Forest disturbances and ecosystem management in mountain areas

Impacts of climate change driven disturbances

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Forest Ecology and Management
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Education

M.Sc. Forest Sciences: University of Firenze (Italy).
"Progeny test and clonal comparison in *Alnus cordata* Loisel."

Ph.D. Plant Physiological Ecology: Trinity College, Dublin (Ireland).
"The impact of long-term elevated CO_2 concentrations on the water relations, stomatal behavior and hydraulic architecture of shrubs, and stem growth of trees in a Mediterranean forest ecosystem "

Research interests: Physiological Ecology of Forest Production

Research experience:

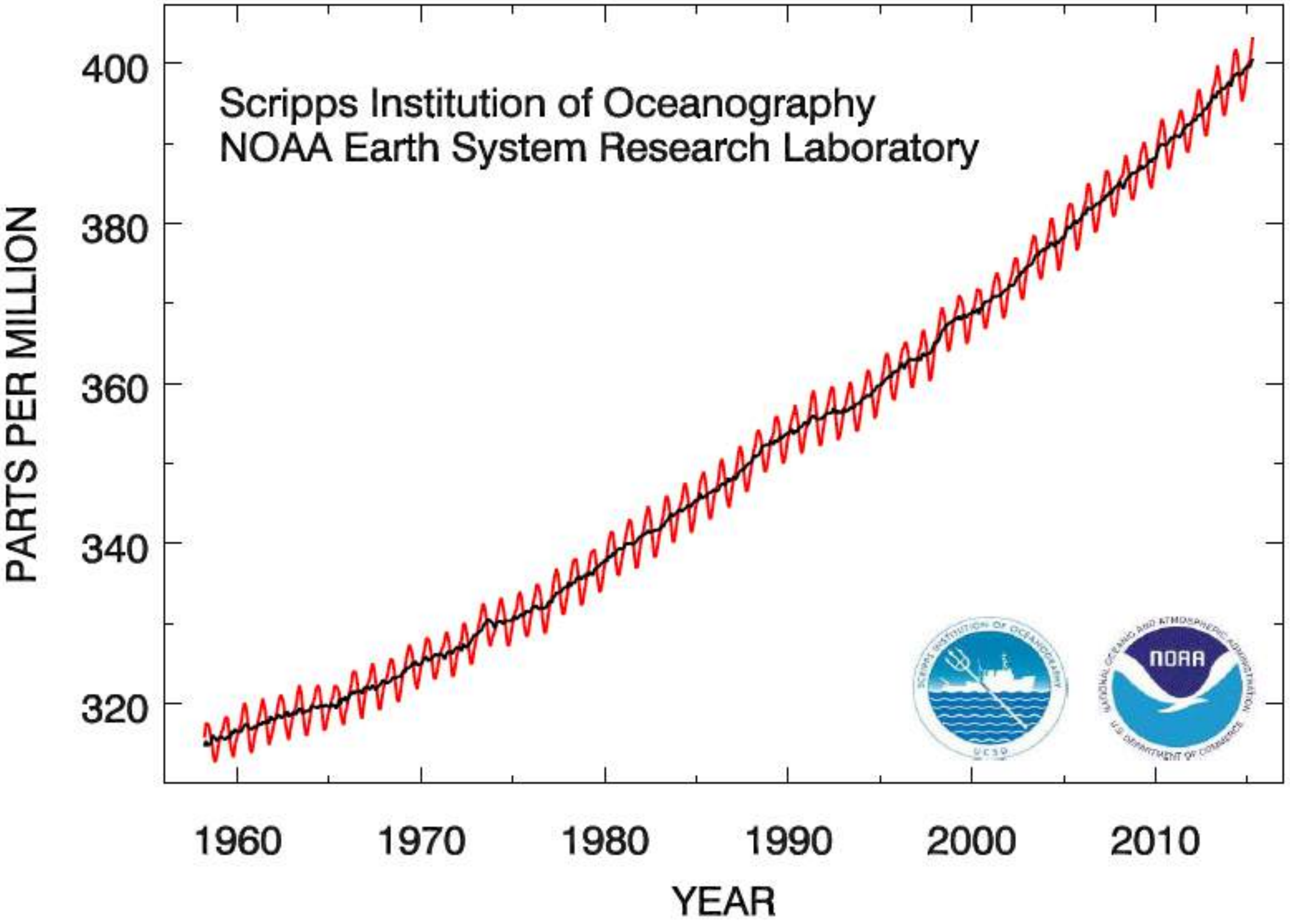
- *Disturbance ecology and stress physiology*
- *Structure and function of woody plants*
- *Plant water requirements*
- *Environmental indicators*
- *Tree growth*

Editor: *Tree Physiology, iForest*

Several concepts on climate change…

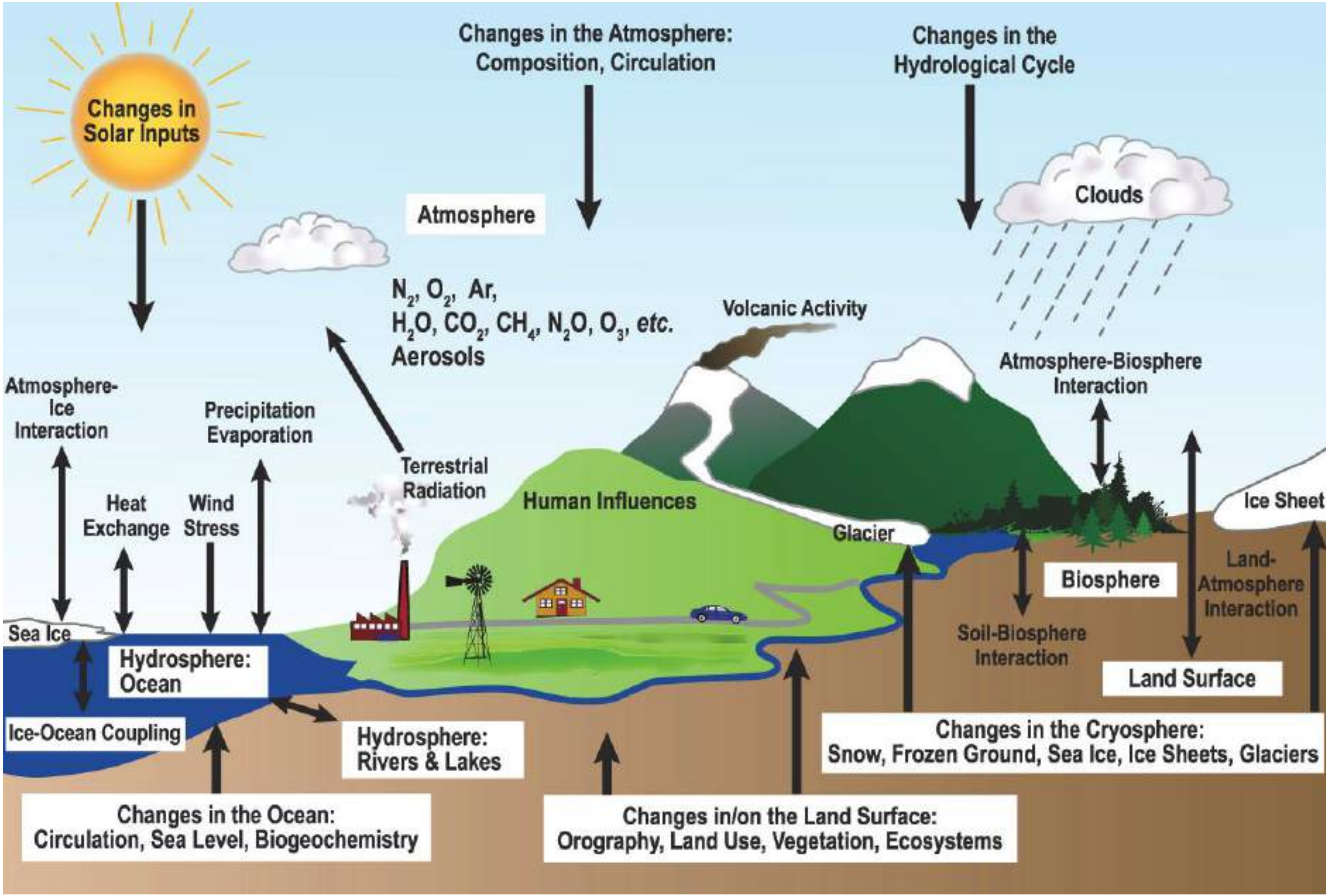
- Humans influences on the climate system are clear.
  - –Human-caused emissions of greenhouse gases, especially CO2 are the highest in history.
  - –The result is a changing climate that impacts both natural and human systems.
- Earth System Models present increasingly accurate simulation of current condition and future potential.
  - –Improving projections of climate features (Monsoons, ENSO) and Regional climates.
  - –Changed regional climates impact water resources, ecosystems, agriculture, and human settlements among others.
- Mountain climates are complex so projection of changes are more uncertain.

Atmospheric CO_2 at Mauna Loa Observatory

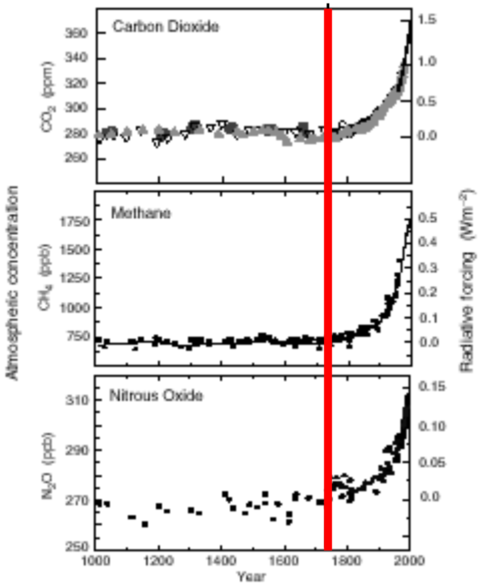


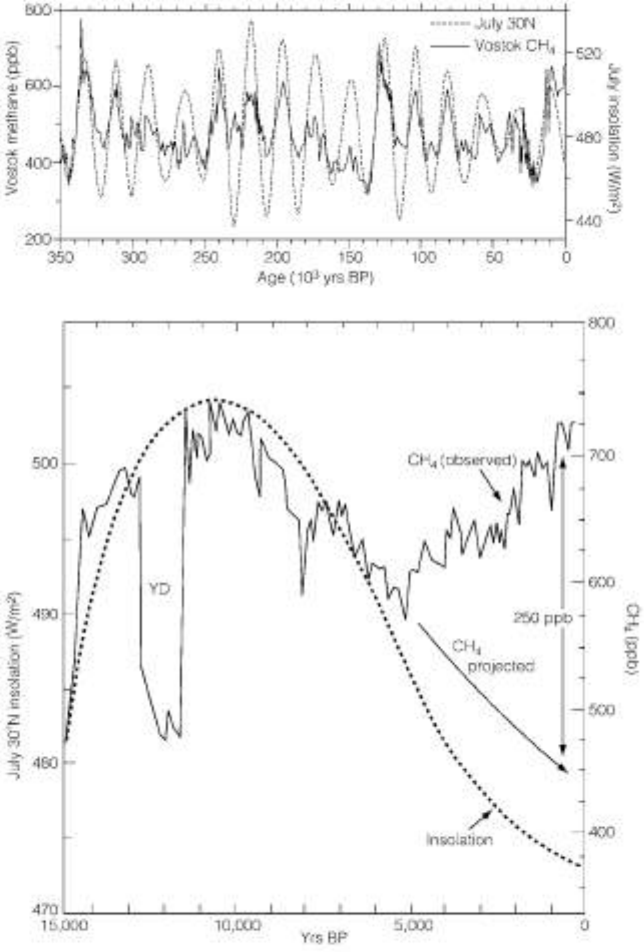
…and several certainties…

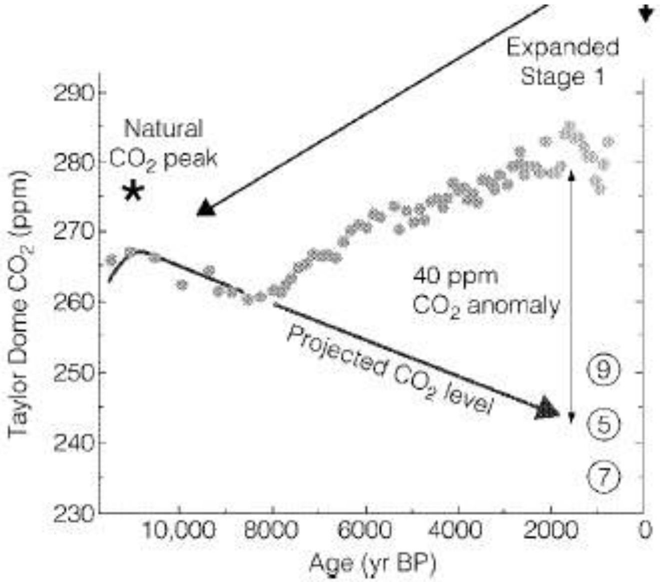
- The concentration of CO_2 in the atmosphere is higher than it has been for at least the last 800,000 years.
- All plausible causes for the size of CO_2 increase are human:
  - –burning fossil fuels,
  - –making cement
  - –manipulating land cover - deforestation, urbanization, etc.
- Increased CO_2 captures more of the Earth’s heat, in turn, forcing a new global energy balance and resulting in a warmer atmosphere, the greenhouse effect.
- A new global energy balance alters the “atmosphere ocean general circulation” system and, in turn, the whole Earth System


Changes in Solar Inputs
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Clouds
Atmosphere
N_2, O_2, Ar, H_2O, CO_2, CH_4, N_2O, O_3, *etc.*
Aerosols
Volcanic Activity
Atmosphere-Biosphere Interaction
Atmosphere-Ice Interaction
Precipitation Evaporation
Terrestrial Radiation
Heat Exchange
Wind Stress
Human Influences
Glacier
Ice Sheet
Biosphere
Land-Atmosphere Interaction
Sea Ice
Hydrosphere: Ocean
Soil-Biosphere Interaction
Land Surface
Ice-Ocean Coupling
Hydrosphere: Rivers & Lakes
Changes in the Cryosphere: Snow, Frozen Ground, Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean: Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

Global change



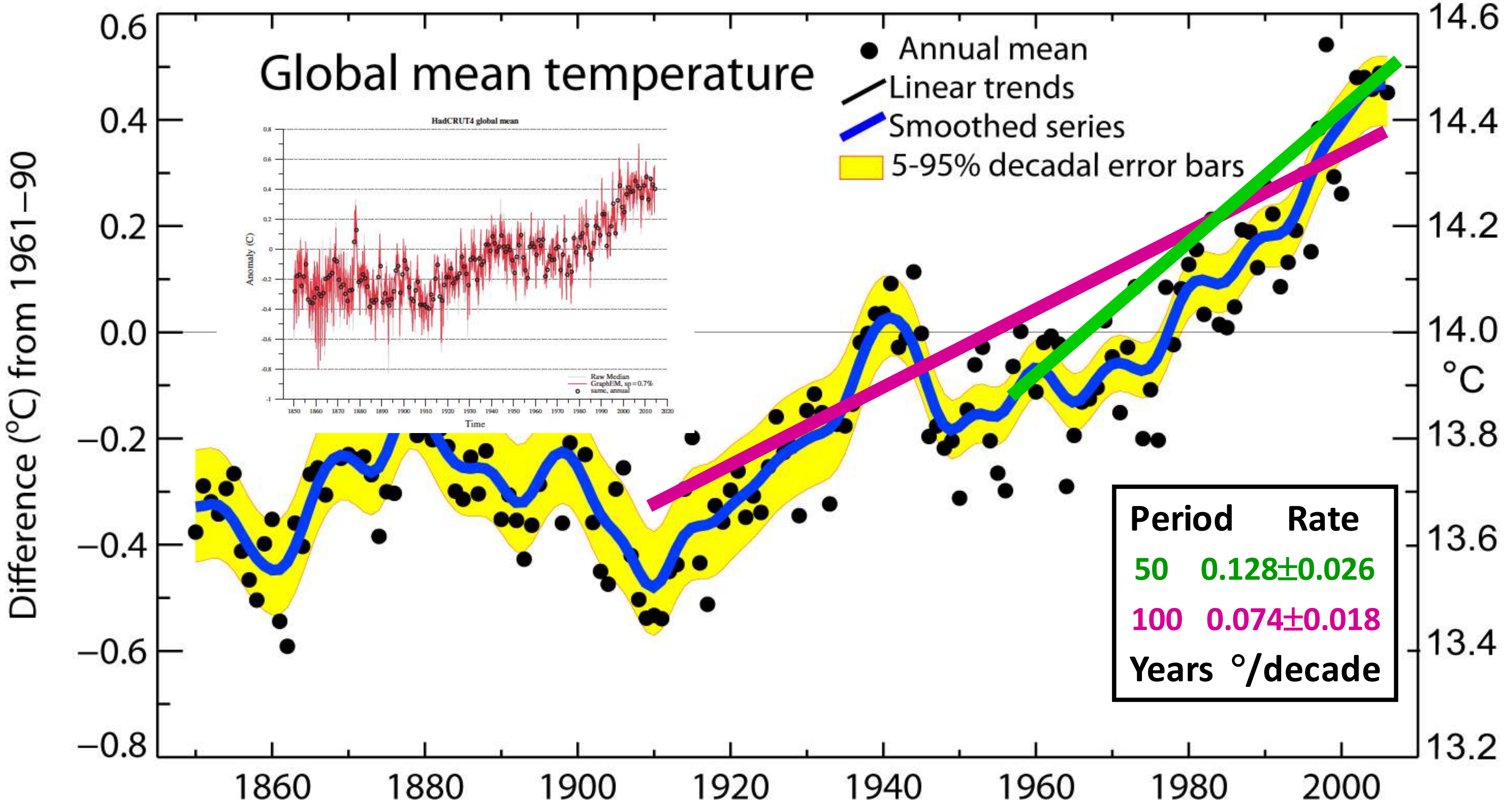




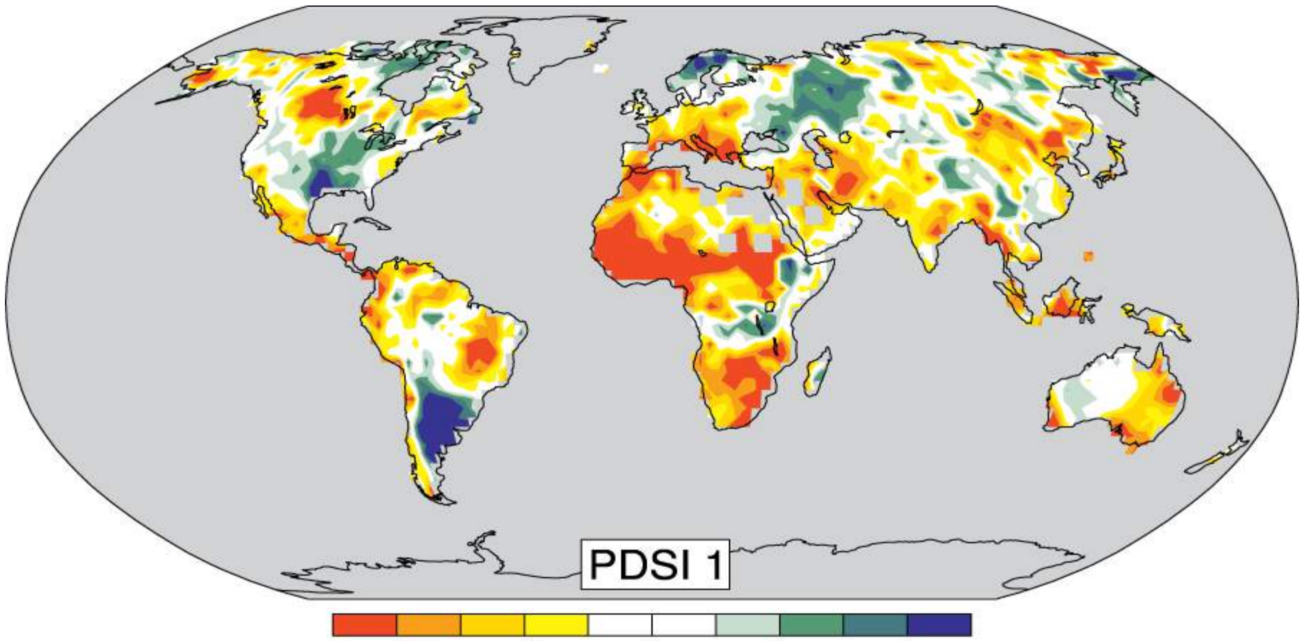
Did the human impact start before?

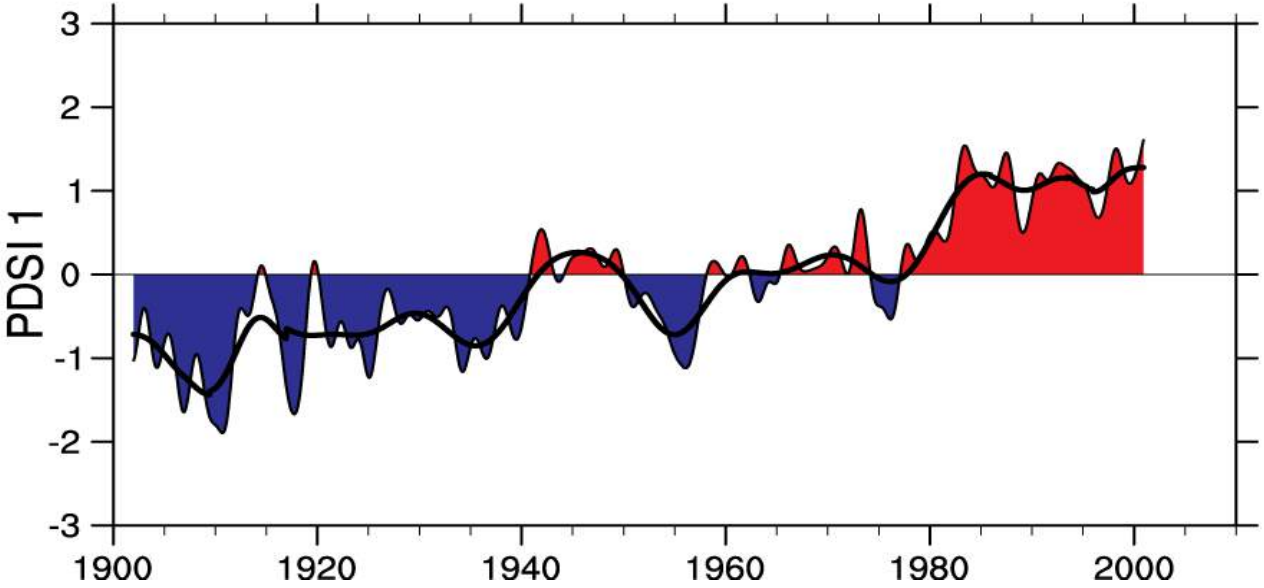
Industrial revolution

Global mean temperatures are rising faster with time

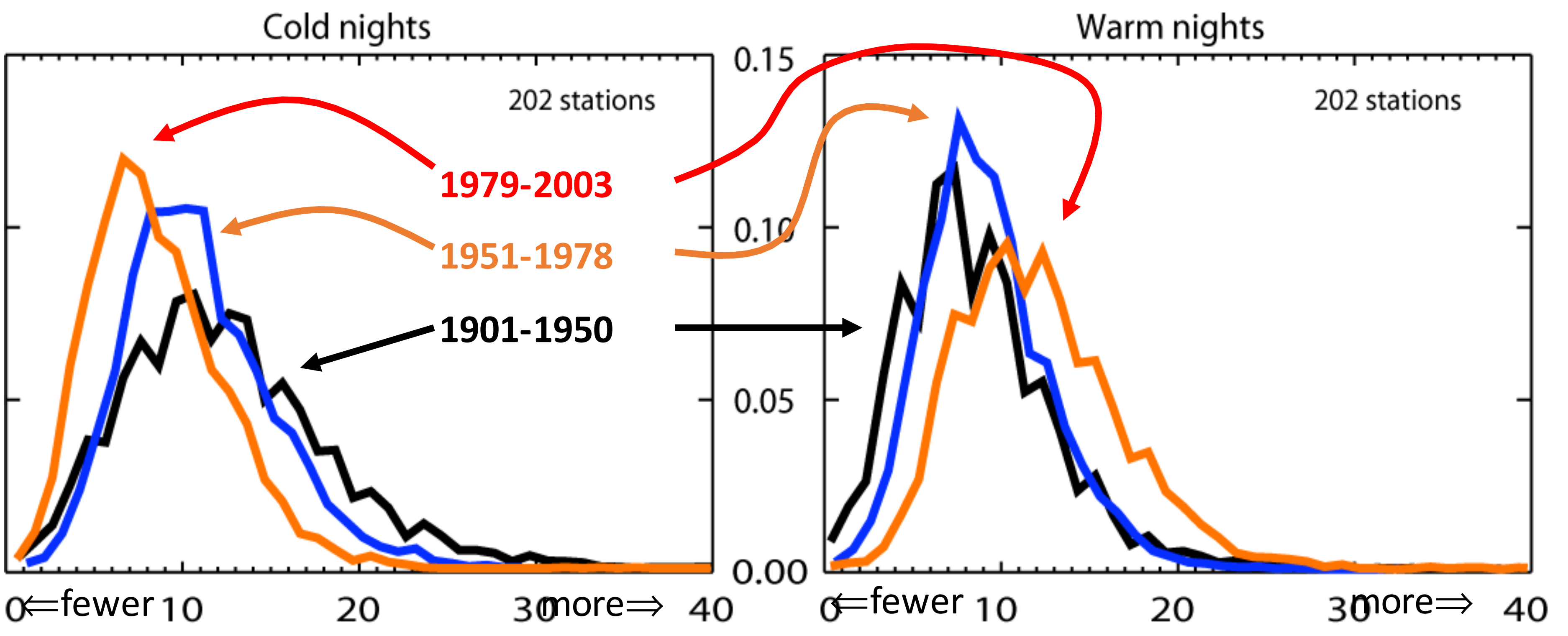


Drought is increasing most places



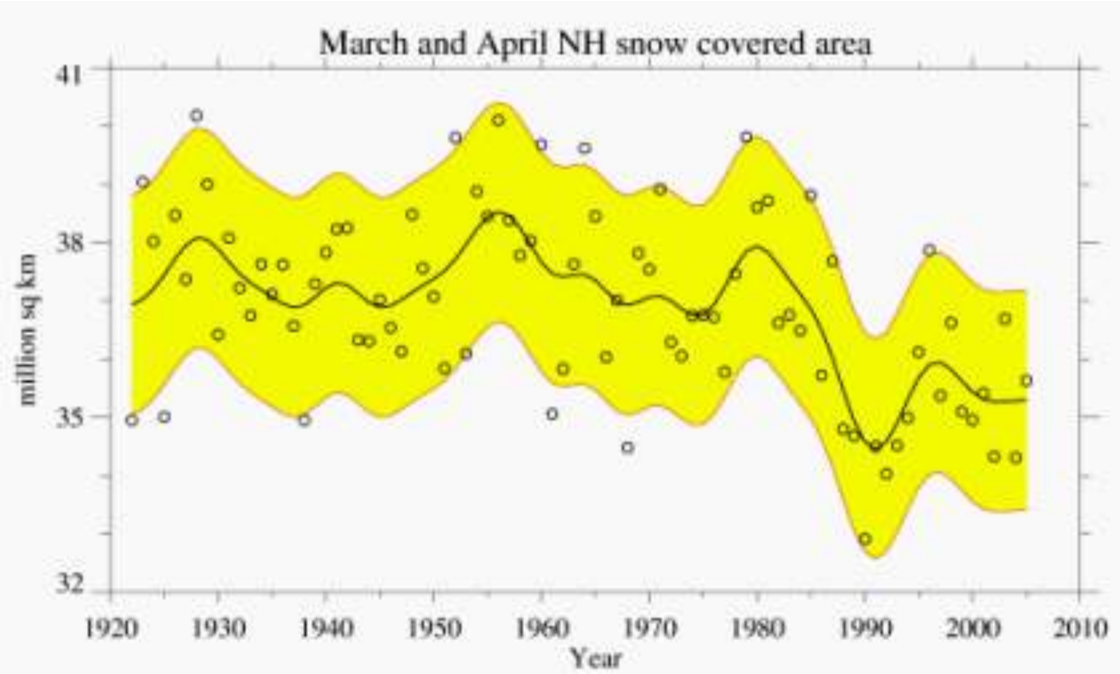


Warm nights are increasing, cold nights decreasing

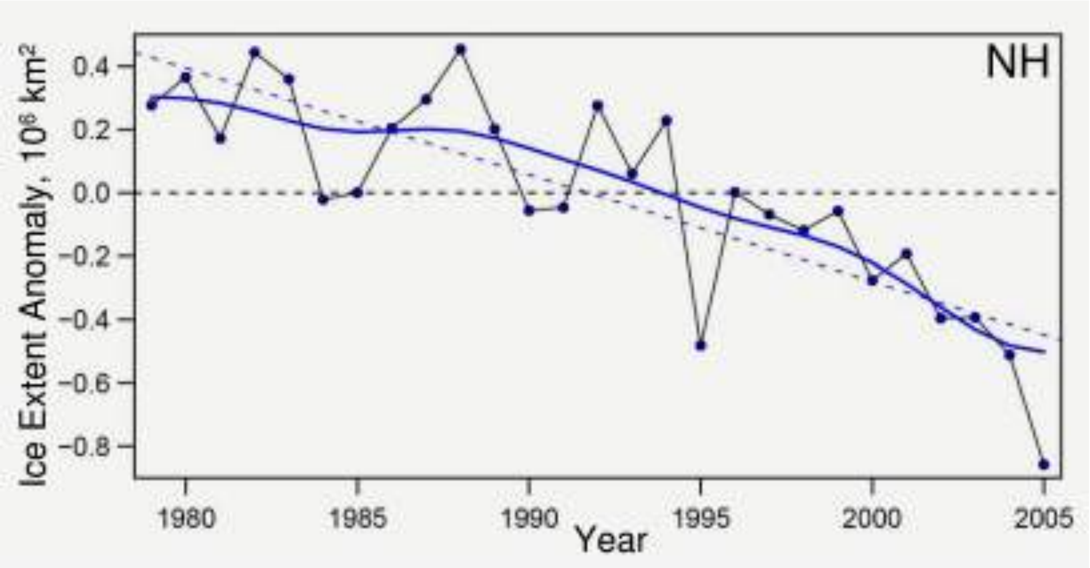


Frequency of occurrence of cold or warm temperatures for 202 global stations for 3 time periods: 1901 to 1950 (black), 1951 to 1978 (blue) and 1979 to 2003 (red)

Snow cover and Arctic sea ice are decreasing

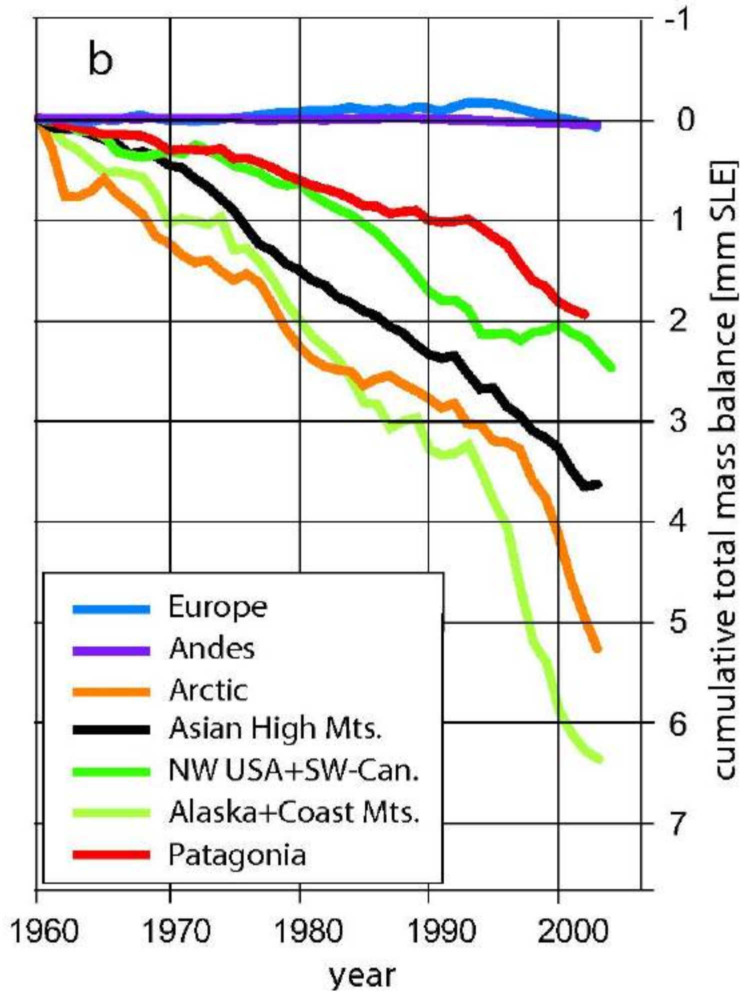


Spring snow cover shows 5% stepwise drop during 1980s

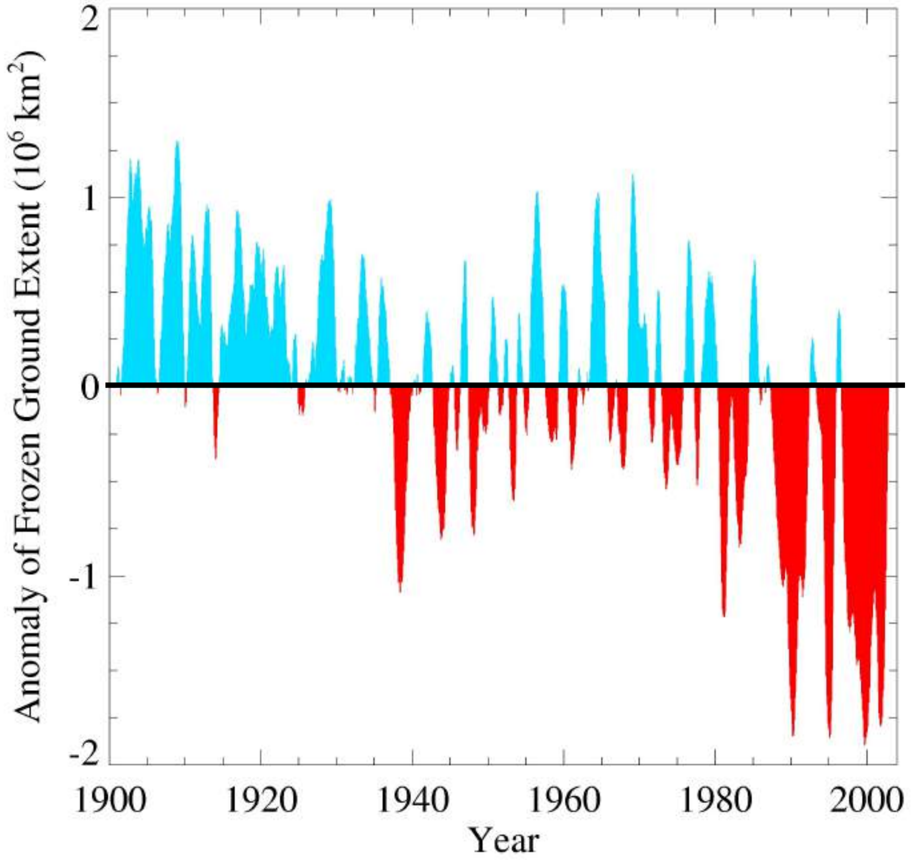


Arctic sea ice area decreased by 2.7% per decade (Summer: -7.4%/decade)

Glaciers and frozen ground are receding

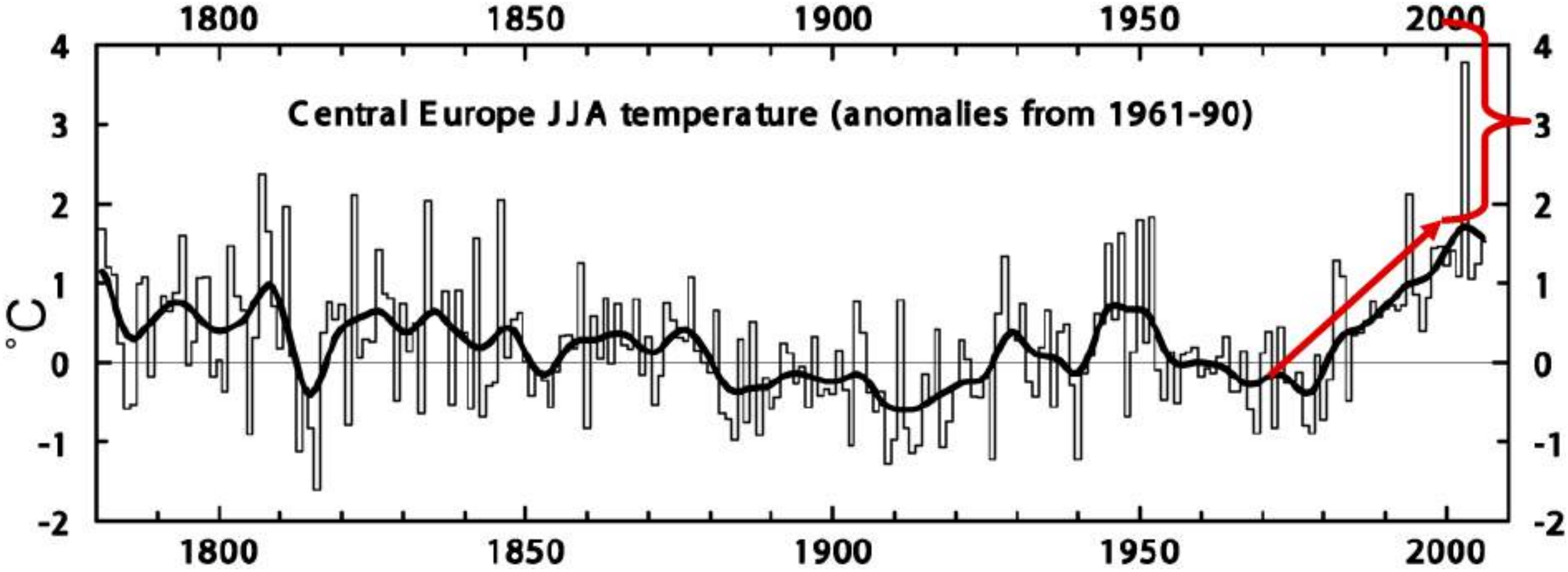


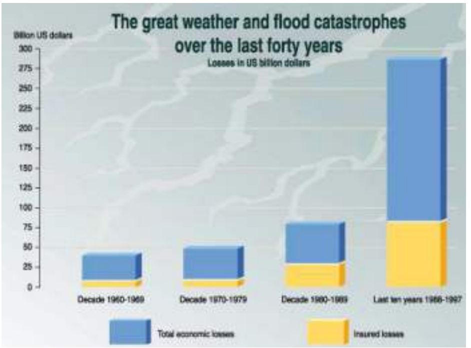
Increased Glacier retreat since the early 1990s



