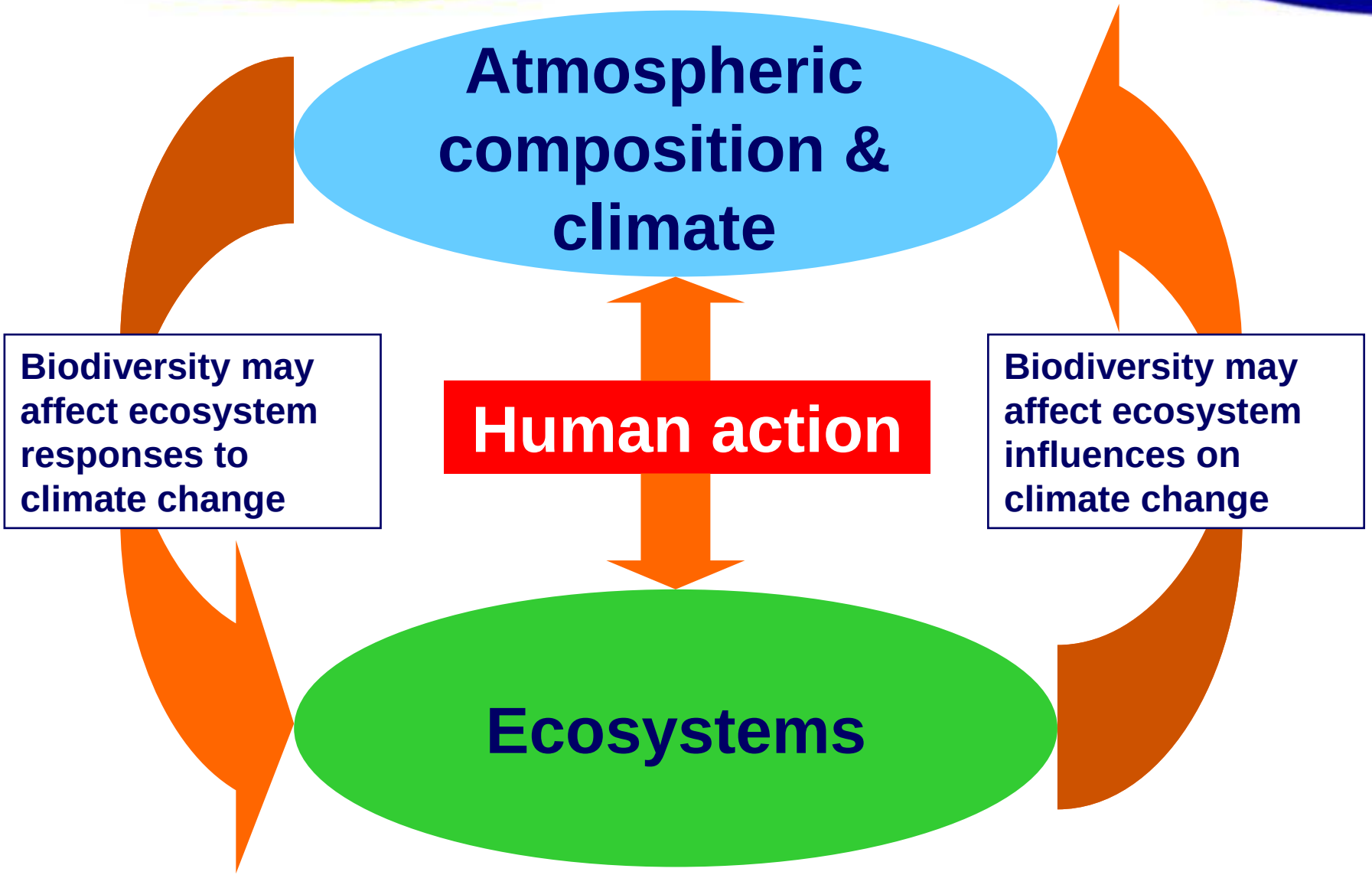
Biodiversity – ecosystem and climatic functioning

Richard Betts
Met Office Hadley Centre

Biodiversity-Climate Interactions, Royal Society, London, 12th June 2007

Roles of biodiversity in the Earth System



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Biodiversity and the climate system: key questions

- To what extent should biodiversity be represented in Earth System Models?
  - Effects on ecosystem resilience?
  - Effects on biogeochemical cycles?
- To what extent does direct human impact on biodiversity need to be considered as a climate change issue?
  - Influences on Earth System feedbacks?
  - Drivers of climate change?

