Selecting and applying modelling tools to evaluate forest management strategies in the context of climate change.

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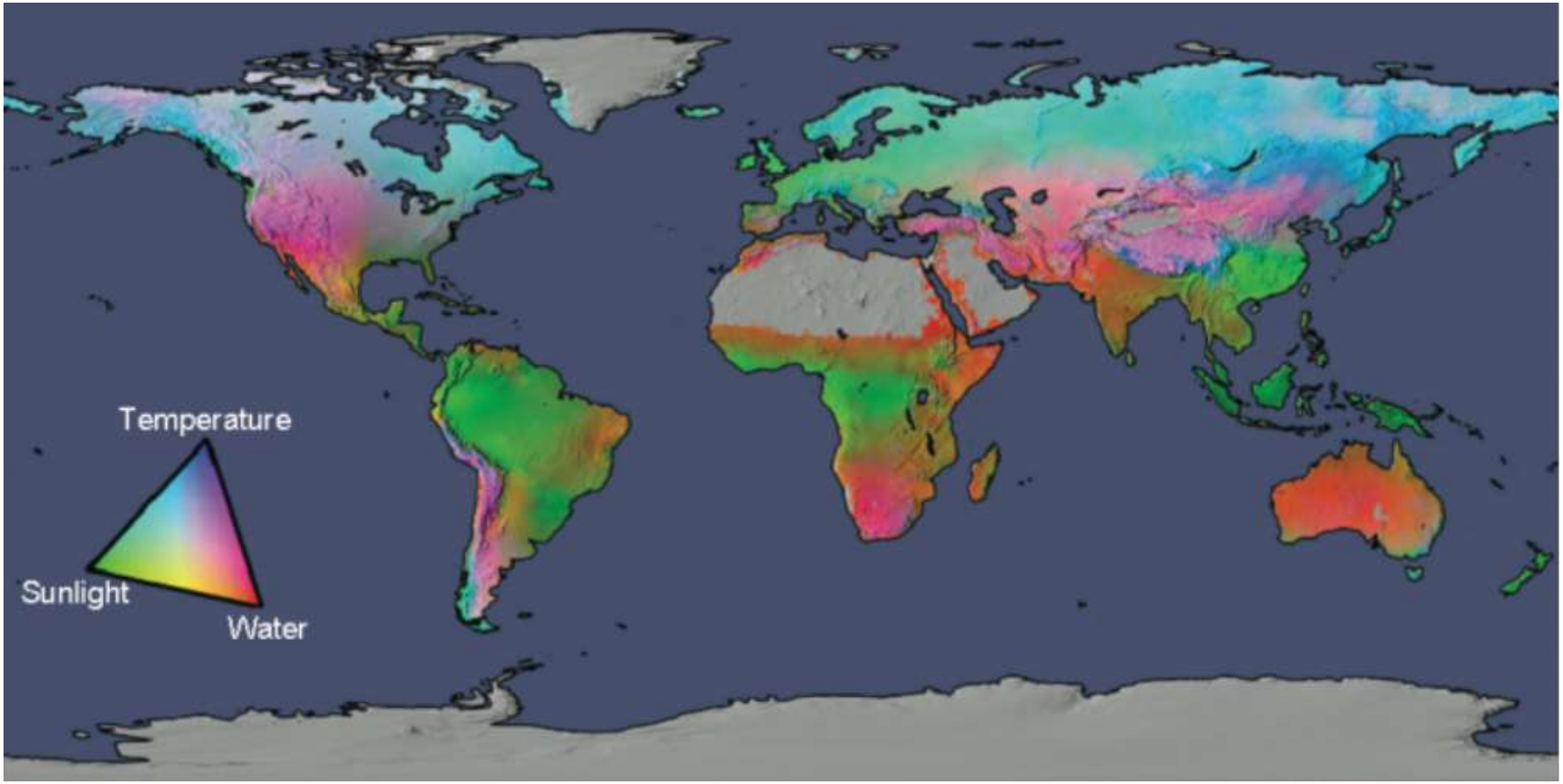
Role of climate in regulating forest productivity