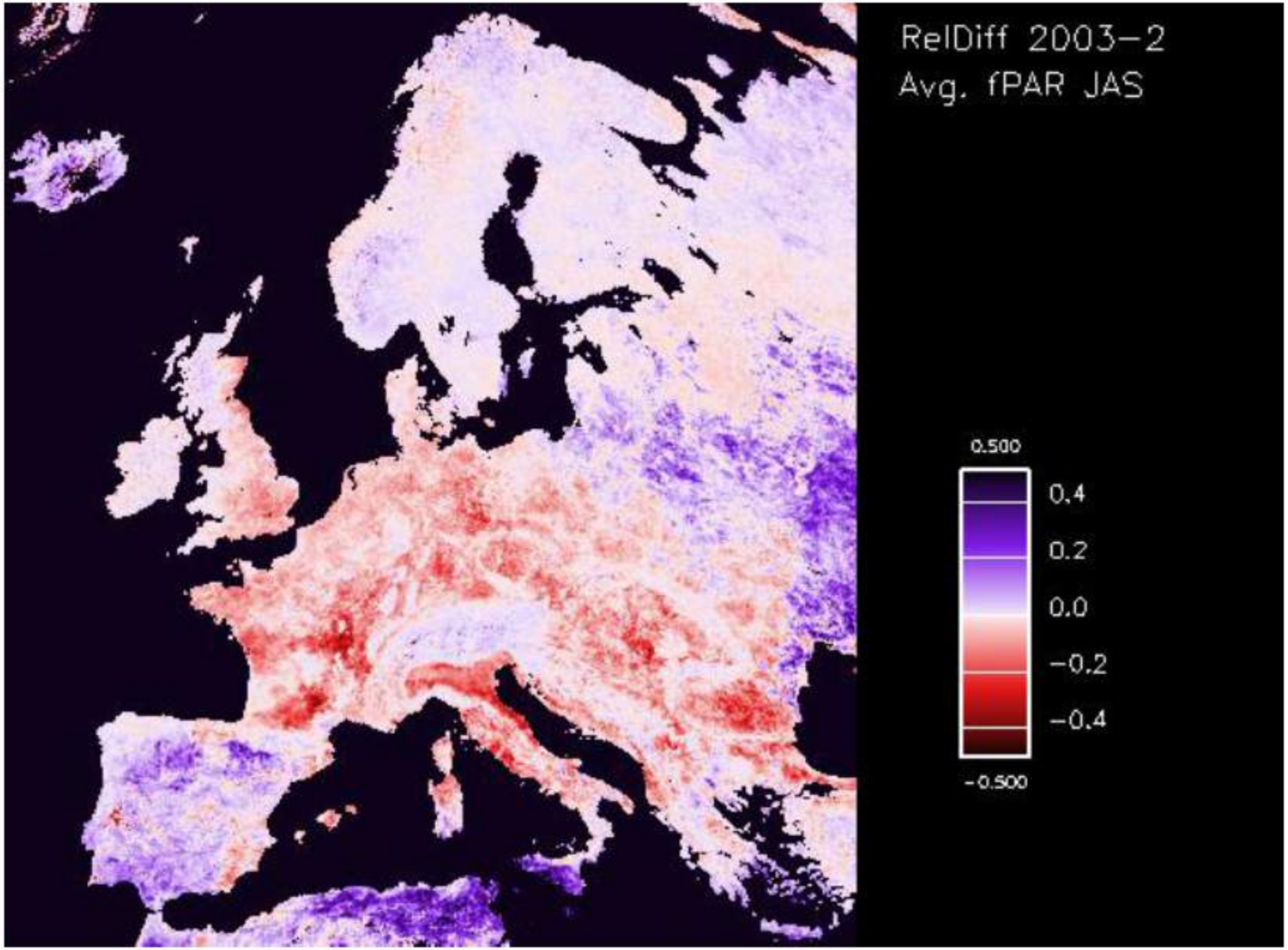
Area of seasonally frozen ground in NH has decreased by 7% from 1901 to 2002

Extreme events are increasing





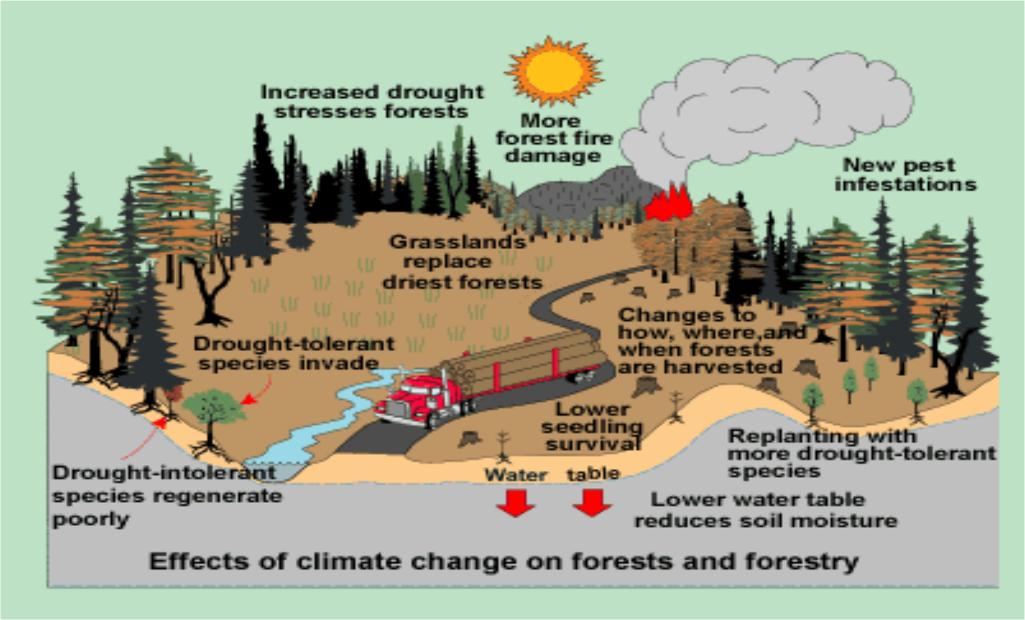
Heat waves: summer 2003 in Europe



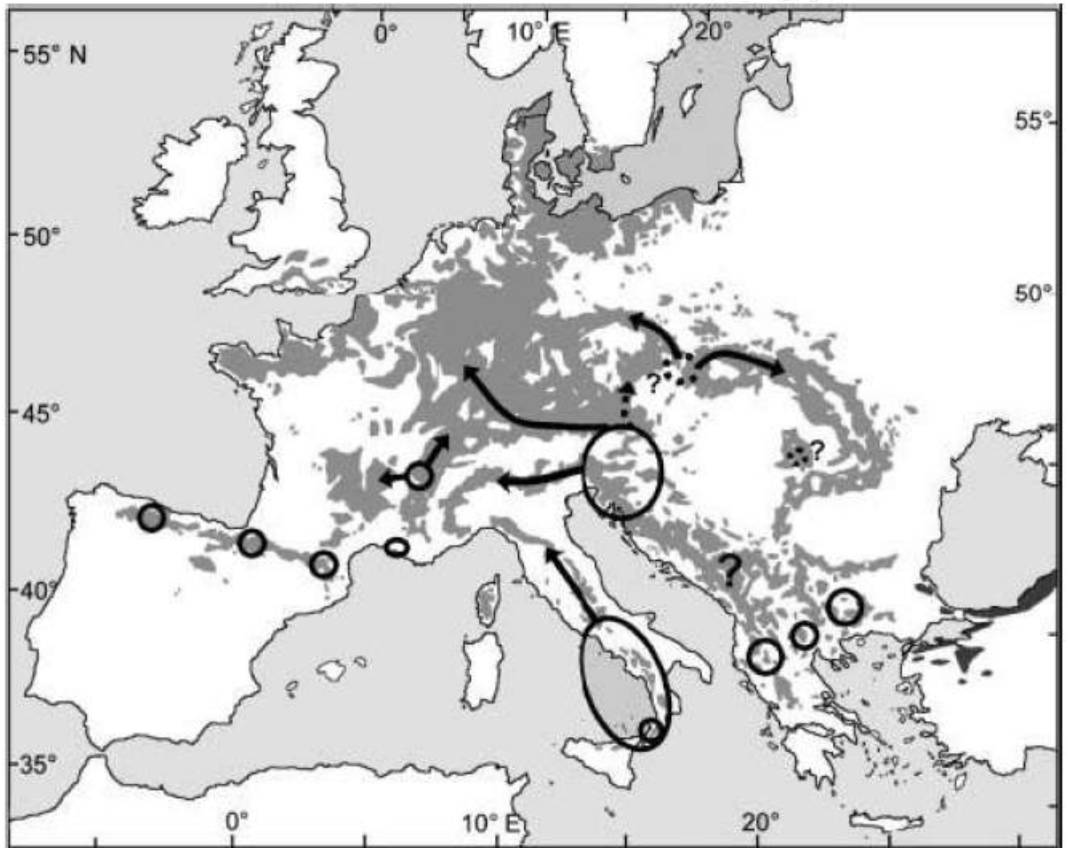
Impact of climate change: heat waves of 2003 and reduction of forest NPP

Climate change impact on forests

1) Long-term impacts (ecology of the species, adaptation)
2) Short-term impacts (disturbance regime)



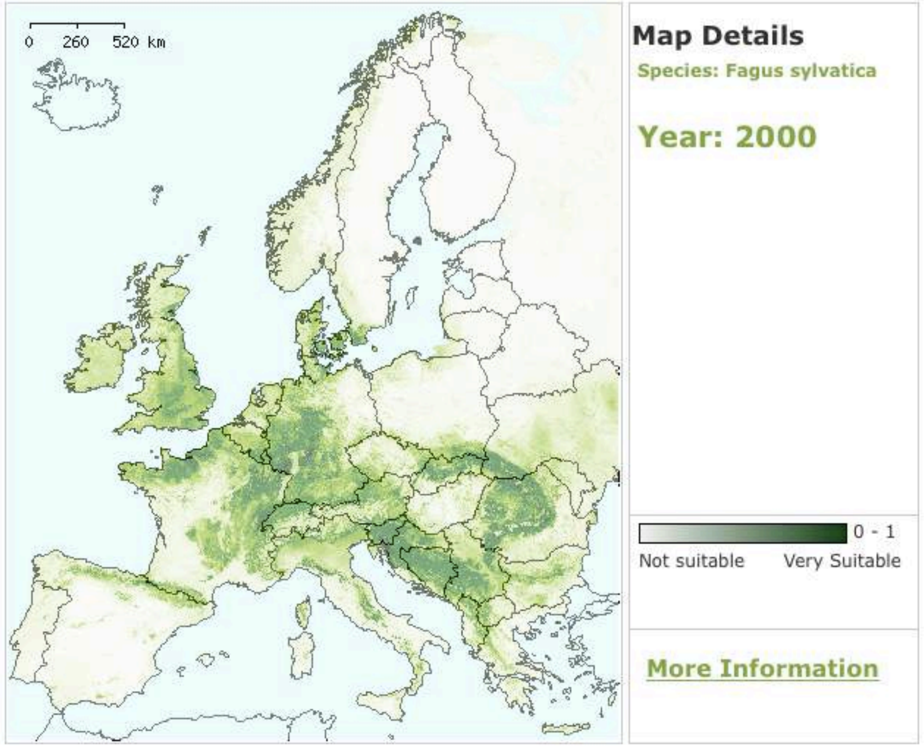
1) **Long-term impact (adapt, migrate, extinct)**

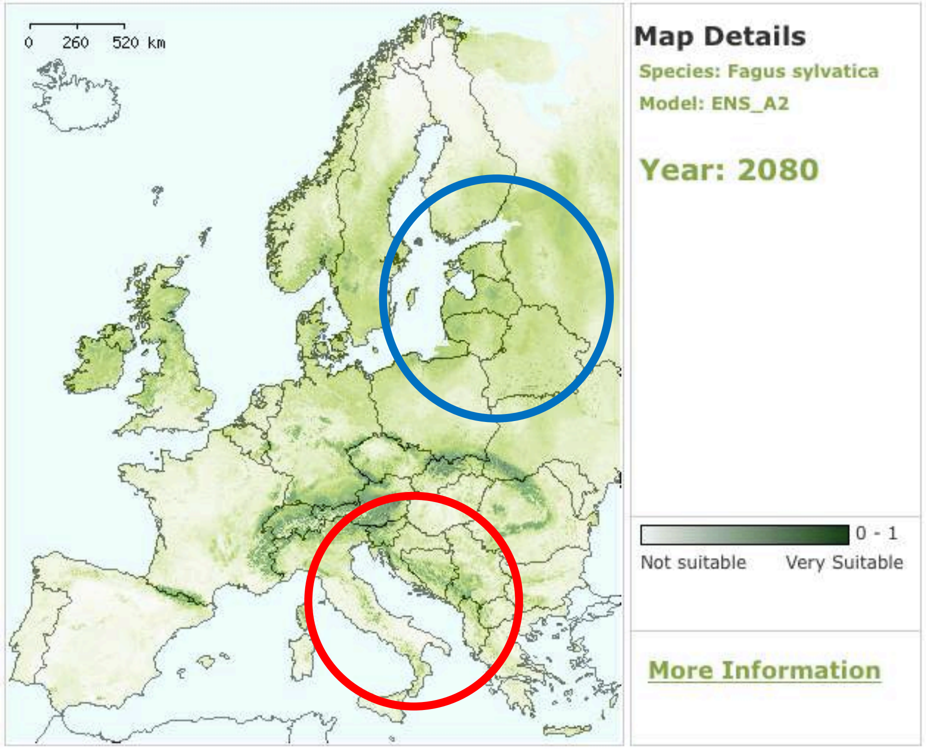


Fagus sylvatica

- Range migration
- Altitudinal shift
- Threats to plant diversity (elevation, drought, …)
- Alien plant invasion

tree species maps - species habitat suitability





e.g., *Fagus sylvatica*

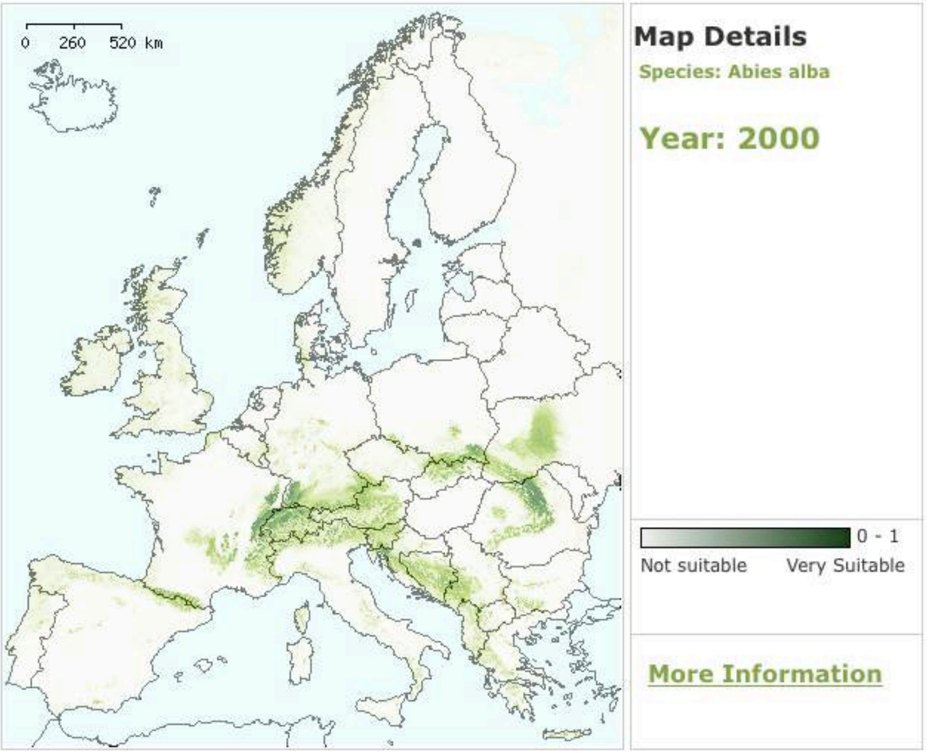
Cookies |

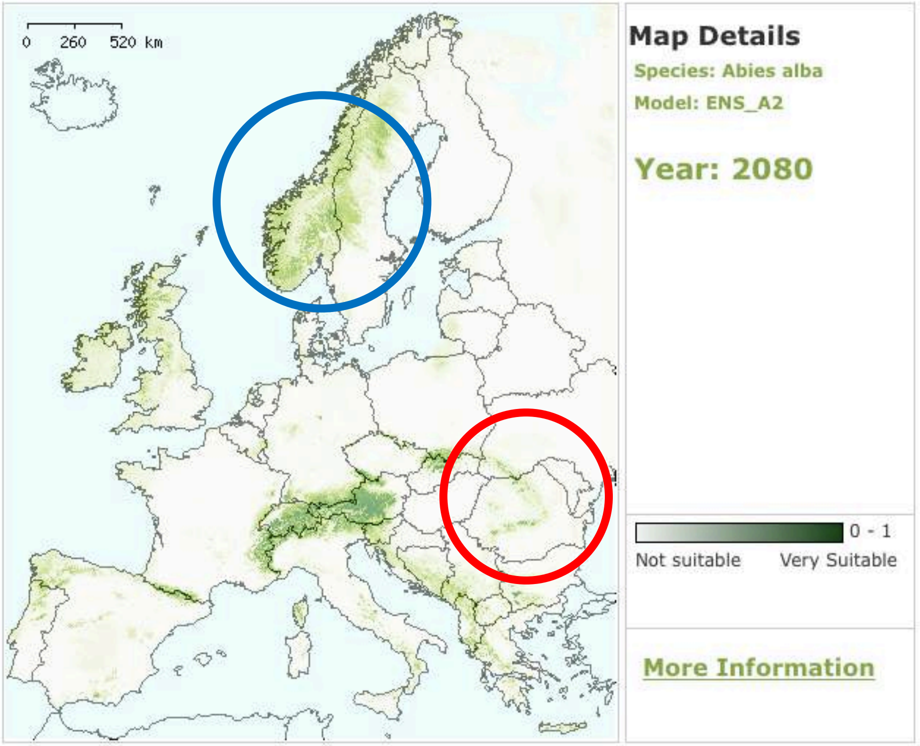
European Commission

JOINT RESEARCH CENTRE

EFDAC- European Forest Data Centre

tree species maps - species habitat suitability





e.g., ***Abies alba***

Cookies |

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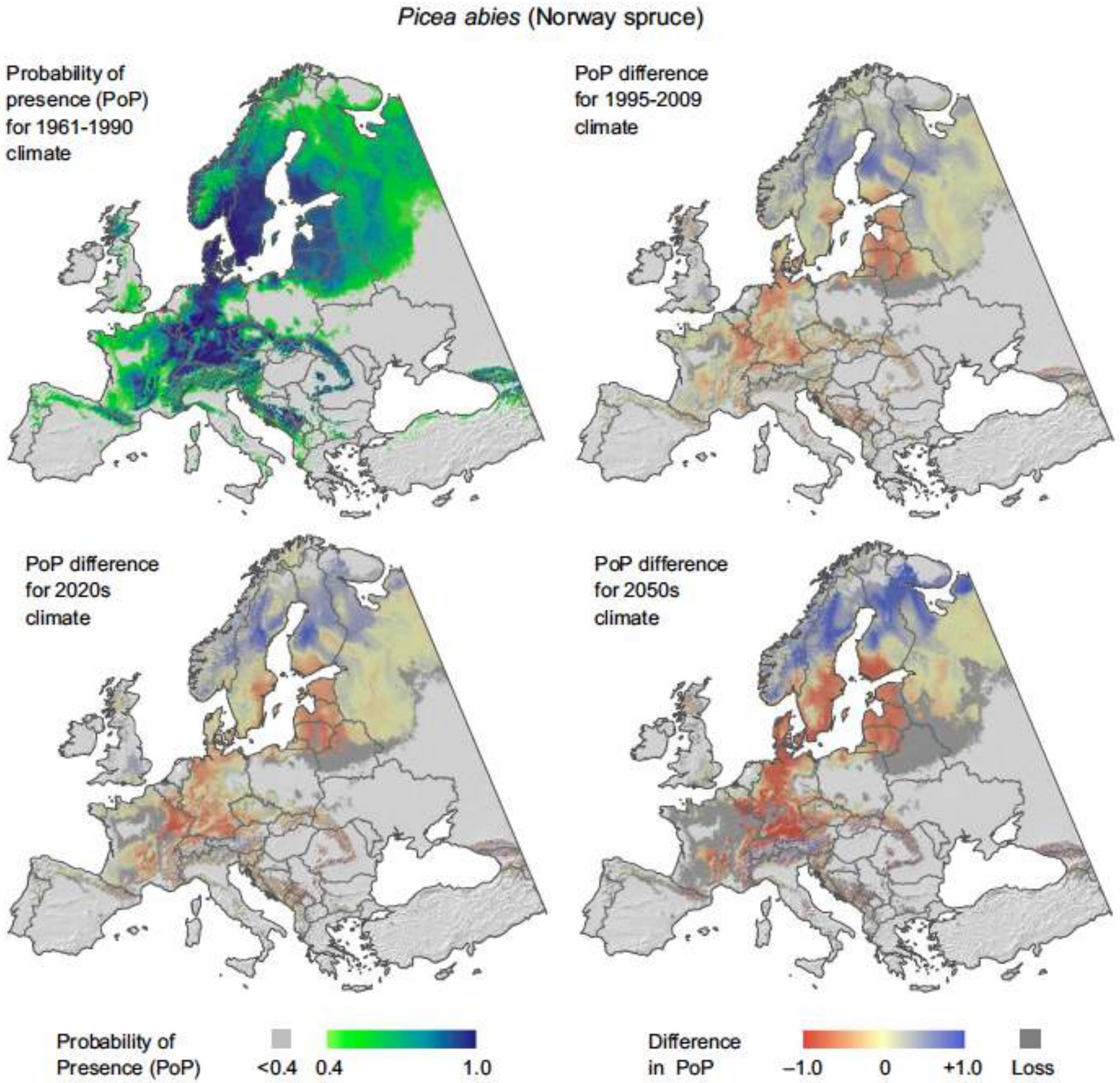
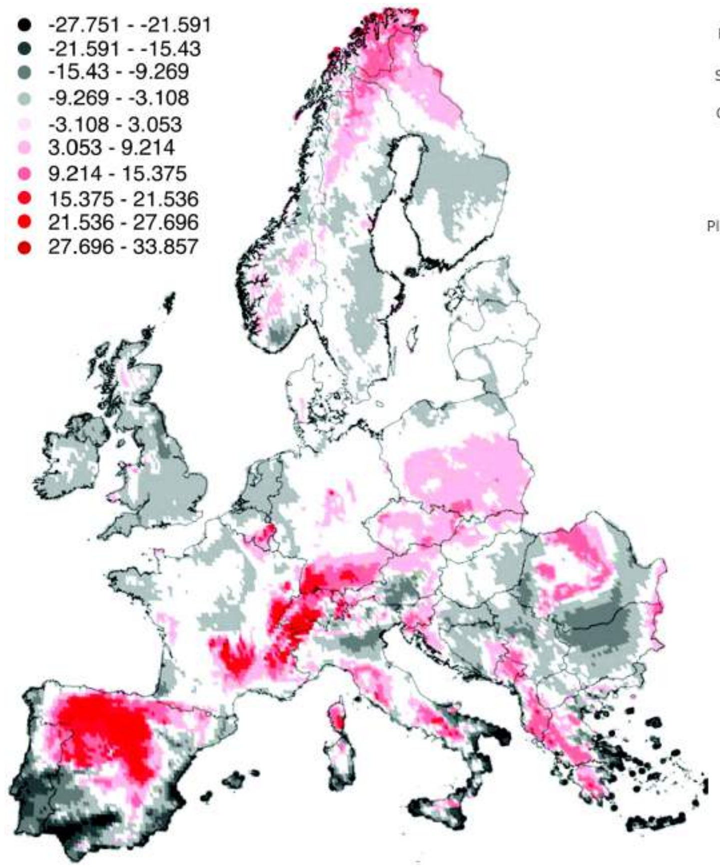
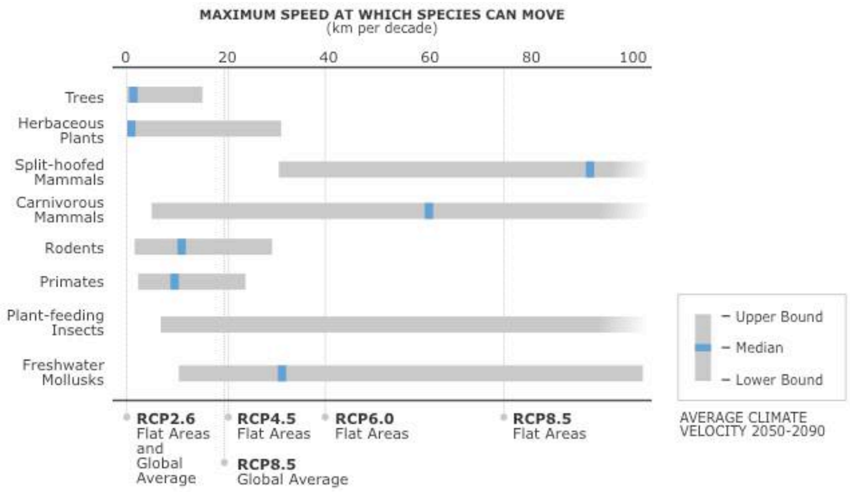
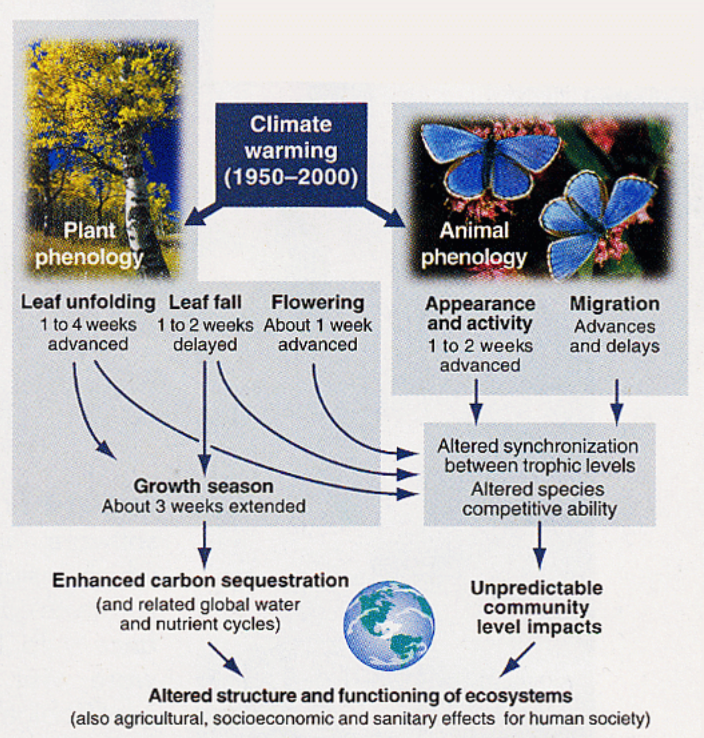


Picea abies (Norway spruce)
Probability of presence (PoP) for 1961-1990 climate
PoP difference for 1995-2009 climate
PoP difference for 2020s climate
PoP difference for 2050s climate
Probability of Presence (PoP)
<0.4
0.4
1.0
Difference in PoP
−1.0
0
+1.0
Loss





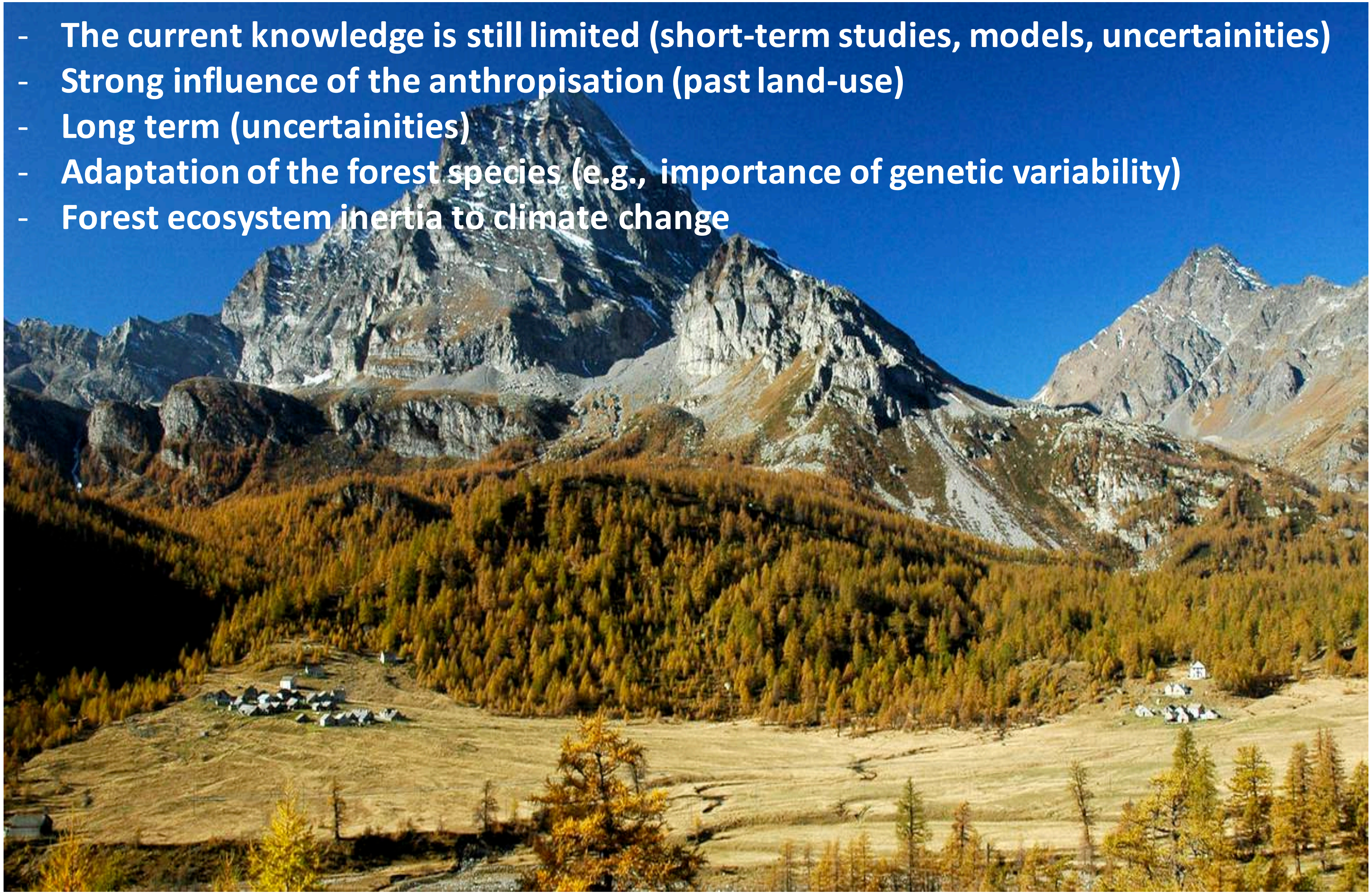
Penuelas and Filella (2001)
Science 294: 793 – 795



Ecological consequences of climate warming on plant and animal phenology.

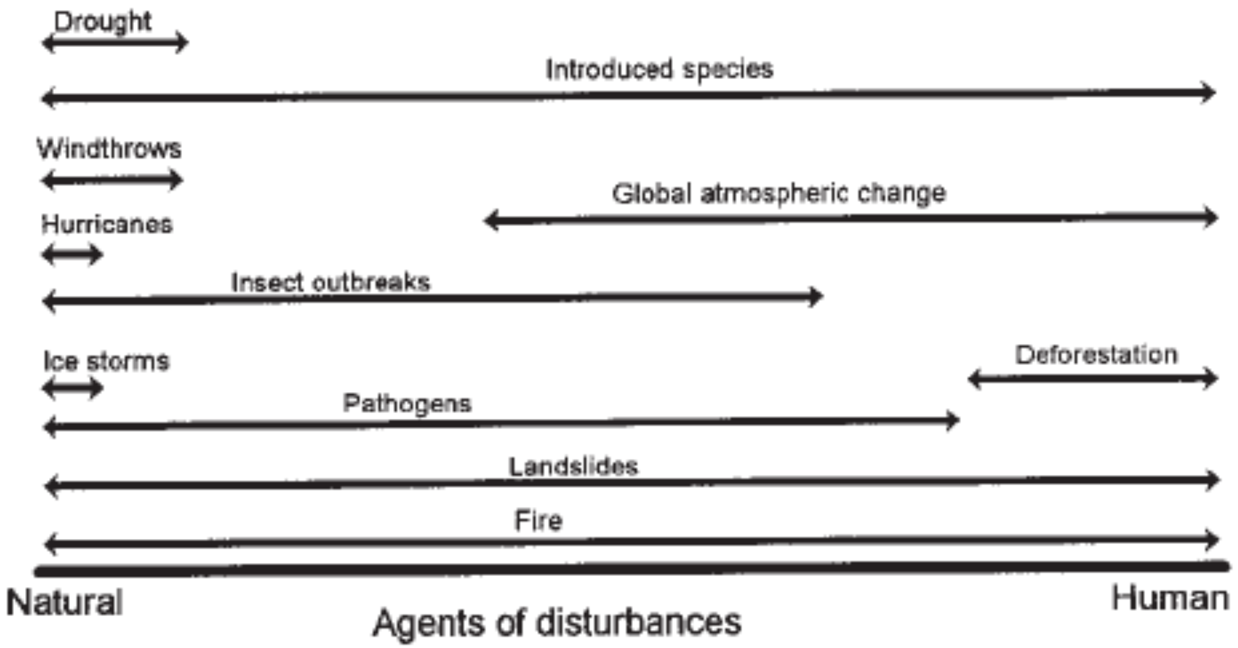
Thuiller W et al. (2005) PNAS 102:8245-8250

Regional projections of the residuals from the multiple regression of species loss against growing-degree days and moisture availability


- The current knowledge is still limited (short-term studies, models, uncertainities)
- Strong influence of the anthropisation (past land-use)
- Long term (uncertainities)
- Adaptation of the forest species (e.g., importance of genetic variability)
- Forest ecosystem inertia to climate change

2) Short term impacts (change of the disturbance regime)

Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, invasive species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides



USA

Disturbance	Average annual impact area (ha)	Average annual economic cost (millions of dollars)
Fire	450,000[a]	261[b]
Hurricane	1,200,000[c]	700[d]
Tornado	450,000[e]	154[f]
Ice	>180,000[g]	>10[g]
Insects and pathogens	20,400,000[h]	1,500[i]
Exotic species	Nationwide	60[j]
Landslide	100,000	1,000[k]
Drought	Nationwide	Severity dependent

What is Disturbance?

- Definition
- Types
- Spatial and temporal considerations
- Ecosystem wide effects

Stress vs. disturbance

Both stress and disturbance are potential components of climate change:

Stress: "external constraints limiting the rates of resource acquisition, growth or reproduction of organisms" (Grime, 1989); "Any environmental factor which restricts growth and reproduction of an organism or population'' (Crawford, 1989).

Disturbance: "discrete events that cause tree mortality and destruction of plant biomass" (Pickett and White, 1985).

Stress: long term process, chronic or background environmental variability
Disturbance: short term (event), discrete in time cause a notable change (a perturbation) in the state of the system.

Agents of Pattern Formation: Disturbance

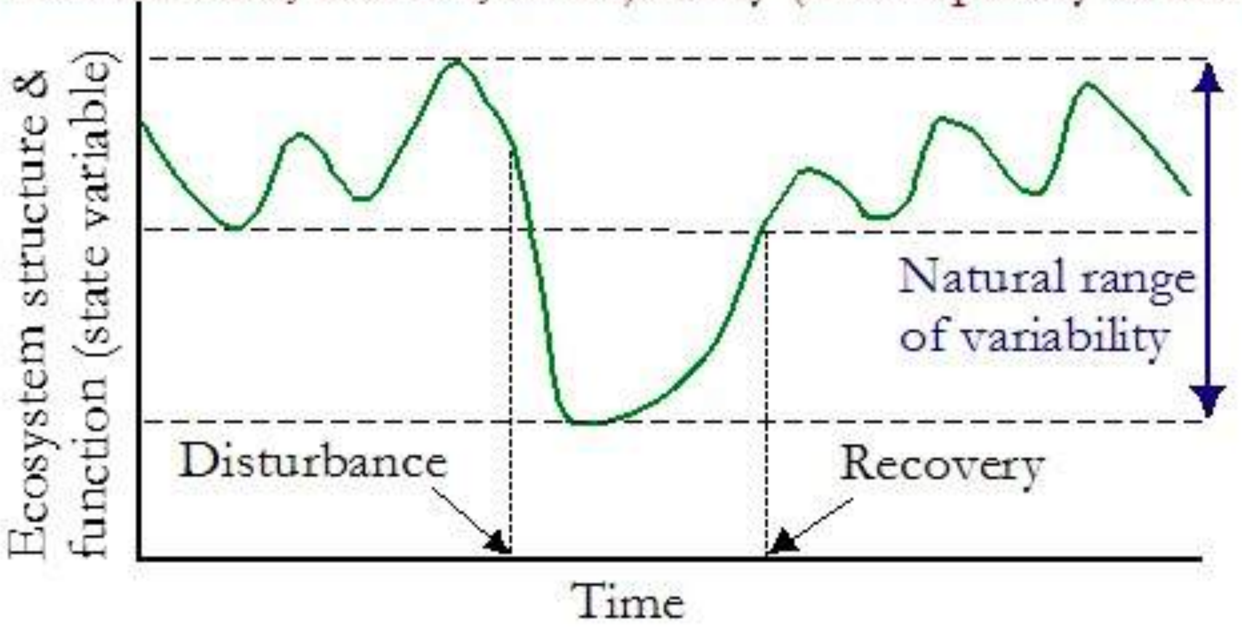
What is a Disturbance?

- Any relatively *discrete* event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment, including both destructive, catastrophic events as well as less notable, natural environmental fluctuations. Typically, a disturbance causes a significant *change* in the system under consideration (White and Pickett 1985).

Agents of Pattern Formation: Disturbance

What is a Perturbation?

- A change in a parameter (state variable) that defines a system; that is, a departure (explicitly defined) from a normal state, behvior, or trajectory (also explicitly defined).

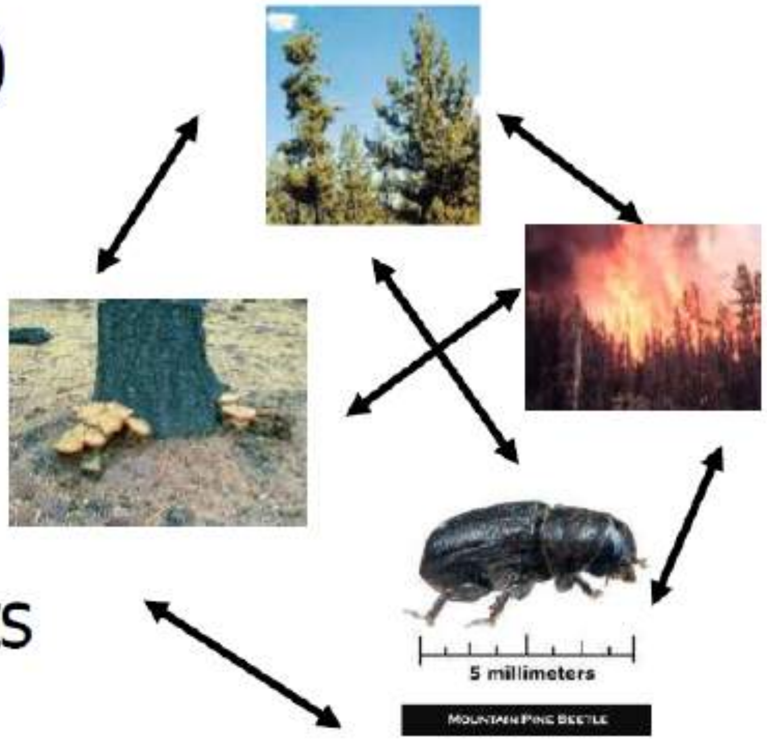


Characteristics of Disturbance Regimes

- Type
- Frequency
- Magnitude
- Predictability
- Extent
- Timing
- Synergism
- Severity

Disturbance Regimes

- Agent (fire, insects, disease, climate change, invasive species)
- Scale (tree, stand, landscape)
- Severity
- Pattern
- Seasonality
- Frequency
- Interactions of multiple agents



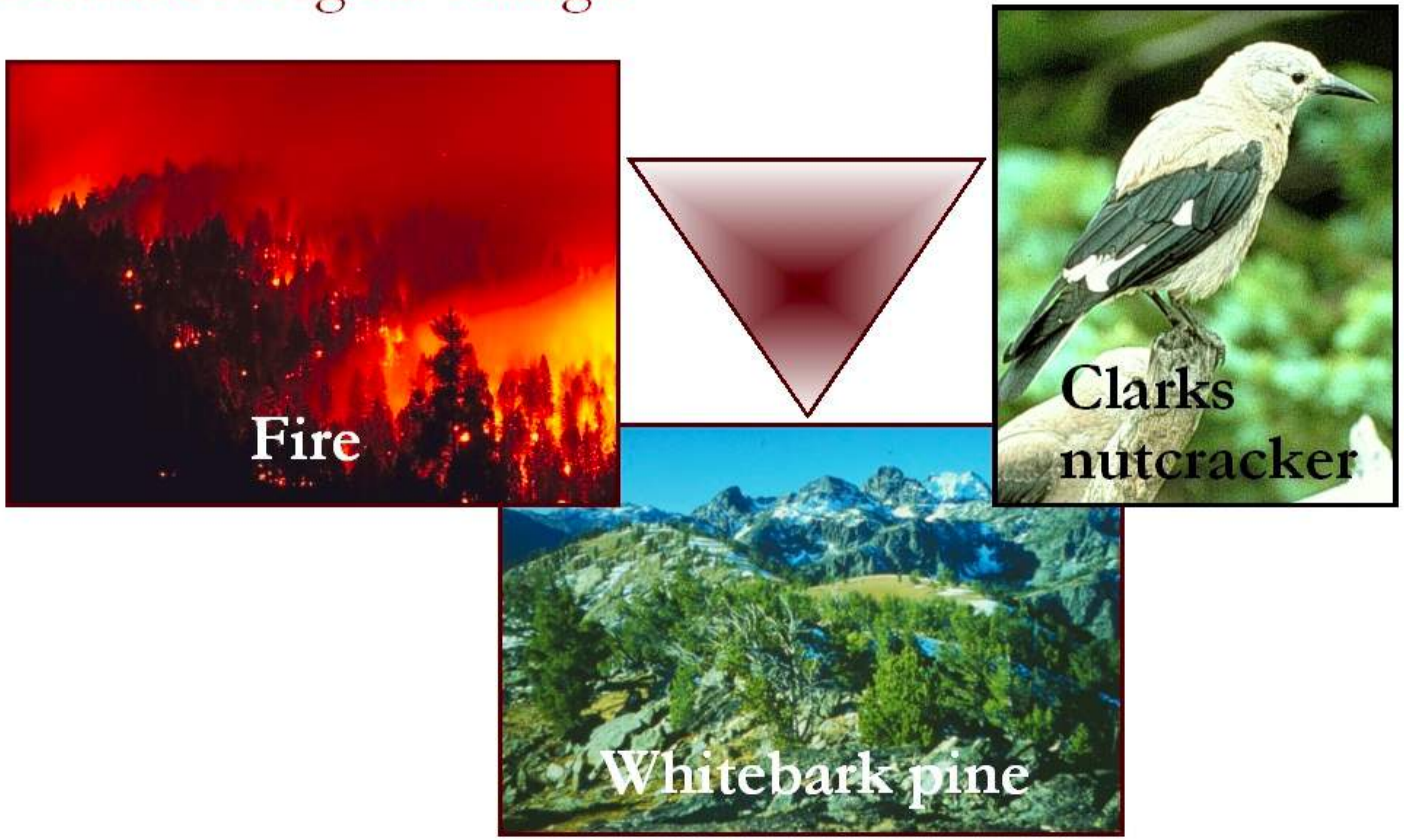
Disturbances can be characterized in a variety a ways, and these attributes collectively describe and characterize a disturbance regime.

