Ecosystems and Environmental Change, part 2

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- Environmental Change Concepts and Results
  - Phenology/Pollination
  - Fire
  - Land Use Change
  - Trophic Level Matches and Mismatches
  - Range Shifts
  - Extinctions
  - Evolution and Plasticity
  - Biodiversity/Invasion/Disease

Topics of this section

Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate.

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Phenology is an important topic in ecosystem ecology. It is the timing of life events. Often they are cued by temperature, so changes in temperature can make phenological events occur earlier or later. Phenological records are simple, examples of citizen science, and exist hundreds of years in some circumstances (flowering of cherries in Japan, timing of leaf out at estates in England and botanical gardens in Europe). Hence, they provide an integrative and unbiased measure of global change. Ecological issues involve asynchrony between flower and insects, or the extra mining of soil water with earlier leaf out.

Trends in Length of Season, Temperate Vegetation

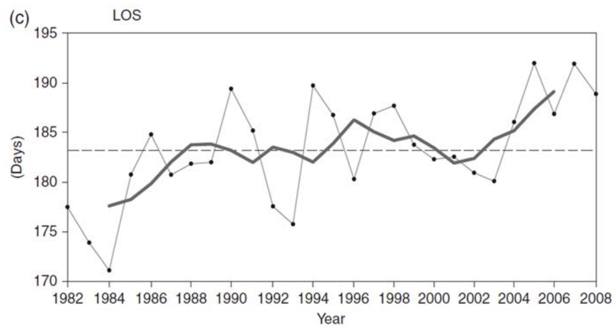

Fig. 3 Interannual variations of area-averaged SOS, EOS, and LOS of temperate vegetation in the Northern Hemisphere for 1982–2008.

Jeong et al 2011 GCB

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Many records are showing longer growing seasons. This one is based on satellite records, going back to the early 1980s

PHENOLOGY SHIFTS AT START VS. END OF GROWING SEASON 2397

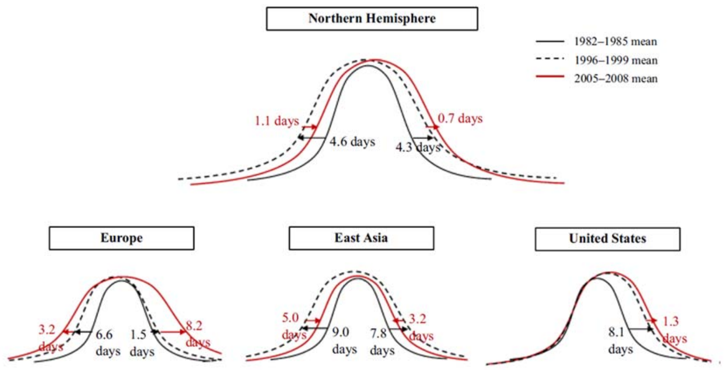

Fig. 8 Schematic diagrams of summarized growing season changes over the Northern Hemisphere (≥ 30°N), Europe (0°–30°E, 40°N–60°N), East Asia (30°E–60°E, 110–130°N), and the United States (90–130°W, 30–50°N).

Jeong et al. 2011 GCB

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Lengthening is happening by earlier springs and later autumns in many locales.

Pdf of Slopes in Temporal Trends of Phenology across Europe

1974 A. MENZEL *et al.*

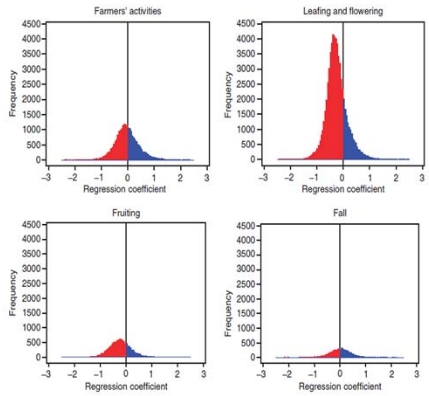

Fig. 3 Histograms of phenological trends in Europe. All temporal trends (1971–2000, time series 15 + years) as linear regression coefficients (days yr^{-1}) systematically reported to the COST725 meta-analysis ($n = 103\,199$) for four different groups.

Leafing/Flowering: -0.25 day/yr

Fruit Ripening: -0.237 day/yr

Fall Colour: + 0.017 day/yr

Menzel et al 2006 GCB

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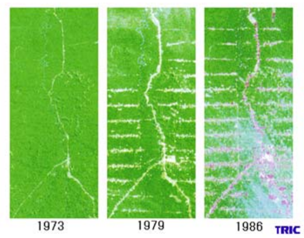
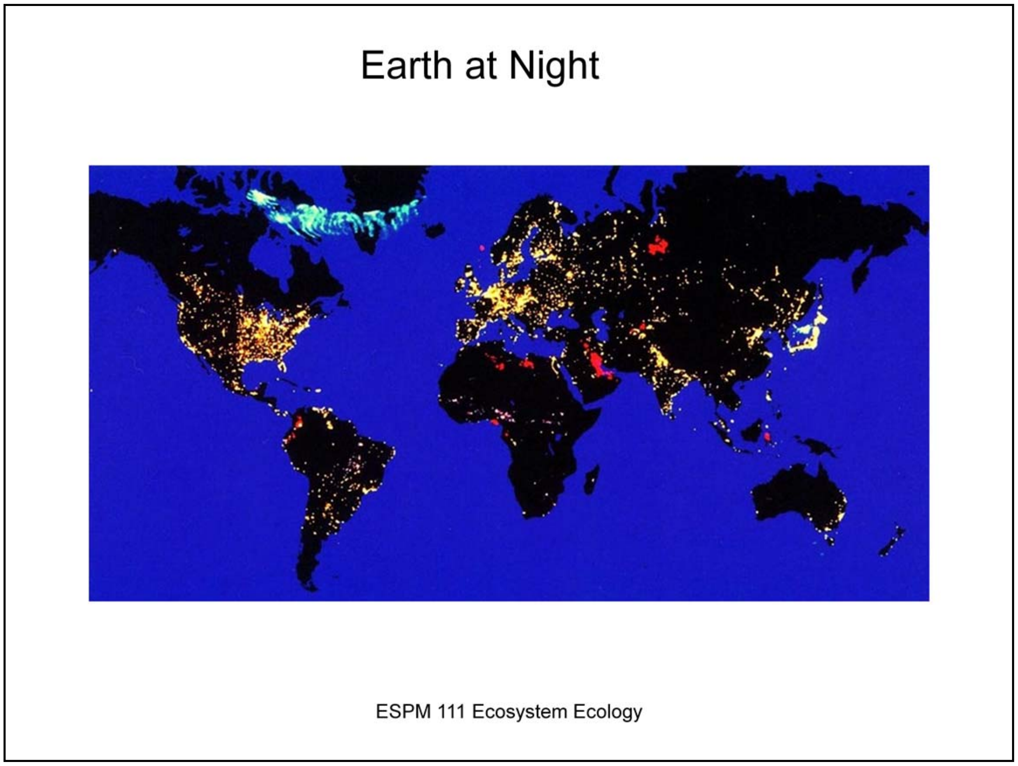
Other phenological metrics. Based on extensive studies of phenology gardens in Europe