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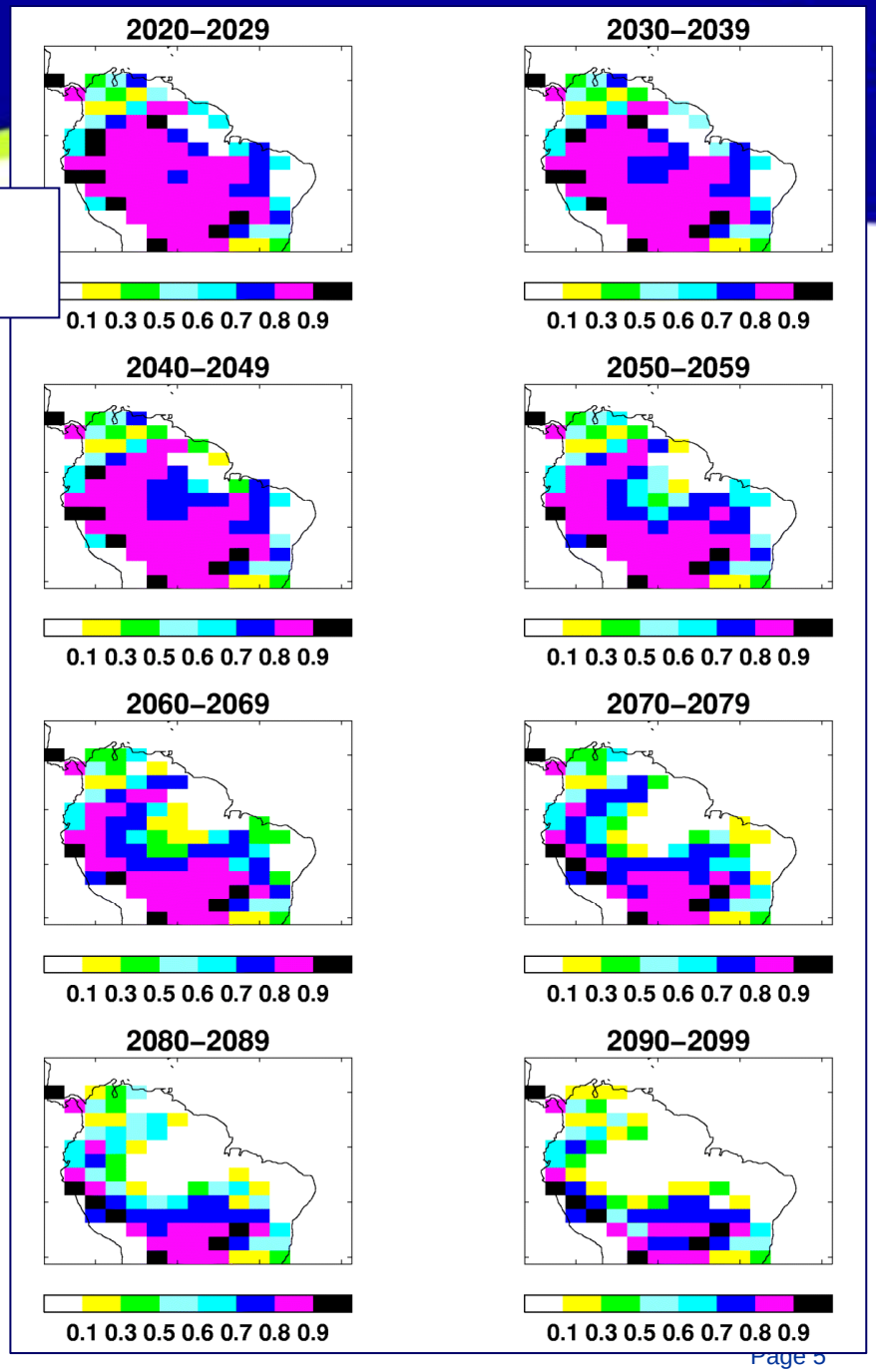
Roles of biodiversity in land ecosystem responses to atmospheric change

Simulated “Amazon die-back” due to climate change

Fractional cover of Broadleaf Tree functional type



- Drying of Amazonian climate driven by sea surface temperature changes causing shifts in atmospheric circulation
- Forest die-back reduces local “recycling” of rainfall and contributes to acceleration of CO_2 rise and climate change
- Drying becomes more extreme
- But would a more diverse ecosystem, eg: with more drought-tolerant species/ functional types, induce smaller feedbacks on climate change?