- **Area/Size** –The areal extent of the disturbances, including the size of disturbance patches; the area per event per time period, and the total area per disturbance per time period.
- **Spatial distribution** –The spatial distribution of the disturbance; that is, the distribution of events relative to topography, soils, and so on. This typically would also impart or reinforce a characteristic spatial scale as well. This would include contagion -- tendency to, and rate of spread, and factors affecting the dispersion of the event.
- **Frequency** –The mean number of disturbance events per time period within a specified area. This is perhaps one of the most commonly reported attributes of a disturbance regime.
- **Recurrence Interval** –The mean time between disturbance events within a specified area. This is equal to the inverse of the disturbance frequency.
- **Return Interval** –The mean time between disturbance events at the same location; that is, how frequently is the same spot of ground disturbed. This is a critical component of the disturbance regime because it directly affects the amount of time the ecosystem, community, or population has to recover (e.g., as in succession) before the next disturbance.

- **Rotation Period** – The mean time to cumulatively disturb an area equivalent to the entire study area. In other words, given the frequency of disturbance events and the area/size disturbed by each event, how long does it take to cumulatively disturb an area equal to the size of the entire study area. Note, this is not equal to the time required to disturb every location in the study area at least once, since some areas may get disturbed many times while others may not get disturbed at all within the rotation period. Also, the rotation period is equal to the return interval and is thus simply another way to describe the same phenomenon.
- **Predictability** – The variance associated with the recurrence or return interval and/or frequency. If the variance is low, there is high predictability concerning when an area is likely to be disturbed based on the time since last disturbance. If the variance is high, there is a lot of variation in the return interval, making it difficult to predict with any confidence when an area is likely to be disturbed.
- **Magnitude** – There are two aspects of magnitude: Intensity refers to the magnitude in physical force of the event per unit area and time; Severity refers to the magnitude of impact on organism, community, or ecosystem.
- **Synergism** – The effects of a disturbance event on the occurrence of other disturbances. For example, there may be a synergistic relationship between insect infestations in certain forest types and the occurrence of fire.
- **Feedbacks** – Some disturbances either engender or constrain others. For example, fire may synchronize other subsequent fires in frequency as well as patch boundaries; reciprocally, lack of fire can reinforce a system's resistance to fire.

Agents of Pattern Formation: Disturbance
Interactions among Physical, Biotic and Disturbance

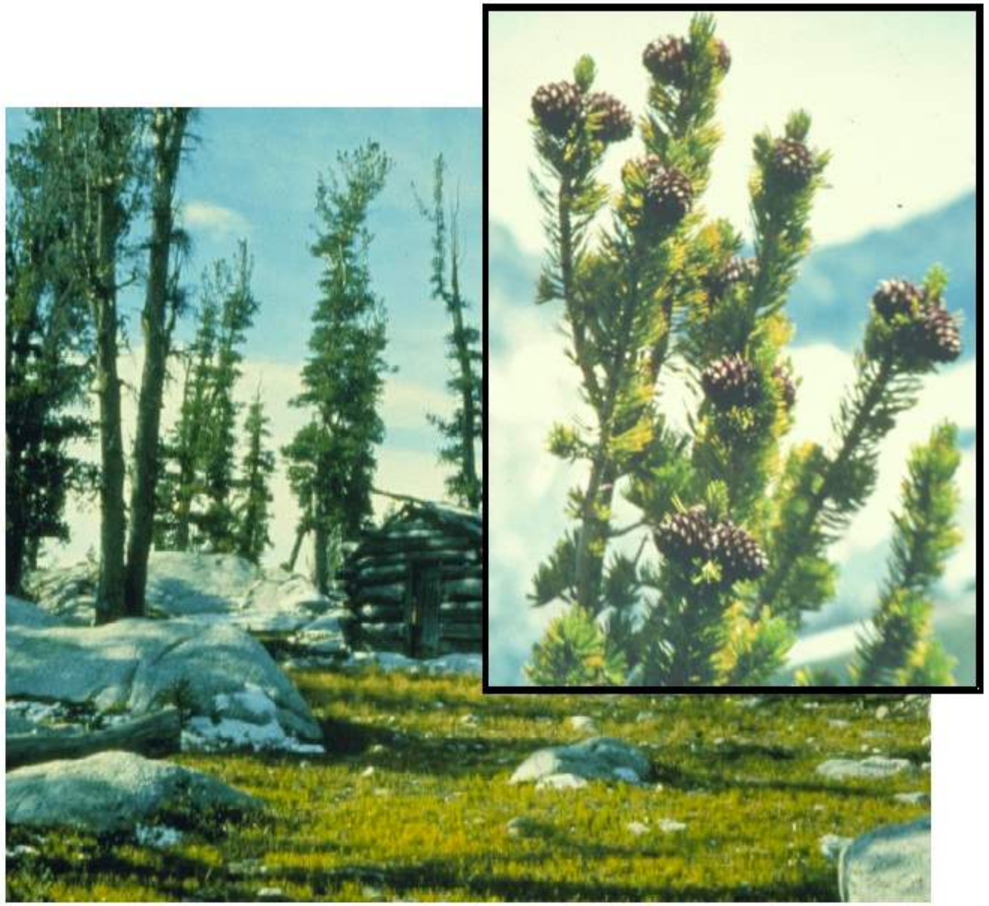
- Whitebark pine ecosystems and the critical ecological triangle



Agents of Pattern Formation: Disturbance

Interactions among Physical, Biotic and Disturbance

- Whitebark pine
  - Good cone crops 3-5 years
  - Large, nutritious, fatty seed
  - Utilized by over 110 species (critical for grizzly bears)
  - Wingless seed
  - Cone scales do not open
  - Cones displayed upward



Agents of Pattern Formation: Disturbance

Interactions among Physical, Biotic and Disturbance

- Clarks nutcracker
  - The bird is sole seed dispersal vector
  - Disperses seeds 10-20 km
  - Buries 1-15 seeds about 1-2 cm in caches on ground
  - Can create 8,000 to 20,000 caches in one year
  - Revisits 50-80 percent of caches
  - Unclaimed seed is sole source of regeneration

Agents of Pattern Formation: Disturbance

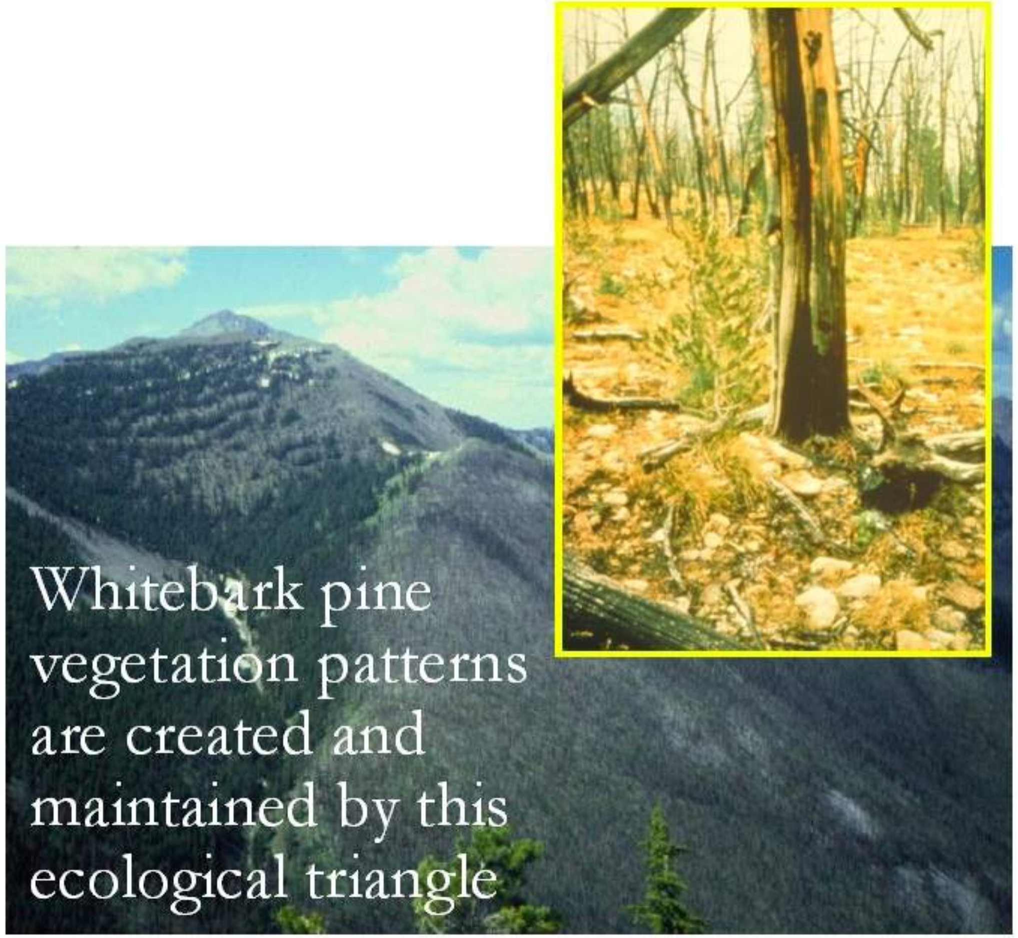
Interactions among Physical, Biotic and Disturbance

- Wildland fire
  - Mixed severity (i.e, patchy) fire regime
  - 80 to 500+ year MRI
  - Lightning caused fires
  - Typically occur during major drought in driest part of summer/early fall

Agents of Pattern Formation: Disturbance

Interactions among Physical, Biotic and Disturbance

- Critical ecological triangle
  - Burned areas are rich in pattern (mixed severity)
  - Nutcrackers like caching in burns and open areas rich in pattern
  - Nutcrackers disperse seed great distances (>10 km)
  - Whitebark has colonization advantage and survives well in burned sites



Equilibrium vs. Non-equilibrium forces influencing community structure

Equilibrium:

stability, climax community

- Competition
- Predation
- Other species interactions

Non-equilibrium:

communities constantly changing

- Disturbances
- Recruitment

What is community stability?

Intuitively, stability means that the population sizes and number of species remain constant over time ("equilibrium")

Components of stability

Resistance defined as the force needed to change the community

Resilience defined as the ability of the community to return to prior state (equilibrium) after perturbation

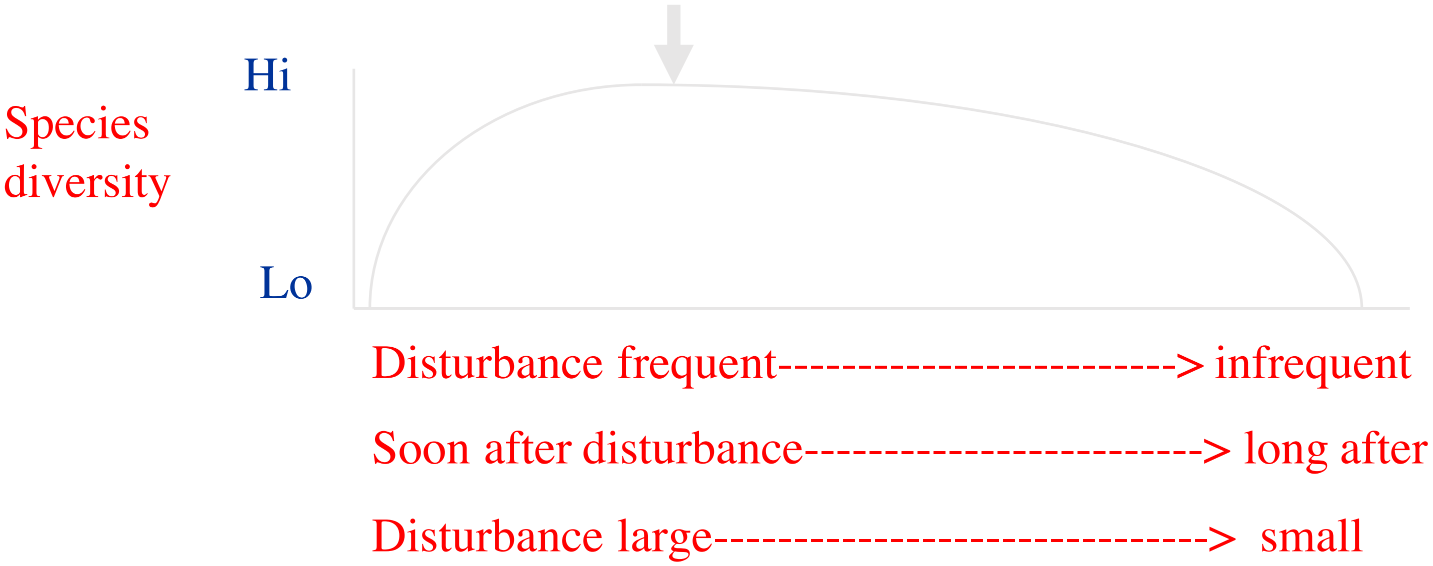
Elasticity = how quickly community returns to equilibrium

Amplitude = how much disturbance community can tolerate, and still return to some kind of equilibrium

Stability may be global (applies to entire system or community) or local (applies to response to low-amplitude disturbances)

Intermediate-disturbance hypothesis

- Hypothesis proposed by Joseph Connell (1978):
  - At high disturbance levels only a few species can persist, which have special adaptations to survive
  - At low levels of disturbance, again a few species predominate in community, namely those that can out-compete all the others in a stable environment
  - At intermediate levels of disturbance, both kinds of species exist, leading to higher levels of diversity



Processes, threats, fragility

- Mountains are subject to both natural and anthropogenic drivers of change
- Mountains are highly vulnerable to human and natural ecological imbalance
- The impacts of disturbances are more rapid, heavier, the recovery of mountain ecosystems from disturbances is typically slow or does not occur

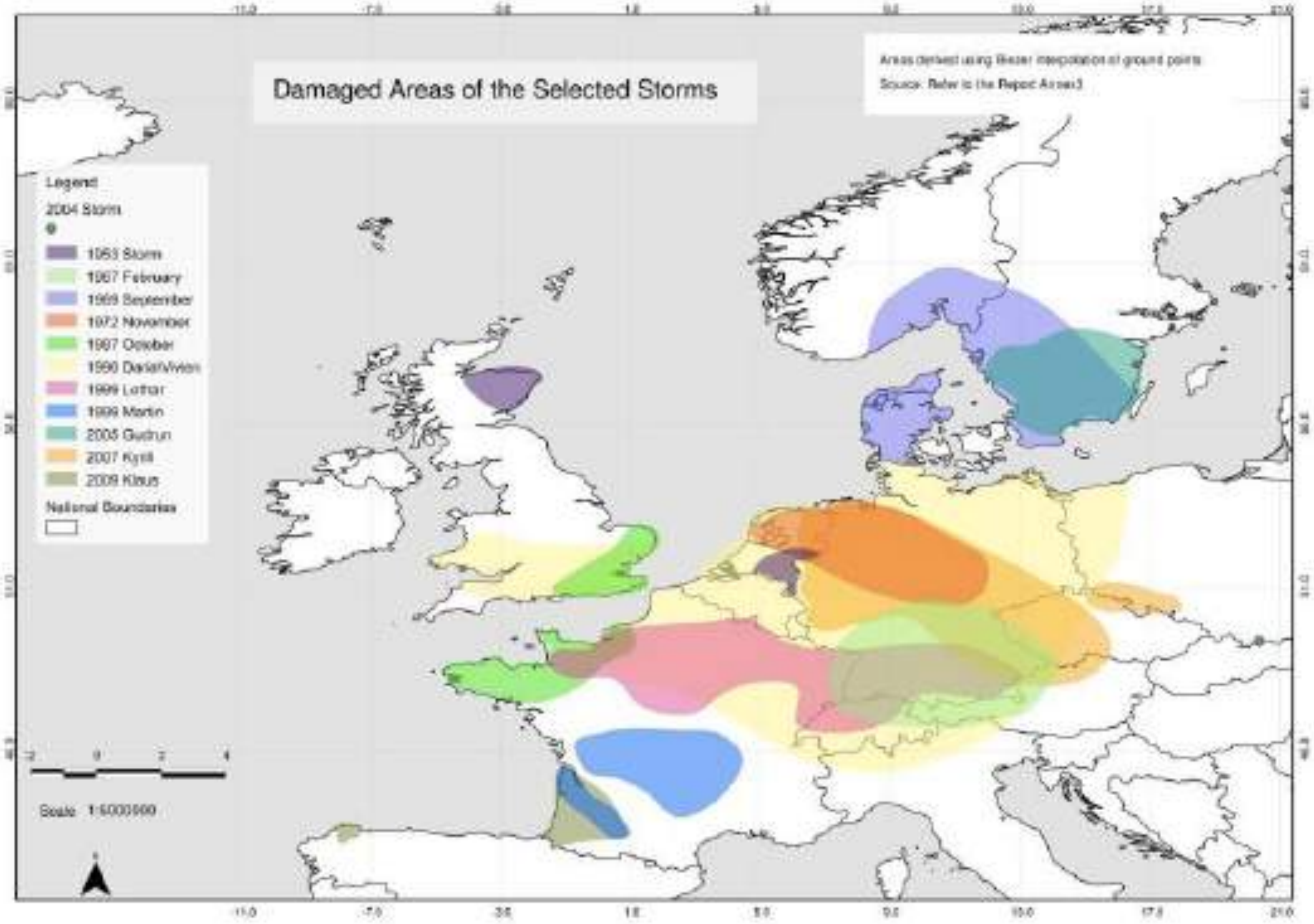

High Tatra Mts. (Slovakia) – November 2004
12.000 ha of forest damaged
Followed by pest outbreak

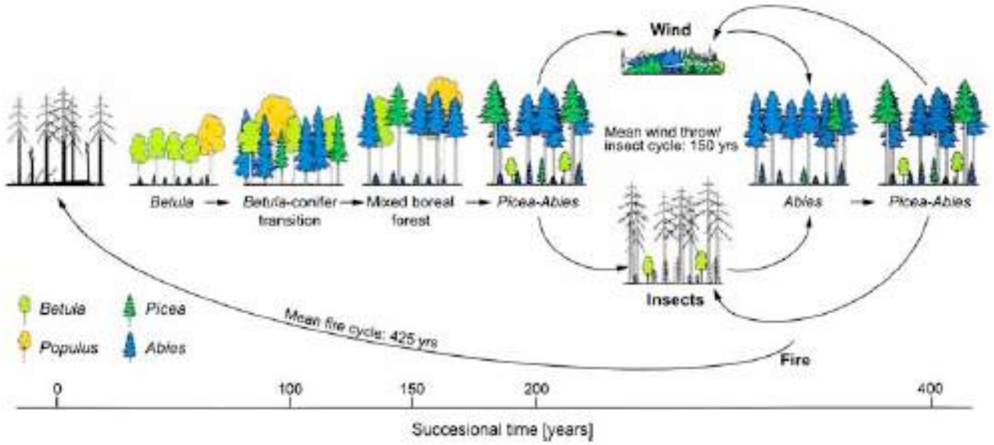
storm „Gudrun“

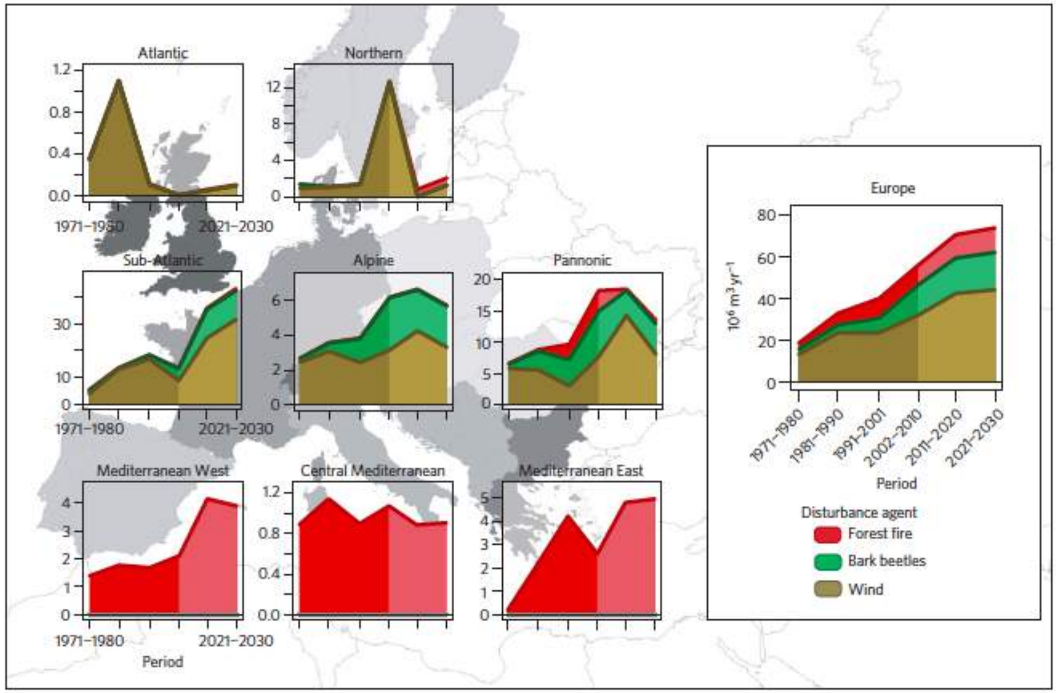
Climate change may cause severe loss in the economic value of European forest land

Marc Hanewinkel[1,2]*, Dominik A. Cullmann[3], Mart-Jan Schelhaas[4], Gert-Jan Nabuurs[5] and Niklaus E. Zimmermann[6]

January 8th 2005


Damaged Areas of the Selected Storms
Areas derived using Bezier interpolation of ground points
Source: Refer to the Report Annex3
Legend
2004 Storm
1953 Storm
1967 February
1969 September
1972 November
1987 October
1990 Daria/Vivian
1999 Lothar
1999 Martin
2005 Gudrun
2007 Kyrill
2009 Klaus
National Boundaries
Scale

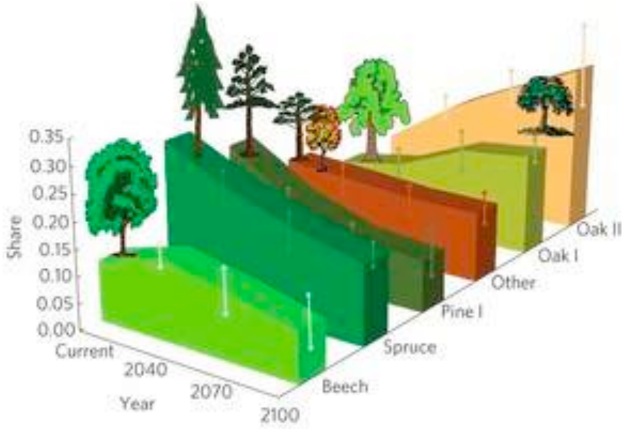




NATURE CLIMATE CHANGE | LETTER

Increasing forest disturbances in Europe and their impact on carbon storage

Rupert Seidl, Mart-Jan Schelhaas, Werner Rammer & Pieter Johannes Verkerk



Mountain pine beetle and forest carbon feedback to climate change

W. A. Kurz[1], C. C. Dymond[1], G. Stinson[1], G. J. Rampley[1], E. T. Neilson[1], A. L. Carroll[1], T. Ebata[2] & L. Safranyik[1]

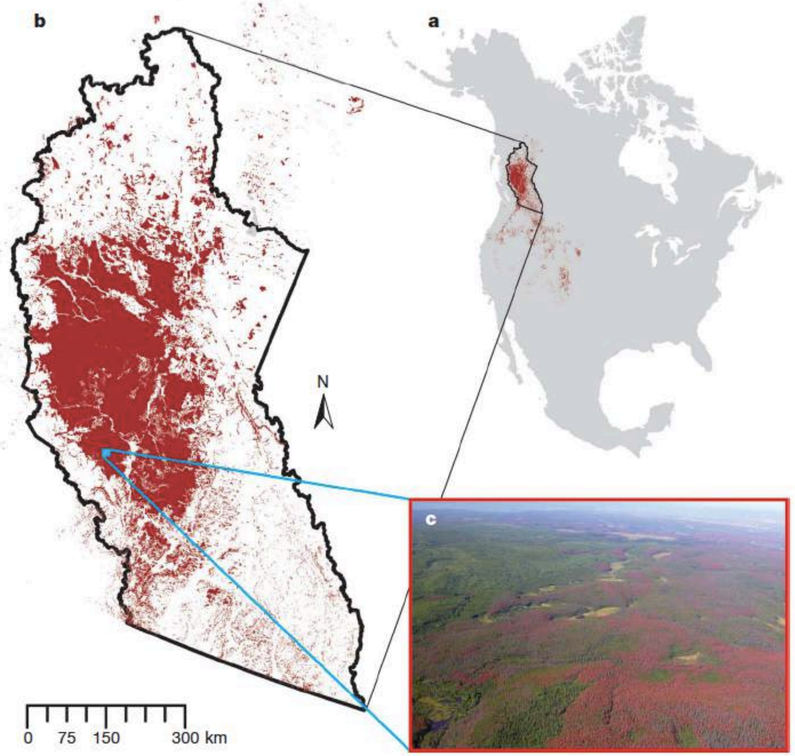
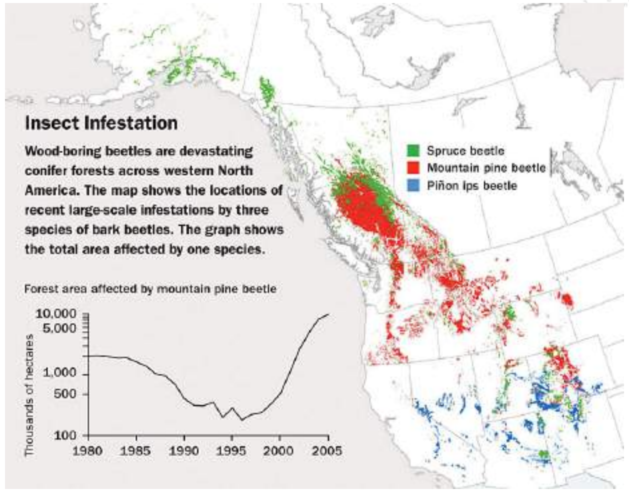


Figure 1 | Geographic extent of mountain pine beetle outbreak in North America. **a**, Extent (dark red) of mountain pine beetle. **b**, The study area includes 98% of the current outbreak area. **c**, A photograph taken in 2006 showing an example of recent mortality: pine trees turn red in the first year after beetle kill, and grey in subsequent years. Photo credit: Joan Westfall, Entopath Management Ltd.



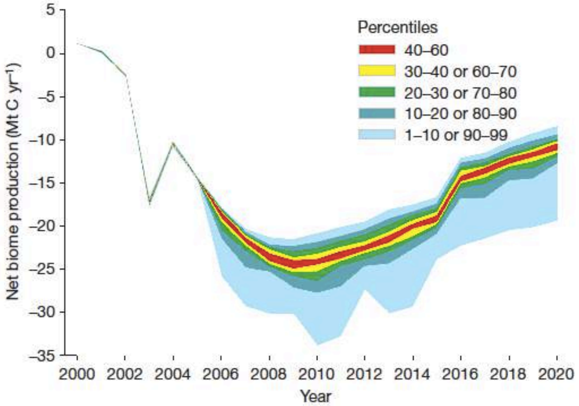
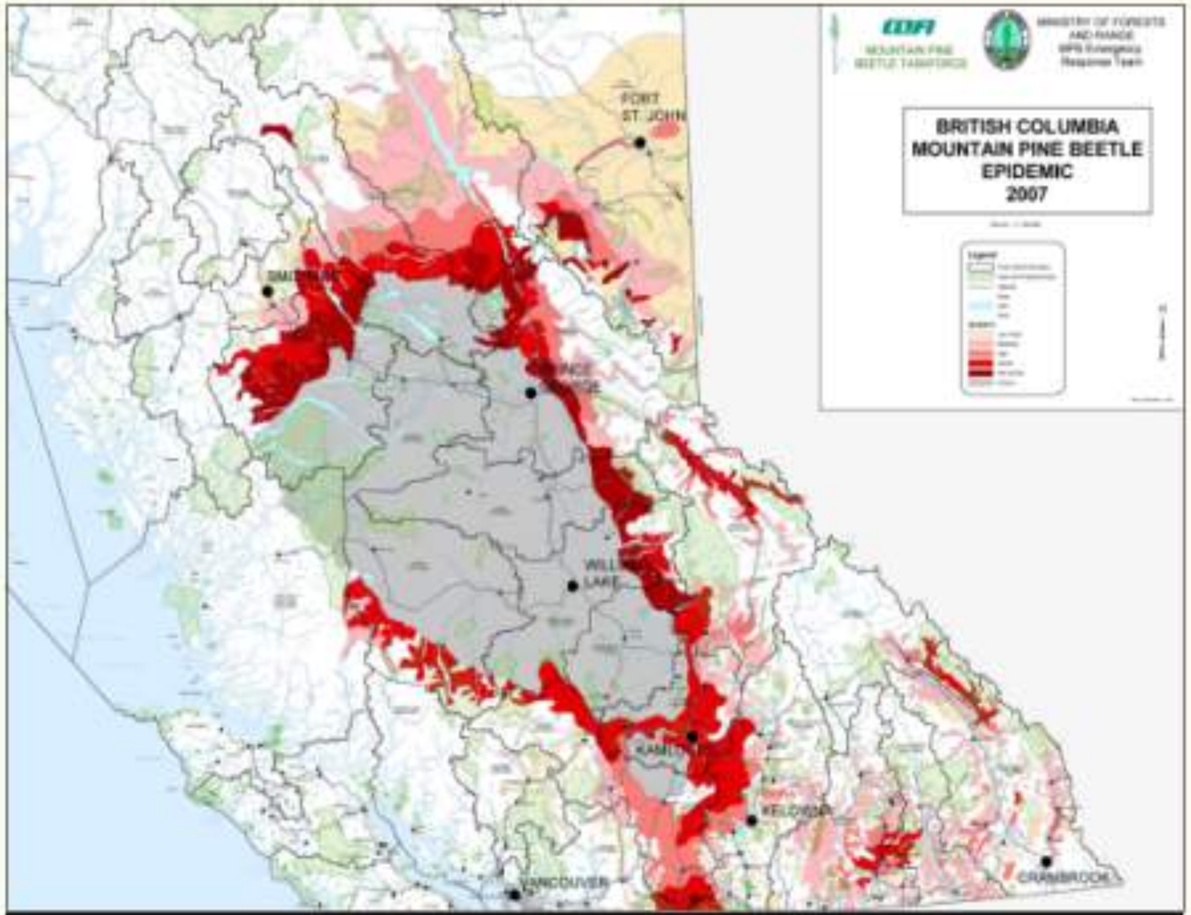


Figure 2 | Annual NBP by percentile from the Monte Carlo simulations. The model results are based on statistics from 2000 to 2006 and projections from 2007 to 2020. Negative values represent fluxes from the forest to the atmosphere (a net source of carbon). Asymmetry of the range of estimates of NBP in any single year is a function of the area burned and the associated direct carbon emissions.

Pine Beetle Infestation in British Columbia 1999-2012



Dilemma:
1. Leave infested trees but this will increase the fire risk
2. Wood can still be used if Harvested within 2 years of infestation
3. What is the Impact on Hydrology with either of the two options???

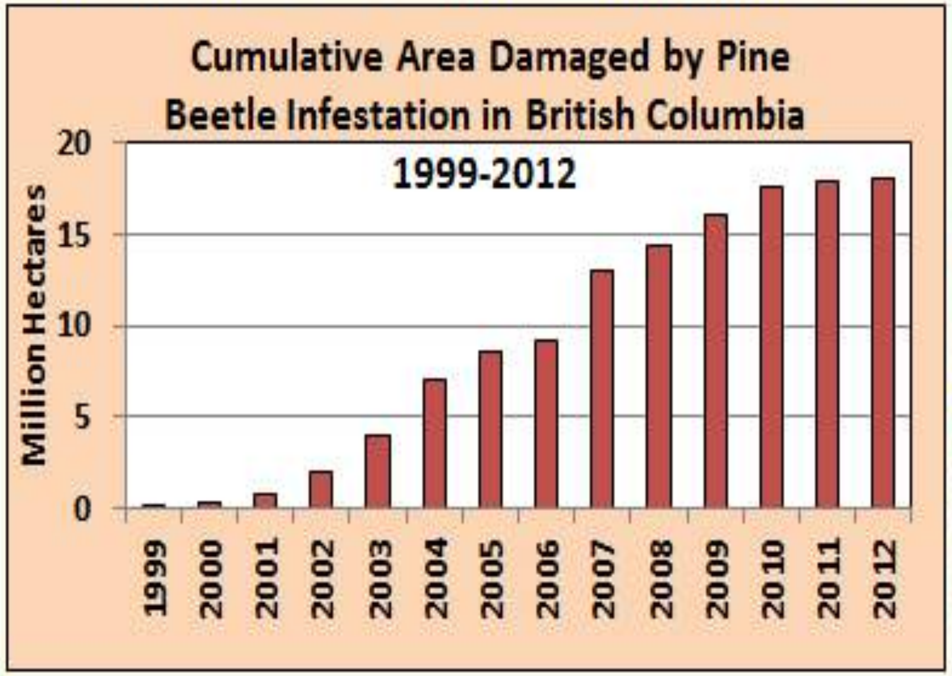
By 2012: 53 % of Merchantable Pine Killed
Cumulative Losses: 720 Million m3 of Timber

Pine Beetle Impacts on British Columbia Forests

Total Area Affected
18 Million ha / 12 years

4x the Size of
Denmark

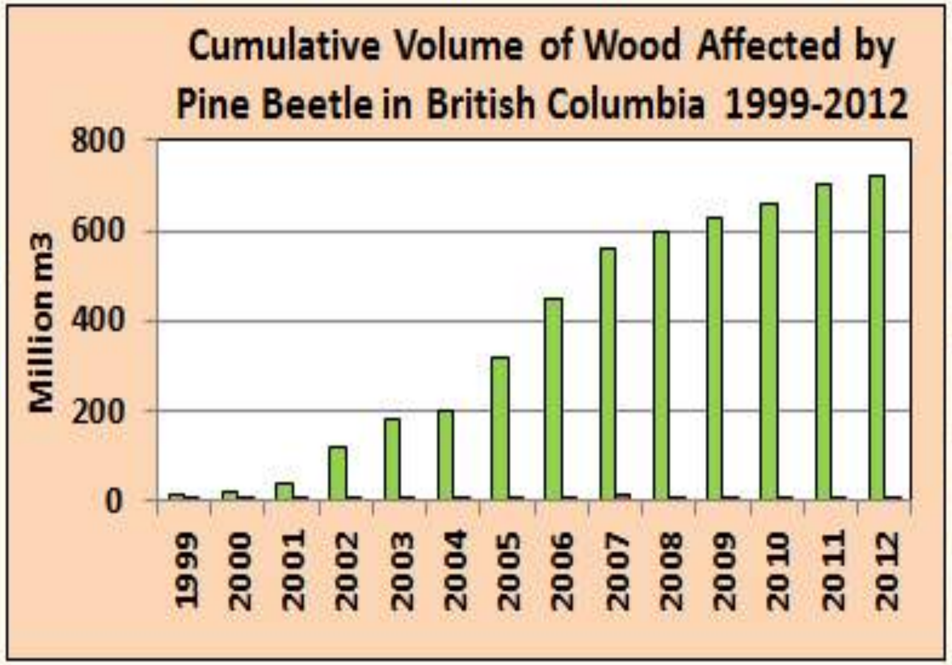
54% of all Pine Forest



720 Million m3
of Timber lost

Red Attack 2-4 years
Grey Attack Needles Lost
Bare Branches
Suseptible to Blow Down

High Fire Risk

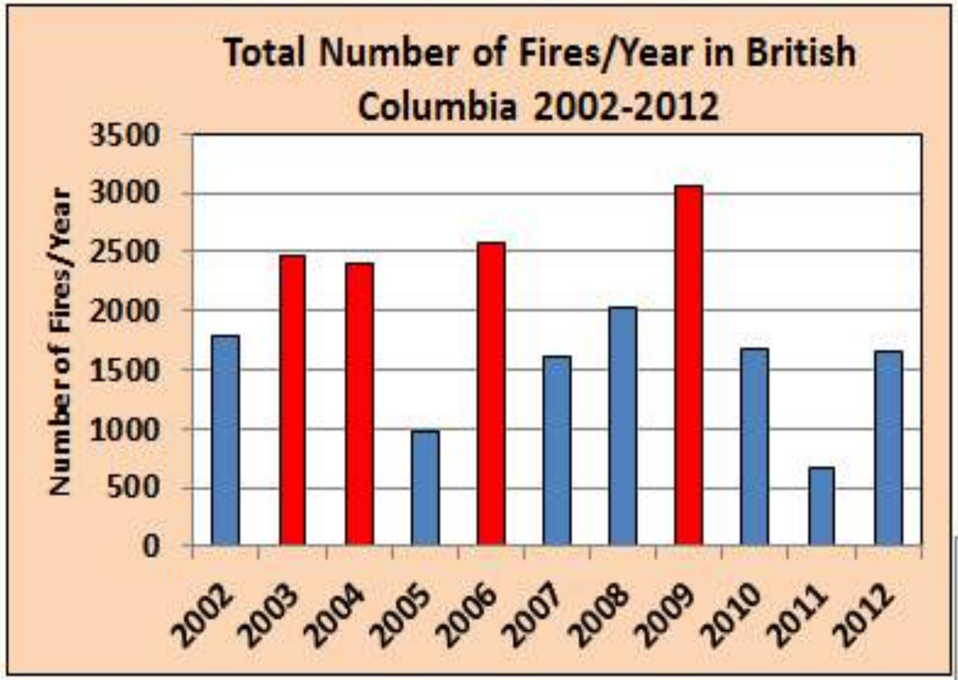


Forest Fire History in British Columbia 2002-2012

Average Number of Fires / Year: 1922

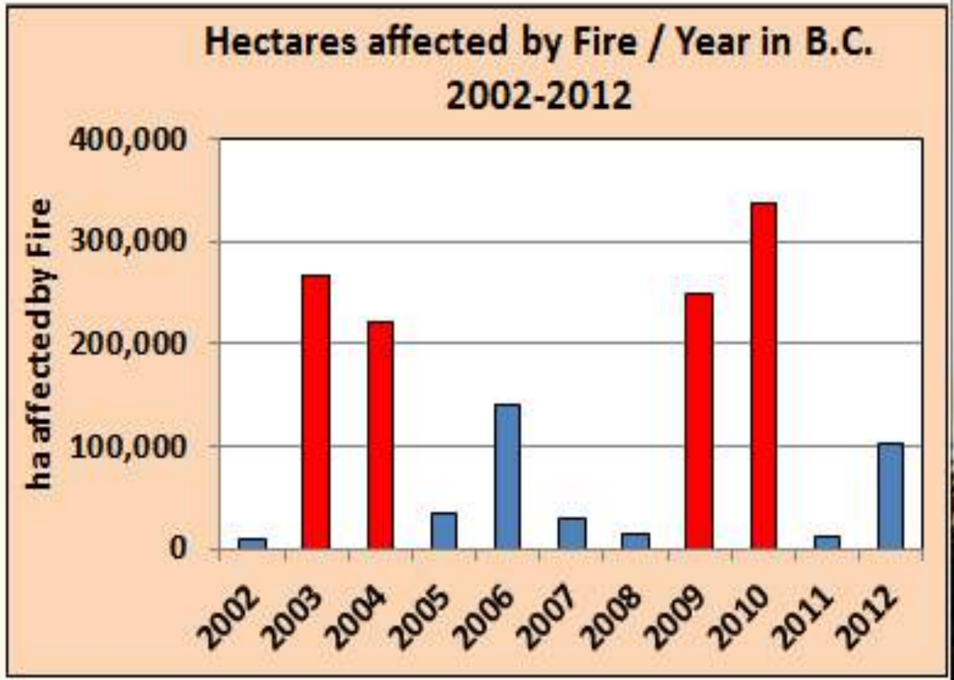
Average Annual Cost of Fighting Fires: $ 160 Million/ Year