Boisvenue and Running (2006) *Glob Change Biol*

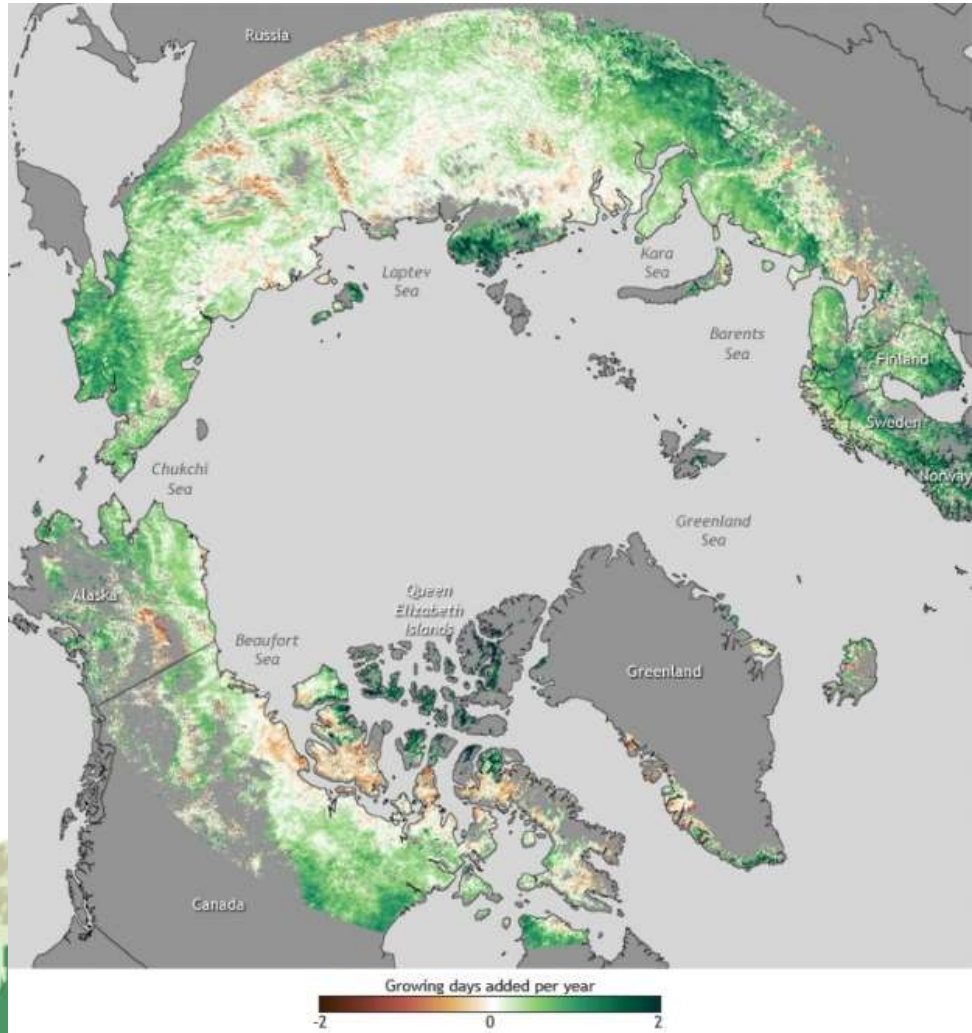
How will climate change influence the growth and development of forest ecosystems?

Warming climate will likely increase growing season length in boreal, temperate and even some sub-tropical forest types