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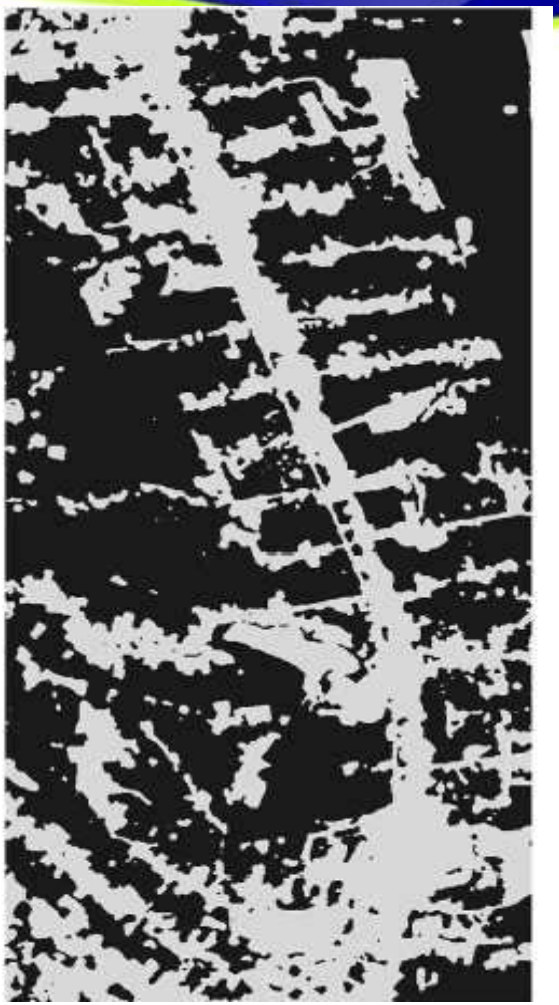
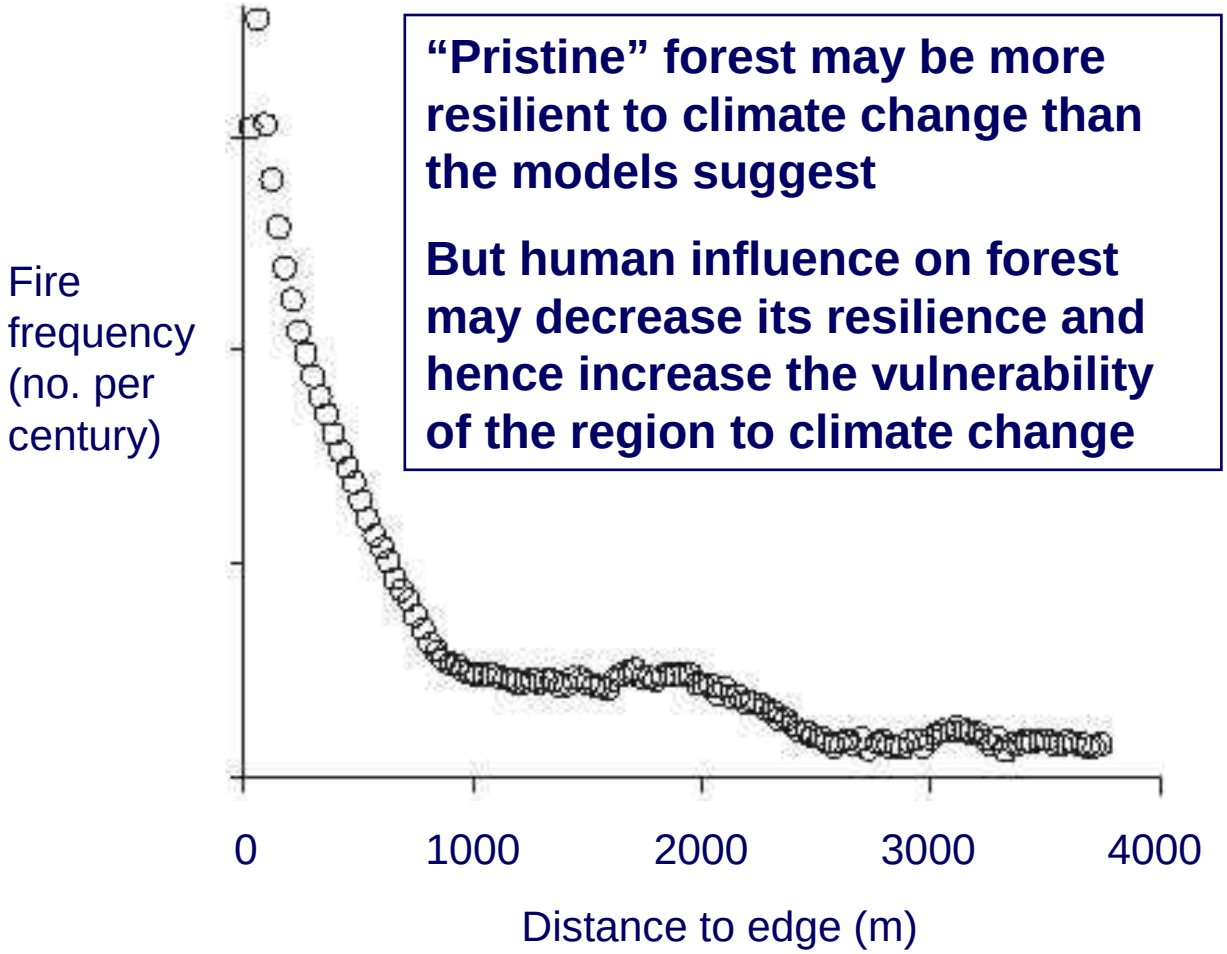
BUT: human influence on forest may increase its sensitivity to climate change