59% Natural Causes
41% Human Induced



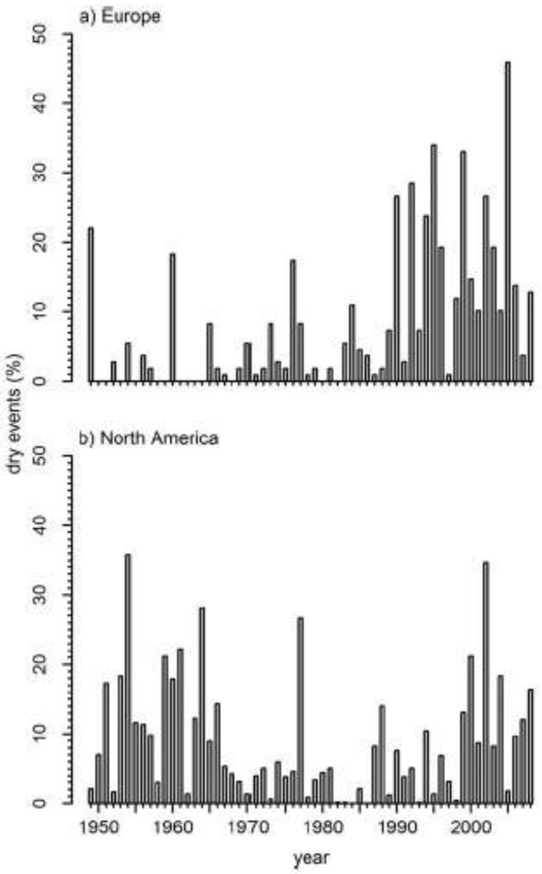
Average Area Affected by Fire: 62 ha

Size of individual Fire is Increasing

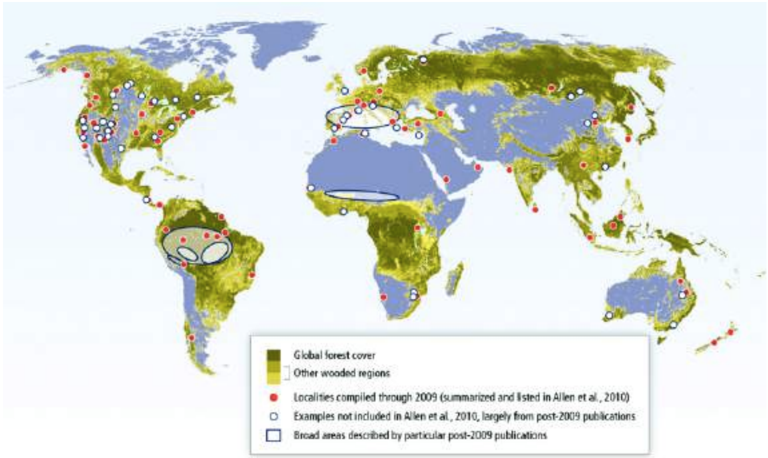


- The increment of disturbances (frequency, intensity, …) has been documented
- Strong influence of the anthropisation (past land-use)
- Interactions among disturbances
- Strong impact on forest structure and ecosystem services

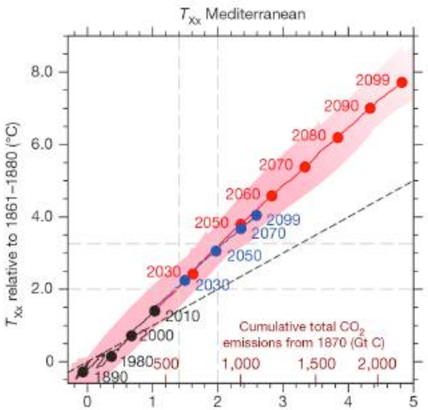
New disturbance regimes



Gazol et al. (*Global. Ecol. Biogeogr*. 2016)



Choat et al. (*PNAS* 2016)



Seneviratne et al. (*Nature* 2016)

The on-going strong El Niño and global warming fuelled by fossil fuel emissions made 2015 the hottest year on record

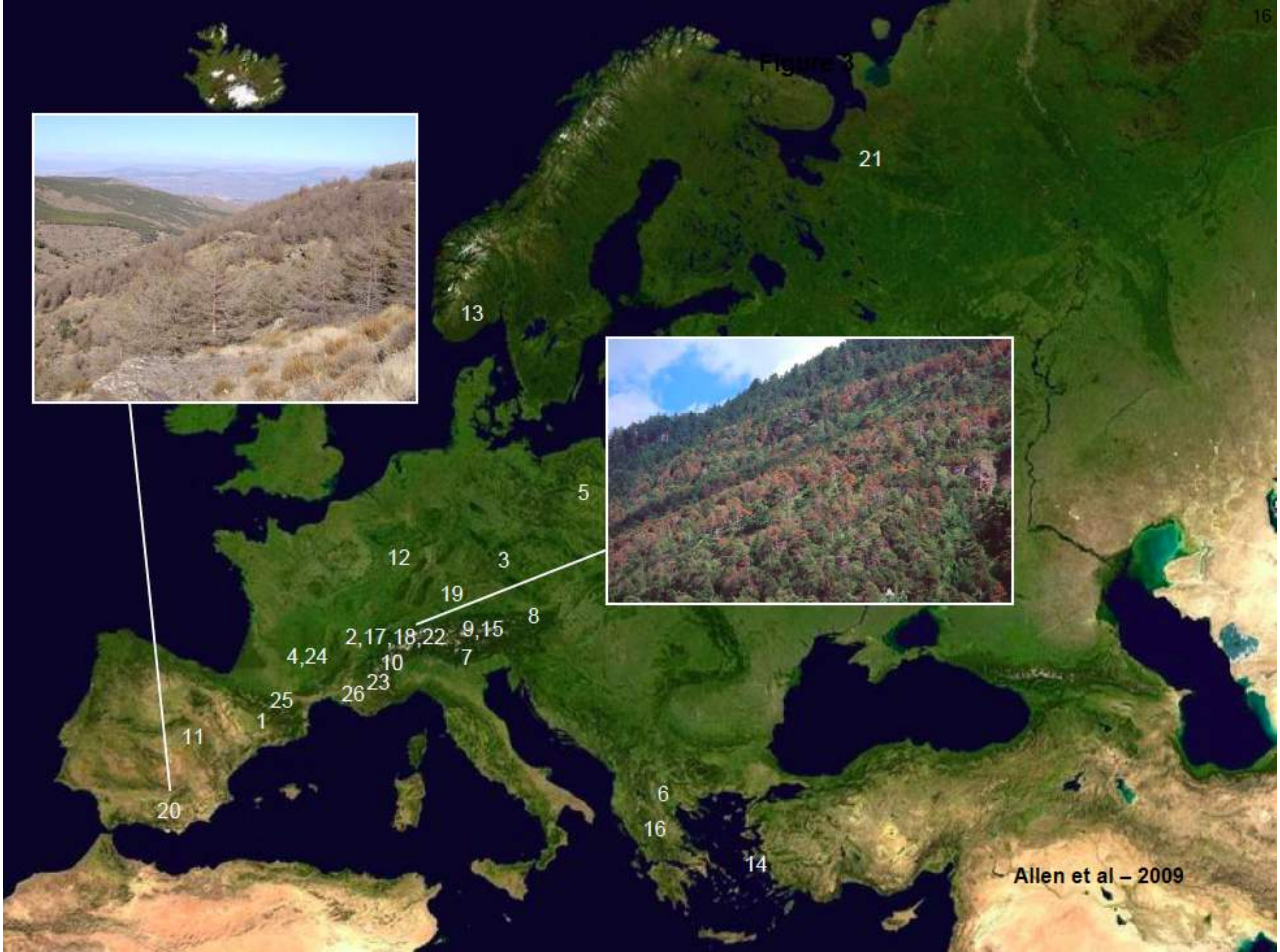
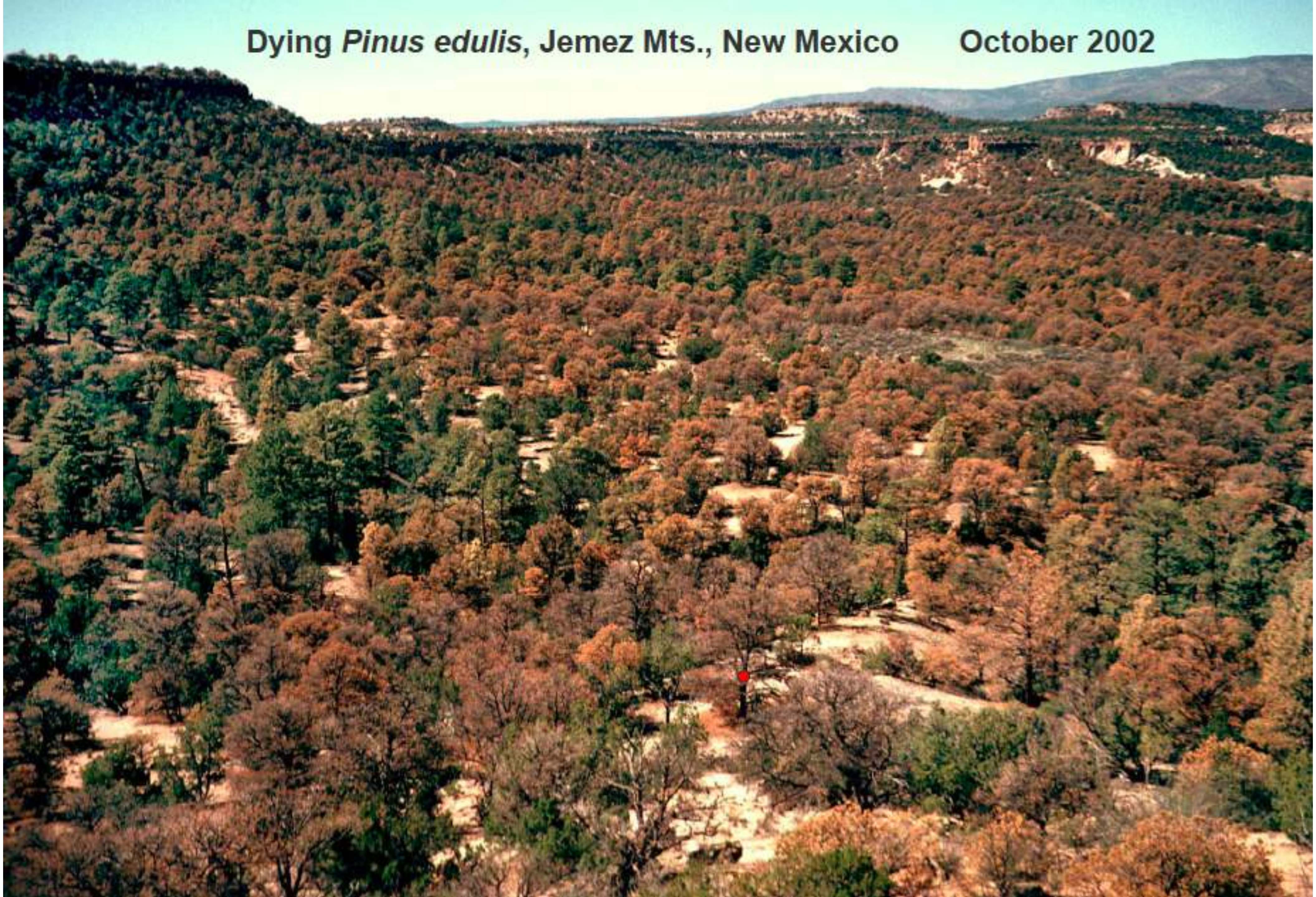
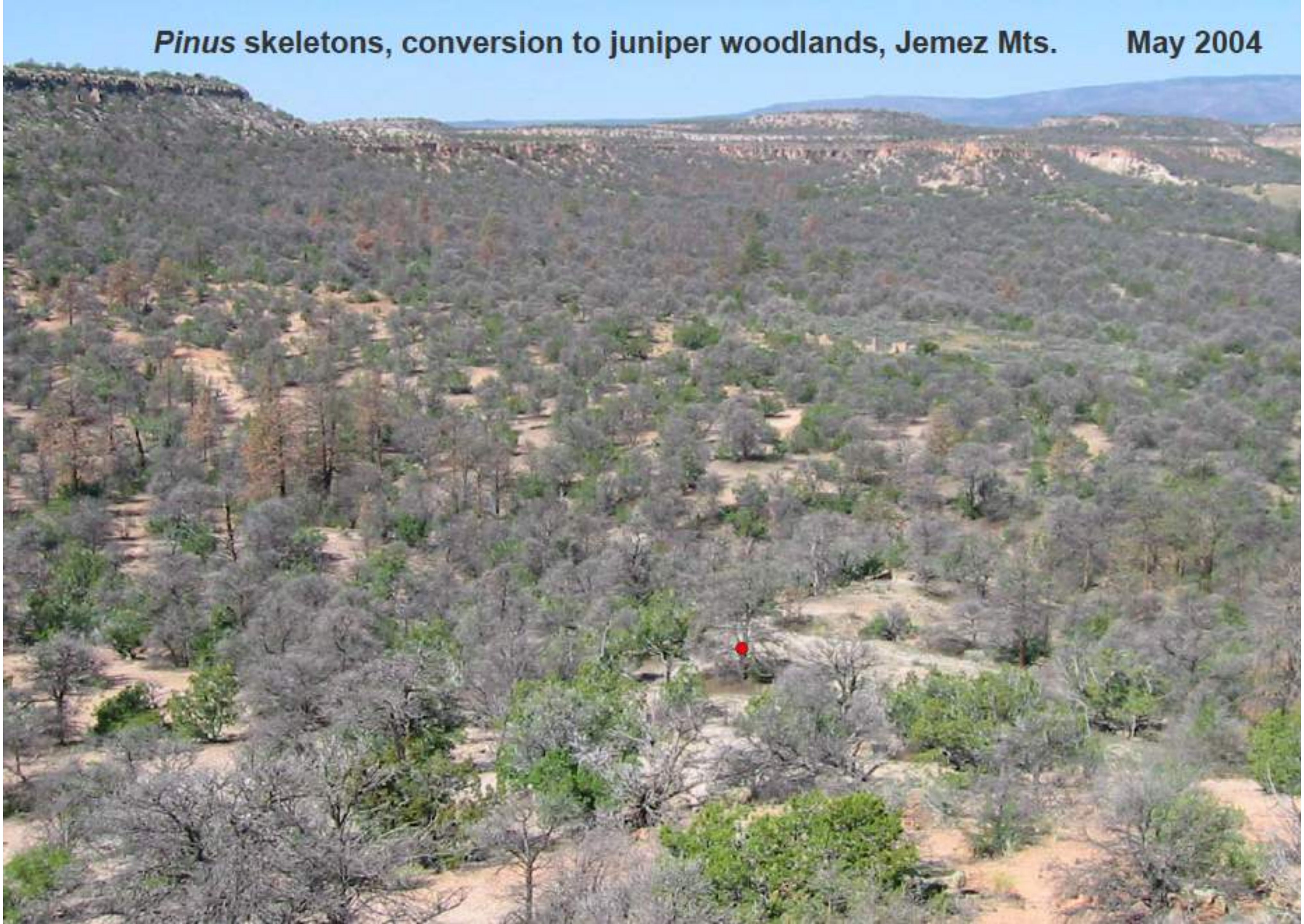
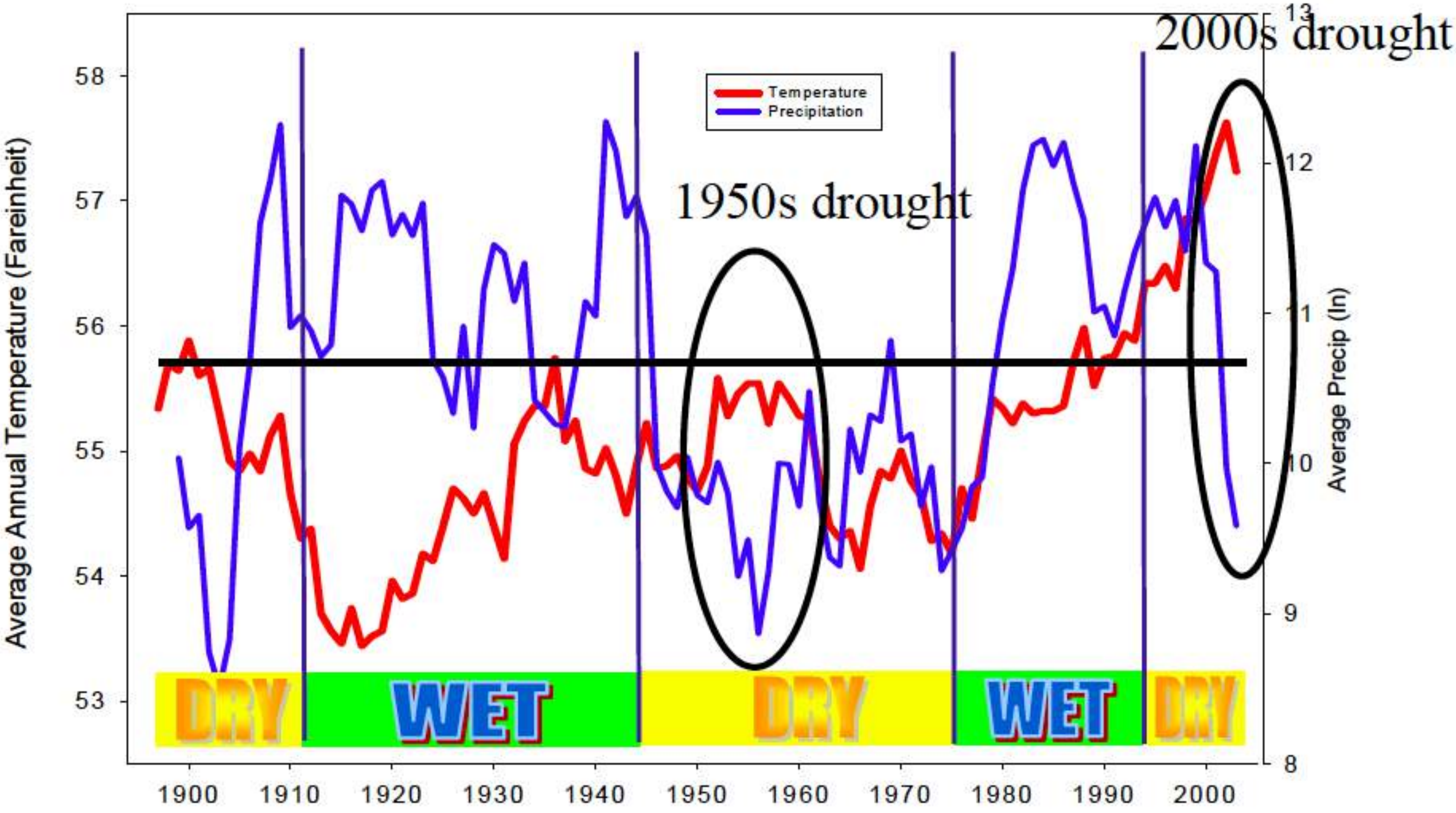


Figure 3
21
13
5
12
3
19
8
2,17,18,22
9,15
4,24
10
7
23
25
26
1
11
20
6
16
14
Allen et al – 2009

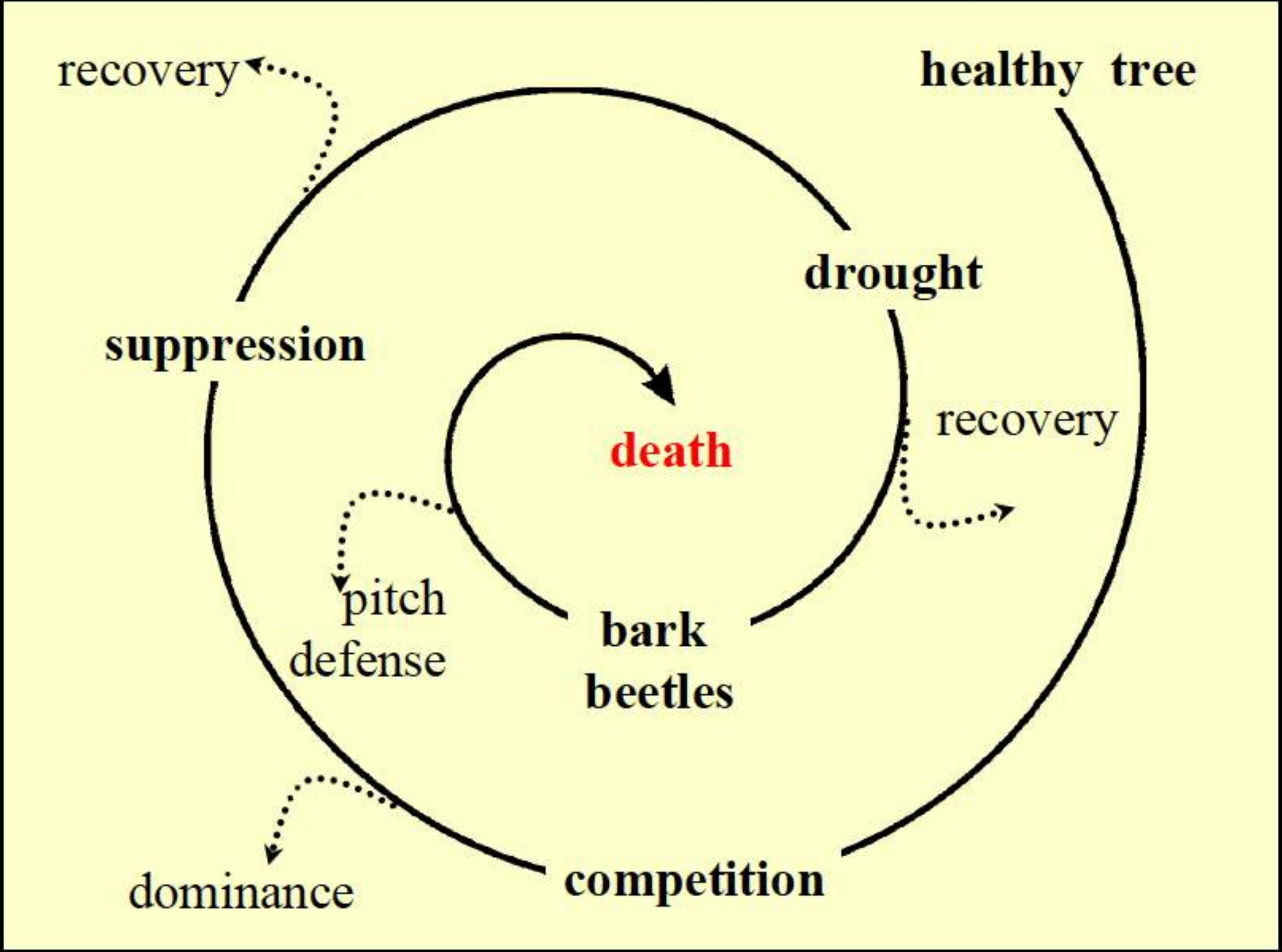

Dying *Pinus edulis*, Jemez Mts., New Mexico October 2002


Pinus skeletons, conversion to juniper woodlands, Jemez Mts.
May 2004

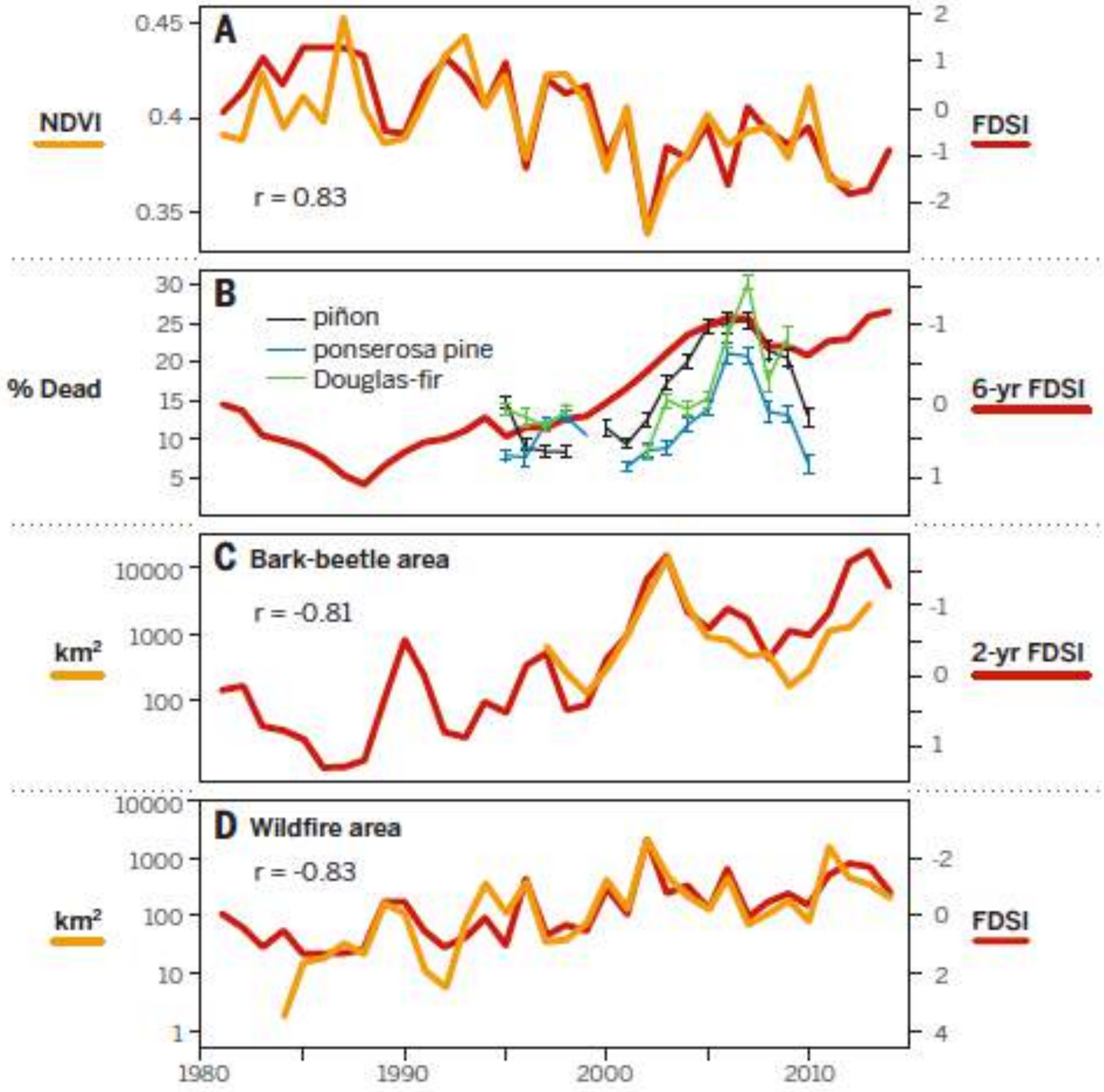


2000s drought
1950s drought
Temperature
Precipitation
Average Annual Temperature (Fareinheit)
Average Precip (In)
58
57
56
55
54
53
13
12
11
10
9
8
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
DRY
WET
DRY
WET
DRY

The decline spiral model of tree death: multiple factors, with inertia and lagged effects.

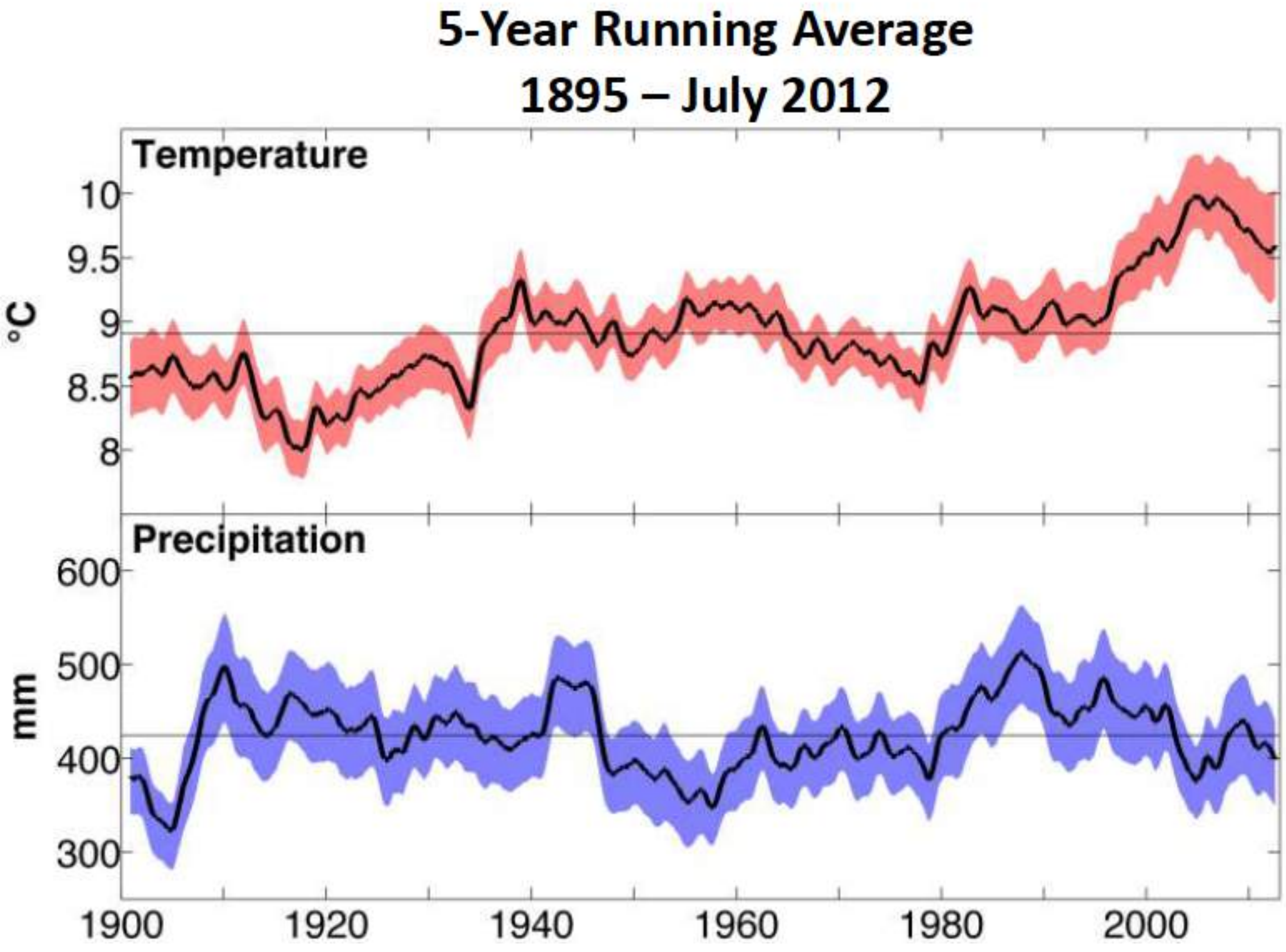


Franklin et al. 1987

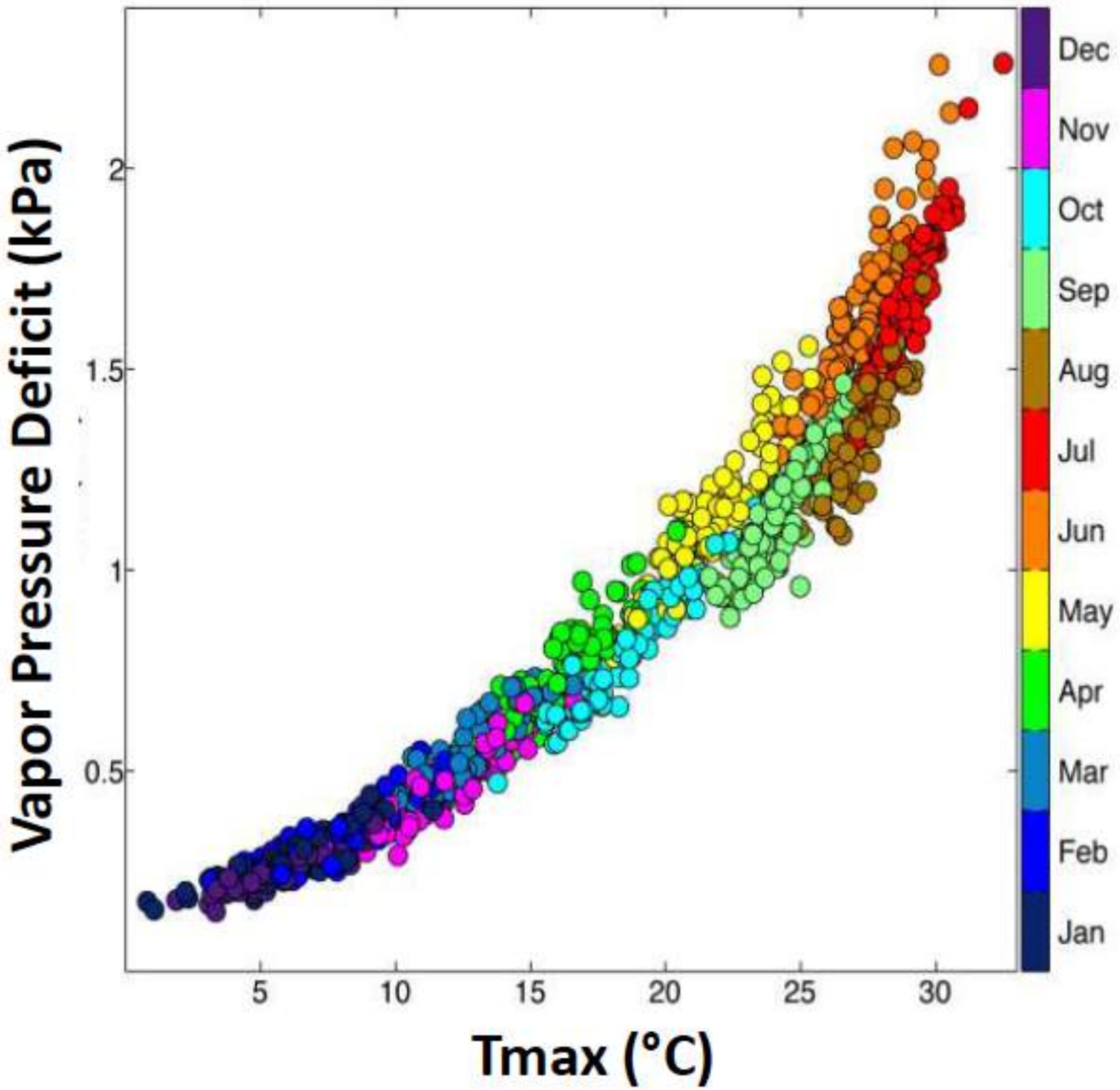


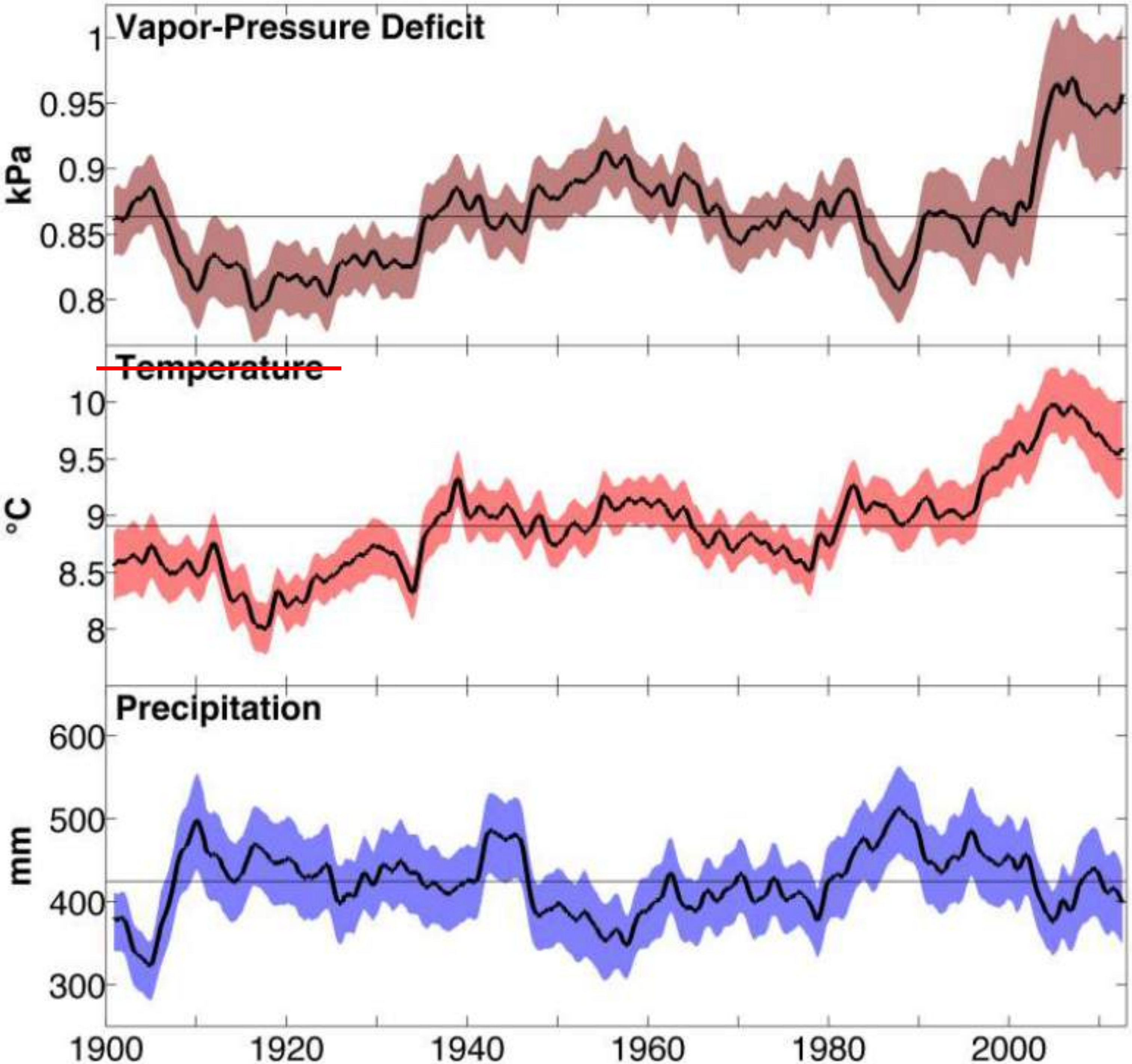
A
NDVI
FDSI
r = 0.83
0.45
0.4
0.35
2
1
0
-1
-2
B
piñon
ponserosa pine
Douglas-fir
% Dead
6-yr FDSI
30
25
20
15
10
5
-1
0
1
C Bark-beetle area
r = -0.81
km²
2-yr FDSI
10000
1000
100
-1
0
1
D Wildfire area
r = -0.83
km²
FDSI
10000
1000
100
10
1
-2
0
2
4
1980
1990
2000
2010

How much does temperature (relative to precipitation) influence regional forest productivity and mortality in semi-arid conditions?