Assessment of growing season length based upon satellite imagery 1982-2008

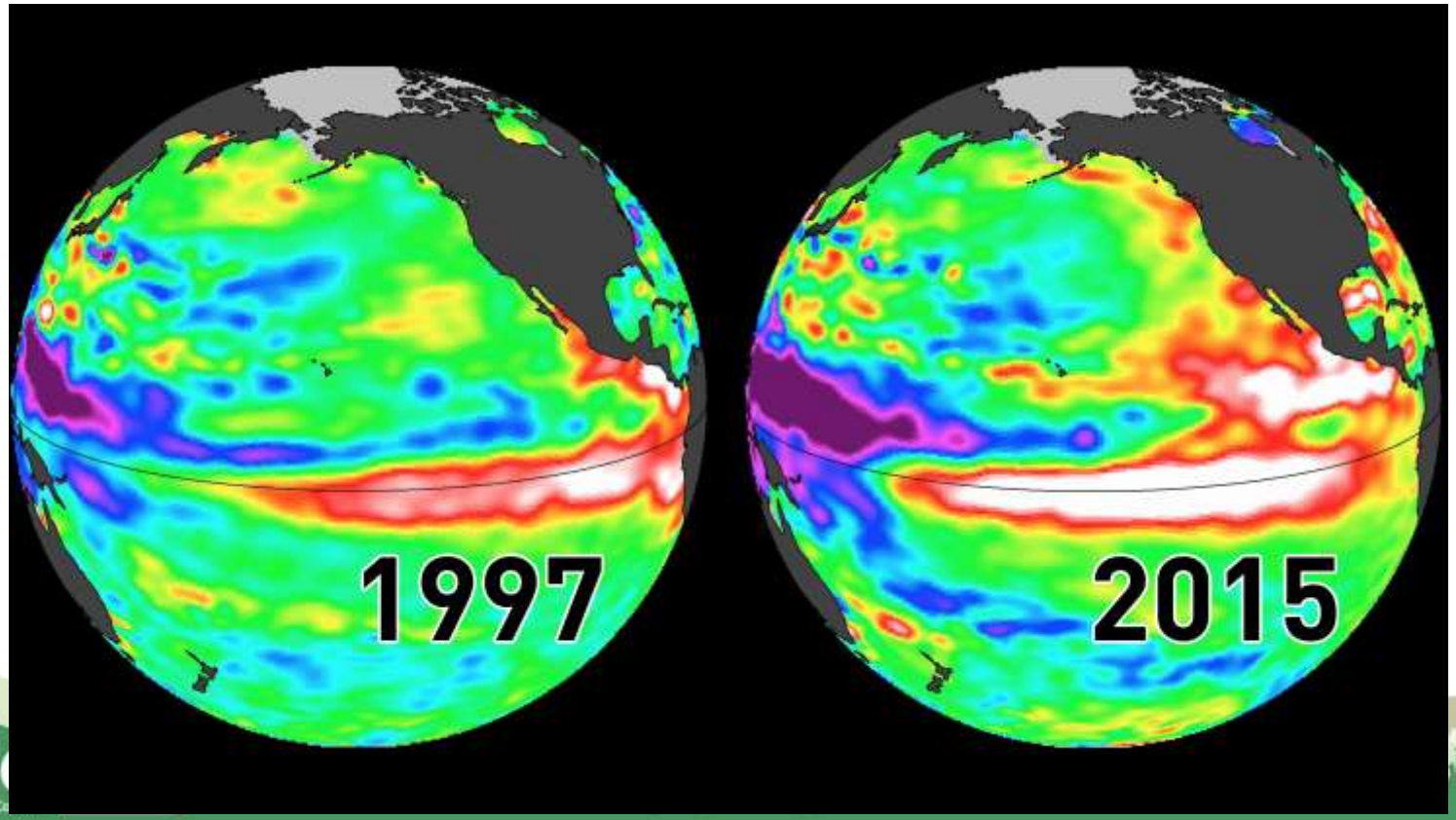
Zeng, et al. (2011) *Environ Res Let*

- Earlier springs
- Warmer soils in early growing season with increased microbial and root activity
- Later arrival of cool temperatures and frost
- Climate models predict these trends will continue
- Less important in SE Asia



Climate change may be altering the frequency and intensity of ENSO events