Disturbance and Land Use Change

- Fires
- Deforestation/Logging
- Urbanization
- Desertification
- Woody Encroachment
- Afforestation/Reforestation
- Storms
- Invasive Species
- Soil Degradation



Disturbance and land use change are other important changes induced by human's impact on this planet. They can come in many direct and indirect forms.



Mankind seems to be everywhere. According to a paper by Sanderson 83% of land is appropriated by human use

Human Footprint on Earth

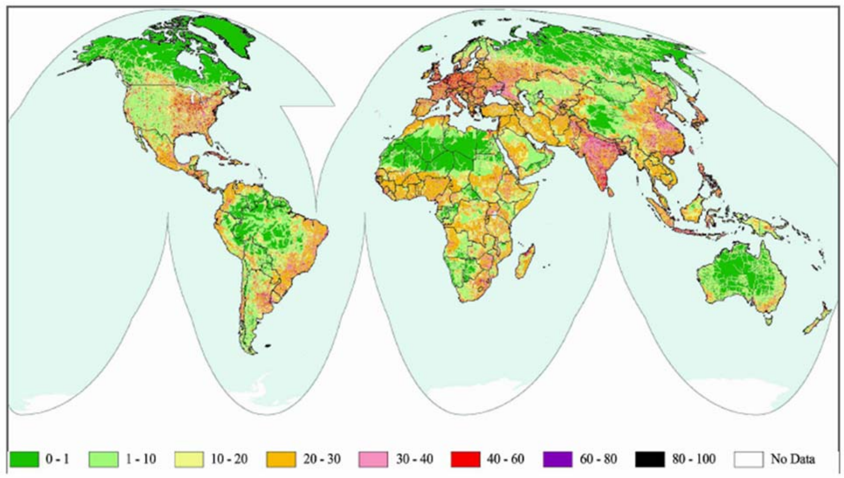
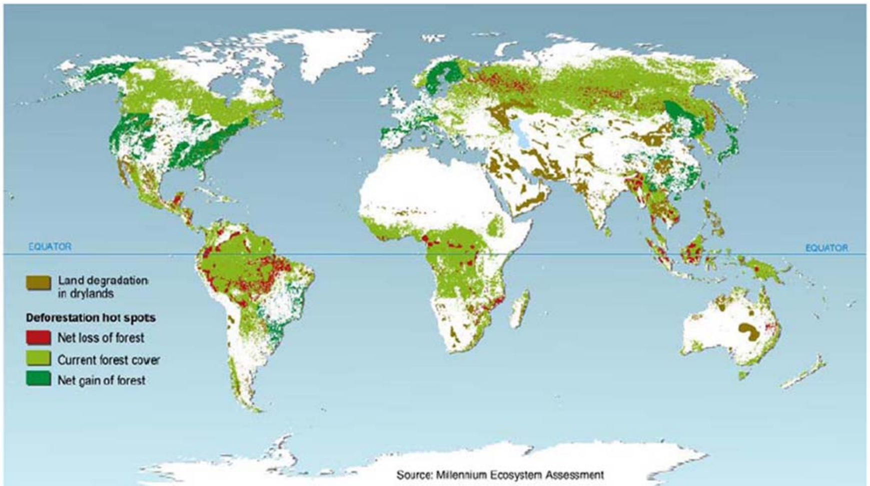


Figure 3. The human footprint, a quantitative evaluation of human influence on the land surface, based on geographic data describing human population density, land transformation, access, and electrical power infrastructure, and normalized to reflect the continuum of human influence across each terrestrial biome defined within biogeographic realms. Further views and additional information are available at "Atlas of the Human Footprint" Website, www.wcs.org/humanfootprint. Data are available at www.ciesin.columbia.edu/wild_areas/. National boundaries are not authoritative.

Sanderson et al 2002 Bioscience

Here is the human footprint across the planet. Few places are unchanged. And as we add more and more roads in remote areas the change comes fast.

Land Use Change:
Gains and Losses are Occurring



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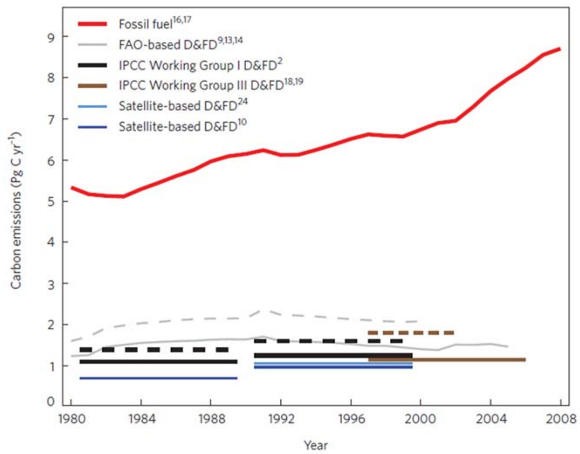
Land use is changing positively and negatively with regards to forests. Temperate forests seem to be aggrading as people abandoned farms and moved to cities. Tropics are experiencing deforestation, as remote areas are open and exploited for resources and landless peasants look for a better life.