Complex pattern of deforestation in Amazonia seen by satellite



"Pristine" forest may be more resilient to climate change than the models suggest

But human influence on forest may decrease its resilience and hence increase the vulnerability of the region to climate change

Laurence (2004)

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Fire as an Earth System feedback

- Responds to climate change
- Releases CO_2, other greenhouse gases, and aerosols
- Influences landscape character and hence physical properties of land surface (eg: albedo and ability to recycle rainfall)

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Roles in fire processes can be species-specific

- Some species much more fire-tolerant than others
- Some require fire for reproduction or to gain competitive advantage
- Some species actively promote fire (eg: eucalypte bark – efficient fuel, also airborne carrier of spark for re-ignition)
- Challenge for Earth System modellers?
- Potential role of invasives in modifying fire regime?

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Species-specific responses to CO_2 fertilization: effects on carbon stores

- Lianas account for little of the total forest biomass
- Affect viability of trees so indirectly influence forest carbon stocks
- More lianas: smaller forest carbon stores

Phillips et al (2002)

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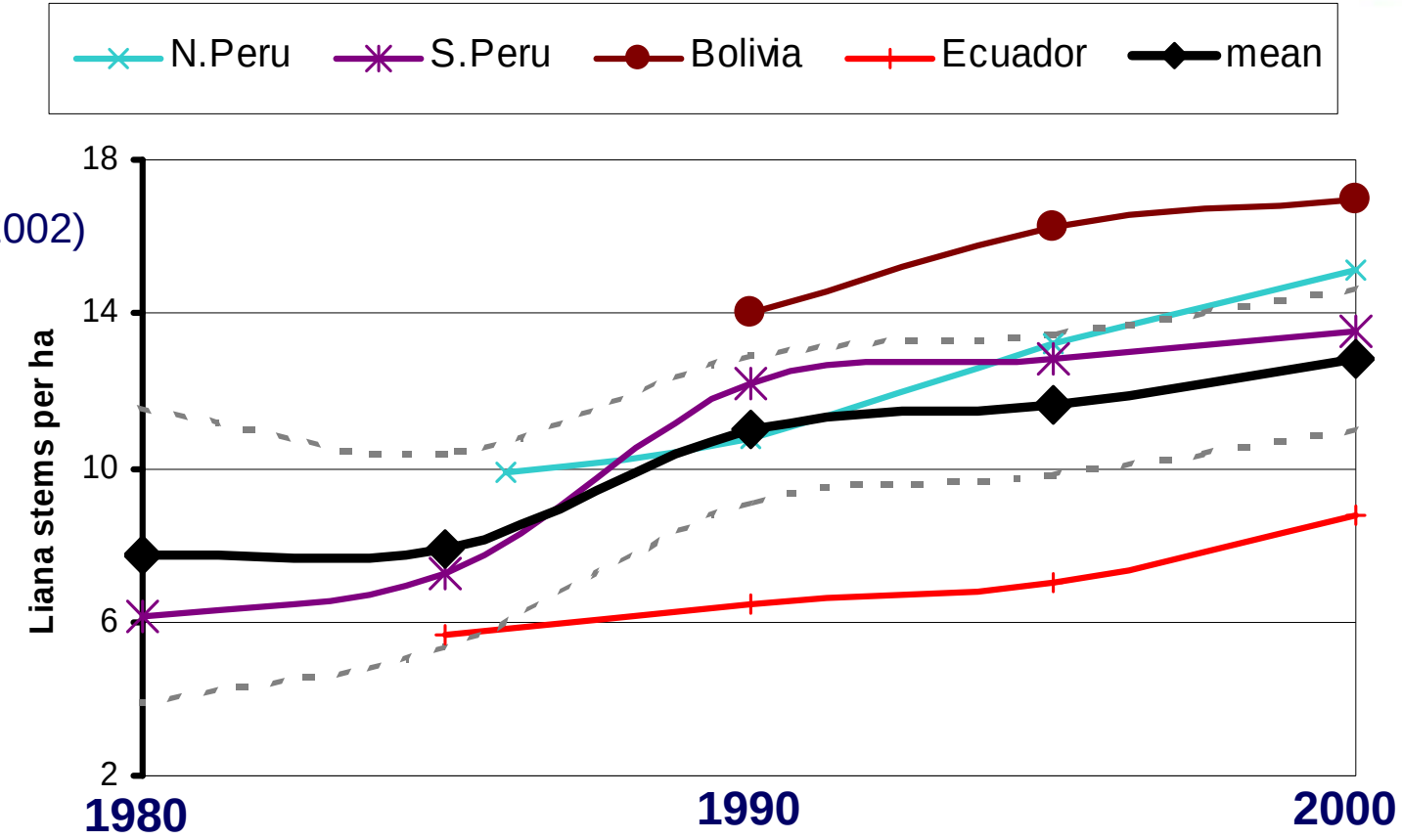
Amazonian lianas increasing in abundance at a rate of 50% per decade

Phillips et al (2002)



- Positive feedback on CO_2 rise through differential responses to CO_2 fertilization within ecosystem?

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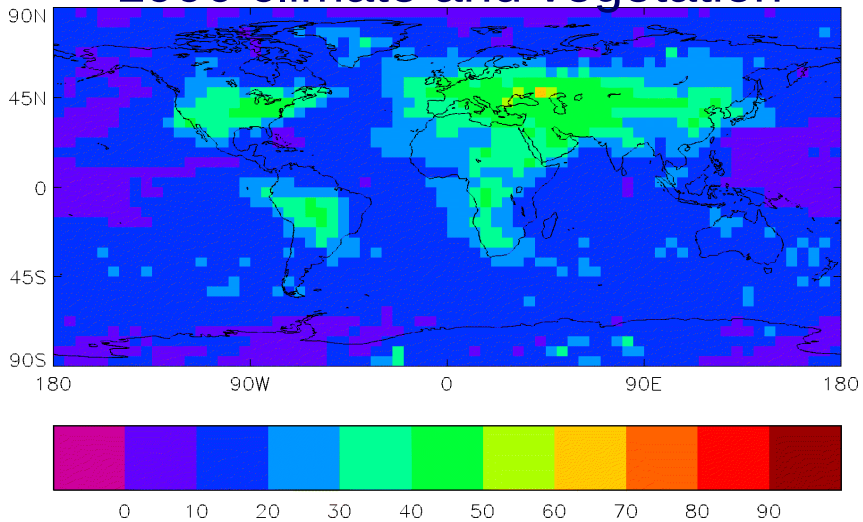
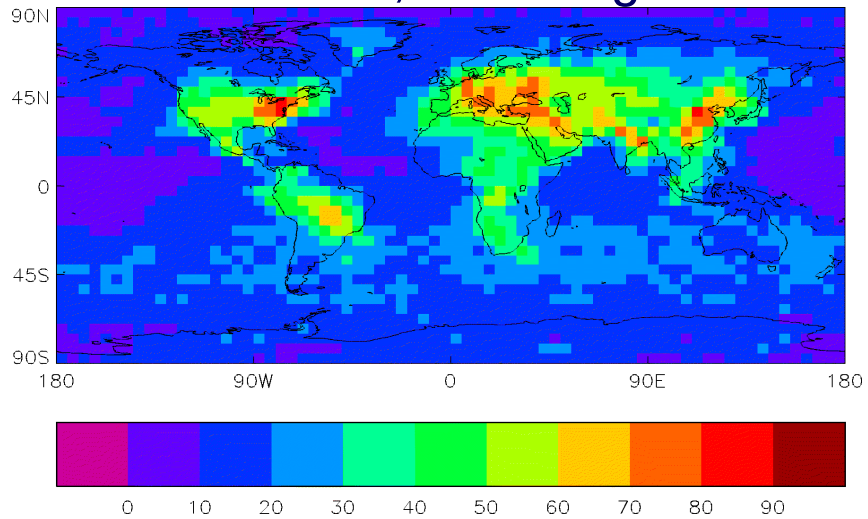
Roles of biodiversity in land ecosystem influences on atmospheric composition, air quality and climate

