Biophysical effects of land use change on surface climate

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Drivers and pathways of atmospheric change

- Atmospheric state
  - Physical state
  - Chemical state
  - Climate-active agents
  - Climate-inactive agents

- Land use change
- Fossil combustion

Effects of deforestation on the climate system

- **Biogeochemical effect**
  - arising from increases in atmospheric CO2 concentration
  - causing changes in radiative forcing of the atmosphere
  - consequences at global scale; no direct local impact

- **Biophysical effect**
  - associated with changes in albedo, surface roughness and evaporation
  - causing changes in energy balance and redistribution
  - impact at both global and local scale

Yatir Forest, Israel

Radiation balance, Yatir Forest

Albedo effect versus carbon sequestration
Yatir Forest

- Albedo effect of tree planting
  - Net radiative forcing, ground surface = 50 W m⁻²
  - Net radiative forcing, Top of Atmosphere = 20 W m⁻²
  - Equivalent carbon emission = 60 t C ha⁻¹

- Net ecosystem production = 2.3 t C ha⁻¹ y⁻¹

- Time to achieve carbon neutral state = 26 y

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Table 3: Radiative forcing at the top of the atmosphere (TOA) and CO₂ equivalence

<table>
<thead>
<tr>
<th>Event</th>
<th>Net radiative forcing (W m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2 × CO₂: TOA radiative forcing (RF) - (Hansen et al. estimate) 2.35 W m⁻²</td>
</tr>
<tr>
<td>2.</td>
<td>Increase in atmospheric concentration by doubling CO₂ concentration 5.71 W m⁻²</td>
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<tr>
<td>3.</td>
<td>Increase in atmospheric concentration by doubling CO₂ concentration by 50% 2.75 W m⁻²</td>
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<tr>
<td>4.</td>
<td>Increase in atmospheric CO₂ by doubling concentration 2.15 × 10⁻³ W m⁻²</td>
</tr>
</tbody>
</table>

Albedo along a jack pine chronosequence
Saskatchewan, Canada

Data source: Alan Barr

Wintertime albedo versus precipitation
Grassland, Brookings, South Dakota

Data source: Alan Barr

Albedo effect of roof whitening, City of Chicago
- Net change in TOA shortwave radiation = 2.8 W m$^{-2}$
- Area affected = 600 km$^2$
- Equivalent carbon sequestration = 500,000 t C

- A 16 in DBH Douglas-fir tree = 1 tonne biomass
- Number of trees in Chicago = 4,000,000

Sources: http://www.ruraltech.org; McPherson et al.

Painting roof white versus planting trees

Map of Jiangsu
Taihu 太湖 Eddy Flux Project

Biogeochemical
Algae growth & spread
CO2 sink
CH4/N2O source
Pollution reduction
Climate policy

Biophysical
Wind-wave interactions
Heat & water fluxes
Regional weather forecast
Air quality management

New land surface model
Climate model

Eddy flux mesonet, Lake Taihu (太湖), China

- Buoy
- Eddy covariance
- Surface station
- Microwave radar /Lidar
- In-lake platform
- Ship-borne isotope measurement
- Helicopter profiling

太湖水文气象和生态气象观测网络

已建系统
浮标站
观测系统
晴雨表
地高气象站
湖中观测平台

待建系统
激光雷达/微波雷达
船载同位素仪
机载廓线观测

太湖水文气象和生态气象观测网络
The Yatir Forest Paradox: The forest is 5°C cooler despite 50 Wm$^{-2}$ more radiation loading than the shrub land.

Radiative forcing versus energy redistributions

Climate sensitivity

Intrinsic sensitivity
- $\lambda_0 = \frac{1}{4F_0}$ and $\Delta T_o = \lambda_0 \Delta Q$
- 0.3 K per W m$^{-2}$ at the global scale
- 0.2 K per W m$^{-2}$ at the surface

Apparent sensitivity
- $\Delta T_a = \frac{\lambda_0}{1 + f} \Delta Q$ ~0.8 K per W m$^{-2}$ at the global scale
- $\Delta T_a = \frac{\lambda_0}{1 + f} \Delta Q - \frac{\lambda_a}{(1 + f)^2} \Delta f Q$ at the surface

Factor separation analysis

- a: Boreal / harvested
- b: Boreal / burnt
- c: temperate humid
- d: temperate semi-arid
- e: tropical
- f: tropical

FluxNet: A global network of CO$$_2$$ flux measurements


Source: http://www.fluxnet.ornl.gov

FluxNet: A global network of CO$$_2$$ flux measurements

Source: http://www.fluxnet.ornl.gov
Difference in mean surface air temperature

Annual mean difference in surface air temperature (open land minus forest)


Annual mean difference in surface air temperature (open land minus forest)

Source: Zhang et al., manuscript in preparation

Diurnal temperature range

Source: Zhang et al., manuscript in preparation
Efficient “convectors”

Source: Farlow, Margolis

Air temperature comparison
Great Mountain Forest vs Norfolk surface weather station

Daytime
nighttime

Air temperature (°C)

Day of year, 2000

Forest min
Forest max
Station min
Station max