- The 1997-98 event was the likely the largest in the last 300 years
- The 2015-16 event has equaled, if not exceeded the 97-98 event
- Dramatic impact on rainfall patterns in the Monsoon climate system of SE Asia



El Nino related drought can have significant impacts on mortality and growth in SE Asian Forests

Teak growth and mortality in Myanmar

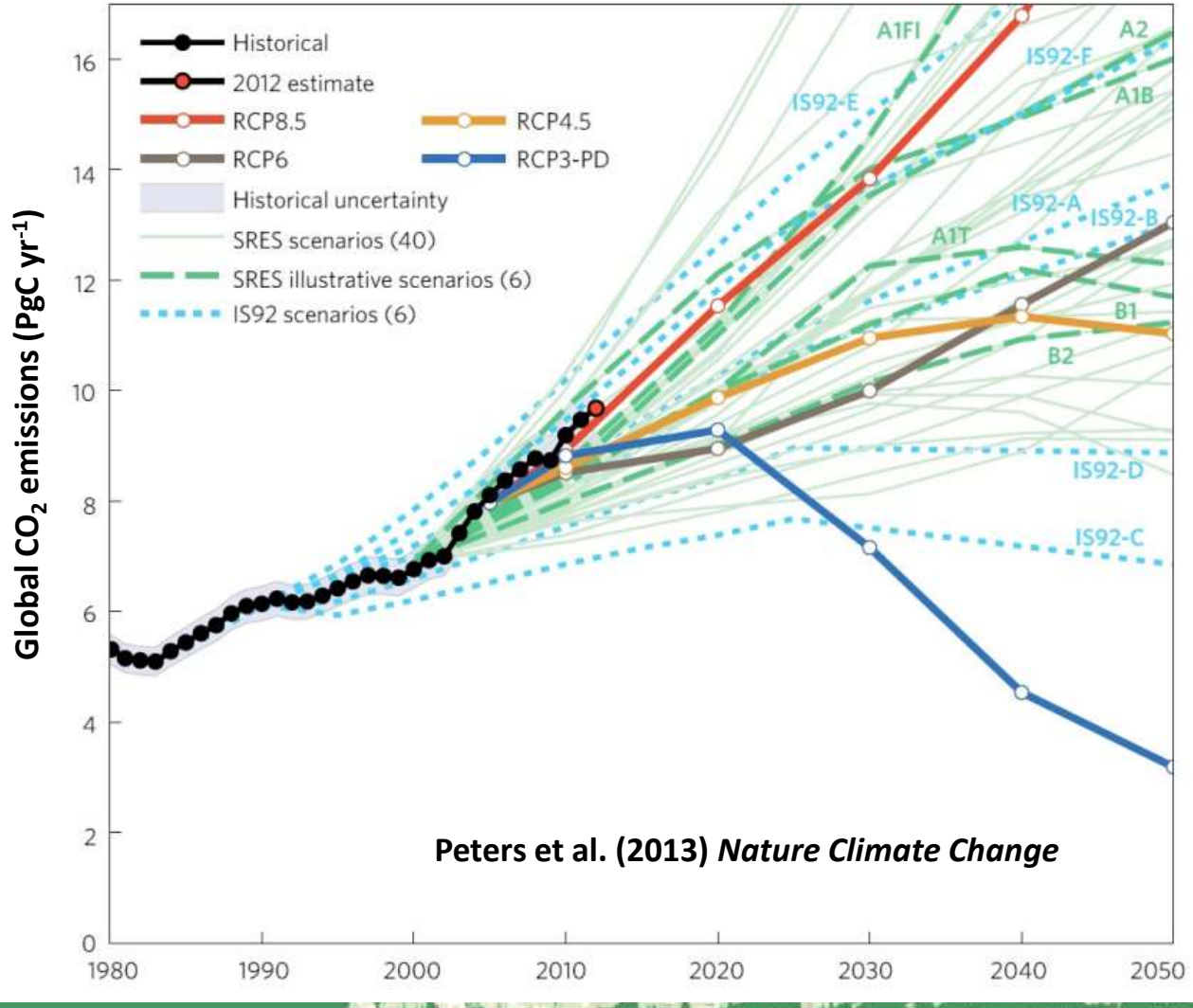
- Depressed growth rates
- Increased mortality