Revised estimates of C loss from deforestation and degradation



igure 1 | Carbon emissions from deforestation and forest degradation (D&FD) and fossil fuel emissions or 1980 onwards. Updated datasets and approaches are depicted with a solid line, outdated ones

Van der Werf et al Nature Geoscience, 2009

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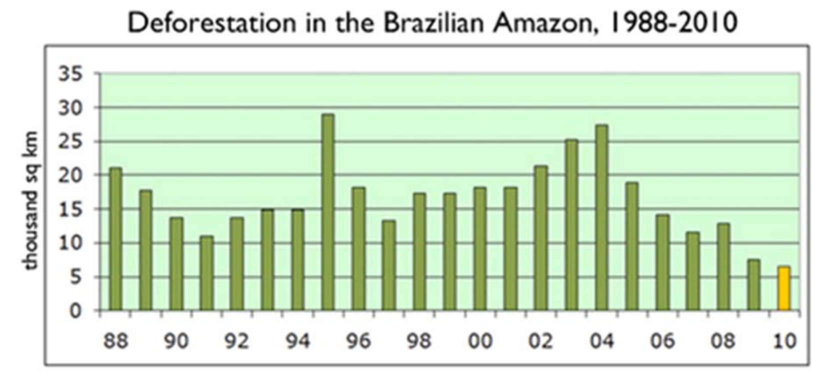
Deforestation is seen as a significant source of carbon to the atmosphere. Estimates are on the order of 1 to 2 PgC/y

Trends in Amazon Deforestation:

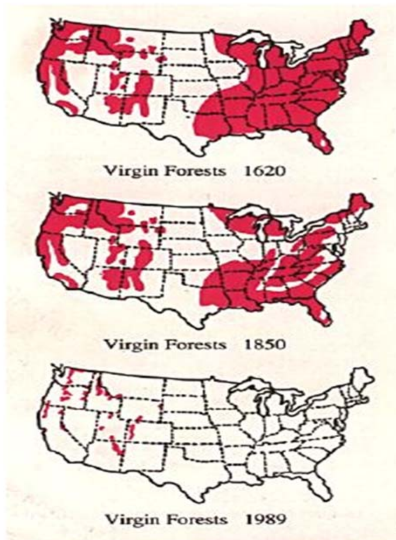
Good News, 40% drop in Deforestation



http://www.ucsusa.org/assets/images/gw/deforestation-brazilian-amazon.gif

There has been a decline in Amazon deforestation

US Deforestation



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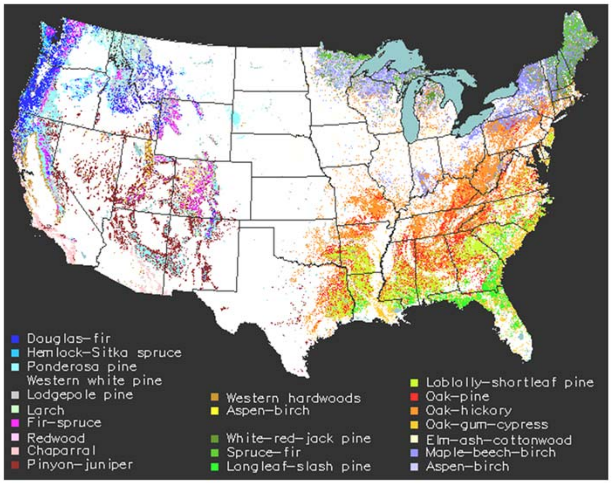
In the US, we already cut down most our forests. Hence, I am a proponent of saving the little virgin forest that exists

US Afforestation



http://www.biology.eku.edu/RITCHISO/envscinotes3.html

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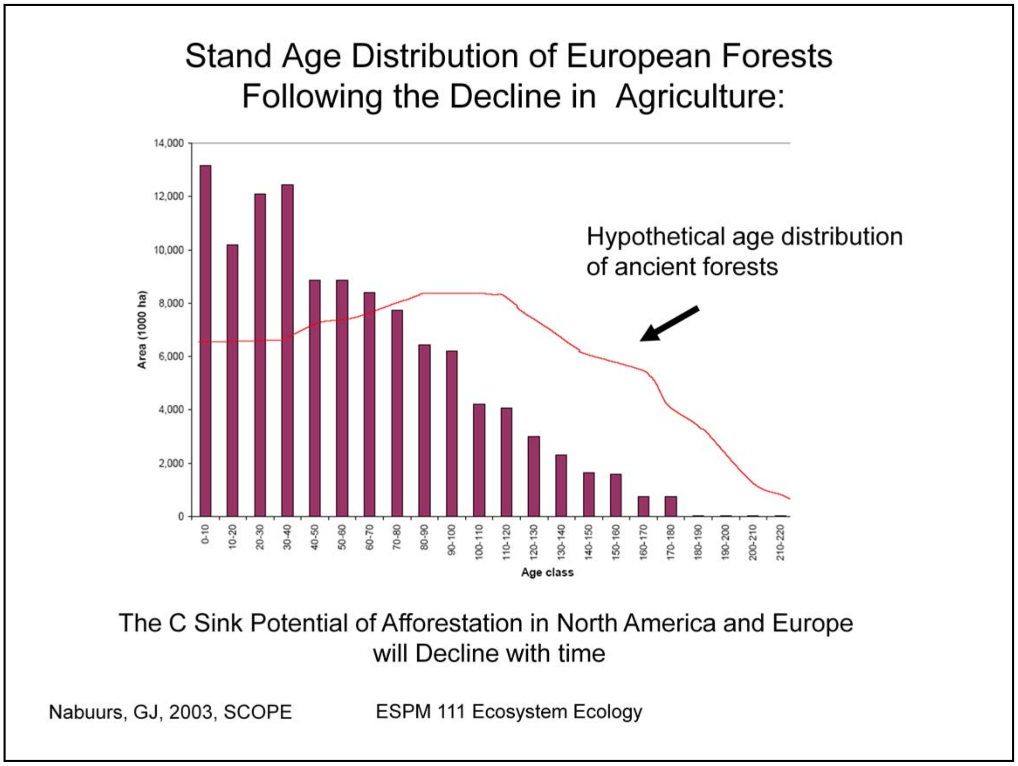
Forest regrowth is occurring



Forest across Europe tend to be young. Go question rises about the ability for these forests to be as strong a C sink as they age.