Effects of climate and vegetation change on surface ozone via isoprene emissions

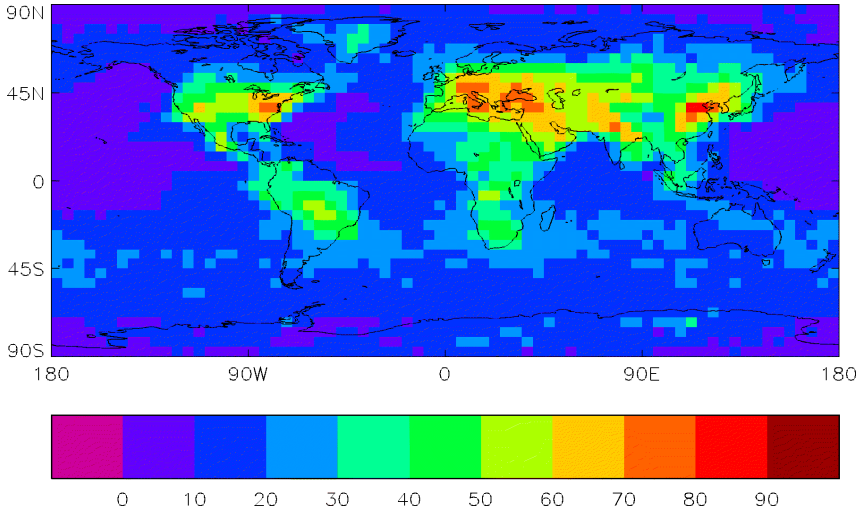
1990 climate and vegetation



2090 climate, 1990 vegetation



2090 climate, 2090 vegetation



July surface ozone concentrations (parts per billion)

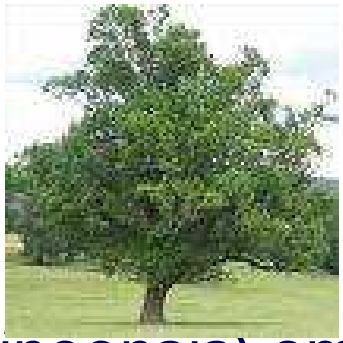
Climate change leads to increased isoprene emissions and therefore increased ozone, but vegetation change (especially Amazon dieback) suppresses this increase.

Sanderson et al., 2003

Species-specific isoprene emissions

- Most (but not all) broadleaf tree species emit isoprene
- Most (but not all) needleleaf tree species do not
- Potential reduction in isoprene emissions in boreal forests due to increasing ratio of broadleaf to needleleaf species

- *Quercus ilex* (mediterranean oak) does not emit isoprene



- But *Q. robur* does

- Oil palm (*Elaeis guineensis)* emits isoprene
- Potential human influence on climate via replacent of native forest with oil palm – more isoprene – more ozone

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Over-prediction of tree cover in savanna regions by climate-vegetation model