(D'Arrigo et al. 2011)

Wide spread mortality in moisture sensitive Dipterocarps and other key tropical species

- Significant understory mortality in Sabah region during the 97-98 drought (Ligenfelder and Newberry 2009)

What are the long-term implications of increasing atmospheric CO_2 concentrations?



Peters et al. (2013) *Nature Climate Change*

What are the long-term implications of increasing atmospheric CO_2 concentrations?

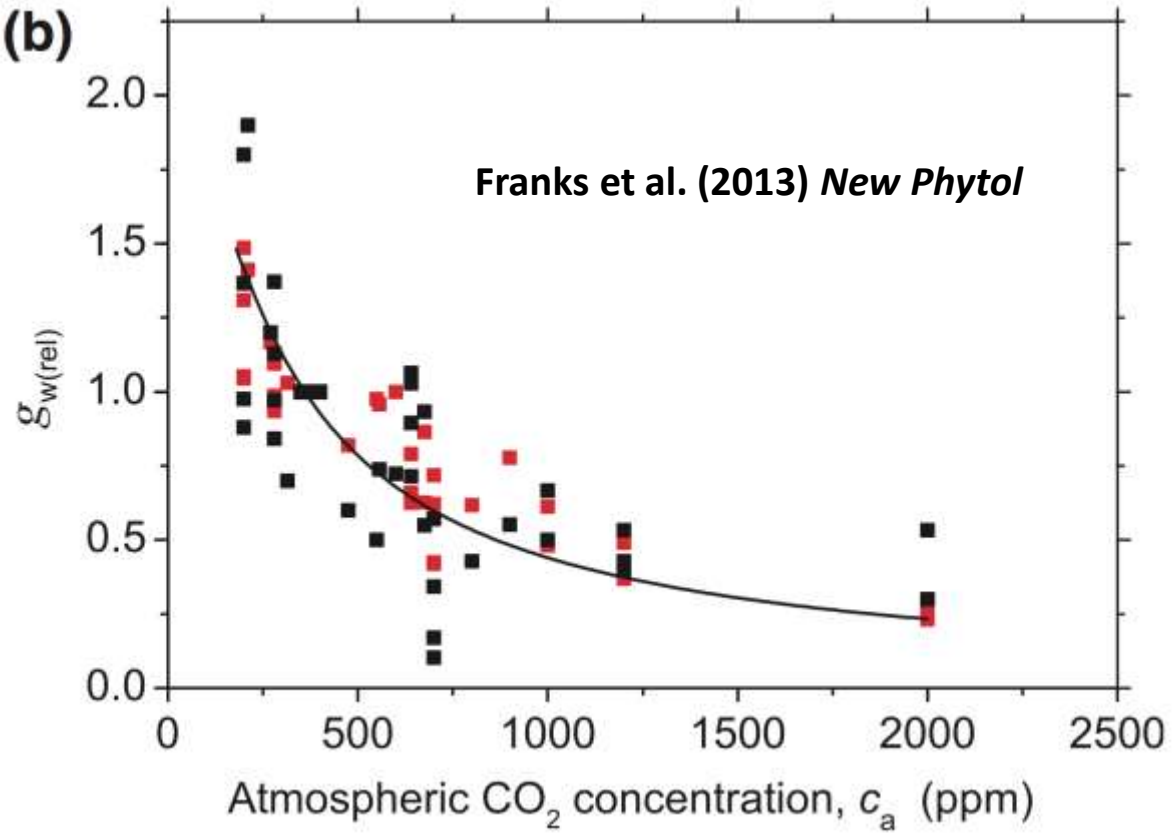
CO_2 fertilization effect?