Forest Mortality

Pinyon Pine Decline in Southwest

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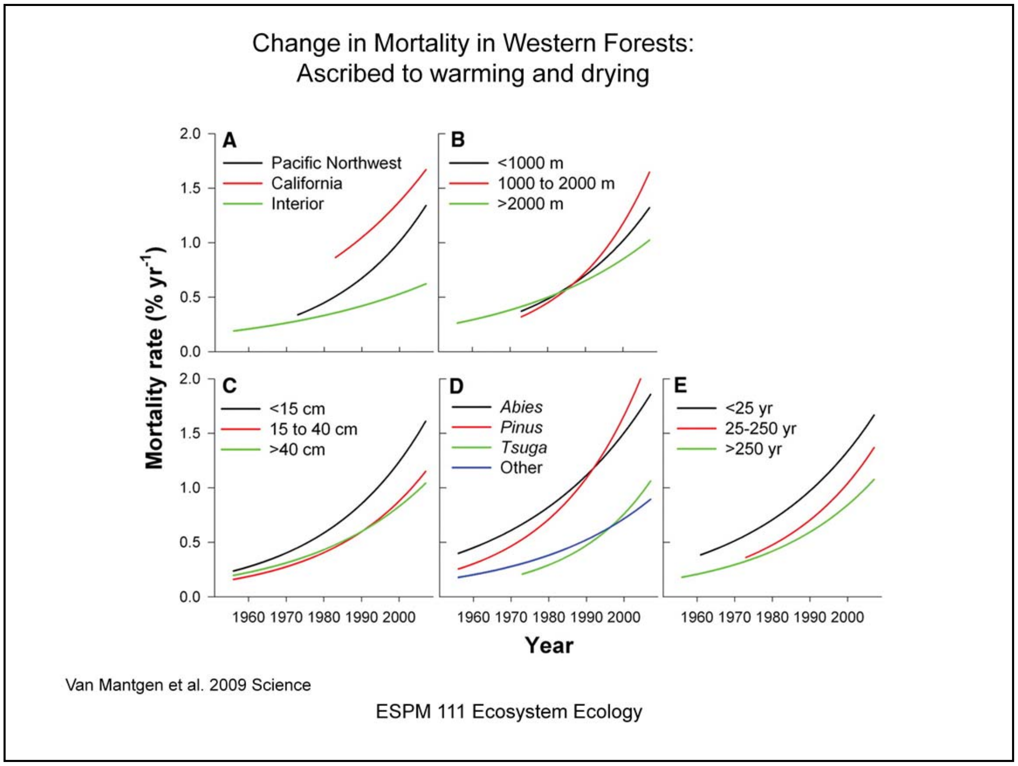
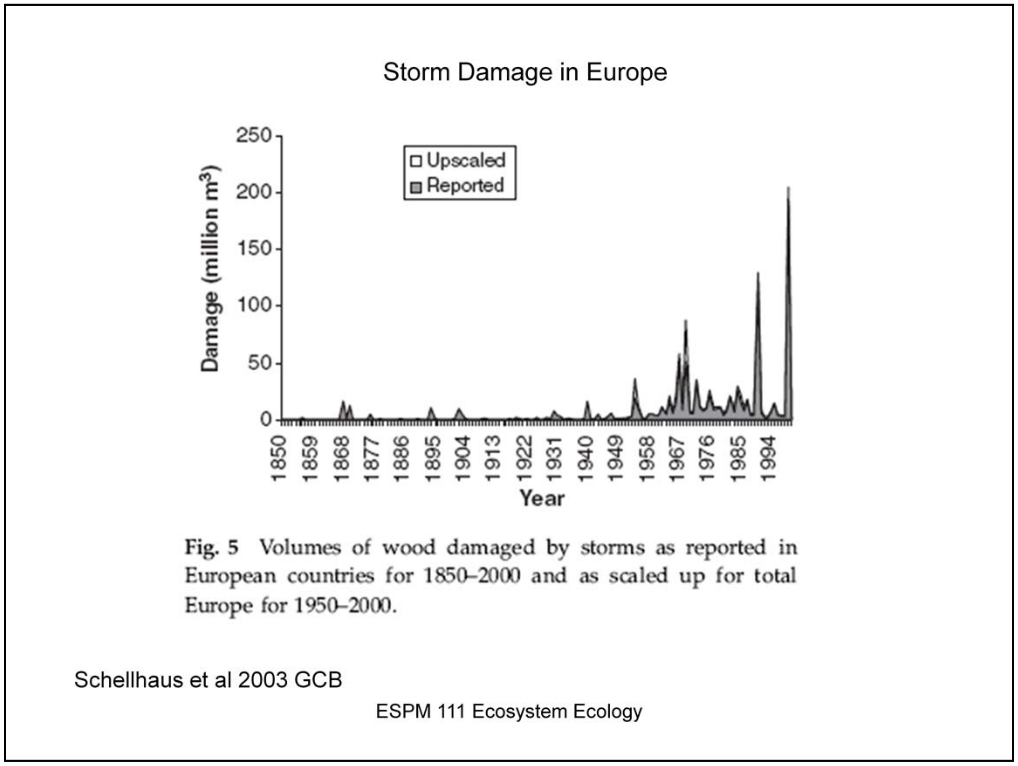
We are seeing natural mortality of forests across the west due to prolonged droughts



Mortality rates have been increasing across regions, species, size and age class and elevations



Storm damage seems higher lately, but this may be a record of watching this statistic, too

Trends in Forest Fires

Hotter, Drier, more Mortality

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Fires are and will be an important factor affecting forests and a signal of climate change

Fire Frequency, Globally

In many Areas Fires are Natural and Frequent

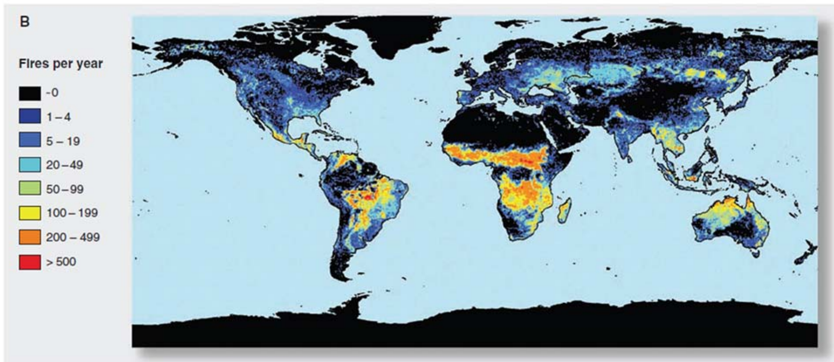

Fig. 2. Current pyrogeography on Earth, illustrated by (**A**) net primary productivity (NPP, g C m^{-2} $year^{-1}$) (*40*) from 2001 to 2006, by 1° grid cells; and (**B**) annual average number of fires observed by satellite (*49*).