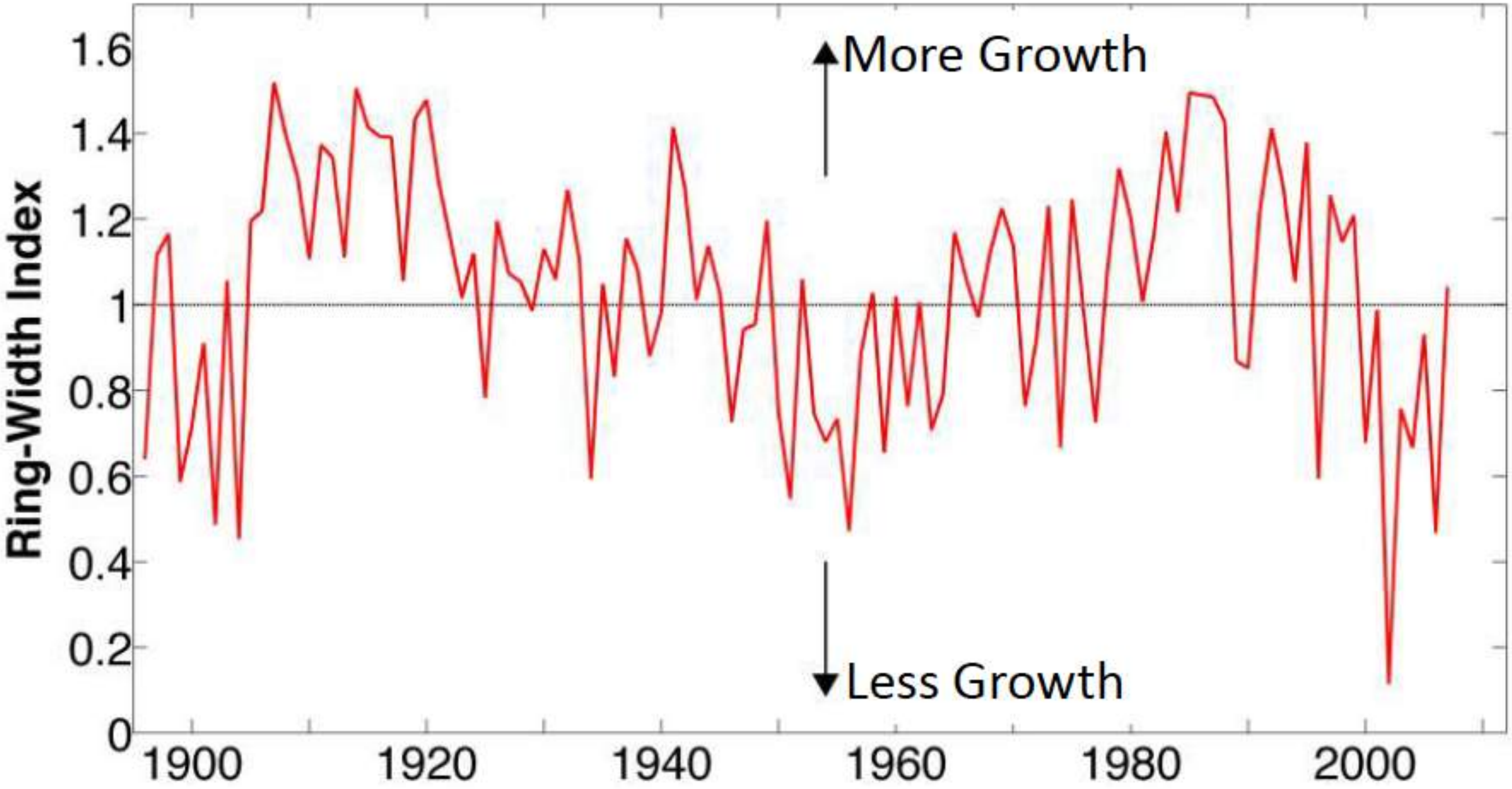


Warming Drives Increasing Atmospheric Moisture Demand



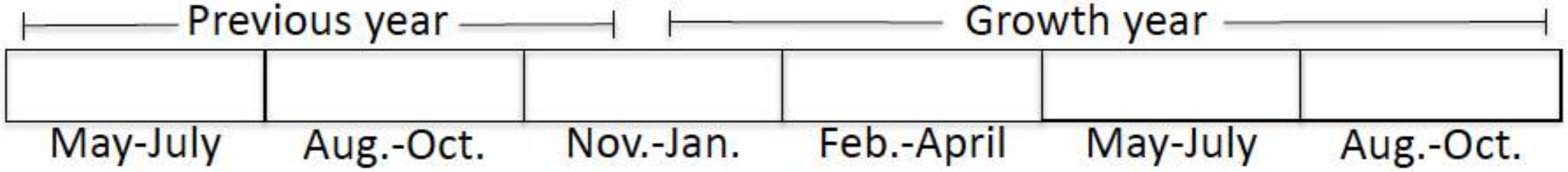

Vapor-Pressure Deficit
kPa
1
0.95
0.9
0.85
0.8
Temperature
°C
10
9.5
9
8.5
8
Precipitation
mm
600
500
400
300
1900
1920
1940
1960
1980
2000

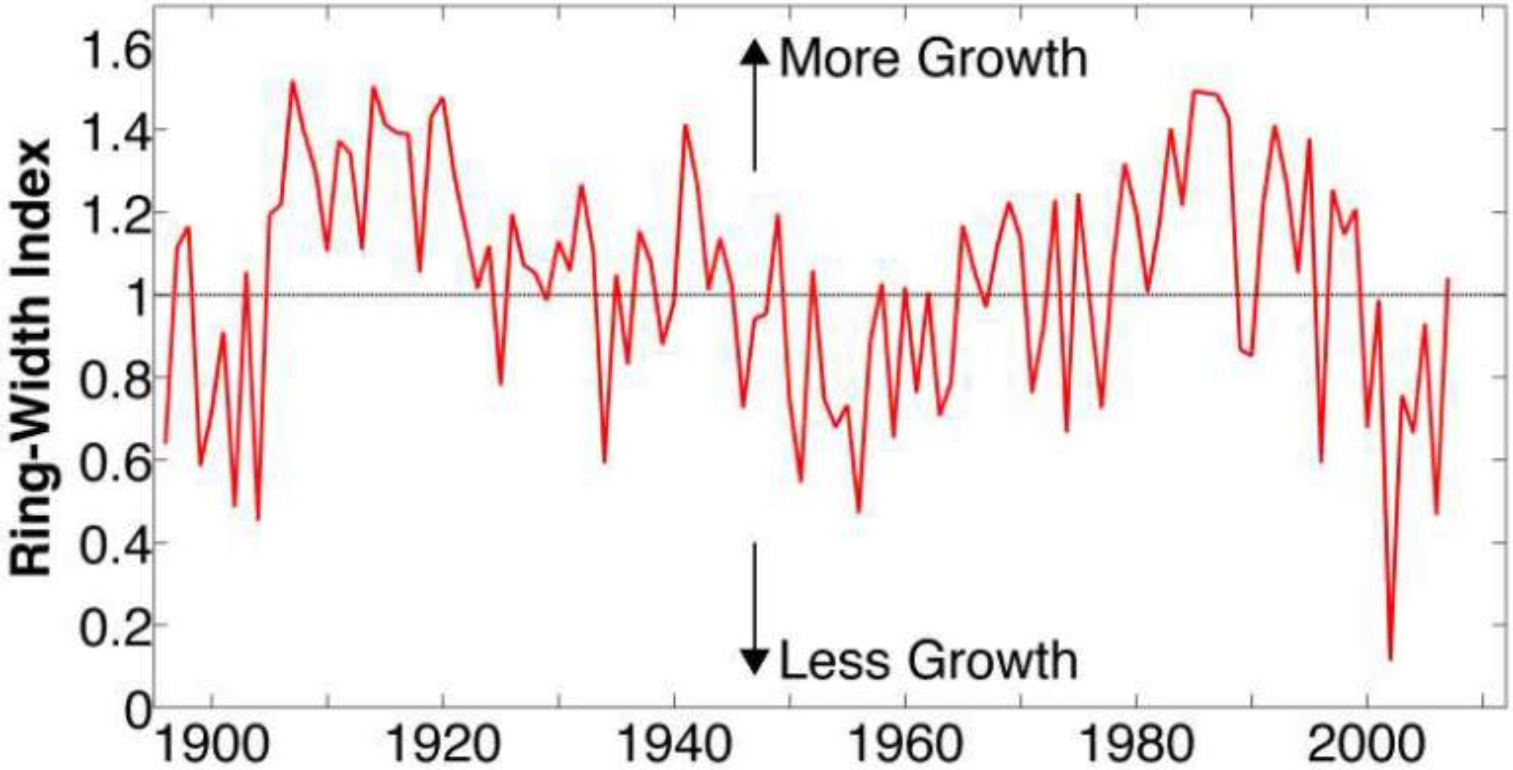
Regional Ring-Width Record



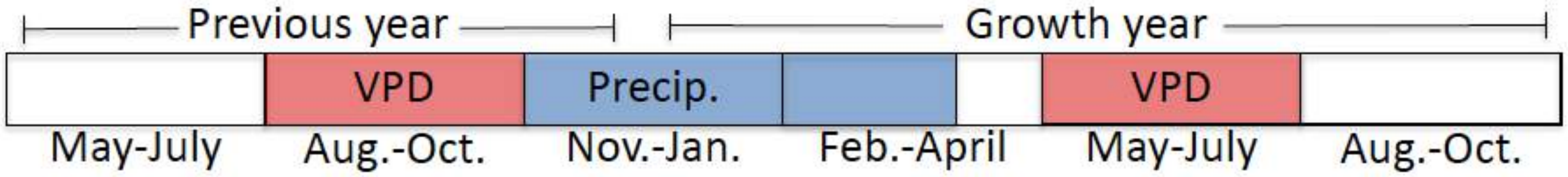
Ring-Widths Vs. Climate

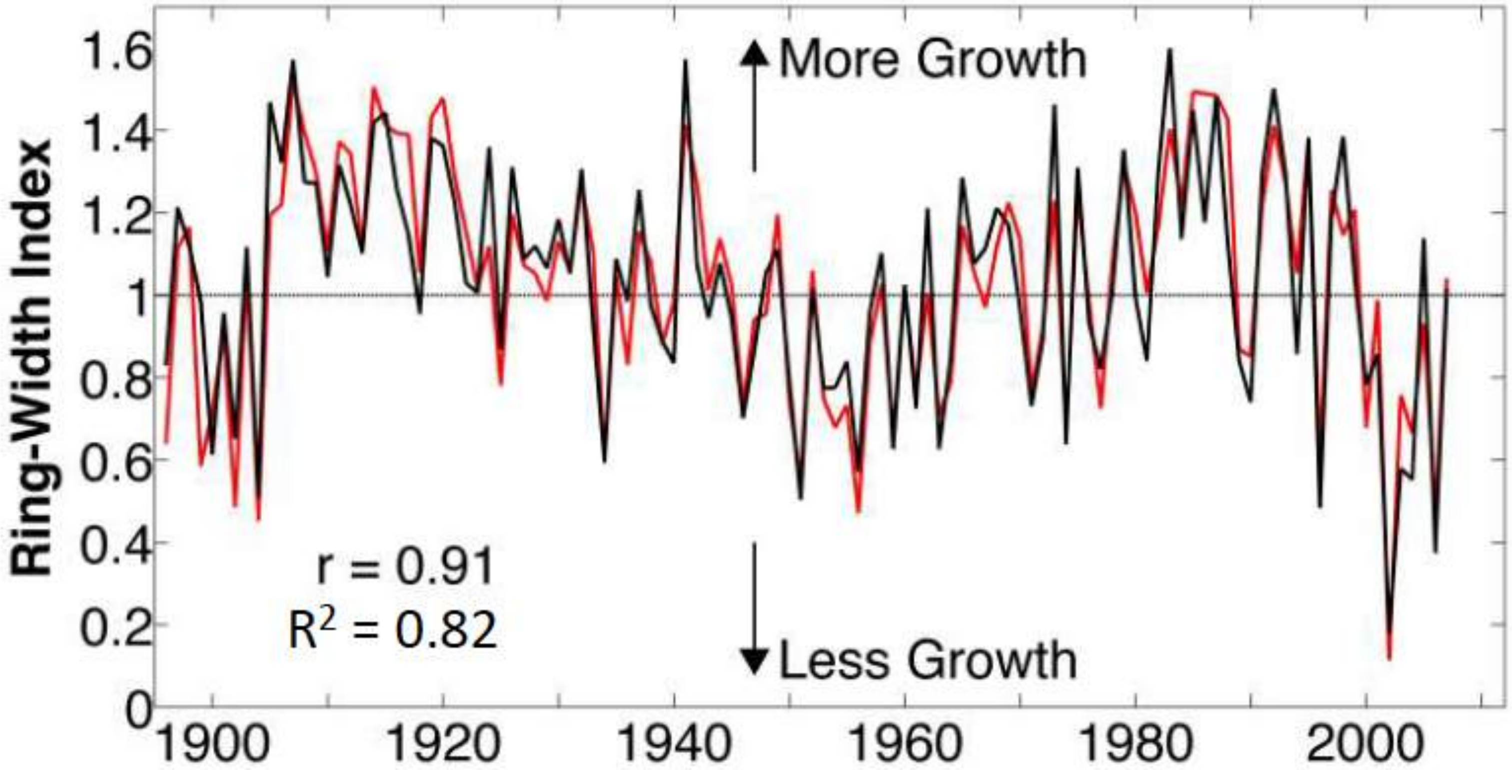
When do precipitation and vapor-pressure deficit dictate regional tree growth?





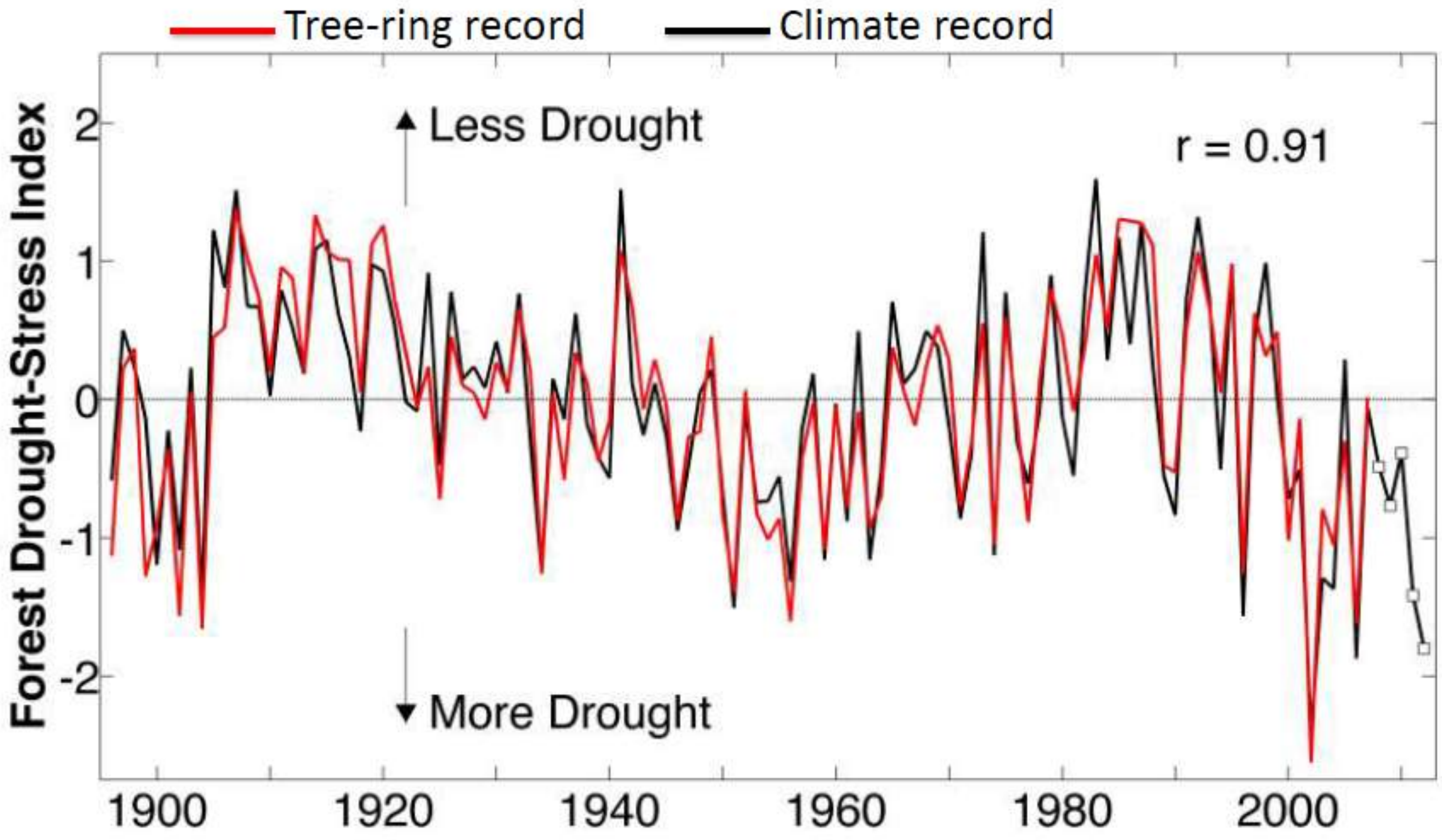
Cool season precipitation and warm-season vapor-pressure deficit dictate regional tree growth.

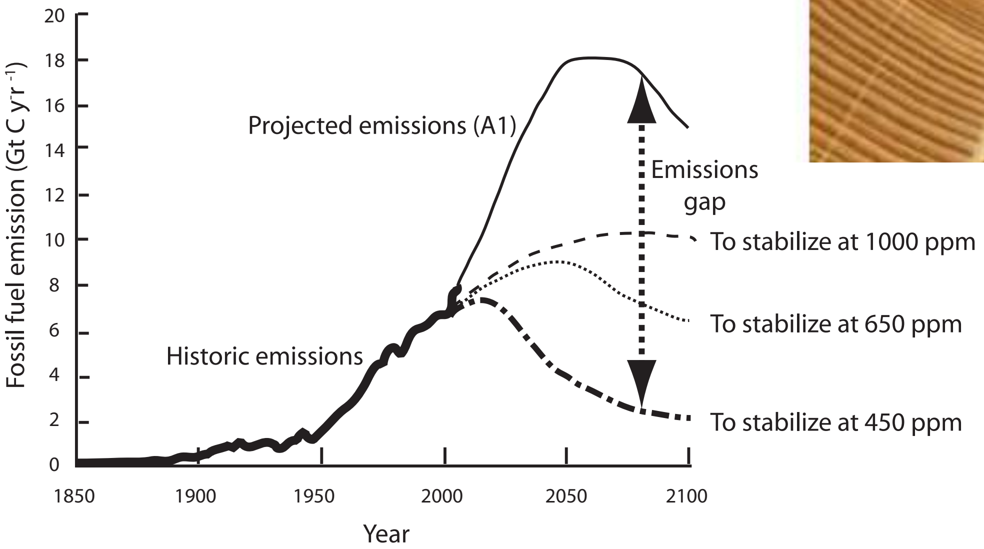




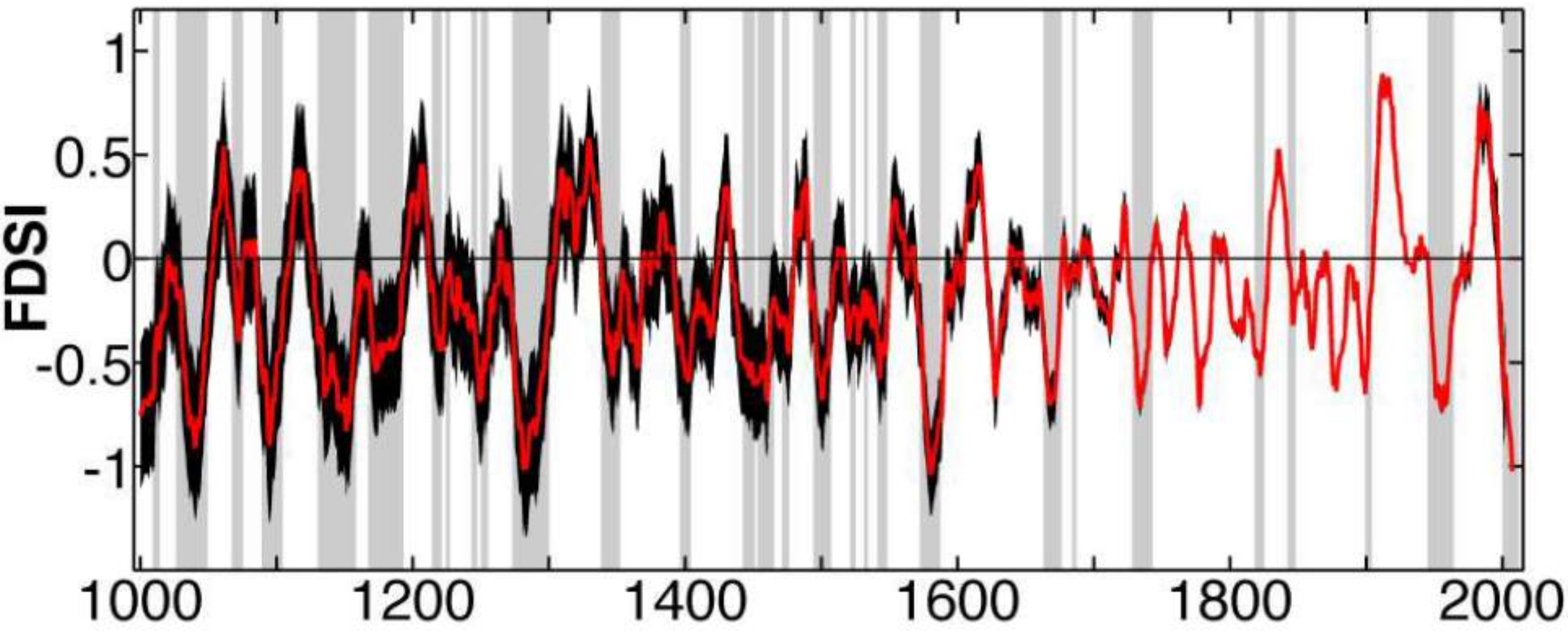
Forest Drought-Stress Index (FDSI)

$$FDSI = 0.44[\text{zscore}(\textit{cold-season Precip.})] - 0.56[\text{zscore}(\textit{warm-season VPD})]$$



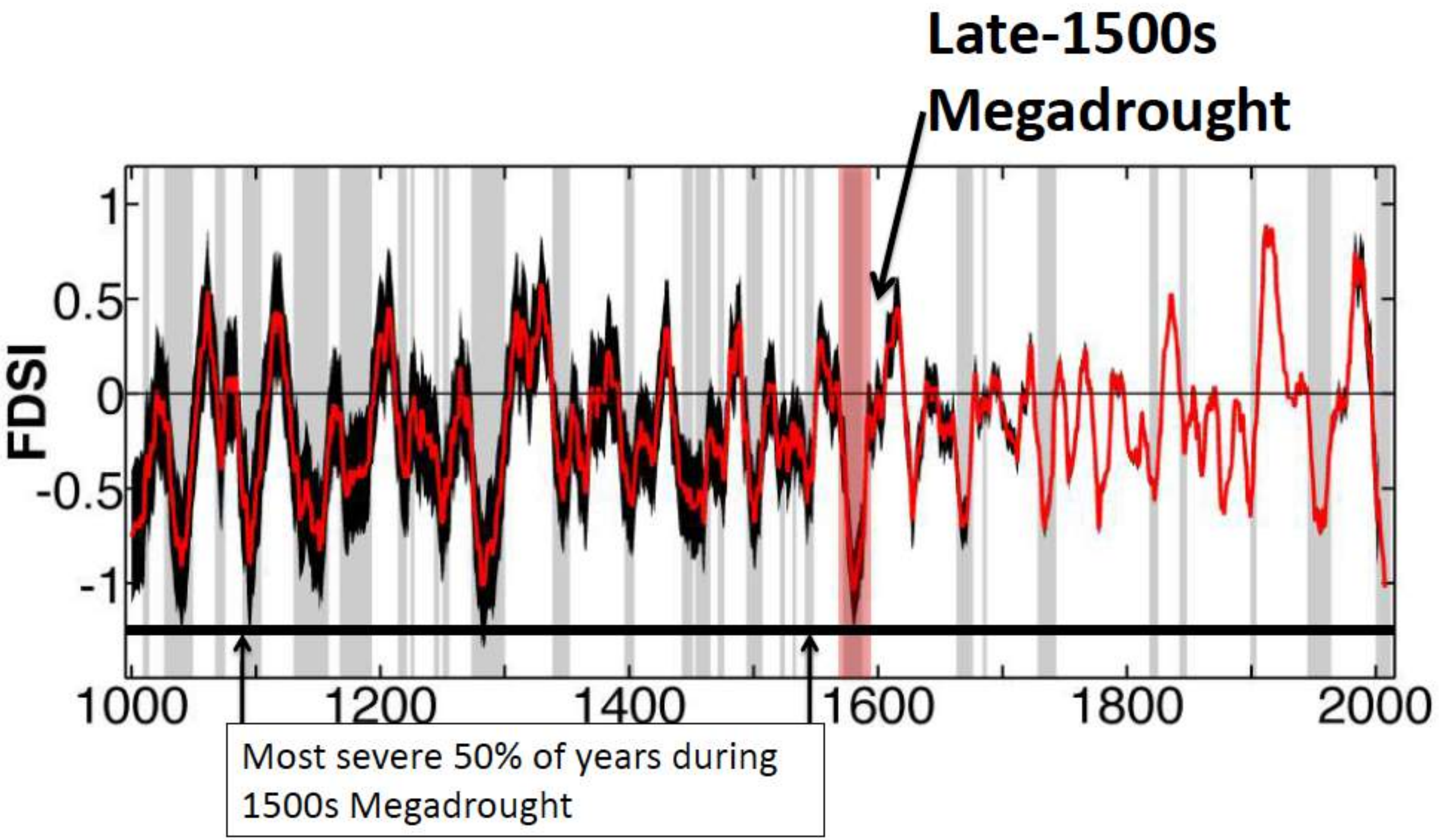


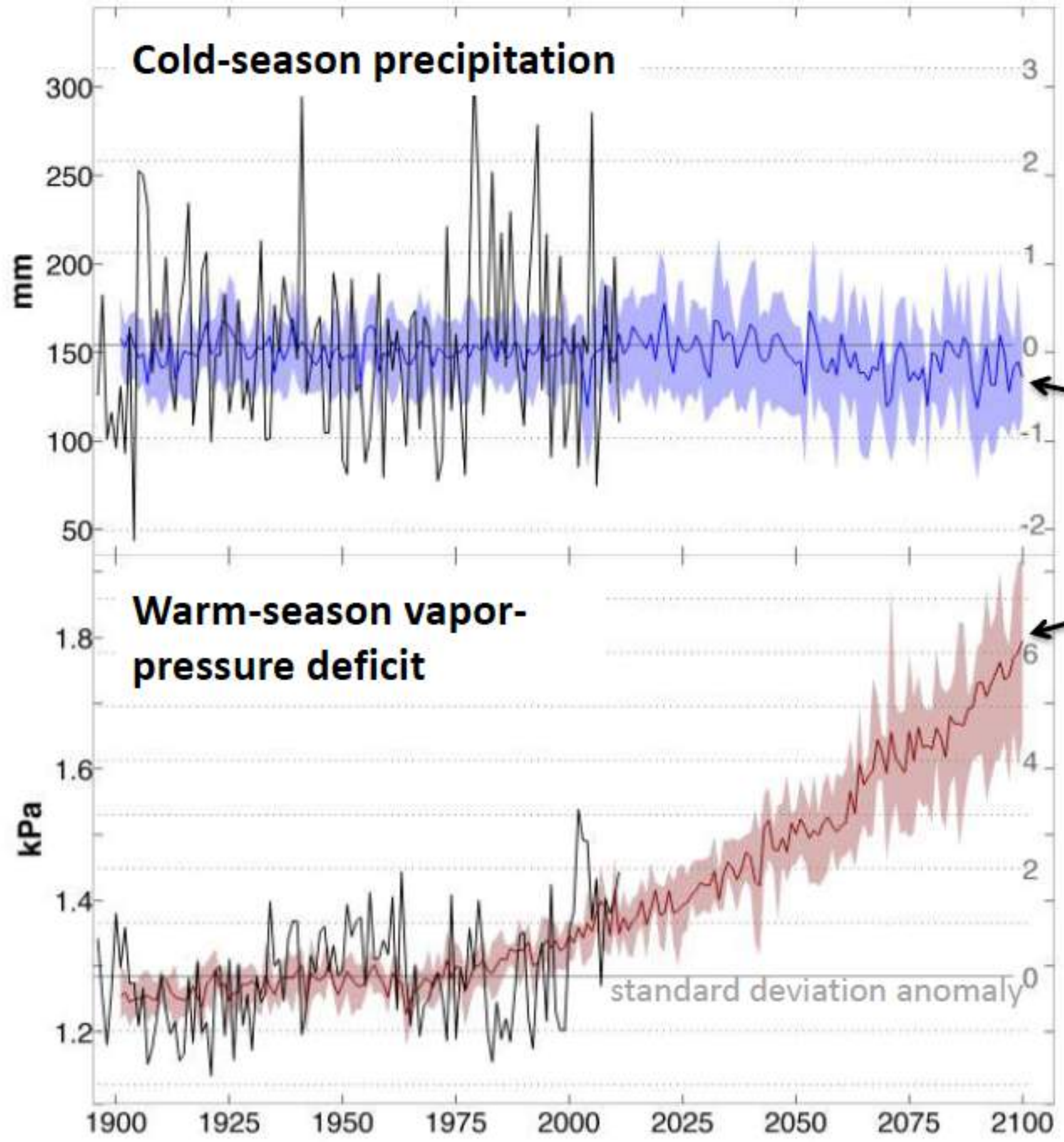
What are the implications for the future?



FDSI
1
0.5
0
-0.5
-1
1000
1200
1400
1600
1800
2000

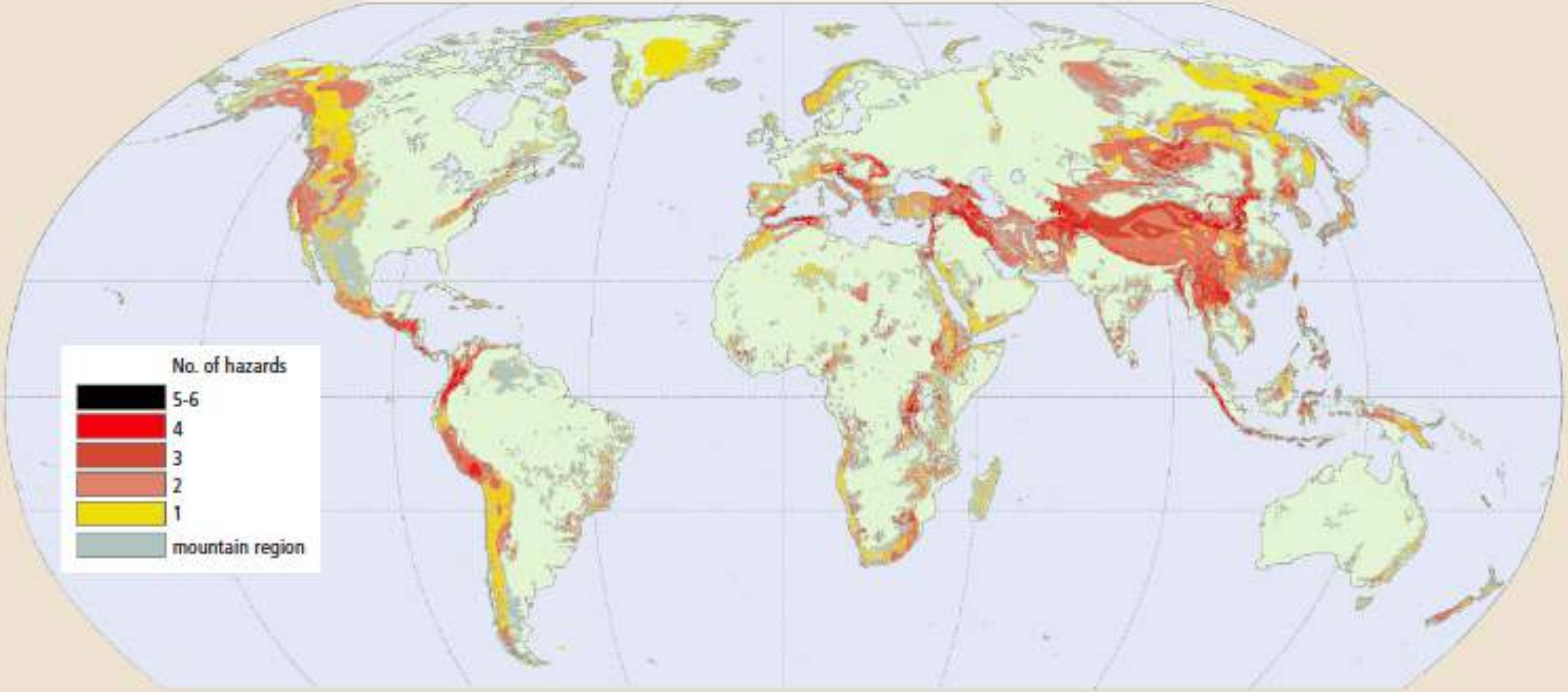
1500s Megadrought is a "Drought-Stress Threshold," beyond which there is probably widespread forest decline





5-15% decrease in cold-season precipitation by 2100

40% increase in warm-season VPD



Most mountain areas are affected by multiple hazards, which magnifies overall negative impacts. The hazards considered are earthquakes, fire, human conflict, suitability for rain-fed crops (drought), the future impact of infrastructure, and climate change (Map: Courtesy of UNEP-World Conservation Monitoring Centre, Mountain Watch 2002).

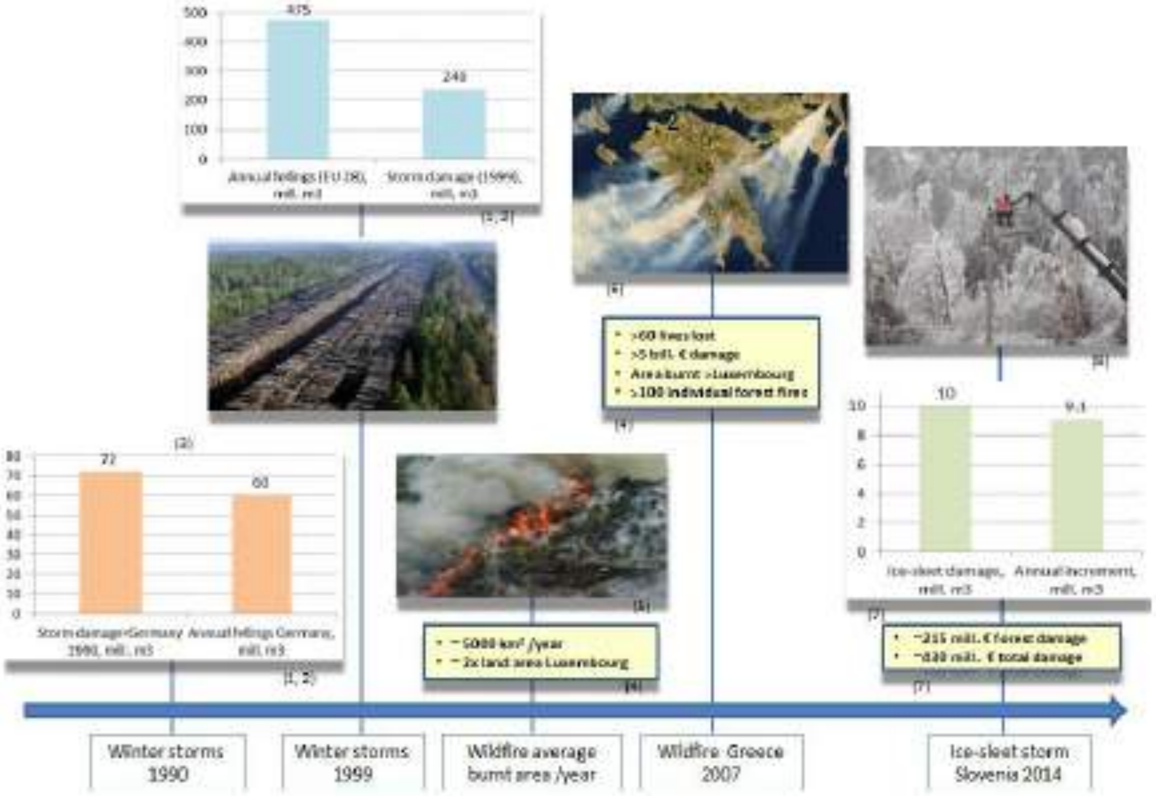
Mountain areas in:	%
South America	88
Australasia and Southeast Asia	71
Eurasia	61
North and Central America	45
Africa	27
Greenland	2
Global average, all mountain areas	55
Global average, non-mountain areas	36

*Level VIII or greater on the modified Mercalli scale (UNEP-WCMC 2002, Mountain Watch)

Hazard	Trend of expected change	Confidence in trend projection	Most affected regions	Economic importance
Seismic hazard	→	high	South America, Southeast Asia, North and Central America	very high
Snow avalanches	→	medium	Northern hemisphere, New Zealand	low
Droughts	↗	high	Africa, Caucasus, Eastern Himalaya	high
Landslides and mud flows	↗	high	Southeast Asia, Central and South America	medium
Glacier lake outburst flood	↗	high	All regions with valley glaciers	low
Floods	↗	medium	Asia, Africa, North America	high
Forest and bush fires	↗	medium	Africa, North and Central America, Eurasia	medium
Insect-borne diseases	↗	medium	Africa, Southern Asia, Central and South America	medium

Ch.Marty 2009; based on IPCC (2007), Iyngararasan (2002), and UNEP-WCMC Mountain Watch (2002)

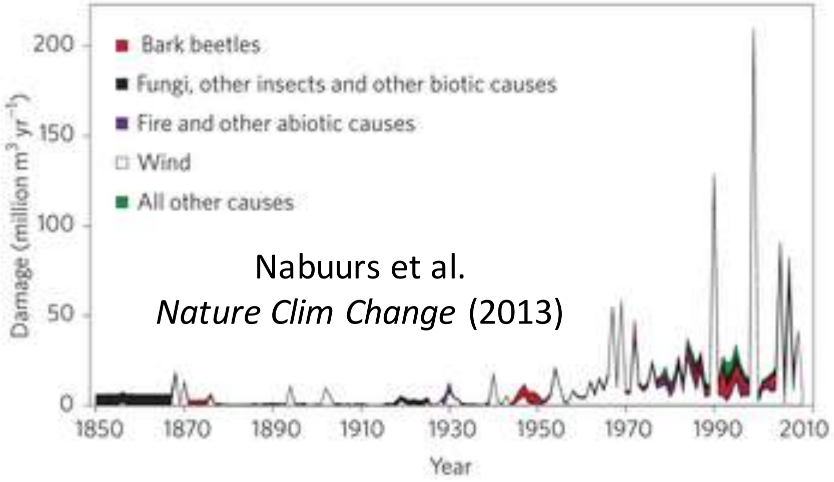
The table shows that climate change will increase the incidence of hazards in mountains with a medium to high level of confidence. This applies for 6 out of the 8 hazards identified, and in most mountain regions of the world. Economic impacts will be mostly medium to high, but may be disastrous in the regions concerned, depending on the type and severity of the hazard.