Free-Air CO2 Enrichment (FACE) project

The Aspen FACE experiment near Rhinelander, Wisconsin

What are the long-term implications of increasing atmospheric CO_2 concentrations?

Effect of increased CO_2 on water use efficiency



How can we cope with all of this complexity?

Summary of Key Factors

- Lengthening growing seasons
- Increased drought and heat stress & associated mortality
- Increased activity of biological disturbance agents
- Effects of increased atm CO_2 concentrations
  - CO_2 fertilization?
  - Increased water use efficiency
- Effects of increased temperature on organic matter decomposition and nutrient cycling

Forest Ecosystem Models can be a useful tool for evaluating long-term impacts and adaptation alternatives

But….

How do I know what model to use???

Adapted from Medlyn et al. (2011) *WIREs Clim Change*

Type	Spatial Scale	Data requirements	Species Change?	Example Models	Management Simulation?
Process-based stand models (complex)	Forest stand	high	no	Gday CABALA Ecosys PnET	Very limited to Limited
Process-based stand models (simplified)	Forest stand to region	Low to medium	no	TRIPLEX FORECAST Climate 3PG	Limited to Extensive
Hybrid Models	Forest stand to region	Low	no	MELA FVS-BGC FULLCAM	Limited to Extensive
Terrestrial biogeochemical models	Regions to global	medium	no	BIOME-BGC TEM HRBM	Very limited
Gap Models	Patches to regions	Medium to high	Yes	SIMA FORSKA FORCLIM	Limited
Dynamic global vegetation models (DGVMs)	Regions to global	Medium to high	Yes	LPJ CLM-DGVM Orchidae SDVGM	Very limited

What issues / questions do you wish to explore?

How might climate change influence regional forest productivity?

Key Factors	Model Attributes
Growing season	Temperature/moisture limitations on growth
Drought risk	Strong water balance module
	Atm CO_2 impacts on water use efficiency
	Simulation of drought-related mortality
Soil fertility	Feedbacks on nutrient cycling
Large areas	Scalable with linkage to spatial data
Species diversity	Species loss or replacement

What issues/ questions do you want explore?

How might climate change influence ecosystem carbon balance?

Key Factors	Model Attributes
NPP	Changes in growing season length
	Water stress impacts on NPP
	Impacts of changing atm CO_2 on NPP
Litter and Soil C impacts	Feedbacks on DOM decomposition rates
Mortality rates	Drought related mortality

What issues/ questions do you want explore?

Evaluation of the efficacy of alternative adaptation strategies

Key Factors	Model Considerations
Maintenance of ecosystem services	Representation of key indicators
Management options	Species change, rotation length, harvesting systems
Forest Health	Water stress condition Drought related mortality

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Issues with respect to model application