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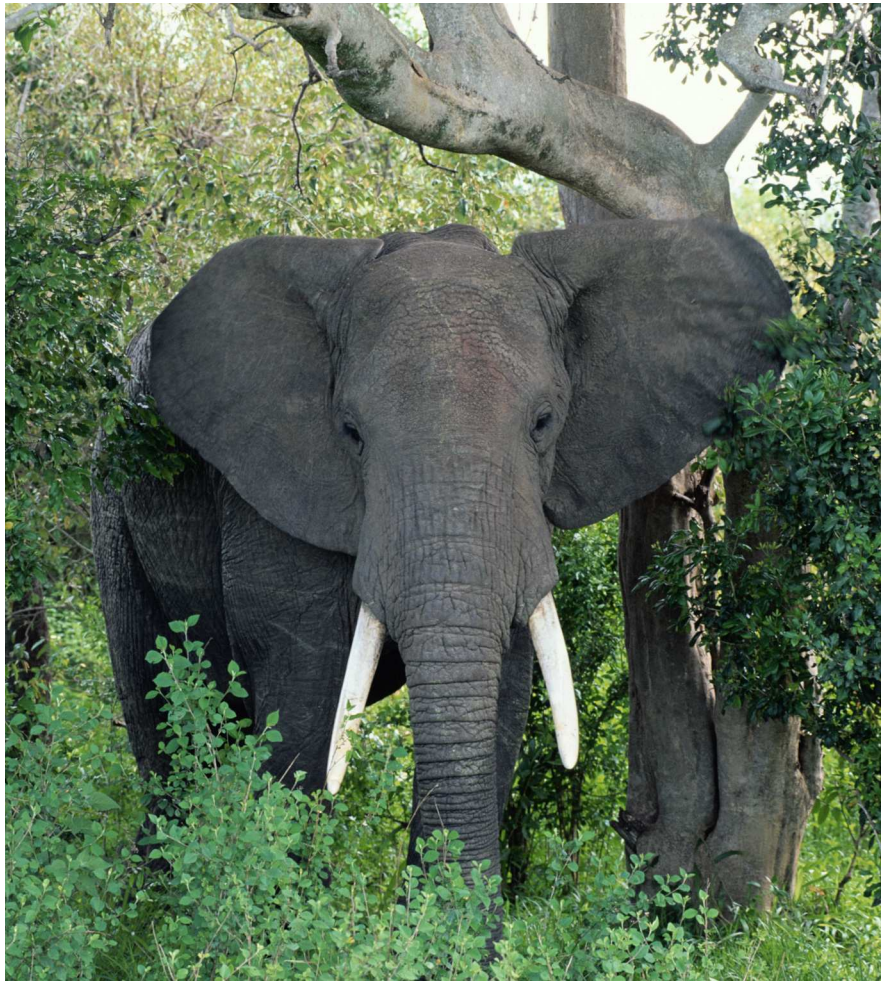
Herbivory as an Earth System process

- Multiple stable states in Serengeti-Mara woodlands, Kenya (Dublin et al, 1990)
- 1960s: observed fire activity could explain decline in woodland
- 1980s: grazing by wildebeast reduced grass fuel so burnt areas small – fire could not explain continued absence of woodland
- Elephants could not remove woodland, but could inhibit woodland recovery



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Herbivory as an Earth System process

- Woody plant encroachment seen in savannas and grasslands worldwide
- Changes in climate, fire regime or CO_2 fertilization?
- In semi-arid North America, encroachment of shrubs such as Prosopis glandulosa (Honey Mesquite) occurred after 98% eradication of black-tailed prairie dogs over 40 million ha in early 20th Century

- Prairie dogs shown to be highly effective in preventing establishment of mesquite (Weltzin et al, 1997)
- Did eradication of prairie dogs result in woody encroachment?
- Indirect human influence on climate through change in carbon store and regional land surface properties….?

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Conclusions

- Poor representation of biodiversity in climate models may mean that simulated resilience of ecosystems to climate change may be too low compared to actual “pristine” ecosystems
- Resilience of tropical forests to climate change may be reduced by fragmentation. Human impact on ecosystems may therefore strengthen climate-carbon cycle feedbacks
- Biodiversity is an issue for fire. Could invasives change fire regimes and hence affect climate feedbacks?
- Species-specific responses to CO_2 fertilization, eg: increased abundance of lianas, may impact negatively on other species and modify ecosystem carbon stocks
- Biogenic volatile organic compound emissions are species-specific. Climate feedbacks and air quality impacts may result from changes in species composition due to climate change or forestry (eg: palm oil).
- Herbivory may play a role in the Earth System, mediating ecosystem-climate feedbacks and/or providing a further means of human impact on the climate system through changes in abundance of herbivore species

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