Bowman et al. 2009 Science

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Fires are a natural component of many of the world’s ecosystems

Carbon Emissions by Fire

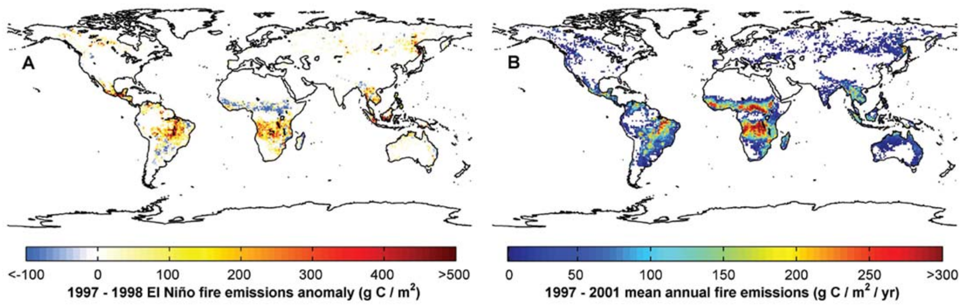
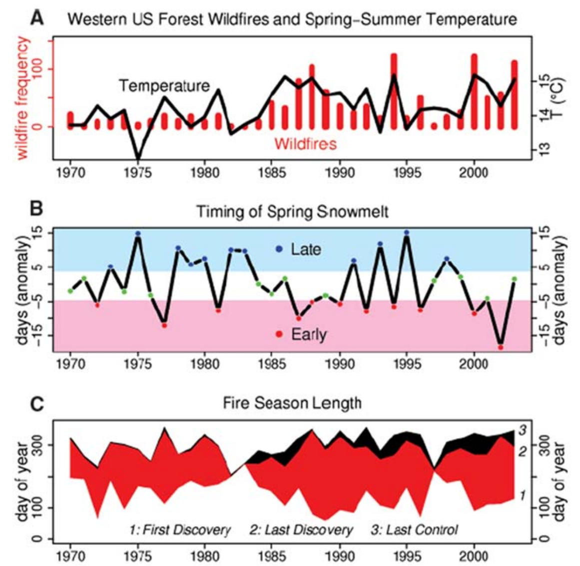


Fig. 1. (**A**) Emissions anomalies from fire during the August 1997 to September 1998 period (g C m^{-2}). This period had the highest emissions during 1997 to 2001 and is defined in the text as the El Niño period because it overlaps substantially with negative indices of the Southern Oscillation Index. Elevated emissions occurred across Central America, South America, southern Africa, Southeast Asia, Canada, and the Russian Far East. Emissions anomalies in each 1° by 1° grid cell were estimated with VIRS, ATSR, and MODIS satellite data and the CASA biogeochemical model. (**B**) Mean annual carbon emissions from fires during 1997 to 2001 (g C m^{-2} year^{-1}).

Van der Werf et al 2004 Science

Fires are a critical factor in emitting carbon to the atmosphere. More carbon is emitted by fire during droughts associated with El Nino



Wildfires in US Since 1980s

- Higher large-wildfire frequency
- Longer wildfire duration
- Earlier Snowmelt Promotes Fires
- Longer Wildfire Seasons

Westerling et al 2006 Science

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Fire frequency in the West is trending upward

Extent and Trends of Global Fires

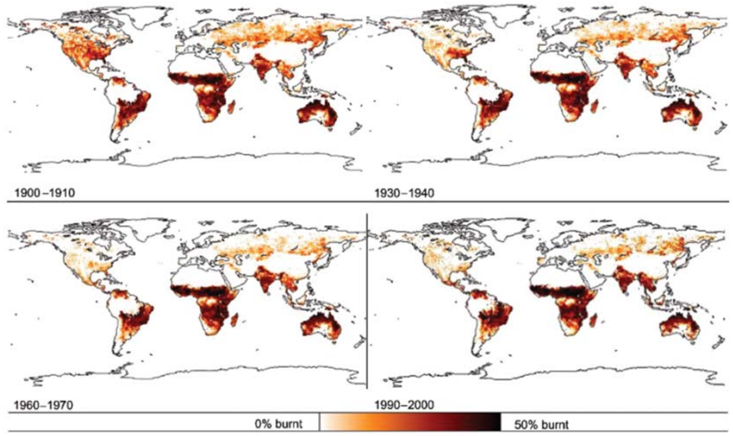

Fig. 4 1° × 1° maps of burned area (% of cell burned) for the periods 1900–1910, 1930–1940, 1960–1970, and 1990–2000.

Moulillot and Field, 2005 GCB

Global Change and Biodiversity

- Rates of Warming may exceed migration capability of species
- Habitat will be lost during shifts in climate
- Species diversity is related to reduction in habitat patch size, $N=cA^n$

Malcom and Markham, WWF, 2000

Ecological Consequences

- Endemic species may fail to migrate
- Weedy species may predominate
- Migration will depend on access to corridors

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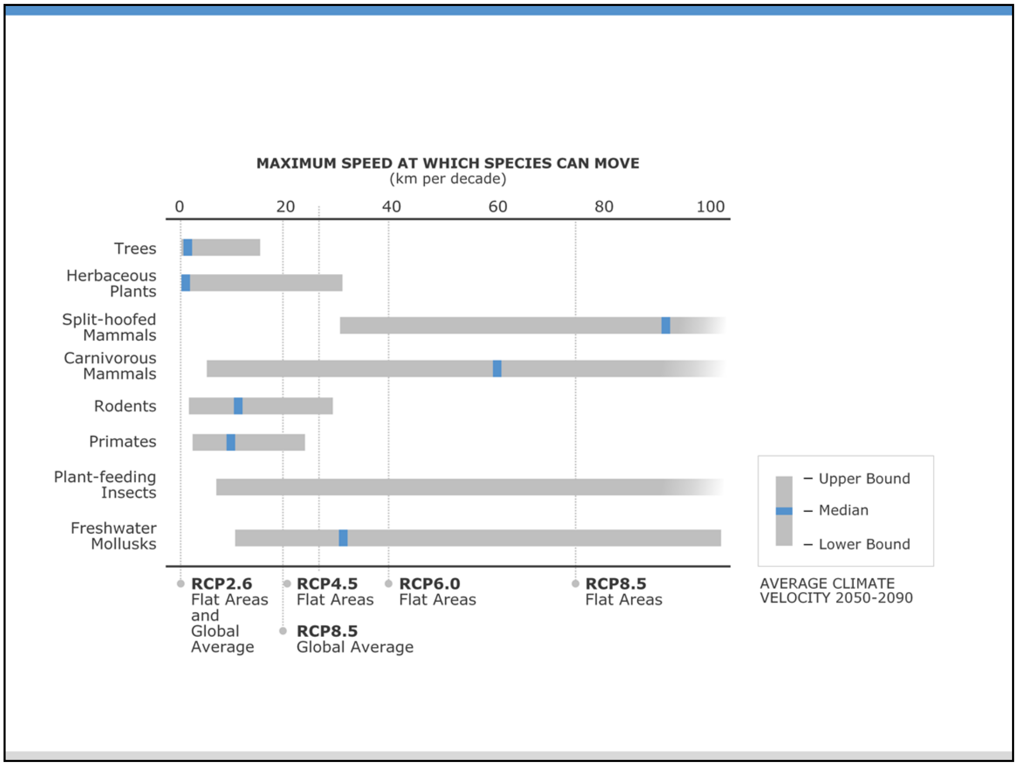
Ecosystem Migration