1. Data Availability
    - Calibration data
    - Driving data
    - Validation data

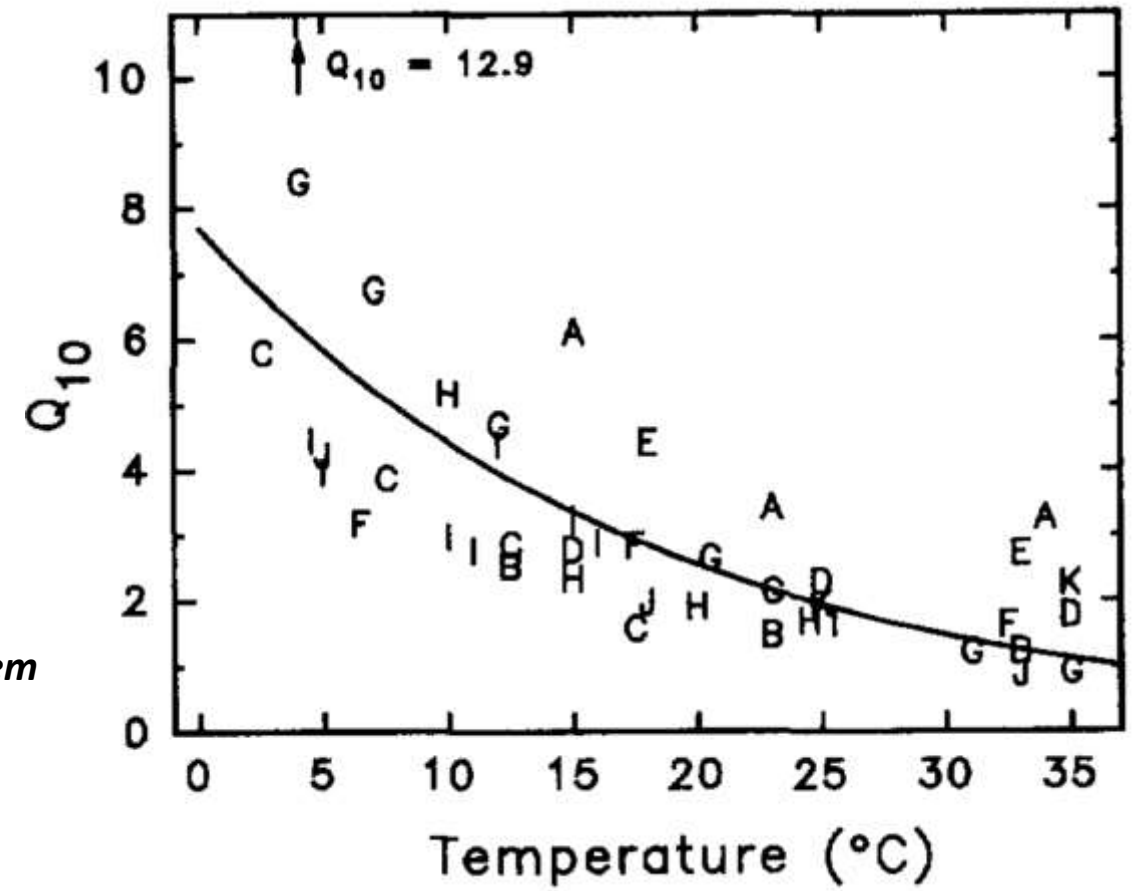
2. Representation of climate change
    - Which GCMs and Emission scenarios (ES)?
    - How to handle downscaling (spatial and temporal)

3. How to represent uncertainty
    - Selection of multiple combinations of GCMs and ESs
    - Increasing climate variation
    - Frequency of extreme events
    - Issues related to phenology

Thank you

How might global warming influence organic matter decomposition and nutrient cycling?

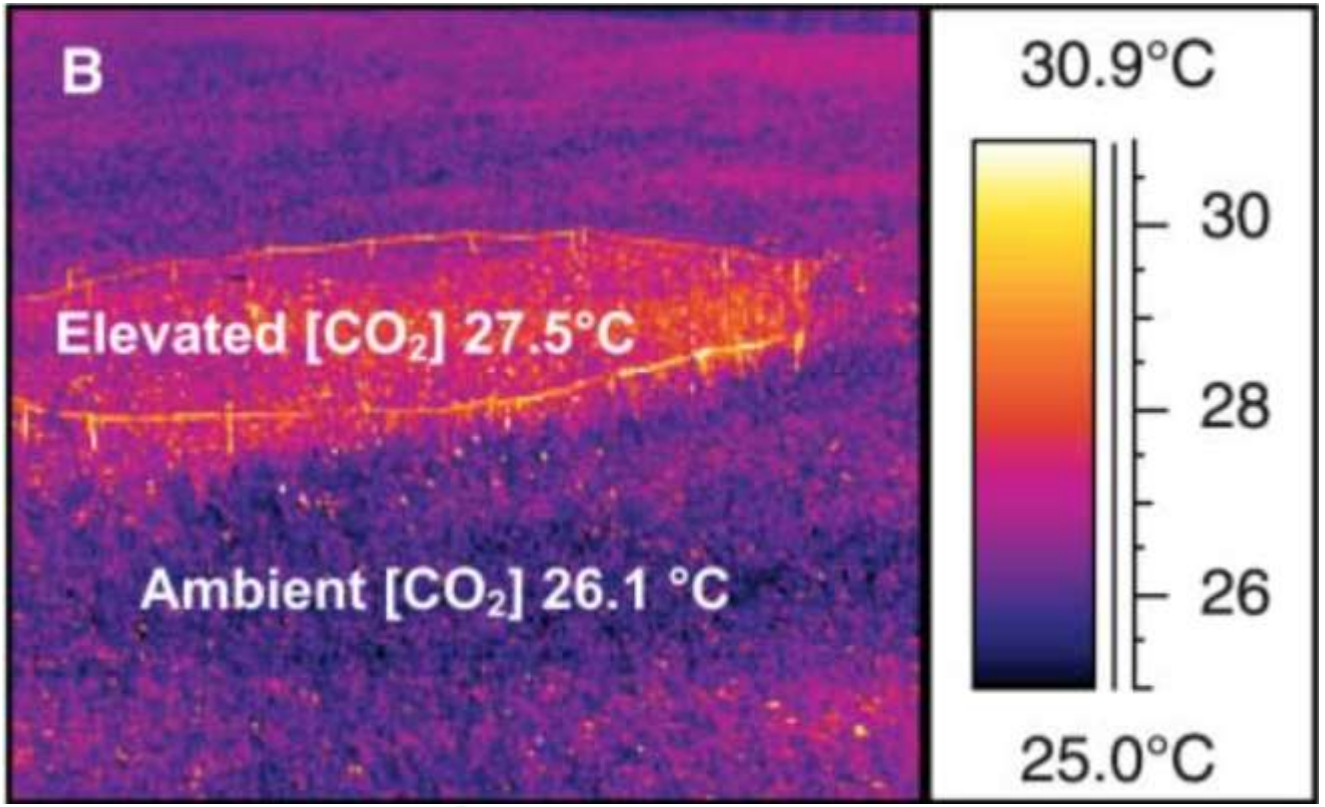
The effect of increasing temperature on decomposition rates is greater in colder climates