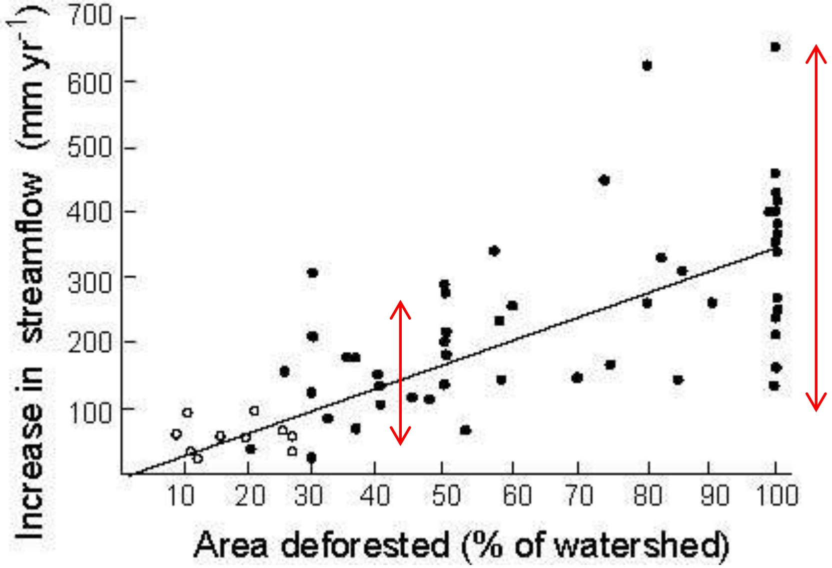
Examples of some major disturbance events since 1990

- Windstorms are a major damaging hazard in Europe’s forests, causing more than 50% of all catastrophic damages by volume to European forests with an average of two destructive storms a year
- Fires account for about 16% of annually recorded damage in terms of volume

Forest disturbance



Nabuurs et al.
Nature Clim Change (2013)



Interactions among climate-related disturbance processes

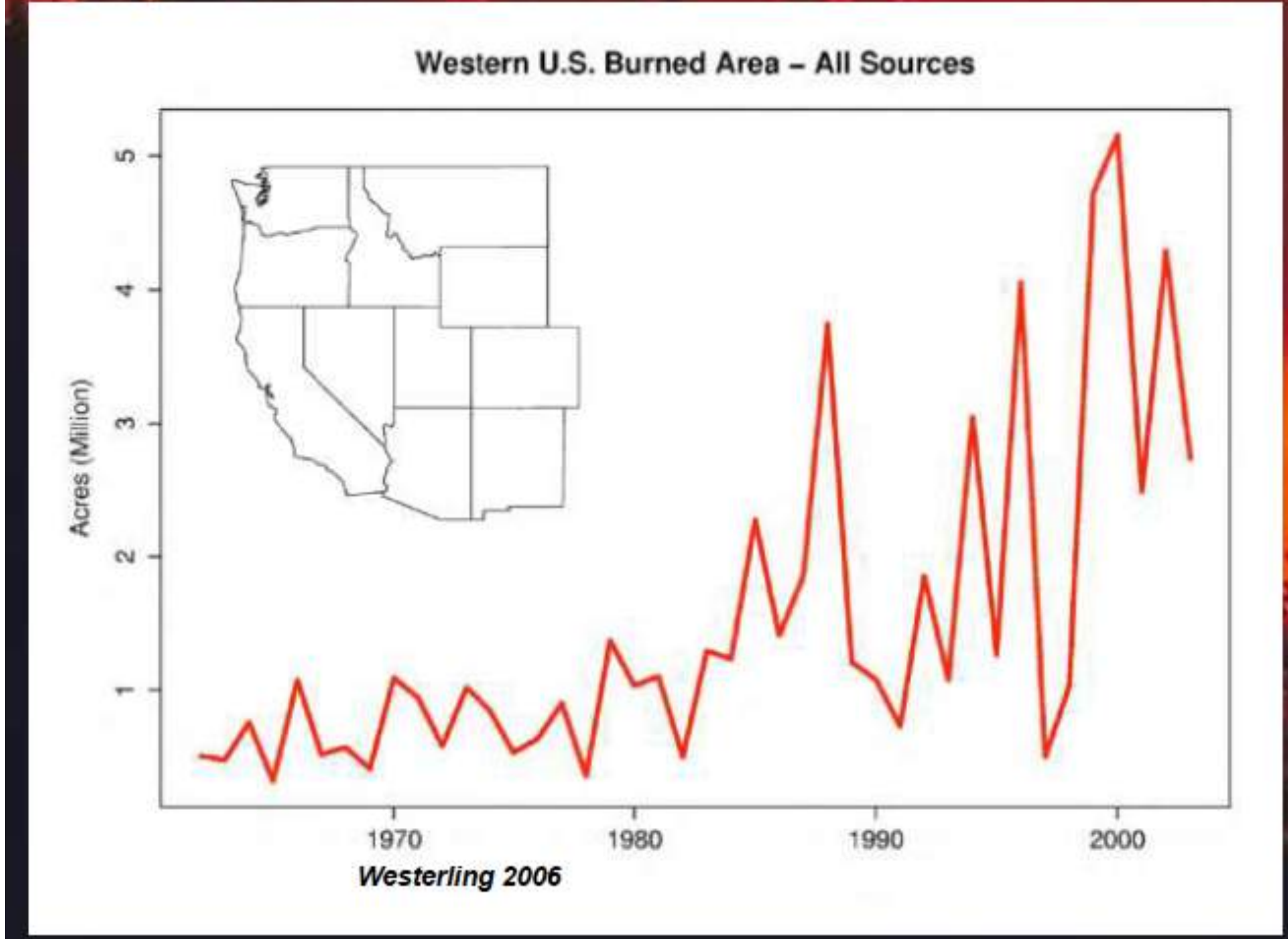
Which mountain resources and ecosystems will be the most sensitive to future climatic change, and what are the possible management responses?

How changing climate and disturbance will affect the composition, structure, and productivity of mountain forests?

How climatic variability and change will affect spatial and temporal patterns of ecological disturbance, and how will climatic variability and change affect hydrologic processes?

Since 1986:

- Western fire season 78 days longer
- 4-fold increase in fires greater than 1000 acres
- 6-fold increase in number of acres burned
- Greatest change in forests above 6500 ft



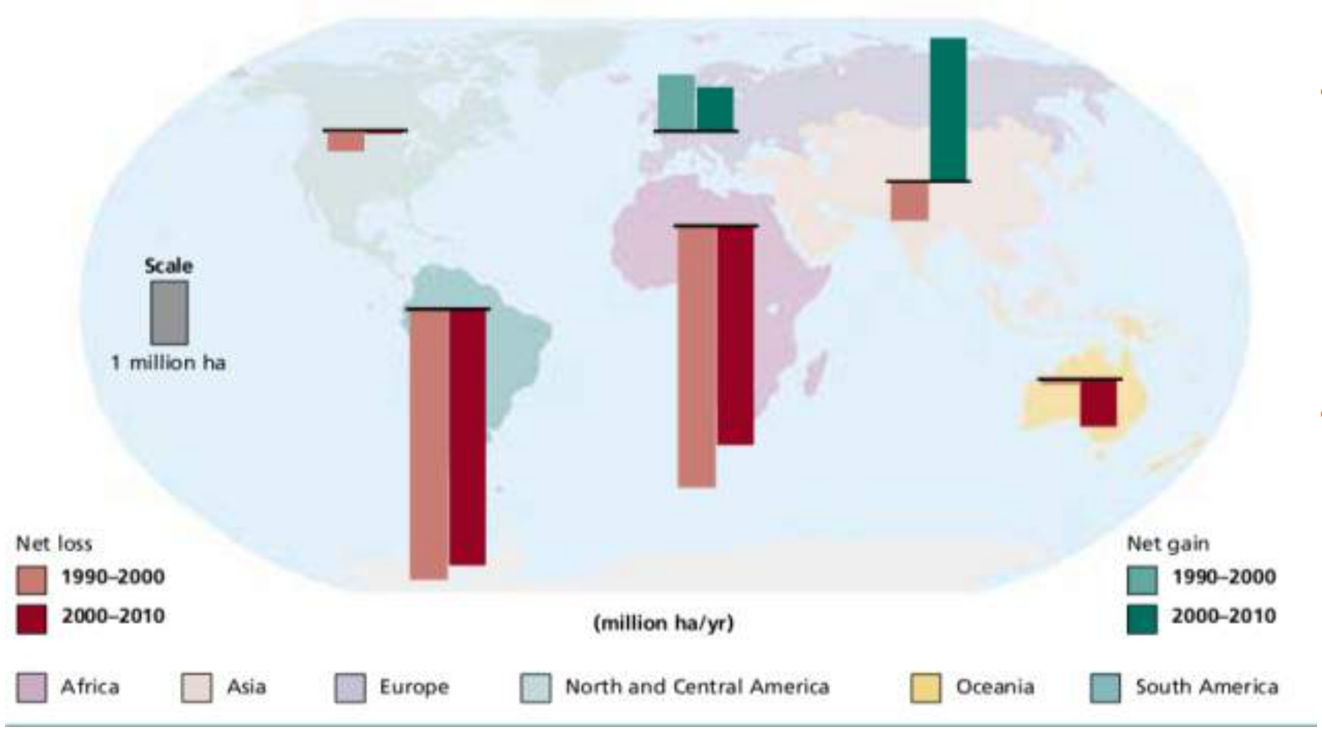
Economic impacts

- **Numerous and complex**, and often interrelated with social impacts
- Lost revenues for producer countries' governments
  → **market distortions + erosion of funds** for poverty alleviation
- Non-sustainable forest management can decrease forest productivity →**harming informal and subsistence economies**



Economic impacts

Annual change in forest area by region, 1990–2010



- The present situation is better then 10 years ago, but losses are partly compensated by plantations
- Degradation (and loss of forest value) processes are not considered

Source: 2011, FAO – FRA 2010

Social issues

- Forests are home to an estimated **60 M indigenous people**
- Important **cultural and social role** of forests in many countries
- Commercial logging **competes for access to the land**
- **Low concern for labour rights, health and safety** along the supply chain




Impact of illegality in the forest sector

- Revenues from illegal logging have **fuelled armed conflicts** (Liberia, RD Congo)
- Illegality in the forest sector is often **linked to criminal activities** involving corruption, violence and money laundering
- **Low concern for labor rights, health and safety** along the supply chain
- The diffusion of illegal timber at low cost **hinders improvement of forest management practices**
- Illegality in the forest sector creates **unfair conditions** of competition in the market

European Commission

Legal = sustainable?

Concepts not always connected

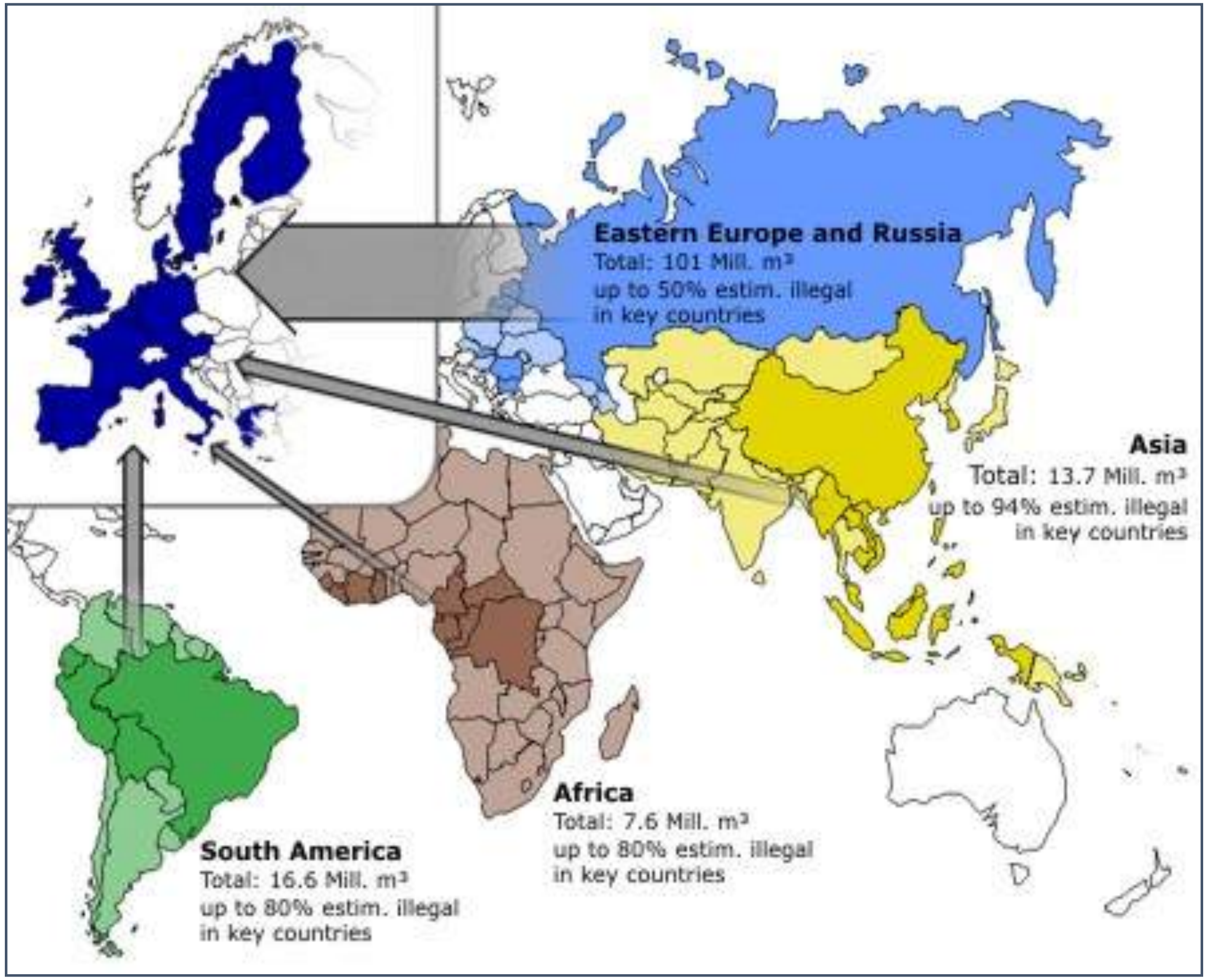
Forest management in contrast with equity and justice criteria

Logging without compliance with laws

Non-sustainable management of forests

?

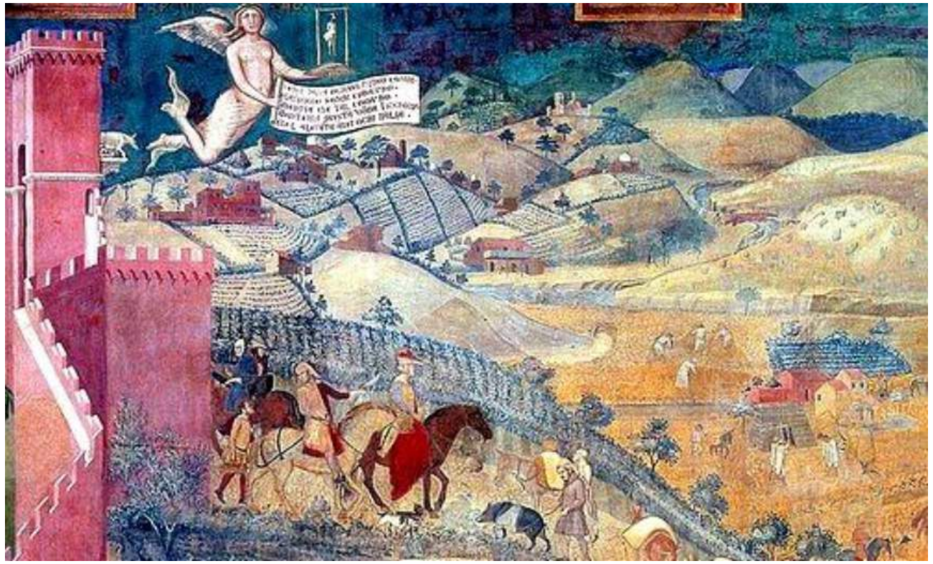
EU responsibilities in illegality



2003, EU:
import 82,24 Mmc of illegal timber (~ 20%)
(EC and WWF UK, 2004)

Deforestation

Land degradation



In Siena (Montagnola senese) there are oak coppice forests that have been managed since XIII century (sustainable management!), as reconstructed from middle-age management plans

Land use conversion

Landscape modification with the introduction/diffusion of new species since Roman time (Pinus pinea, Cupressus sempervirens, Castanea sativa)

The trend in forest area from 1990 to 2015 by sub-region (K ha) (FAO, 2015). All totals involve rounding.

Sub-region	1990	2000	2005	2010	2015
Central America	26,995	23,448	22,193	21,010	20,250
Caribbean	5,017	5,913	6,341	6,745	7,195
East Asia	209,198	226,815	241,841	250,504	257,047
East-Southern Africa	319,785	300,273	291,712	282,519	274,886
Europe	994,271	1,002,302	1,004,147	1,013,572	1,015,482
North Africa	39,374	37,692	37,221	37,055	36,217
North America	720,487	719,197	719,419	722,523	723,207
Oceania	176,825	177,641	176,485	172,002	173,524
South America	930,814	890,817	868,611	852,133	842,011
South-Southeast Asia	319,615	298,645	296,600	295,958	292,804
West-Central Africa	346,581	332,407	325,746	318,708	313,000
West-Central Asia	39,309	40,452	42,427	42,944	43,511
Total	4,128,269	4,055,602	4,032,743	4,015,673	3,999,134

Rates of change in natural forest area (calculated as total forest area minus planted forest area) and planted forest area from 1990 to 2015 by climatic domain (K ha y^{-1}) (calculated from FAO, 2015). All totals involve rounding.

Period	1990–00	2000–05	2005–10	2010–15
Natural forest				
Boreal/polar	−1.022	−1.445	−0.261	−0.741
Temperate	0.279	0.571	0.812	1.385
Sub-tropical	−0.338	−0.483	−1.166	−0.034
Tropical	−10.387	−9.127	−8.101	−6.379
Total	−11.467	−10.483	−8.716	−5.770
Planted forest				
Boreal/polar	1.073	1.252	1.465	0.657
Temperate	2.011	3.086	2.038	0.823
Sub-tropical	0.273	0.310	0.306	0.123
Tropical	0.844	1.264	1.493	0.859
Total	4.200	5.911	5.302	2.462

Net rates of change in the areas of forest and other wooded land from 1990 to 2015 in different global climatic domains (M ha y^{-1}) (FAO, 2015).

	1990–00	2000–05	2005–10	2010–15
Forest				
Boreal (inc. polar)	0.051	−0.193	1.204	−0.084
Temperate	2.290	3.657	2.851	2.208
Sub tropical	−0.064	−0.173	−0.860	0.089
Tropical	−9.543	−7.863	−6.608	−5.520
Grand total	−7.267	−4.572	−3.414	−3.308
Other wooded land				
Boreal (inc. polar)	−0.348	0.371	0.482	−0.162
Temperate	−0.305	1.007	0.834	0.704
Sub tropical	−0.104	0.460	−0.158	49.698
Tropical	−1.644	−1.989	2.936	−4.178
Grand total	−2.401	−0.151	4.094	46.062

Mean rates of change in natural forest area in 2000–10 (K ha y^{-1}) in countries with the highest mean rates of population growth in 2000–10 (K persons y^{-1}) above 1000 K persons y^{-1}.

	Rate of population growth	Rate of forest area change
India	16,336	3
Nigeria	3,683	−625
Indonesia	3,174	−1,002
Pakistan	2,932	−71
Ethiopia	2,107	−169
Brazil	2,071	−3,030
Bangladesh	1,874	−4
Philippines	1,579	9
Democratic Republic of the Congo	1,524	−467
Mexico	1,401	−187
Tanzania	1,095	−595

AGRICULTURE GLOBAL PRACTICE

THE WORLD BANK
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CLIMATE-SMART AGRICULTURE INDICATORS

WORLD BANK GROUP REPORT NUMBER 105162-GLB

JUNE 2016

The CSA Technology and Practices Index comprises 27 indicators clustered into three main themes: Productivity (P), Resilience (R), and Mitigation (M). Ex ante application of the index reveals

Productivity
Resilience
Mitigation

How forest management helps tackle climate change

Carbon sequestration
through increases in forests and trees and forest carbon stock enhancement

- Afforestation, reforestation and forest restoration
- Increase of tree cover in farming systems (agroforestry), rural landscapes and cities
- Enhancement of carbon stocks and sequestration capacity through management practices

Strenghtening adaptive capacity of trees and forests
especially in fragile forest ecosystems

- Management of forest biodiversity
- Forest health and vitality to reduce vulnerability
- Intensifying fire management systems
- Adaptive management practices

Forest carbon stocks conservation
through reduction of deforestation and forest degradation

- Sustainable practices of forest management and use
- Integrated fire management
- Management of forest health and vitality
- Management of` forest biodiversity
- Management of protected areas and wildlife

Strenghtening adaptive capacity of forest dependent communities

- Strengthening coping strategies
- Diversifying forest management-related employment opportunities and livelihoods
- Adaptive land use planning and management

Food and Agriculture Organization of the United Nations

Two goals of our time

1. Achieving food security
    - food production must increase 70% by 2050
    - adaptation to Climate Change is critical

2. Avoiding dangerous climate change
    - target of limiting the global temperature rise to +2 °C (COP 21 in Paris) requires major CO_2 emission cuts
    - agriculture accounts for about 15% and land-use change (largely deforestation) another 15% of net GHG emissions to the atmosphere

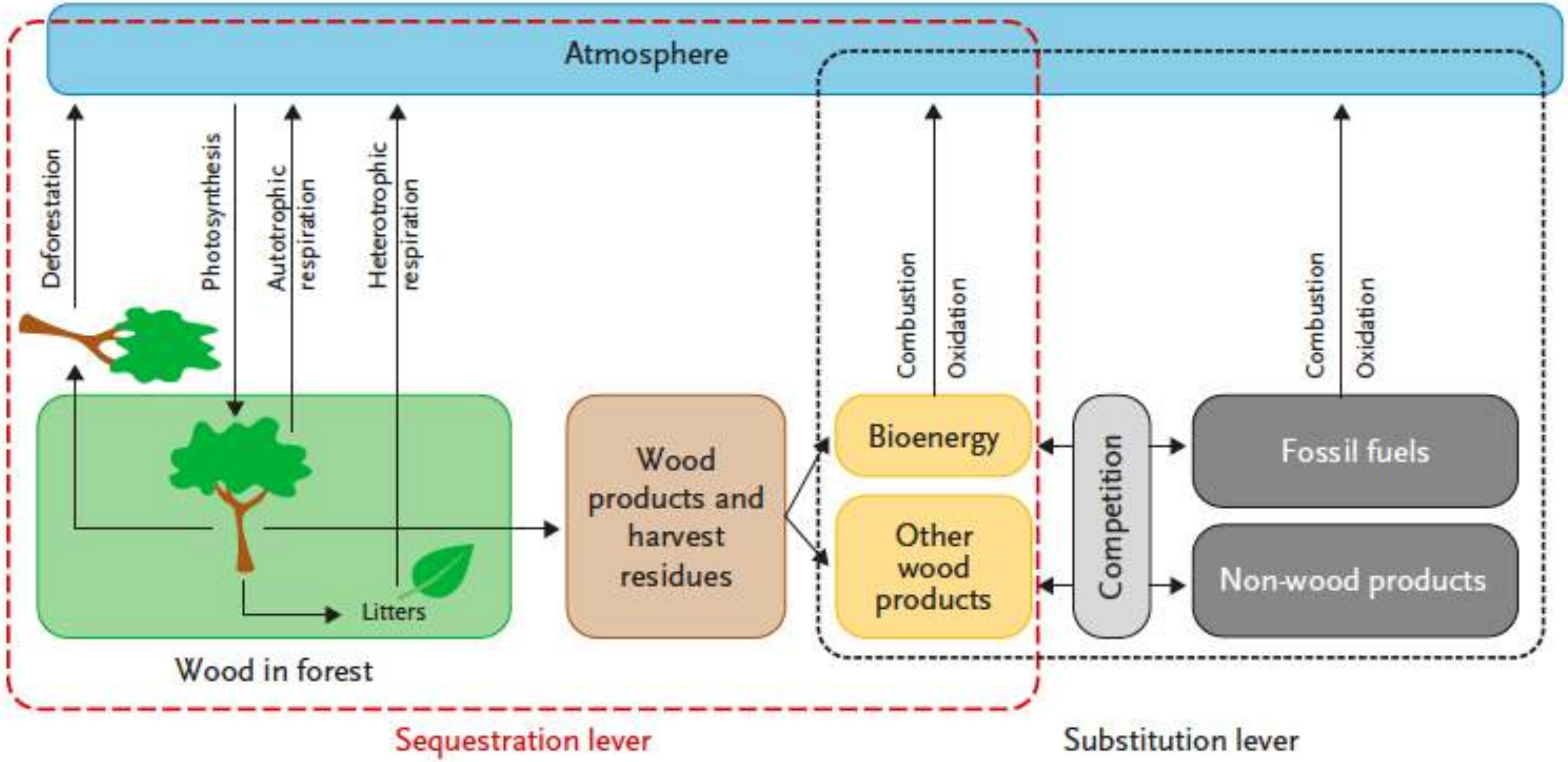
Climate-Smart Forestry

- whole forest and wood products chain, including material and energy substitution effects.

- includes adaptation to climate change and strives to achieve synergies

- CSF's 3 pillars: 1) reducing and/or removing greenhouse gas emissions, 2) adapting and building forest resilience, and 3) sustainably increasing forest productivity and incomes

Greater human demands on forests



Nabuurs et al. (*EFI* 2015)

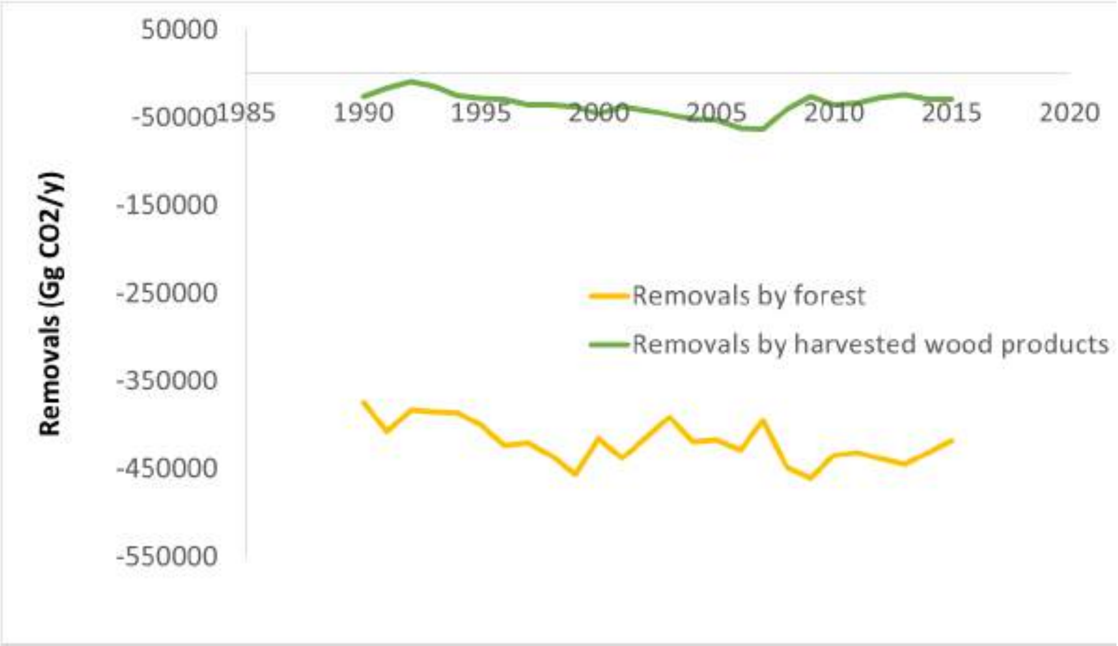
Forests and the use of forest products can contribute to climate change mitigation by increasing sequestration and through substitution effects

Europe

- Sink of 450 Mt CO2, or **10%** of total EU emissions
- Harvested wood products: sink of 44 Mt CO2
- Biomass for bioenergy producing 3% of total EU energy need
- Some signs of possible saturation

The only sector that has made a consistent and significant contribution, every year since 1990!

..ask Volkswagen what they achieved in 25 yrs..



Forest management and HWP sink as reported by MS to UNFCCC

Options for mitigating climate change through forest management

Option		current offset of total EU emissions (%)	Short-term *relative* impact of > harvest	*Reported/accounted in:*
Increase in C stock	**in existing forests (CO_2 sink or "removal")** 	≈ 10% (only 1% accounted under KP in 2008-2012)	<<	*LULUCF*
	in wood products 	≈ 1%	>	
Substitution effects by wood (approximate figures)	**Material** 	≈ 1-2%	>	*Other GHG sectors*
	Fossil-fuel energy 	≈ 4-5%	*	

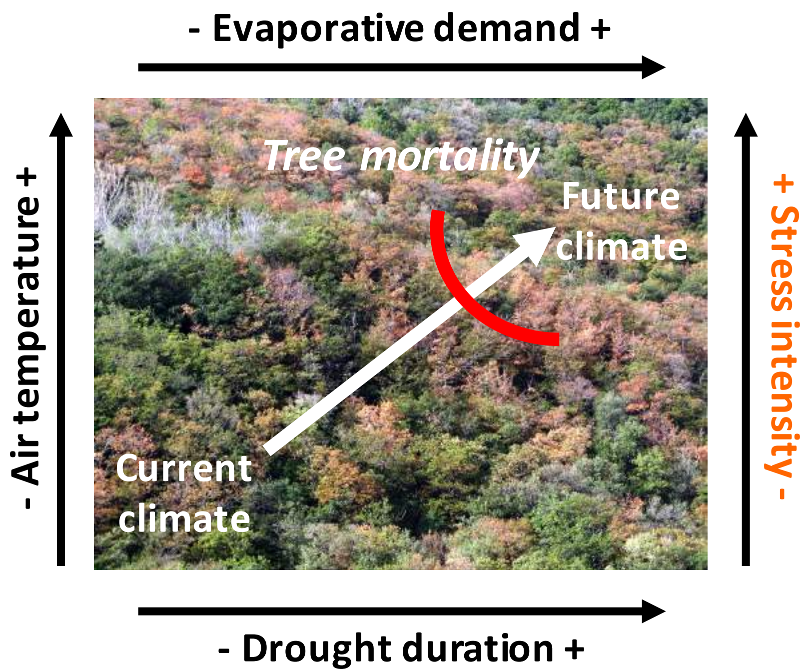
* While the emission saving by material substitution are immediate, when wood replaces fossil fuels the emissions saving highly depends on the context, assumptions and time frame.

Trade-offs exist between options, each with its **temporal dynamics** of emissions. E.g. *more harvest may mean less forest sink in the short term but more substitution effects.*

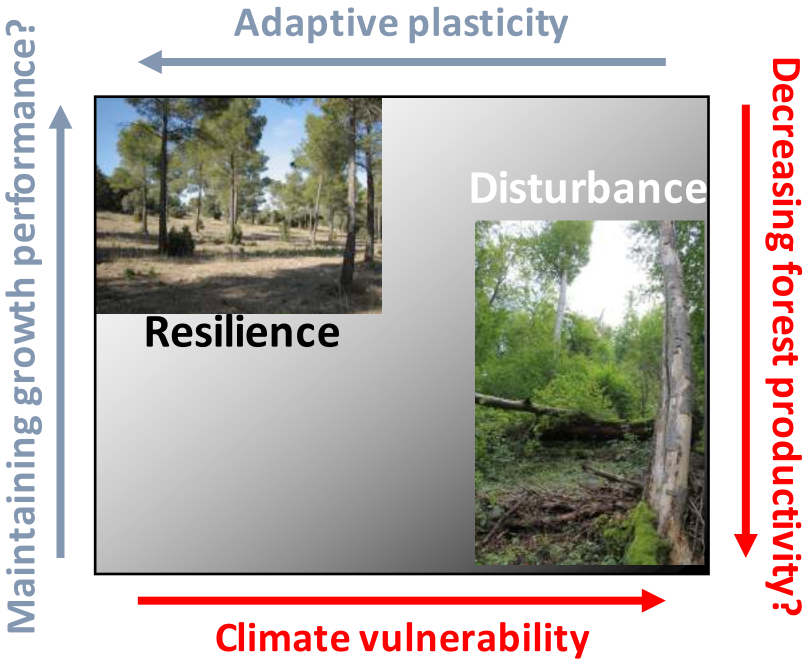
The most effective forest mitigation strategy is the one that optimizes the sum of the above options in a given time frame.

The response

Thresholds of mortality



Ranges of variability



Mitigate climate change, sustain species diversity and reverse land degradation can become major goals for mountain forestry, but not the only ones!

What Is Adaptation?

Adjustment in ecological, social, or economic systems in response to climate change, in order to *minimize potential negative effects*.

- Supports sustainability of ecosystem services
- A long-term, experimental management approach
- *Adaptive management* is a component of adaptation

What is Resilience?

Capability of an ecosystem to *accommodate gradual changes and return to a previous condition* after disturbance.

- Plan for change rather than resist it
- Enable systems to adapt as effects of climate change occur
- Requires a long-term perspective

The Adaptation Process

3 steps:

- Establish an educational dialogue.
- Conduct a vulnerability assessment.
- Develop adaptation options.

1) Establish an educational dialogue

- Scientists educate resource managers about climate change science.
- Resource managers educate scientists about management objectives and priorities.
- Workshops for all personnel ensure a common understanding of climate change science.

2) Conduct a vulnerability assessment

- Scientists lead a synthesis of data and other information on sensitivity of resources.
- Resource managers need information that is accessible, in useful spatial scales, and focused on resources of interest.
- Scientists need to communicate about uncertainty in modeling and other information.

3) Develop adaptation options

- Knowledge elicitation - Scientists pose scenarios, managers give responses.
- Adaptation options can be strategic or tactical in nature, as preferred by managers.
- The scientific basis for adaptation needs to be documented.

Adaptation tactic #1

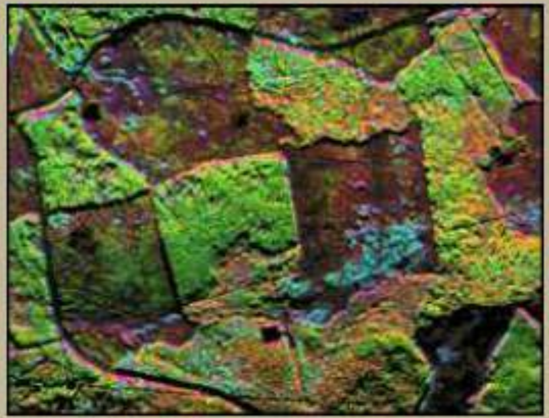
Increase landscape diversity

Increase resilience at large scales.

-- Treatments and spatial configurations that minimize loss of large number of structural and functional groups

Increase size of management units.

-- Much larger treatments and age/structural classes



Increase connectivity.

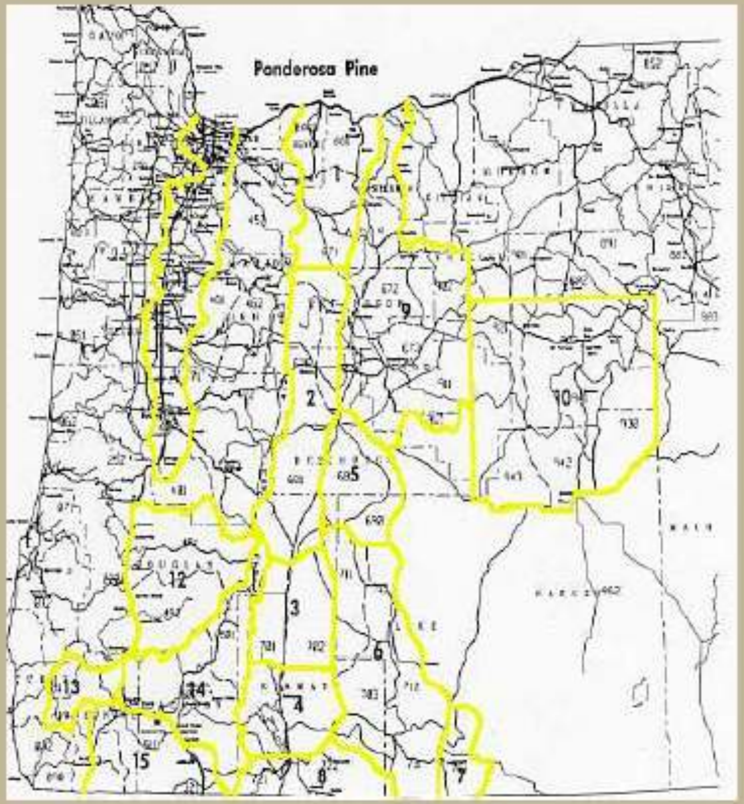
Adaptation tactic #2

Maintain biological diversity

Experiment with mixed species, mixed genotypes.

Modify genetic guidelines.

Identify species, populations, and communities that are sensitive to increased disturbance.



Adaptation tactic #3

Plan for post-disturbance management

Treat fire and other ecological disturbance as normal, periodic occurrences.

Incorporate fire management and other disturbance options in land management considerations.

Adaptation tactic #4

Implement early detection / rapid response

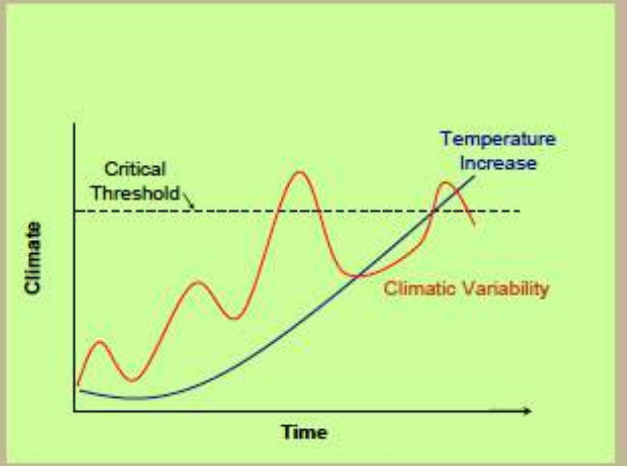
Identify and monitor adverse trends in ecosystem structure and function.

Eliminate or control exotic species.

Monitor post-disturbance conditions, reduce fire-enhancing species (e.g., exotic annual grasses).

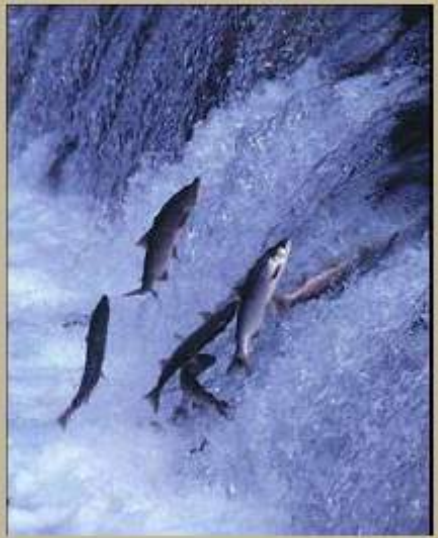
Adaptation tactic #5

Manage for realistic outcomes



Identify key thresholds for species and functions; determine which thresholds will be exceeded.

Prioritize projects with high probability of success; abandon hopeless causes.



Identify species and vegetation structures tolerant of increased disturbance.

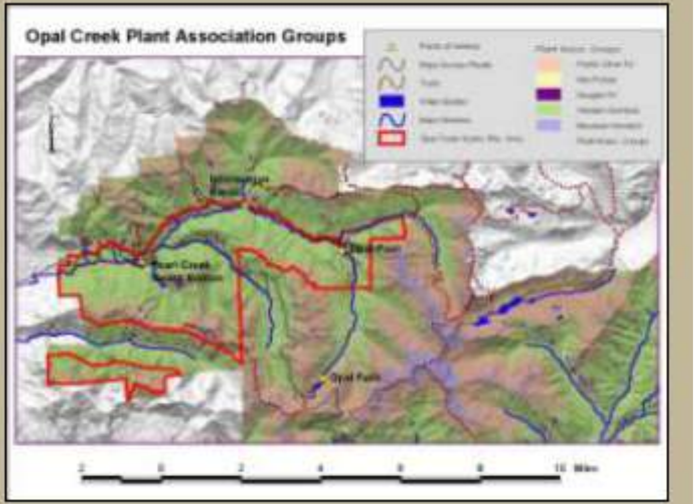
Adaptation tactic #6

Incorporate climate change in restoration

Reduce emphasis on historical references.

Reduce use of guidelines based on static relationships (e.g., plant associations).

Develop performance standards that consider climate change in restoration trajectories.