- ‘Dynamic’ equilibrium models assume that the rate of climate change and rate of vegetation response is similar
- Holocene migration of boreal forest: 10-45 km/century
- Expected shift in boreal zone due to global warming: 17-50 km/decade

Kirilenko et al. 2000



Ipcc AR5 report. Plant species and ecosystems don't move so fast, compared to larger animals, insects and mollusk that move with currents

Extinction



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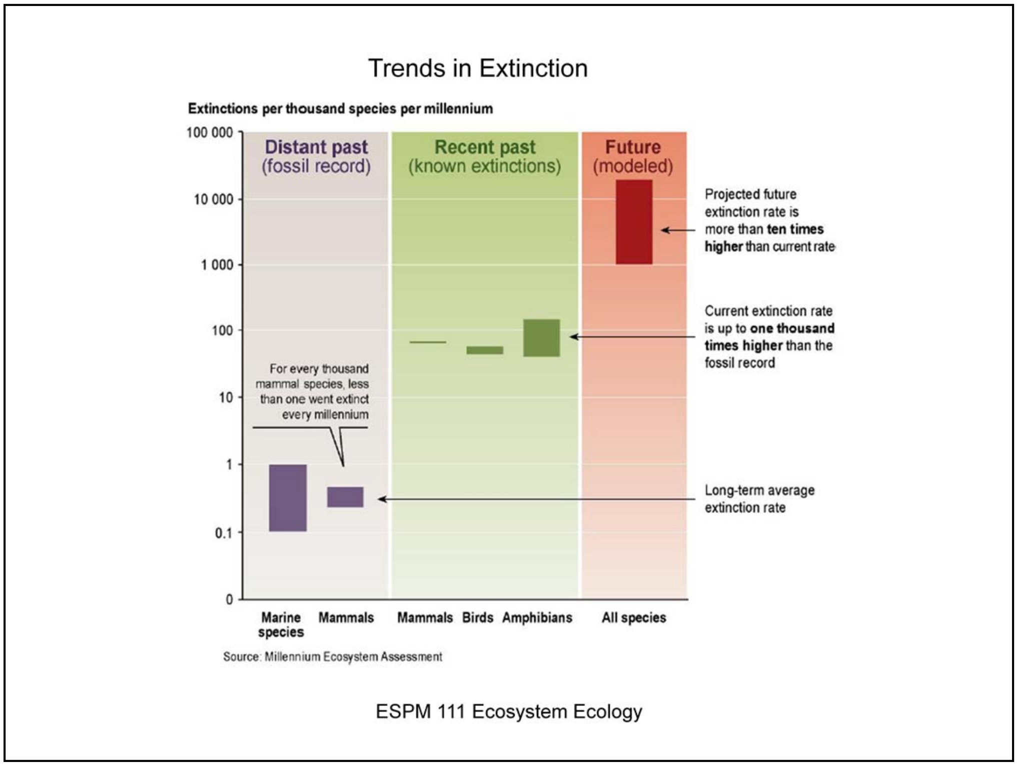
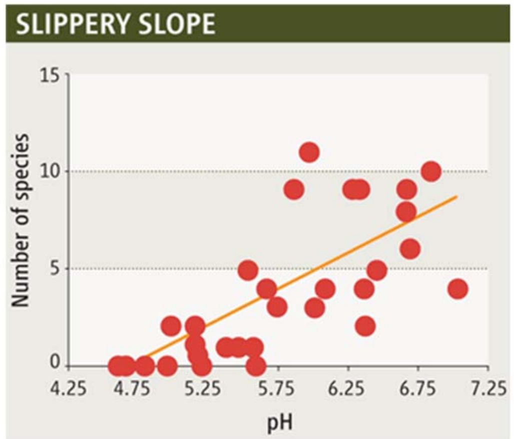


Current extinction rates are much greater than natural and historical rates

Biodiversity and Lake Acidity



Science, 2010

They reveal the often complex—and sometimes surprising—ways that acid rain has reshuffled aquatic food webs in sensitive waters. One trend is crystal clear, a team led by Nierzwicki-Bauer reported this past July in *Environmental Science & Technology*: More acid meant less biodiversity. The researchers came up with a grim rule of thumb: For every one-digit drop in pH (from 6 to 5, for instance, which represents a 10-fold increase in acidity), there were 2.5 fewer genera of bacteria, 1.43 fewer bacterial classes, and 3.97 fewer species of phytoplankton. A one-digit drop in pH also meant nearly two fewer crustacean species and about four fewer species of aquatic plants, rotifers, and fish. “Lots of studies had examined acid rain's impact at a chemical level,” says Nierzwicki-Bauer. “We tried to quantify how it changes the biota.”