Kirschbaum (1995) *Soil Biol Biochem*

What are the long-term implications of increasing atmospheric CO_2 concentrations?

Effect of increased CO_2 on water use efficiency



Long et al. 2006 – Soybean FACE experiment

- Less evaporative cooling in elevated CO_2 plots

How might global warming influence organic matter decomposition and nutrient cycling?

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Soil warming experiment at the Harvard forest
- Heated 5 °C above ambient

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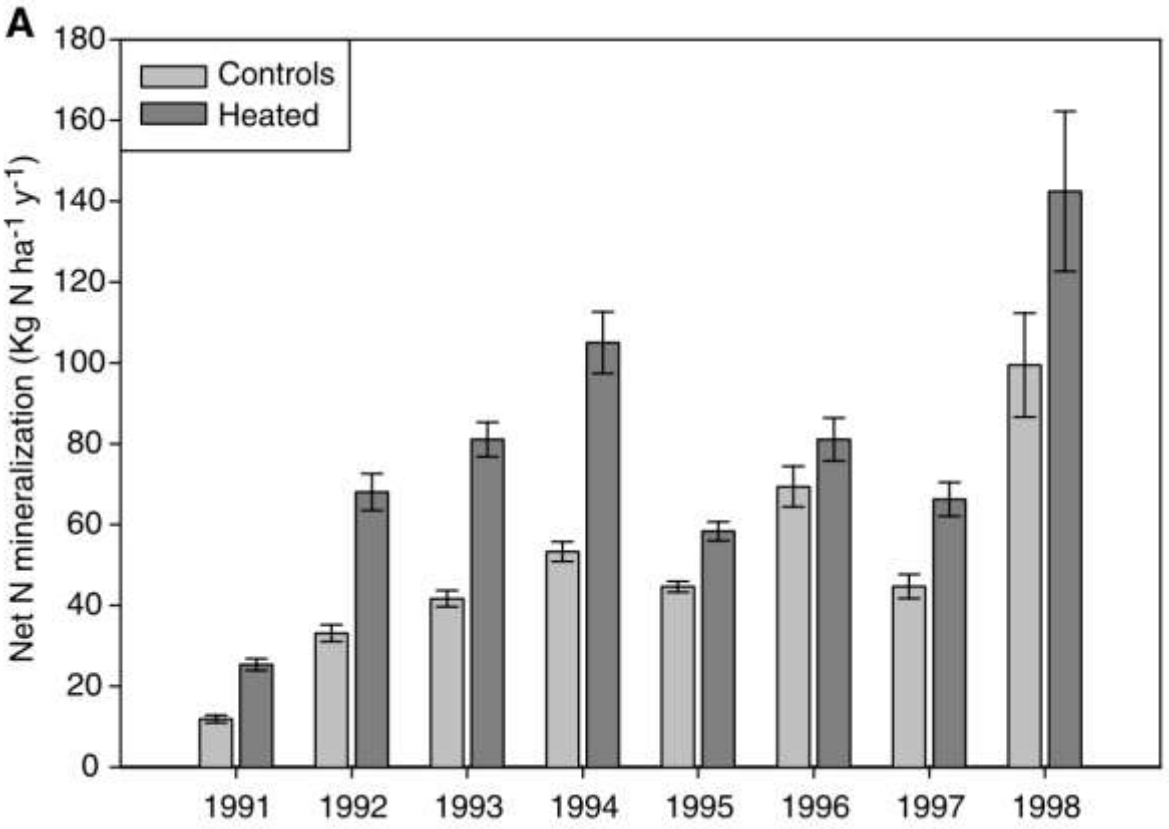
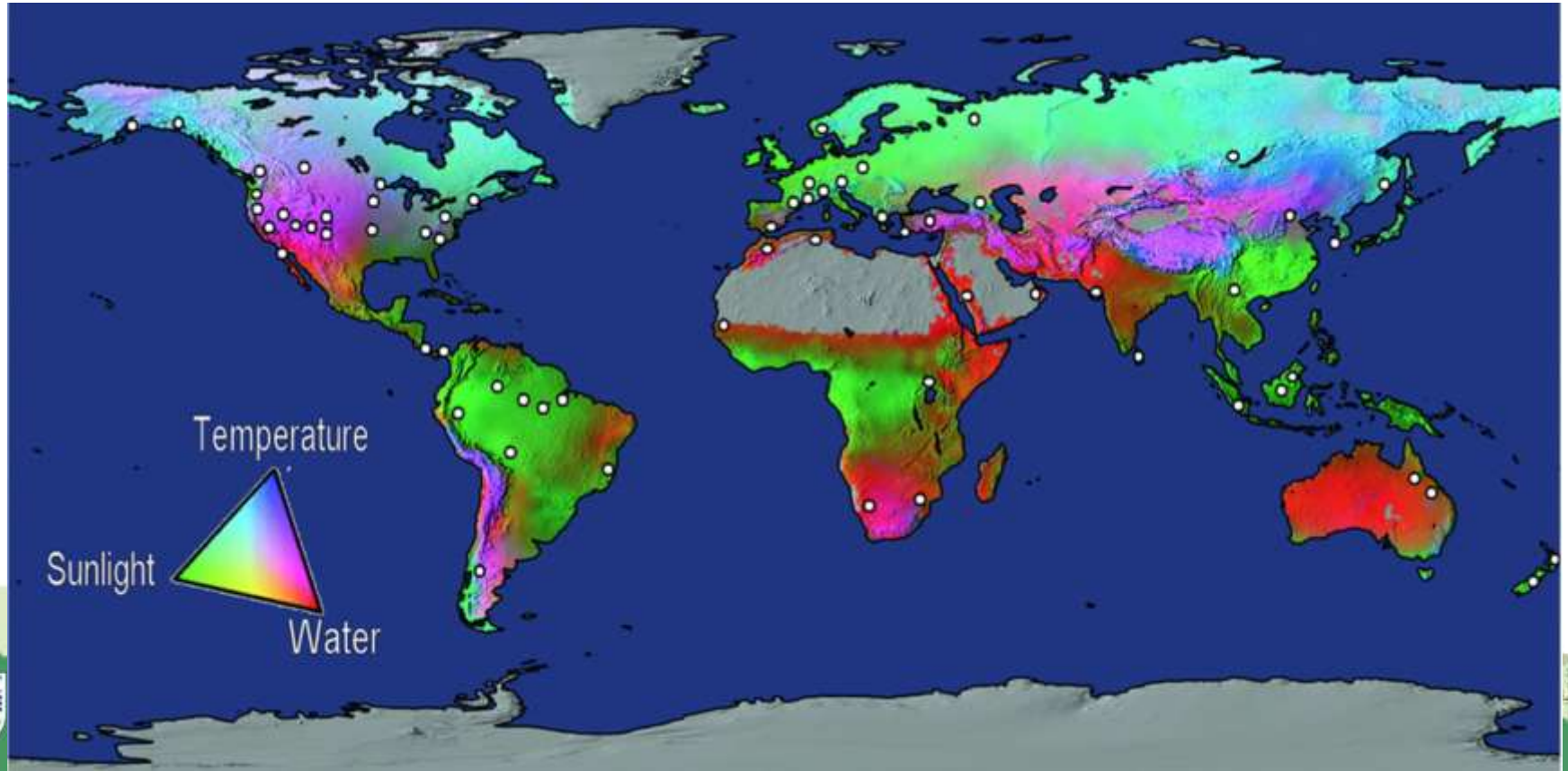


Maybe… but not likely in many parts of the world

There are many other factors that must be taken into account

- **Changing precipitation patterns (drought) and heat stress have already led to increased tree mortality in many parts of the world**

Allen et al. (2010) ***For Ecol Manage***



Water stress can reduce tree resistance to biotic disturbance agents

Oak jewel beetle has spread into northern Europe
Agrilus (Anambus) biguttatus

Armillaria root rots have become more prevalent in many regions

Climate change has often led to increased activity of biotic disturbance agents

Mountain pine beetle *(Dendroctonus ponderosae)* has killed more than 18 million ha of lodgepole pine forest in British Columbia in the last 15 years