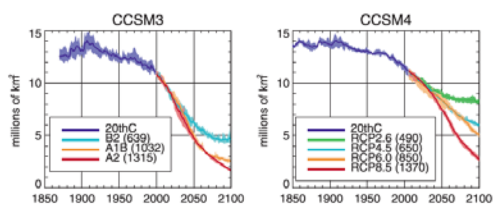

FIG. 6. Time series of Northern Hemisphere near-surface permafrost extent for CCSM3 and CCSM4 for historical and projection periods. Near-surface permafrost extent is the integrated area of grid cells with at least one soil layer within the top 10 soil layers (3.5 m in CCSM3, 3.8 m in CCSM4) that remains frozen throughout the year. Frozen ground underneath glaciers is not included in the near-surface permafrost extent. The greenhouse gas concentration in CO_2 equivalents (ppm) for the year 2100 are listed in parentheses for each SRES and RCP scenario. Shading indicates the ensemble spread.

Lawrence et al., J. Climate, 2012

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Table 5 A comparison of the strengths and weaknesses of alternative NEE scaling approaches (inventory-based, AIMs and TBMs)

	Inventory-based	Atmospheric inversion models (AIMs)	Terrestrial biosphere models (TBMs)
Strengths	1) Employs a large number of repeated biomass measurements 2) Allows estimation of product-related C sources	1) assimilates measurements of atmospheric CO_2 concentration 2) Employs atmospheric mass balance	1) Processes are represented so attribution is possible 2) Sensitive to interannual variation in climate 3) Many opportunities for validation
Weaknesses	1) Not all C pools are measured 2) Possible undersampling 3) Limited attribution ability 4) Missing NEE of unmanaged ecosystems 5) Poorly resolved temporally	1) Transport model uncertainty 2) Limited number of CO_2 measurements 3) Low spatial resolution 4) Limited attribution ability	1) Many inputs, each with their own uncertainty 2) Many parameters, each with their own uncertainty 3) Spatial resolution may not resolve management scale disturbances

Hayes et al., 2012

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Estimates of contribution of ecosystems have high range

Table 2. North American CO2 (Mt CO2 yr-1) sources (positive values) and sinks (negative values) of the early 21st century

Source (positive) or Sink (negative)	United States	Canada	Mexico	North America	
Fossil fuel	5651	554	443	6649	
Ecosystem sources (positive) or sinks (negative)					
SOCCR (Pacala *et al.* 2007)	-1793	-235	176	-1852	
Hayes *et al.* (2012) inventory-based	-1107	-160	67	-1199	
Hayes *et al.* (2012) with "additional fluxes"	na	na	na	-2076	
Hayes *et al.* (2012) AIM ensemble	-2512	-871	-32	-3415	atm. inversions
Hayes *et al.* (2012) TBM ensemble	-1309	-457	-106	-1873	
Huntzinger *et al.* (2012) TBM (prognostic)	-733	-367	*	-1467	terrestrial biosphere models
Huntzinger *et al.* (2012) TBM (diagnostic)	-2567	-367	*	-3300	

Post et al., 2012

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Historical C fluxes from US forests

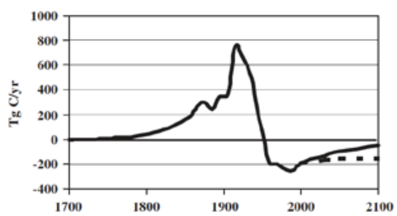

Fig. 5. Carbon emissions in the United States from drain on the saw-timber stand, and sequestration from regrowth, 1630–2000. Projections from 2000–2100 show a continuation of current trends (solid line) and a possible alternate trend (dashed line) that reflects implementation of policies to increase carbon sequestration by the forest sector.

Birdsey et al., 2006

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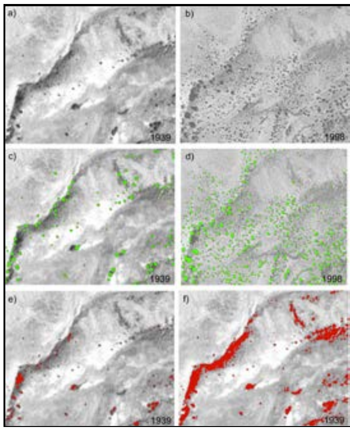
Woody encroachment: meadows

Lepofsky et al., Cons. Ecol., 2003



Woody encroachment: juniper expansion

Strand et al., 2006

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