2000 – Climate-smart forestry – Carbon sink

1980 – Sustainable forest management

1950 – Close-to-nature forestry

1900 – Forest laws – Soil and watershed protections

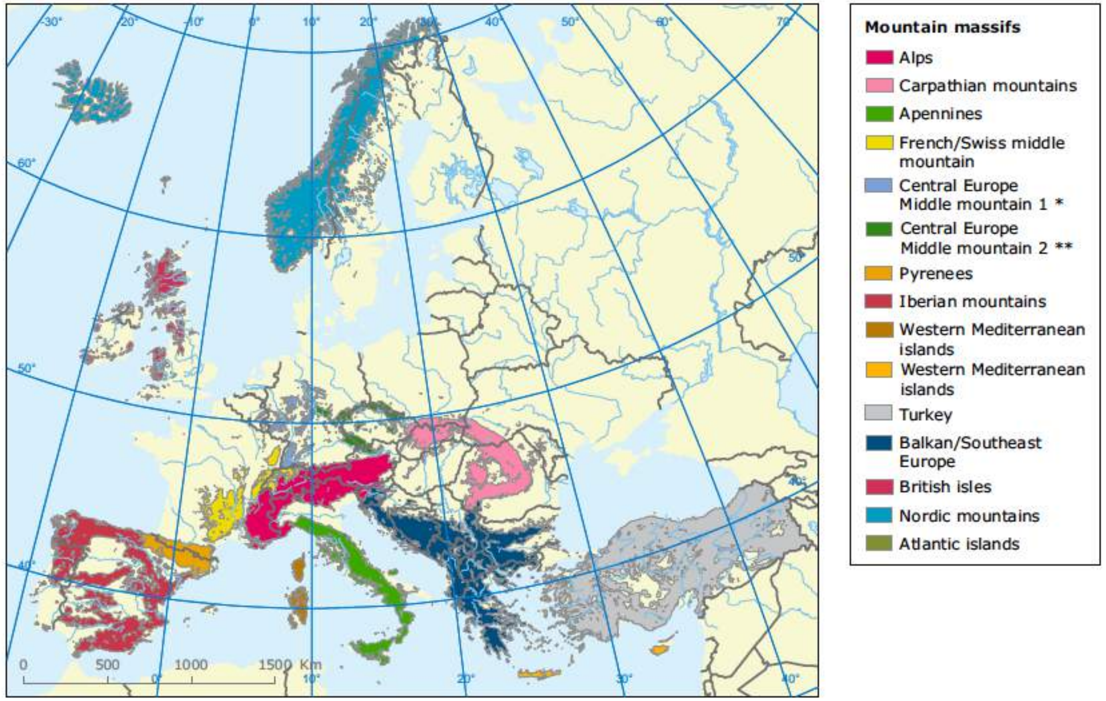
Rupf (1960) “**Wake Theory**” or “**Kielwasser Theory**”:
“the growth of biomass is a primary value to be properly managed, whilst all other functions are secondary values, depending on the former”

1700… | 1900 | 1950 | 2000

The opportunity to become *climate-smart*

CLIMO
CLImate-Smart Forestry in MOuntain Regions

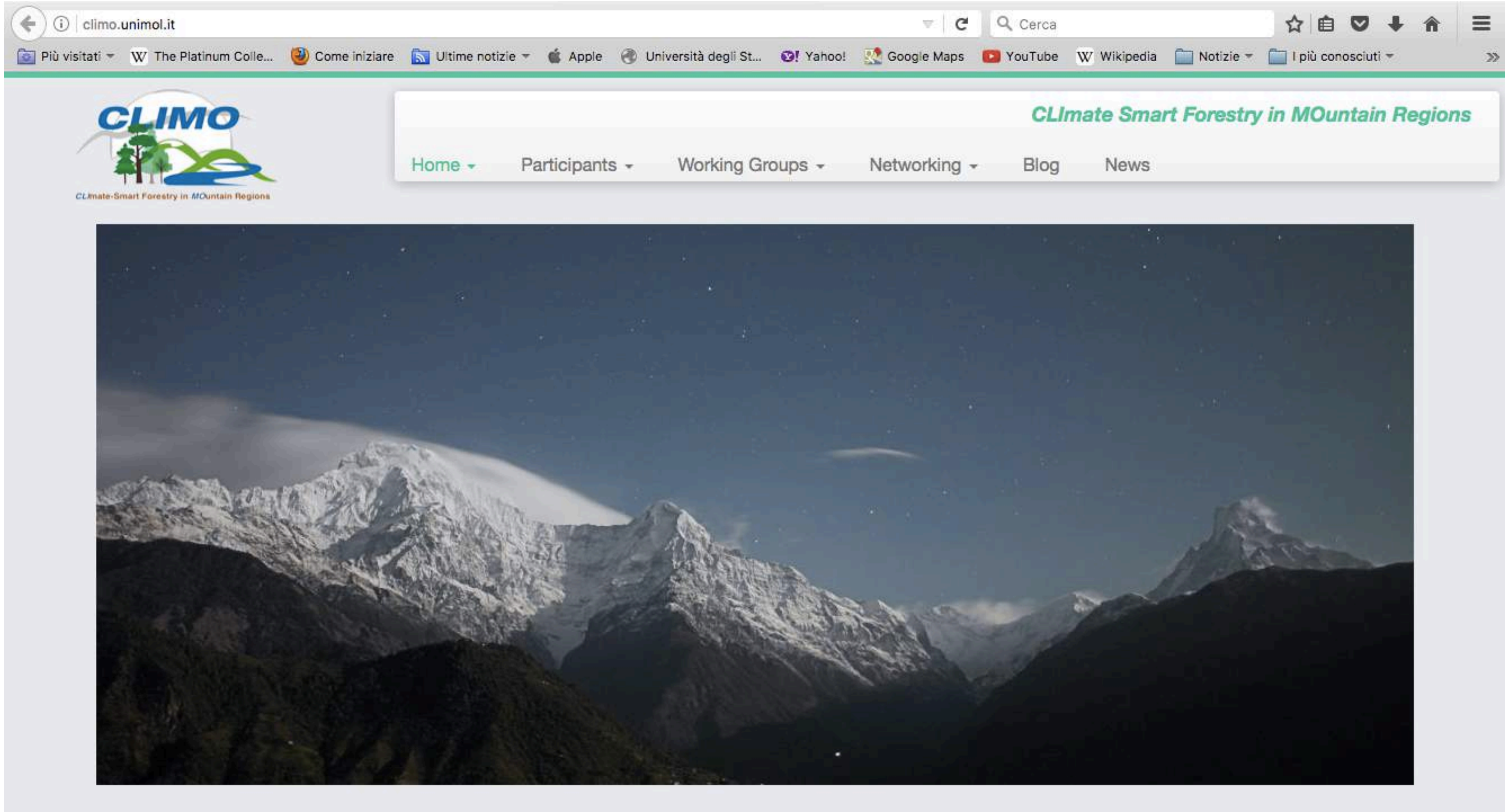
Enable forestry to challenge the adverse impacts of climate change, taking into account the costs for mitigation and adaptation strategies



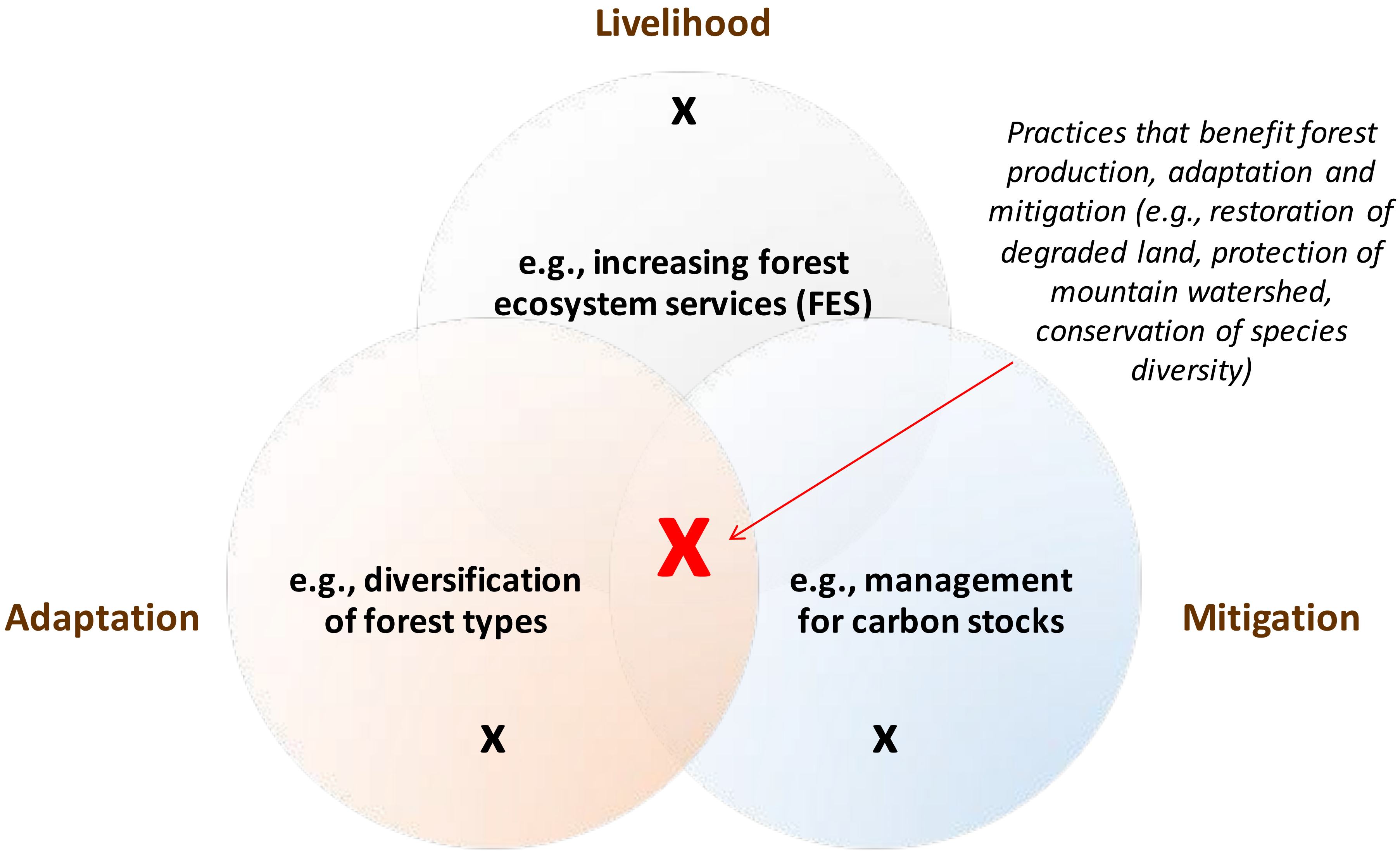
Note: * = Belgium and Germany; ** = the Czech Republic, Austria and Germany.

- Combine carbon sequestration, storage, and substitution
- Integrate trends and extreme events
- Evaluate synergies and trade-offs between forest adaptation and mitigation
- Use of wood in the construction sector
- Use of wood with energy after multiple cycles
- Tackle sustainable forest management
- Implement forest reserves
- Halt land degradation

http://climo.unimol.it/

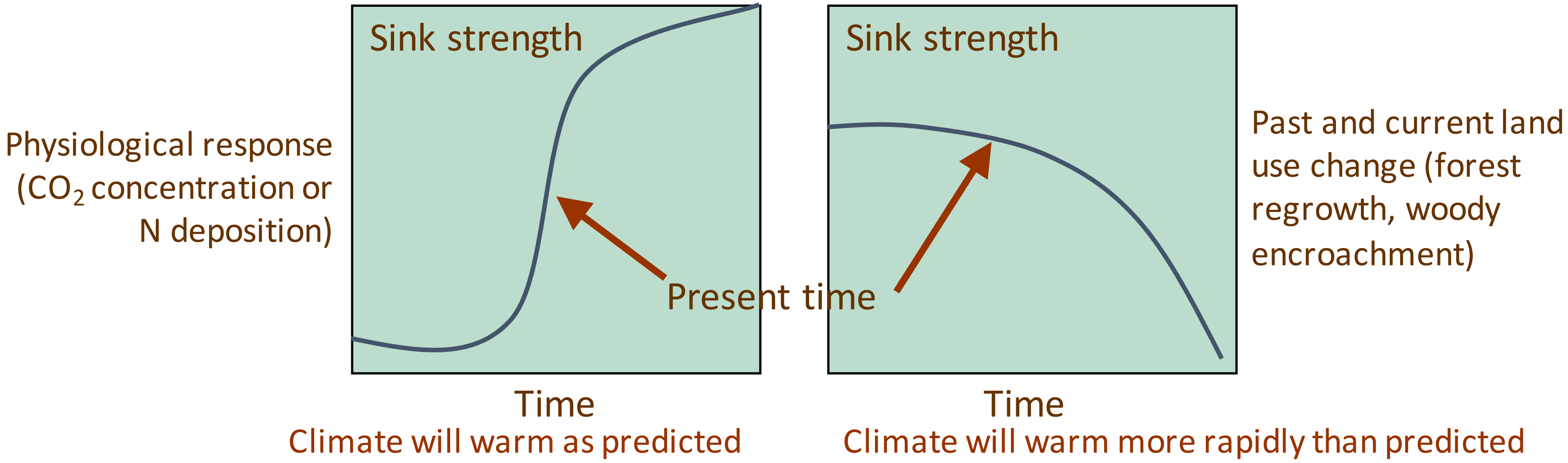


Understanding the synergies and trade-offs amongst the three outcomes of CSF



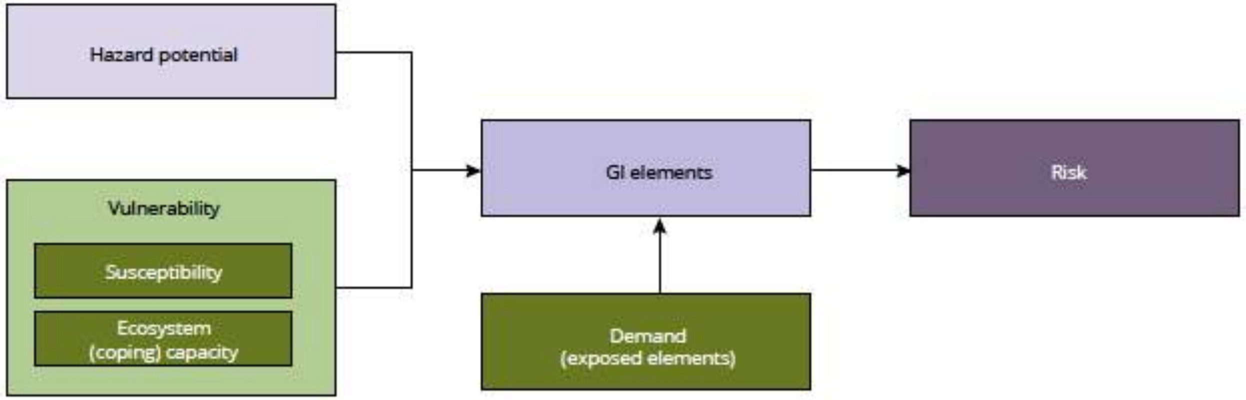
On scope of mountain forest mitigation

- consider the major contribution of emission reductions per produced unit
- sustain the large mitigation potential of forest vegetation in mountain landscapes
- consider the consequences of carbon sink saturation of mountain forests



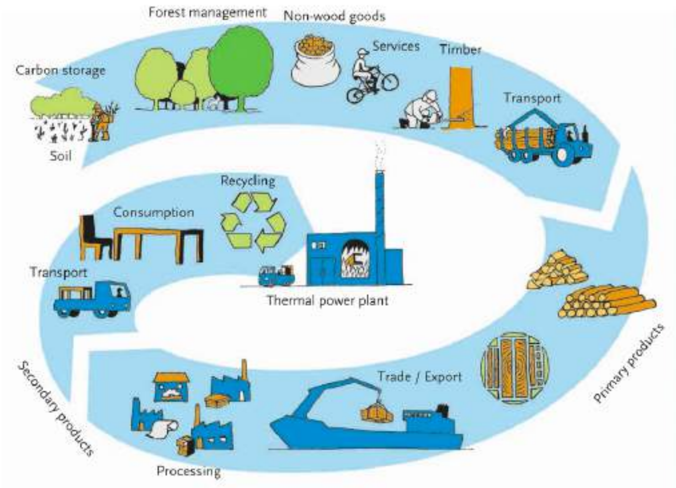
On scope of mountain forest resiliency

- promote the deployment of Green Infrastructure in mountain landscapes to help prevent disasters and protect soils
- foster mountain forests that feature a good mix of species, age and structure to absorb large quantities of water
- establish an integrated technological platform to monitor environmental changes and test adaptive strategies

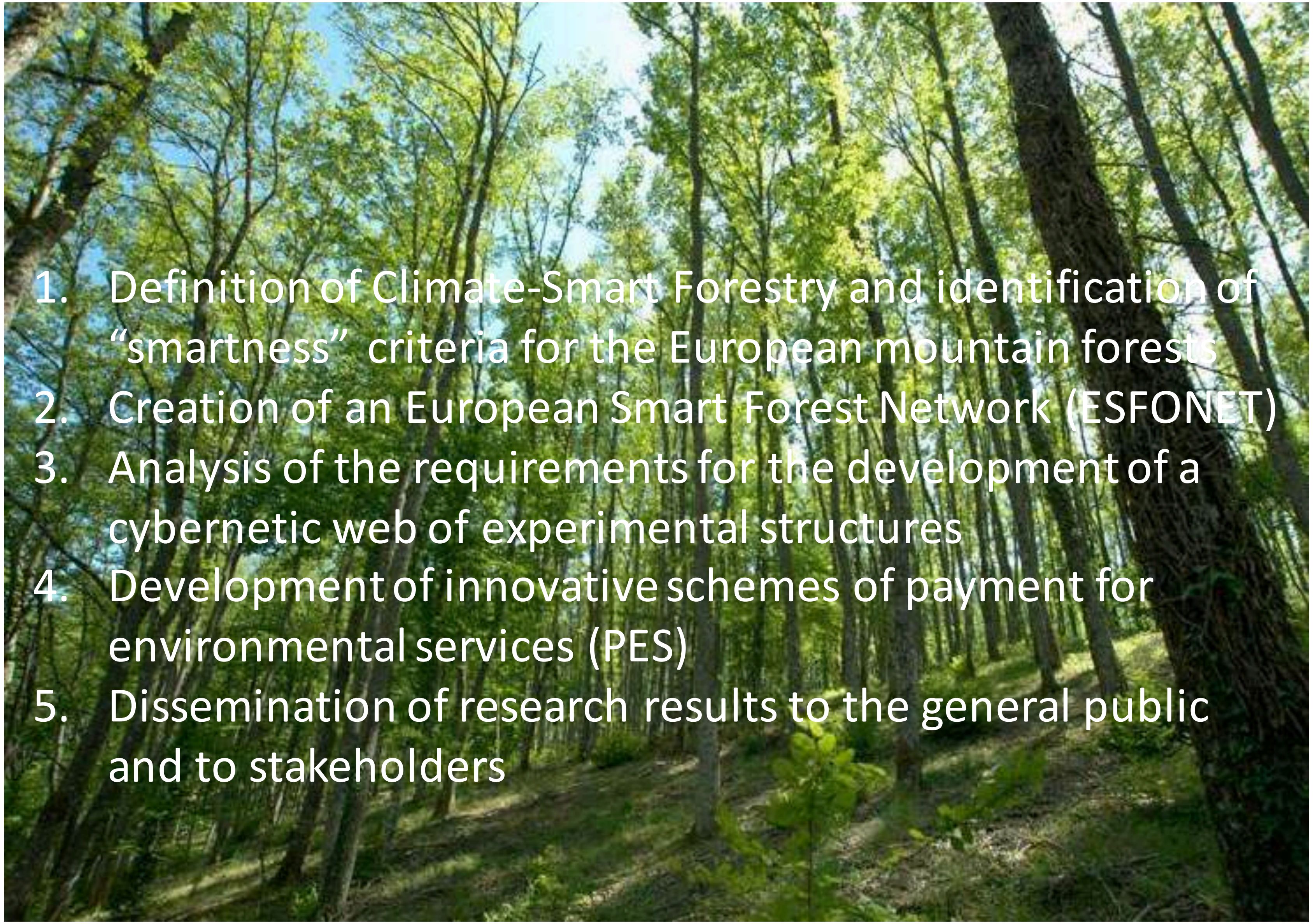


On scope of mountain forest sustainability

- propose innovative schemes of PES useful to develop policies supporting the delivery of ES
- encourage incorporation of climate impact in mountain forestry investment projects
- endorse inclusion of climate-smart mountain areas in REDD+ strategies and finance



Objectives of CLIMO (COST ACTION 15226)



1. Definition of Climate-Smart Forestry and identification of “smartness” criteria for the European mountain forests
2. Creation of an European Smart Forest Network (ESFONET)
3. Analysis of the requirements for the development of a cybernetic web of experimental structures
4. Development of innovative schemes of payment for environmental services (PES)
5. Dissemination of research results to the general public and to stakeholders

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MOUNTFOR is a European Forest Institute (EFI) Project Centre on Mountain Forests hosted by FoxLab, the Research Unit of the Edmund Mach Foundation located in San Michele all'Adige (Italy).

MOUNTFOR is built upon the expertise and structures of a core network of research institutes, associate members of EFI, cooperating in strict teamwork with Headquarters and Regional Offices of EFI, and leading research networking, knowledge sharing and advanced learning.

MOUNTFOR works closely with policy makers and forest managers to craft and implement site-specific adaptation strategies to fulfil all ecosystem services and to preserve water resources.
Following the European and International policies on forest protection, MOUNTFOR works closely with EFI to mobilize forest research and expertise aimed at addressing policy-relevant needs with regard to mountain forest services and products, and to the development of their value chain.

Highlights

COST Action CA15226 "CLIMO" MC&WG Meeting MOUNTFOR EFI PROJECT CENTRE will host in February 2017 the **1st Management Committee and Working Group Meeting** of the **COST Action "Climate-Smart Forestry in Mountain Regions" (CLIMO)** that is ...

Posted Dec 12, 2016, 9:31 AM by Alberto Mattedi

Showing posts **1 - 1** of **9**. View more »

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News

NEW PAPER ACCEPTED
Antonucci S., Rossi S., Deslaurier A., Morin H., Lombardi F., Marchetti M., Tognetti R. (2016) Large-scale estimation of xylem phenology in black spruce through remote sensing. Agricultural and Forest ...

Posted Dec 12, 2016, 5:56 PM by Alberto Mattedi

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Events

COST ACTION CA1522 "CLIMO" (WG & MC meeting)
February 2017: **The 1st Management Committee and Working Group Meeting** of the **COST Action CA15226 "CLIMO"** will take place from Tuesday 07 until Thursday 09 February 2017, at the Fondazione ...

Posted Dec 11, 2016, 7:51 PM by Alberto Mattedi

Showing posts **1 - 1** of **4**. View more »

MOUNTFOR objectives

- Monitoring and inventorying size and quality of forest ecosystem services in pan-European (and beyond) mountain systems
- Identifying tools and criteria to forecast the effects of global change on mountain forests and the water cycle
- Assessing the potential impacts of forest management and land use on mountain hydrology and the availability/quality of water resources
- Incorporating applied research and governance analysis to disseminate the benefits of forest ecosystem services to stakeholders

MountFor

Key message 1: practices

- Criteria to guide CSF practices are needed in mountain areas
- Ecosystem management approach at landscape level is crucial
- Efforts are needed in
  - involving key experts
  - filling data and knowledge gaps
  - monitoring of long-term environmental changes

Key message 2: **sites**

- Long-term and field-scale experimental manipulation facilities are needed
- Information on ecosystem responses to interactive effects of pressures is crucial
- Efforts are needed in
  - searching ecosystem-level facilities
  - operating long-term experimental sites
  - implementing flexible experimental platforms

Key message 3: **technologies**

- Standardized technology for collection and transmittal of measurements are needed
- Near real-time access to environmental sensor data from core sites is crucial
- Efforts are needed in
  - using dynamic ecosystem models
  - applying data quality assurance procedure
  - exchanging, handling and storing data openly

Key message 4: stakeholders

- Participatory approach, through a sustained dialogue between actors, is needed
- Involvement of local forest managers and regional authorities is crucial
- Efforts are needed in
  - sharing assessment plans
  - including local expert partners
  - promoting modularity and flexibility

Starting point: Criteria of sustainable forest management

Criteria characterise or define the essential elements or set of conditions or processes by which sustainable forest management can be assessed (MCPFE, 1998). There are 6 criteria in the Pan-European set:

- ✓ Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles
- ✓ Maintenance of Forest Ecosystem Health and Vitality
- ✓ Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood)
- ✓ Maintenance, Conservation and Appropriate Enhancement of Biological diversity
- ✓ Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably soil and water)
- ✓ Maintenance of other socio-economic functions and conditions

Forest management *vs.* climate change: adapation, increment of the resilience and of the productivity

Natural or near-natural forests (native species, natural regeneration, long rotation)

- Species (mixed *vs.* monospecific), more resistance and resilience
- Structure (multilayered *vs.* monolayered), more resistance and resilience
- Continuous cover (reference disturbance regime)
- Appropriate stocking volume (not too less, not too much)
- CWD and legacies (biodiversity and resilience)
- Retention, forest reserves and ageing islands

Productive forest land (native or exotic species, artificial regeneration, short rotation)

- Productivity
- Forest cover
- Rotation
- Mixed

Increment of the forest cover. Afforestation, reforestation, restoration, rehabilitation

Satellite data

Simulation modelling

Field manipulation

Upscaling

1000 km

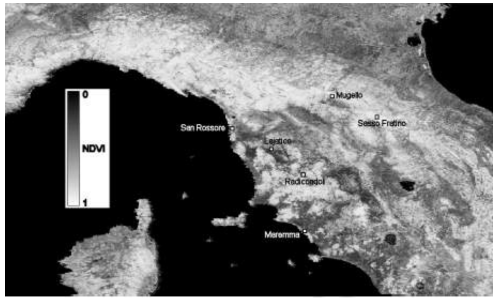
10 km

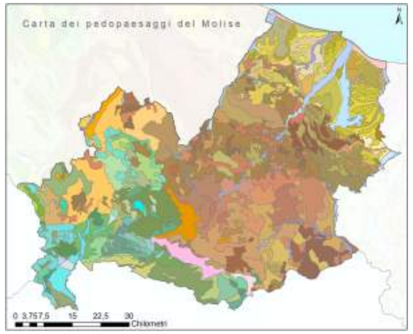
1 km

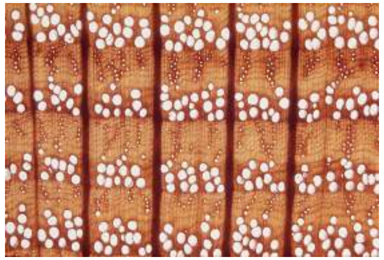
ha

dm

µm





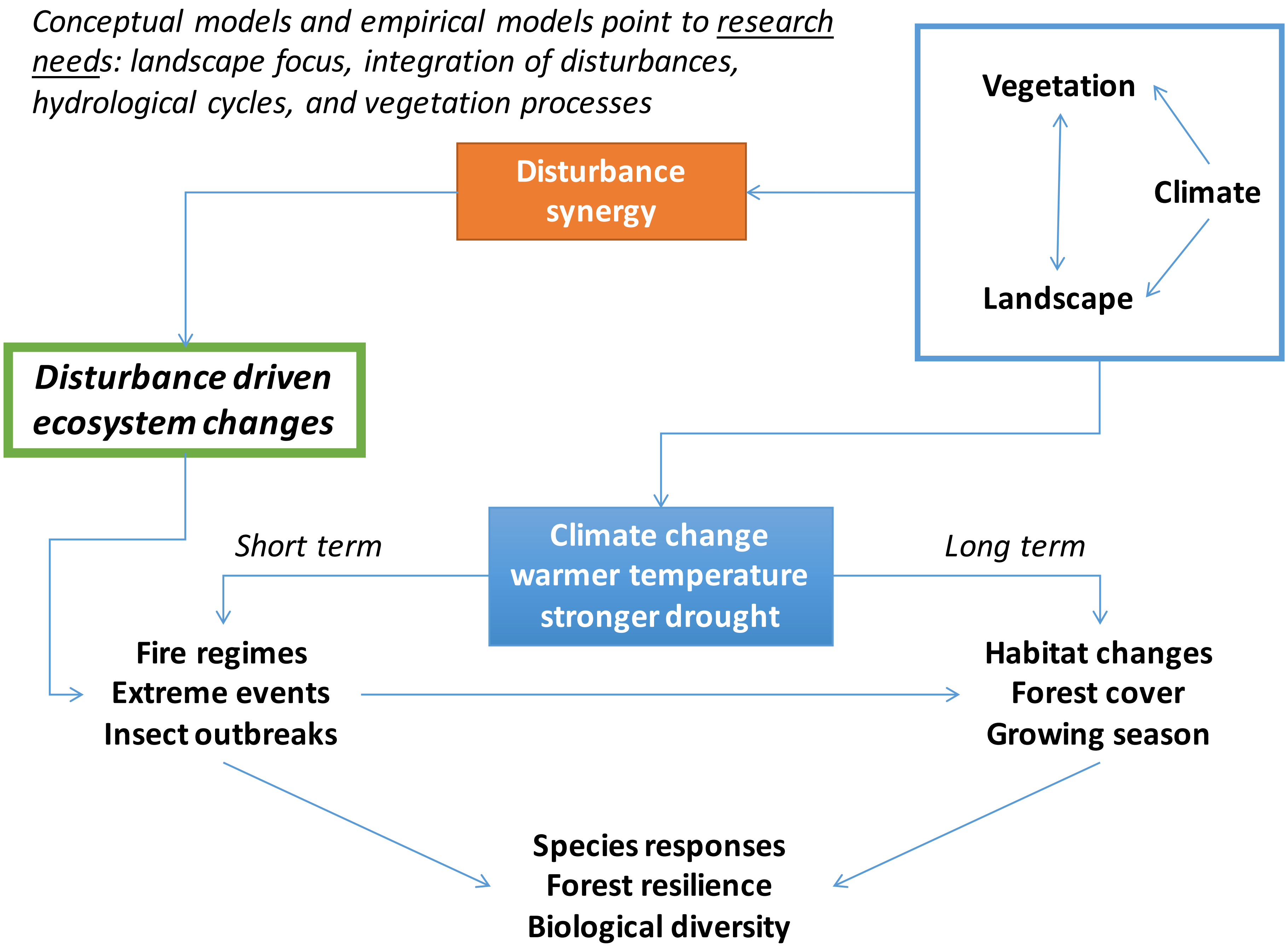


Downscaling

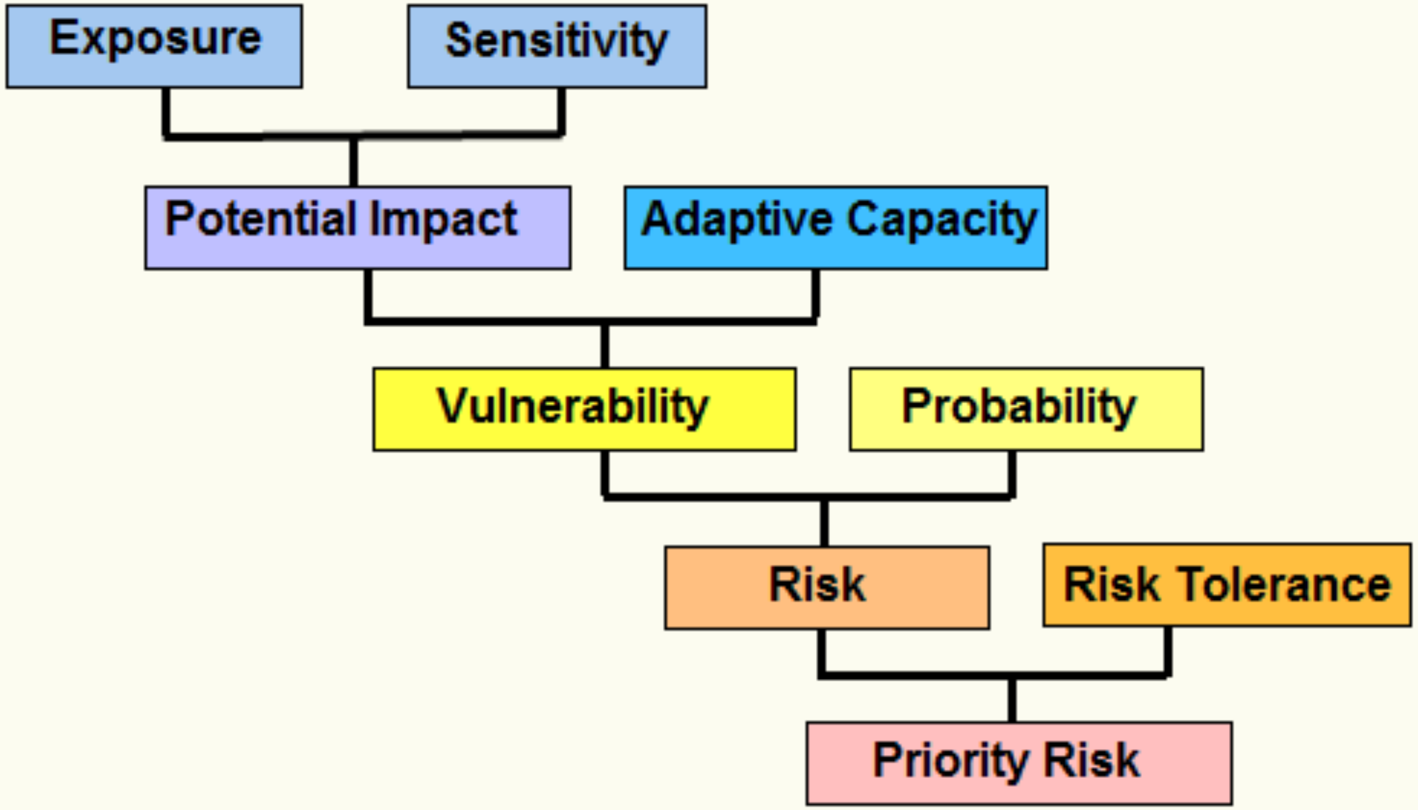
Field observation

Common garden

Controlled environment


Conceptual models and empirical models point to research needs: landscape focus, integration of disturbances, hydrological cycles, and vegetation processes
Disturbance synergy
Vegetation
Climate
Landscape
Disturbance driven ecosystem changes
Short term
Climate change warmer temperature stronger drought
Long term
Fire regimes
Extreme events
Insect outbreaks
Habitat changes
Forest cover
Growing season
Species responses
Forest resilience
Biological diversity

Approach

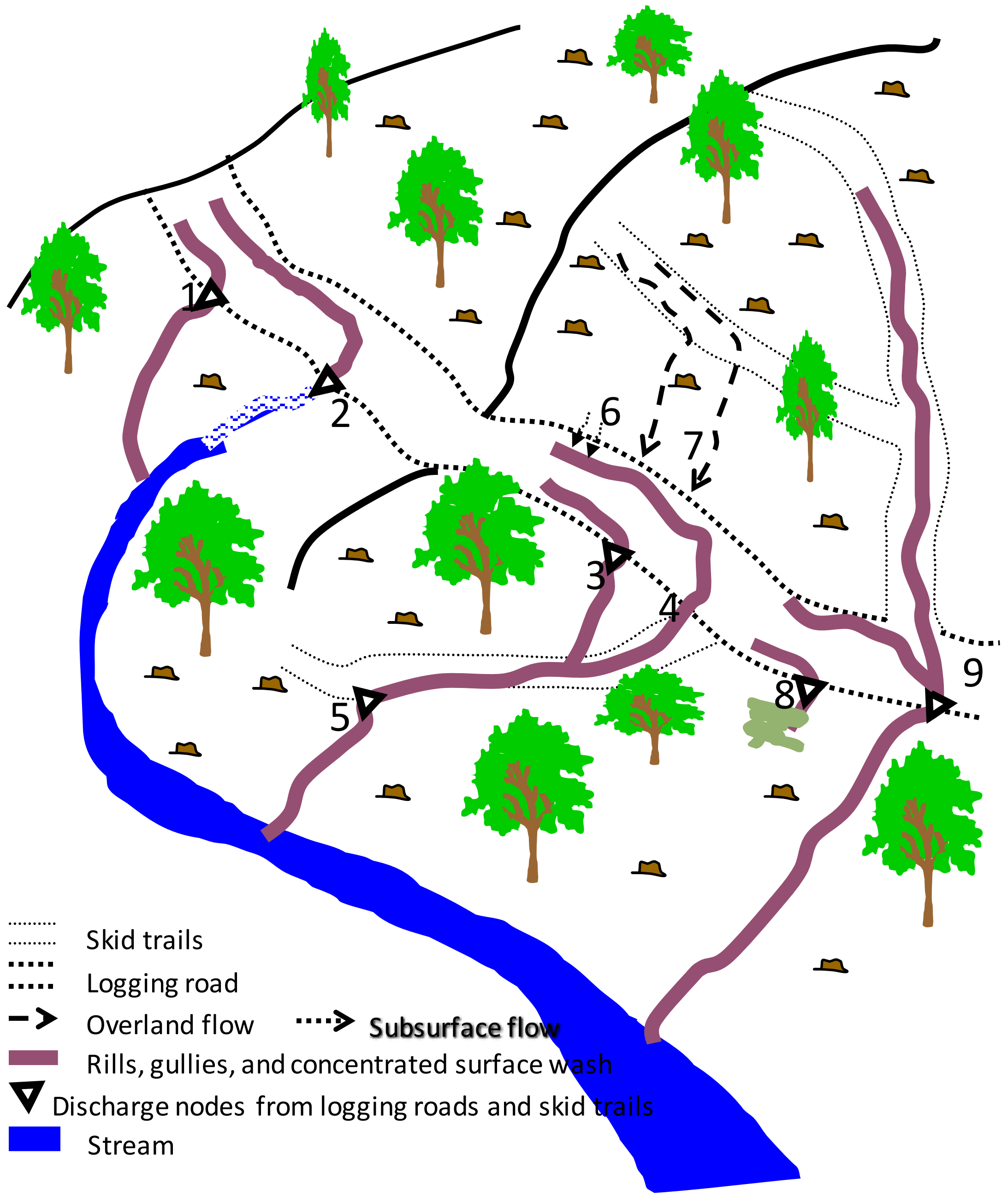


Vulnerability = Exposure x Sensitivity x Adaptive Capacity

Risk = Vulnerability x Probability

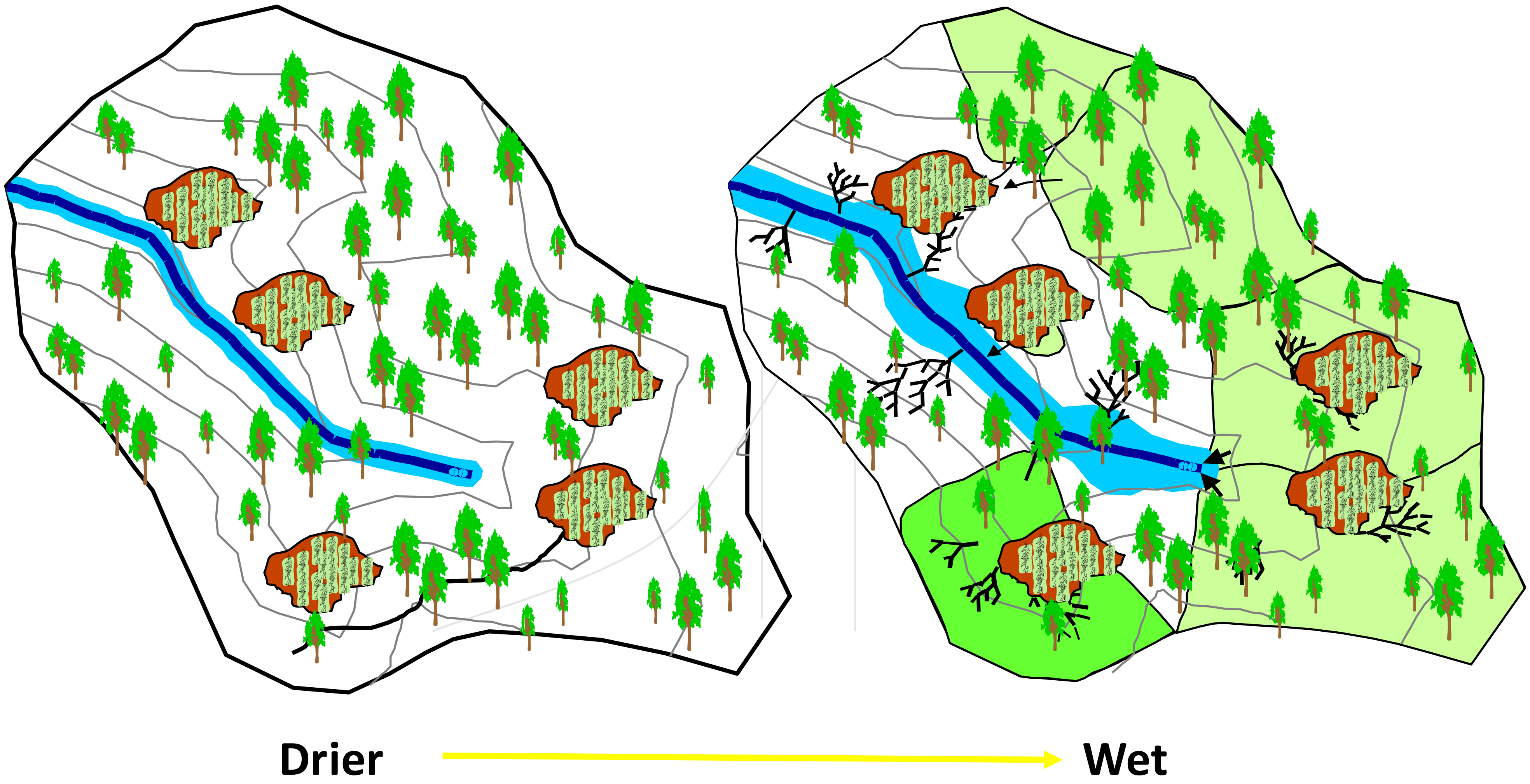
Reforestation can reduce hazard

Forest Management Effects – Roads & Trails



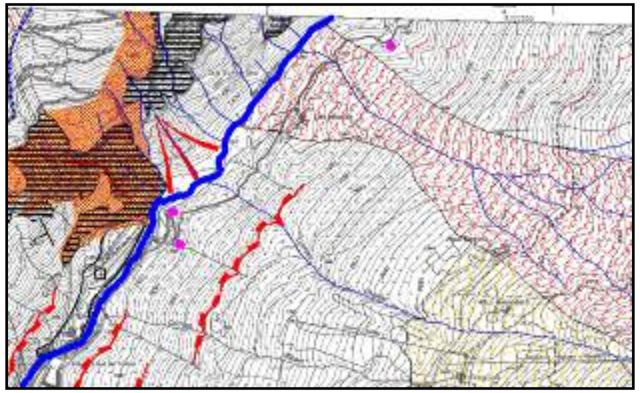
- Connectivity of roads and trail networks is more important than road density in terms of water and sediment delivery to streams
- Runoff occurs from compacted surfaces, but also from water intercepted along cutslopes