Ecosystems and Climate Change

- The advance of spring events (bud burst, flowering, breaking hibernation, migrating, breeding) has been documented on all but one continent and in all major oceans for all well-studied marine, freshwater, and terrestrial groups.
- Variation in phenological response between interacting species has already resulted in increasing asynchrony in predator-prey and insect-plant systems, with mostly negative consequences.
- Poleward range shifts have been documented for individual species, as have expansions of warm-adapted communities, on all continents and in most of the major oceans for all well-studied plant and animal groups.
- These observed changes have been mechanistically linked to local or regional climate change through long-term correlations between climate and biological variation, experimental manipulations in the field and laboratory, and basic physiological research.
- Shifts in abundances and ranges of parasites and their vectors are beginning to influence human disease dynamics.
- Range-restricted species, particularly polar and mountaintop species, show more-severe range contractions than other groups and have been the first groups in which whole species have gone extinct due to recent climate change.
  - Tropical coral reefs and amphibians are the taxonomic groups most negatively impacted.
- Evolutionary responses have been documented (mainly in insects)
  - there is little evidence that observed genetic shifts are of the type or magnitude to prevent predicted species extinctions.

Parmesan 2006 Ann Rev Ecol

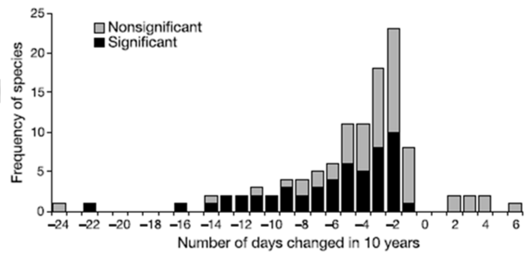
Ecological Impacts of Climate on Biota

- Fitness to new environment
- Population dynamics
- Migration ability and speed
- Distribution and abundance of species
- Ecosystem structure and function

Parmesan et al, 2000 BAMS; Kirilenko et al. 2000 Ecol Modeling

Meta Analysis of Temperature-Related Traits

- Changes in:
  - Density and Range
  - Phenology (flowering, egg laying, migration)
  - Morphology and body size
  - Genetic frequencies



Root et al, 2003, Nature

Vulnerability of Biodiversity to Climate

- Vulnerability
  - extent to which a species or population is threatened with decline, reduced fitness, genetic loss, or extinction owing to climate change
- Exposure
  - extent of climate change likely to be experienced by a species or locale
- Sensitivity
  - degree to which the survival, persistence, fitness, performance, or regeneration of a species or population is dependent on the prevailing climate
- Adaptive Capacity
  - capacity of a species or constituent populations to cope with climate change by persisting in situ, by shifting to more suitable local microhabitats, or by migrating to more suitable regions.

Dawson et al Science 2011

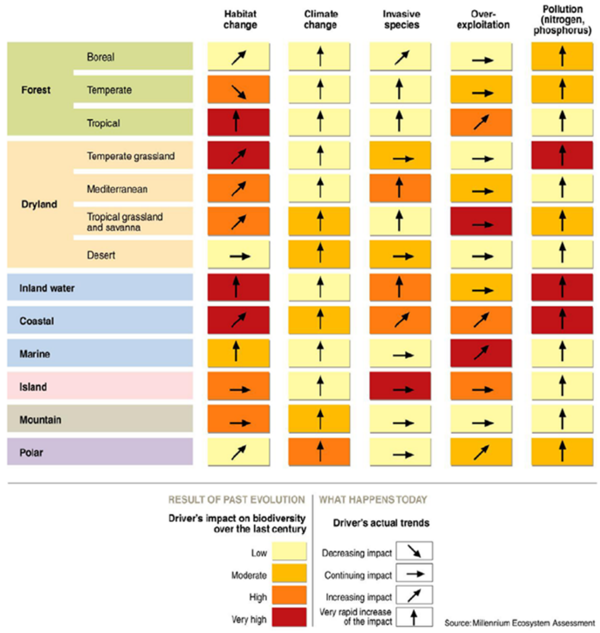
Required Rates of Migration

- High rates of migration (> 1000 m/yr) are required for 17 to 21% of worlds surface, based on 2 vegetation models and climate change scenario
- High Rates of Migration are 10 times historical rates since past glaciation
- Highest rates of Migration, Taiga/tundra, mixed and boreal conifer forests

Malcom and Markham, 2000

Climate and Avian Habitat and Populations in Great Plains

- Reproductive success
  - Habitat suitability
  - Food availability
  - Predation
  - Disease



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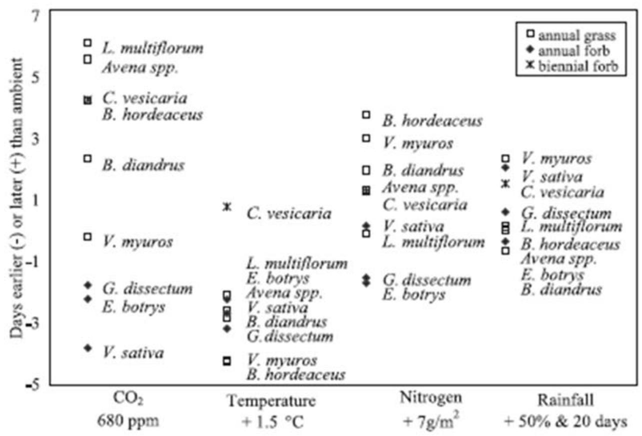
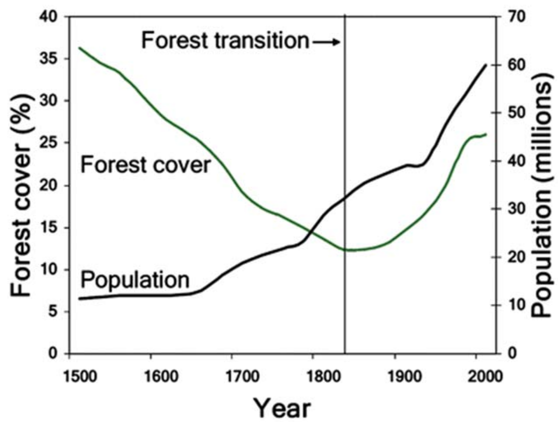
Phenology and Global Change



Cleland et al. 2006 PNAS

Trends in France



Kauppi et al. 2006 PNAS

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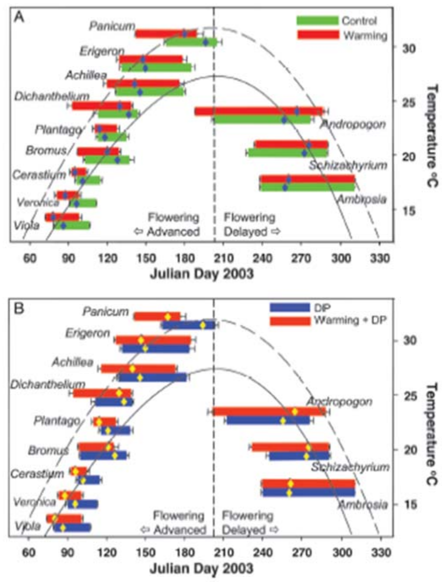
Phenology and Global Change



DP = 2x ppt

Sherry et al PNAS 2006

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DP double precipitation

Europe and the Middle East at Night

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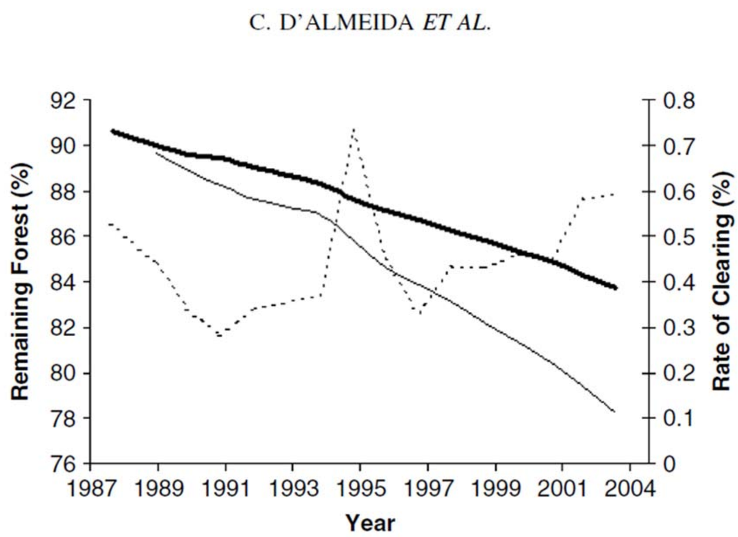
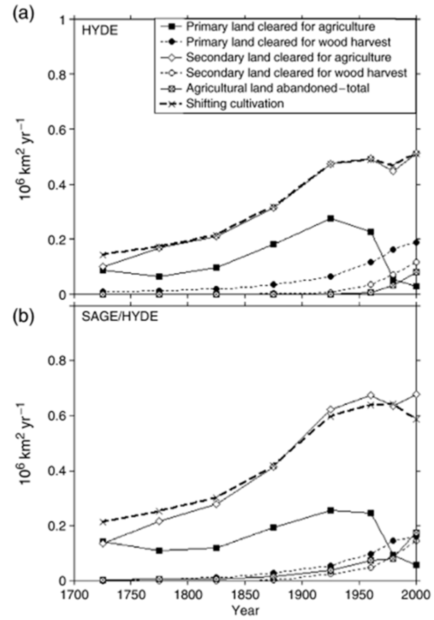
Amazon Deforestation



2007 Int J Climate

Land Use History



Hurtt et al 2006 GCB

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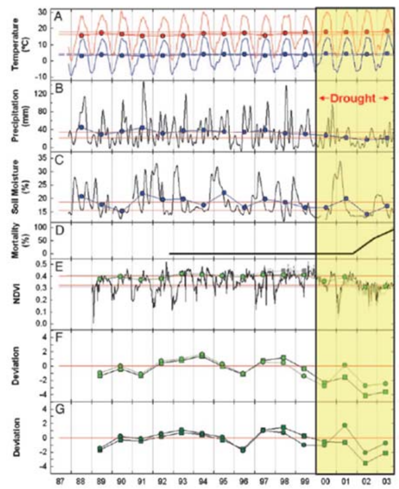
Large Scale Tree Die-Off

Breshears DD, et al. (2009) Tree die-off in response to global-change type drought: Mortality insights from a decade of plant water-potential measurements. *Front Ecol Environ, in press.*



Land Use Trends in Central Valley

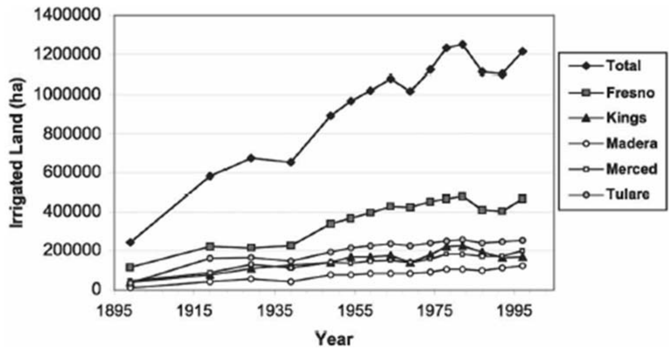


FIG. 1. Land area on which irrigation was applied in five counties utilized in this study. Mariposa County had negligible land under irrigation.

Christy et al 2006 J Climate

Fire and Mankind

REVIEW

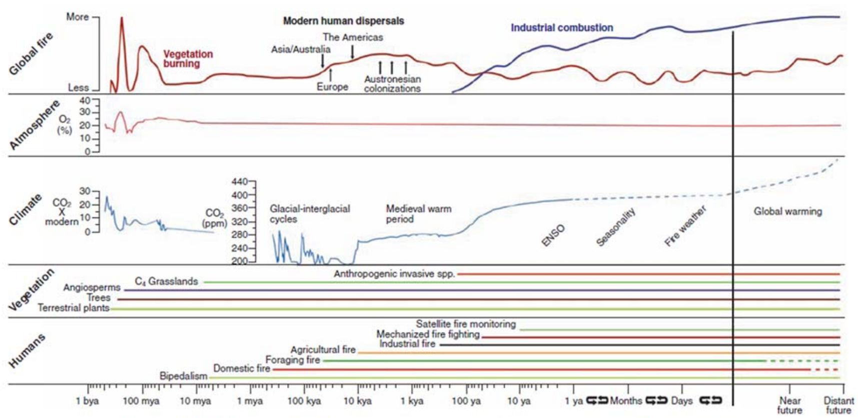


Fig. 1. Qualitative schematic of global fire activity through time, based on pre-Quaternary distribution of charcoal, Quaternary and Holocene charcoal records, and modern satellite observations, in relation to the percentage of atmospheric O_2 content, parts per million (ppm) of CO_2, appearance of certain vegetation types, and the presence of the genus *Homo*. (See supporting online text for data sources used.) Dotted lines indicate periods of uncertainty.

Bowman et al., 2009, Science