Timber harvesting by itself does not have a large impact of storm runoff during wet season events, but when combined with other catchment disturbances…

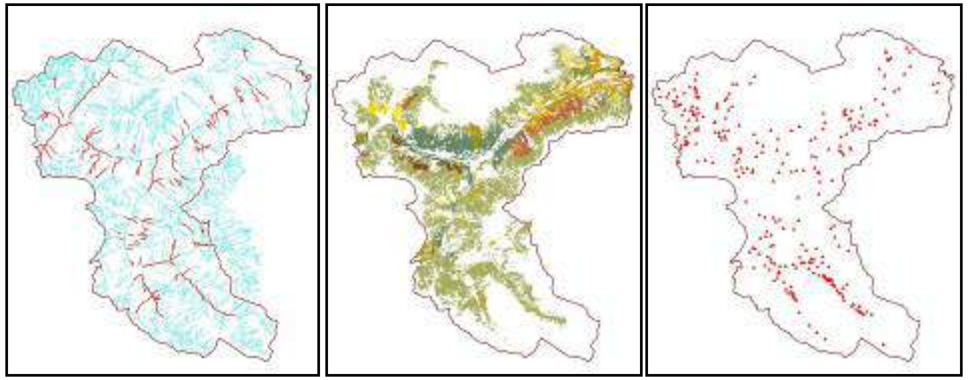


Natural hazard management

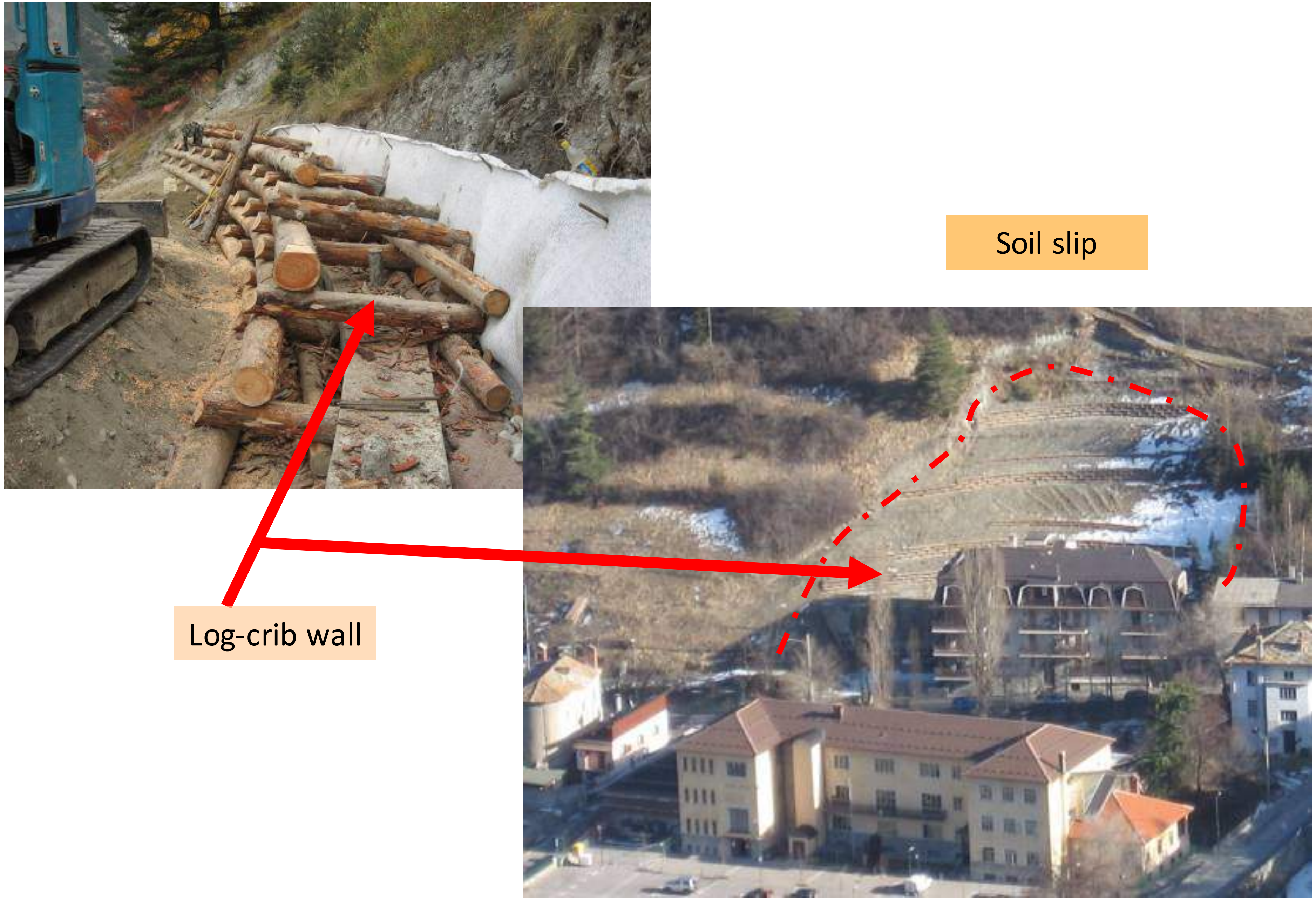
Territorial planning



Scientific knowledge



Risk reduction


Soil slip
Log-crib wall

After three years

development of vegetation within the log crib-wall

insertions willow branches in the defenses with blocks

.... After two years

development of the willows

insertions willow branches in the defenses with blocks

…. After ten years

development of the willows

consolidation of large landslides

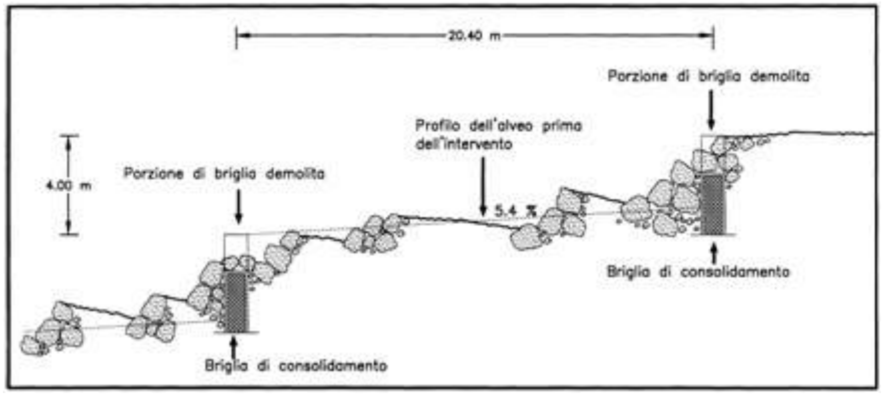
Erosion control with log systems (45°) and drainage systems with stones

log ceck-dams systems for erosion control

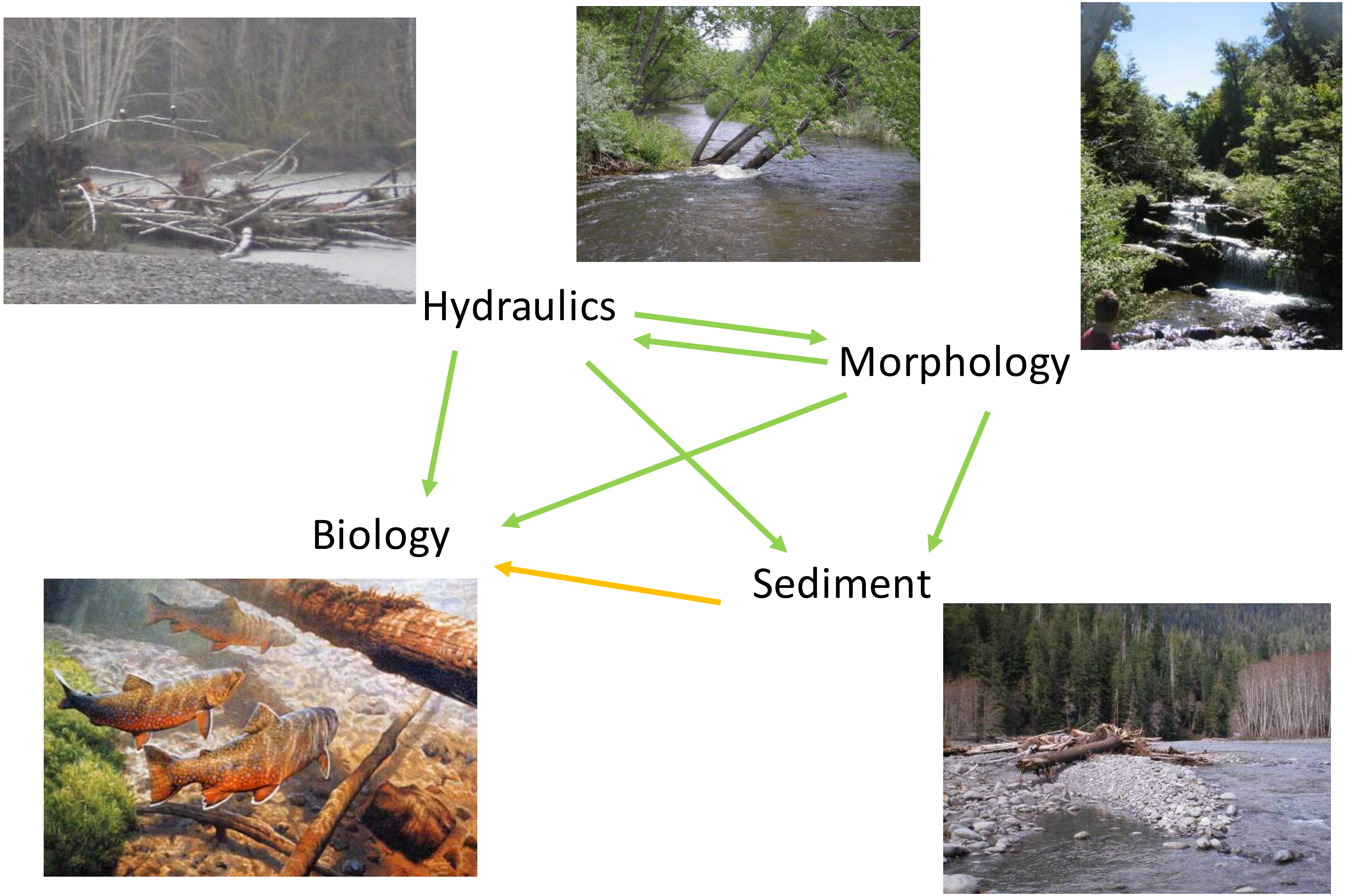
reforestation and revegetation

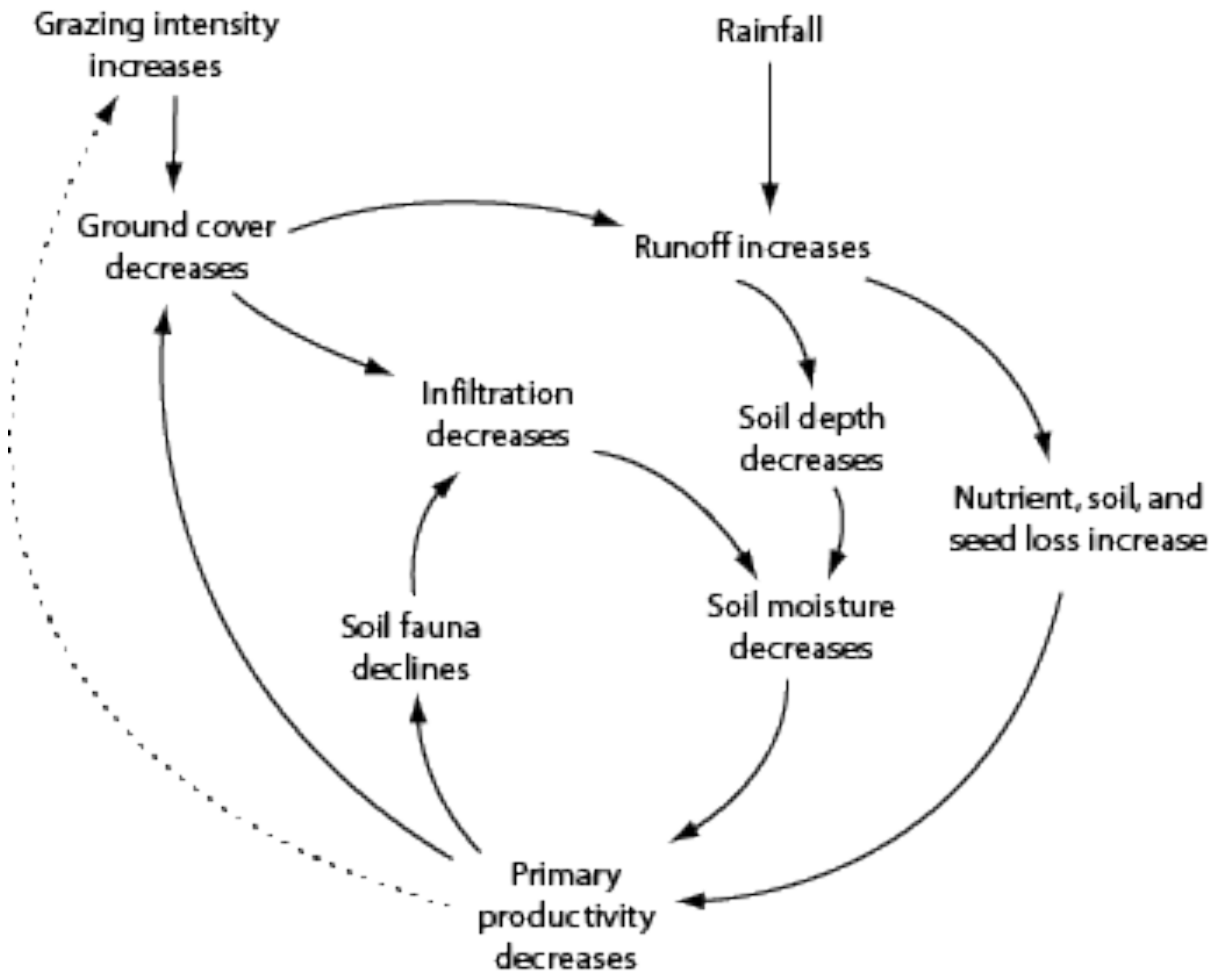
Low impact defense constructions

Morphological restoration

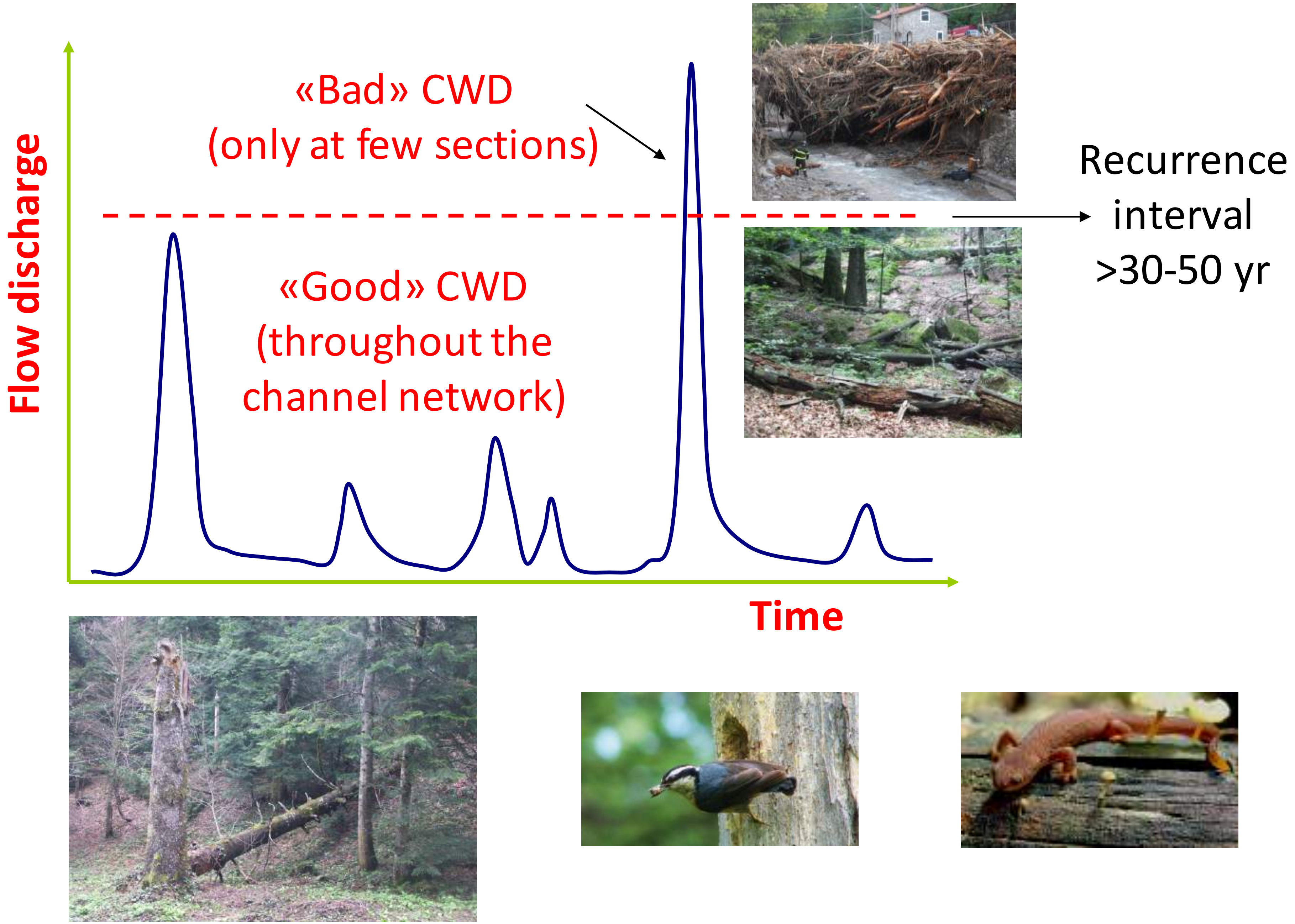


Vegetation and dead wood in rivers: good

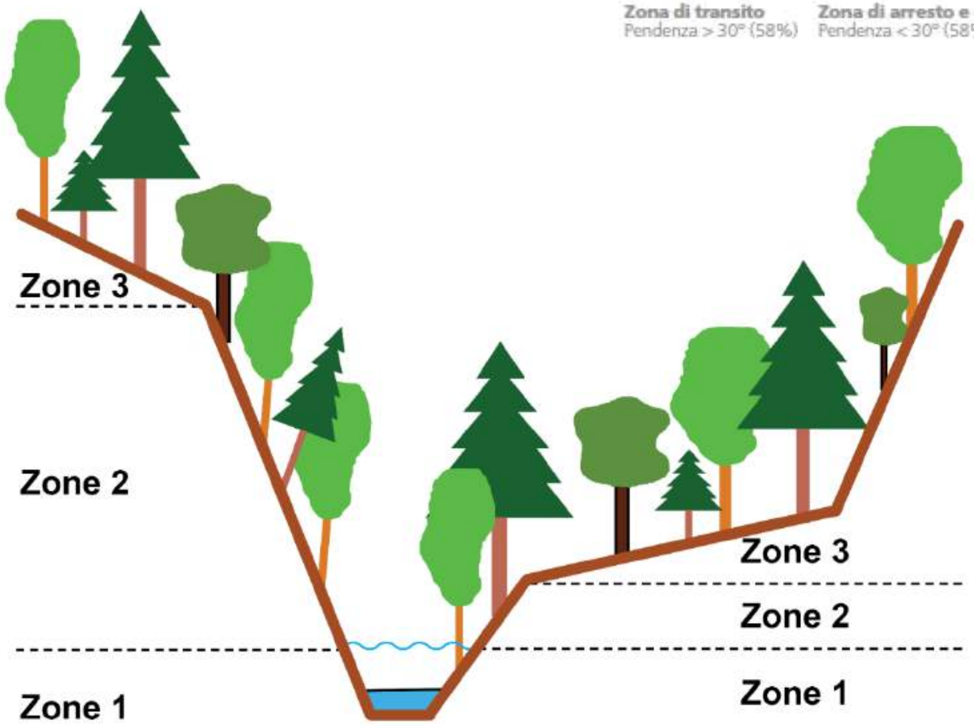



Grazing intensity increases
Rainfall
Ground cover decreases
Runoff increases
Infiltration decreases
Soil depth decreases
Nutrient, soil, and seed loss increase
Soil fauna declines
Soil moisture decreases
Primary productivity decreases

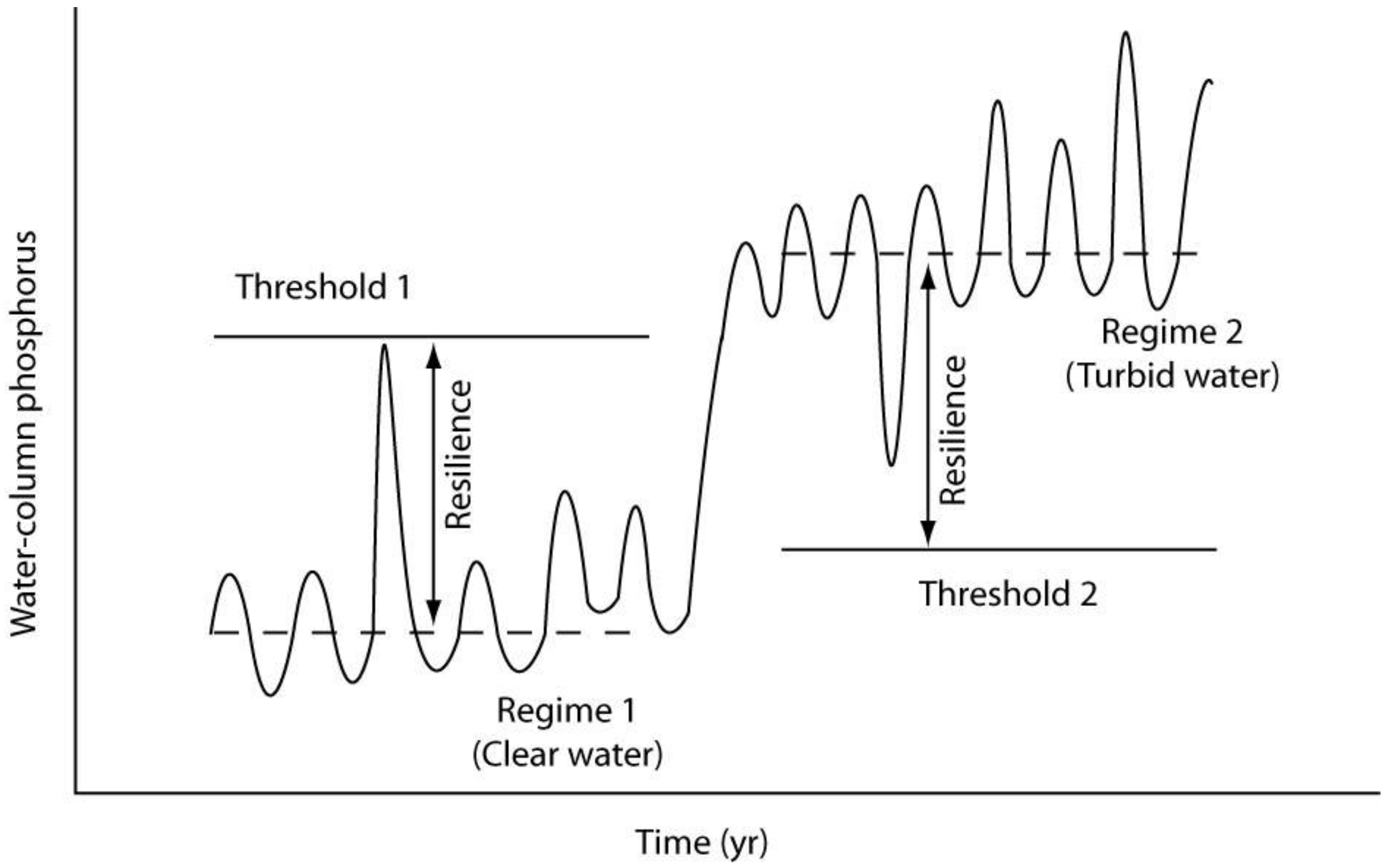
Vegetation and dead wood in rivers: good >> bad



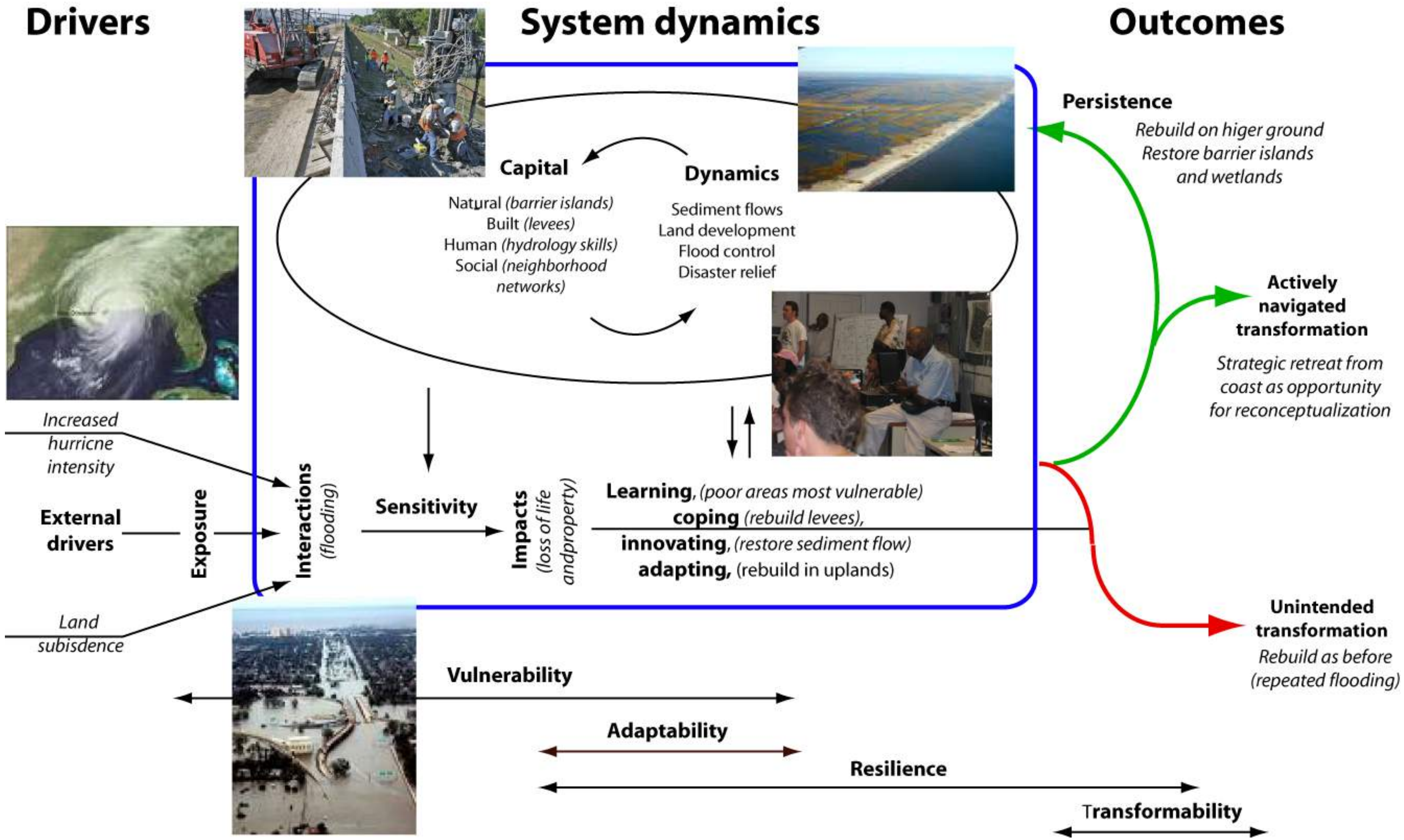
Development of guidelines for silvicultural interventions in protective forests



Resilience: Capacity of a system to absorb disturbances and maintain its structure and function (flexibility)



Hurricane Katrina: The consequences of low resilience



New common agricultural policy 2014-2020 -Rural Development Regulation

Measure 226: Restoring forestry potential and introducing preventive actions (new Art. 25)

- *Continuous forest cover*
- *Maintaining and developing riparian forests*
- *Afforestation of agriculture land*
- *Filter strips, swales, dams, and other sustainable drainage systems*
- *Rainwater harvesting techniques to increase infiltration*
- *Retention (Buffer) Basins and Ponds*
- *Floodplain restoration (i.e. floodplain forests)*

Examples of Natural Water Retention Measures

European Commission

Rural Development

- New programme: Member States need to identify 4 out of 6 priorities.

- Priority 3: Promoting food chain organisation, animal welfare and risk management in agriculture
  - Article 19 Restoring agricultural production potential damaged by natural disasters and catastrophic events and introduction of appropriate prevention actions
- Priority 4 : Restoring, preserving and enhancing ecosystems dependent on related to agriculture and **forestry**
  - Article 26 Investments improving the resilience and environmental value of forest ecosystems
- Priority 5: Promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in agriculture, food and **forestry** sectors
  - Article 35 Forest-environmental and climate services and forest conservation

European Commission

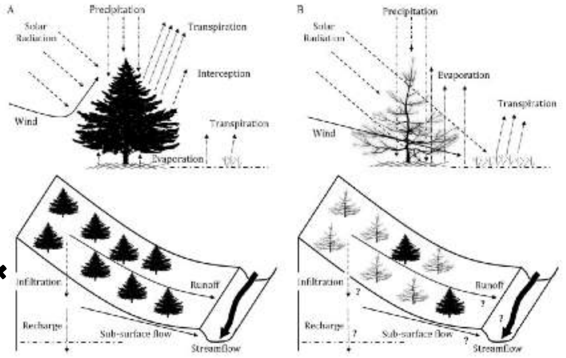
Energy-water nexus: hydrologic cycles interact with radiative forcing

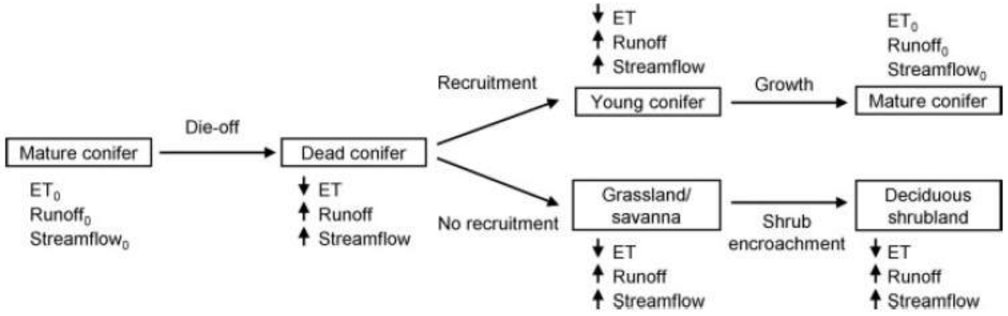
Global warming

Increasing precipitation

Energy-limited forests:
high elevations
wet sites

Increasing drought





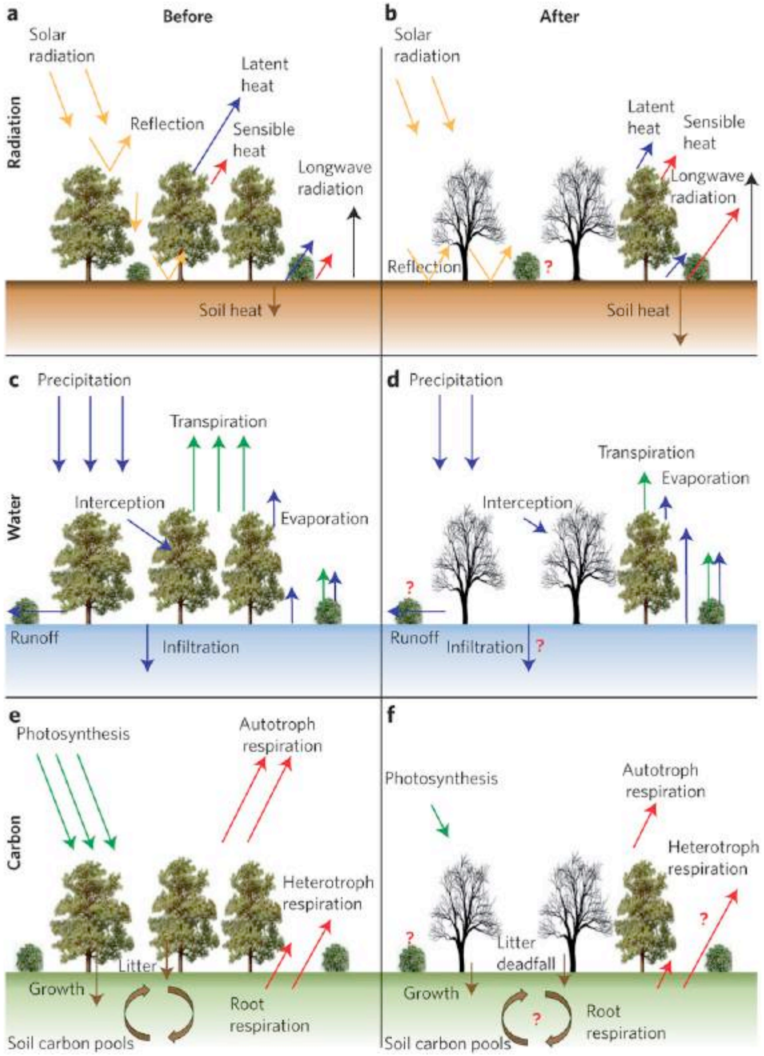
Water-limited forests:
fire-prone ecosystems
dry sites

Adams et al., *Ecohydrol.*(2011)

Increasing temperature

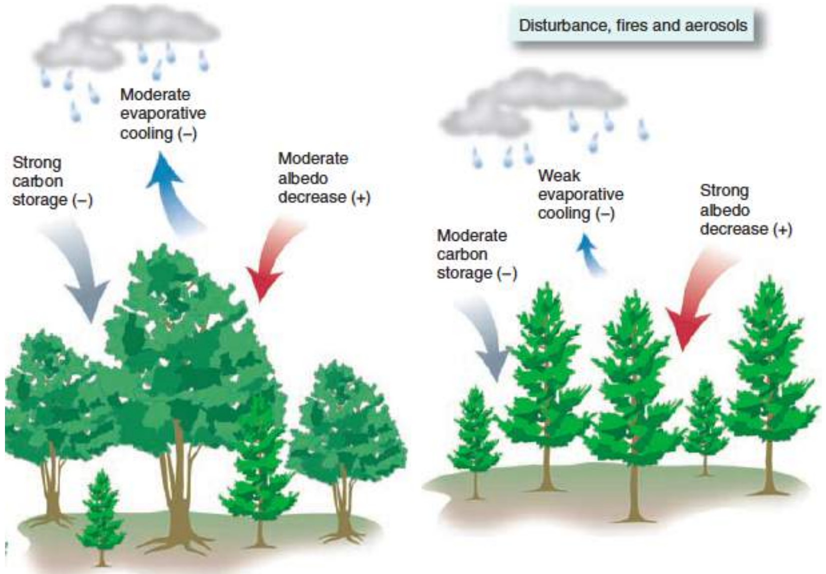
Through albedo, evapotranspiration, the carbon cycle, and other processes, forests can amplify or dampen climate change

Can forest watershed management mitigate climate change effects on water resources?



Anderegg et al., *Nature Clim. Change* (2012)

Bonan, *Science* (2008)



Mixed temperate *vs* boreal coniferous

Thinning and mortality bring along changes at the forest–atmosphere interface (light interception and atmospheric turbulence)
Uneven-aged stand management with drought-adapted, diverse, and resilient species mixtures, to combine forest diversity with timber production

A broadened paradigm: watersheds

- As natural ecosystems...

- .....and as human-made lanscapes

A broadened paradigm: goals

- Conserving ecological balance .....

- .....and managing its processes and perturbations

A broadened paradigm: means

- Hydraulic engineering…

- …..and sustainable land use

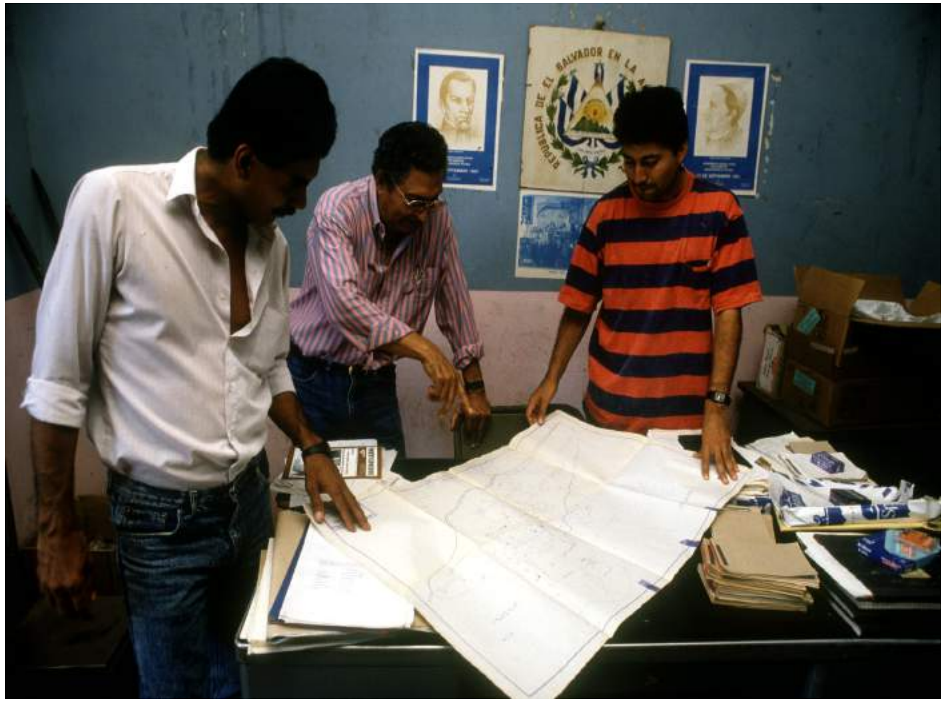
A broadened paradigm : water as an unifying element

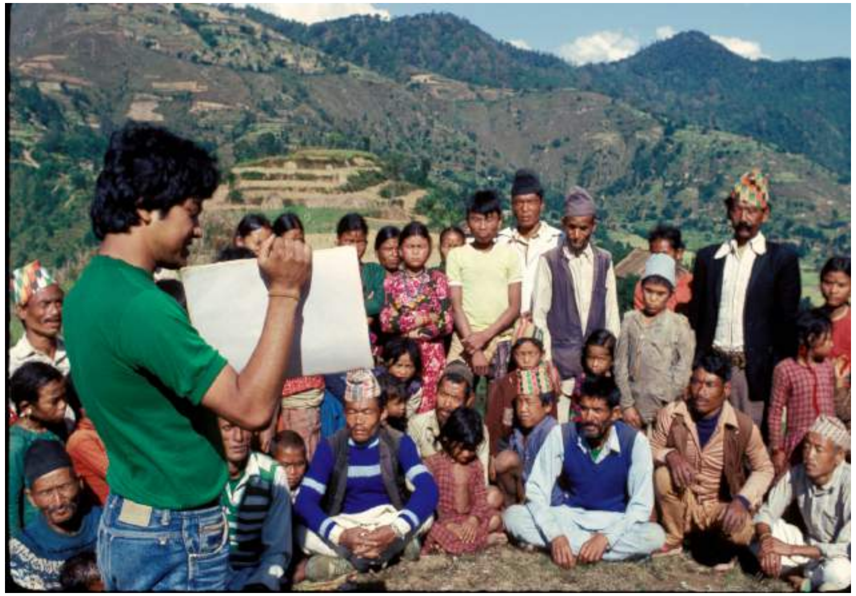
On-site water management….

...to provide water services downstream

A broadened paradigm: social aspects

- Participation from the grassroots….





- …..and involvement of local government and institutions

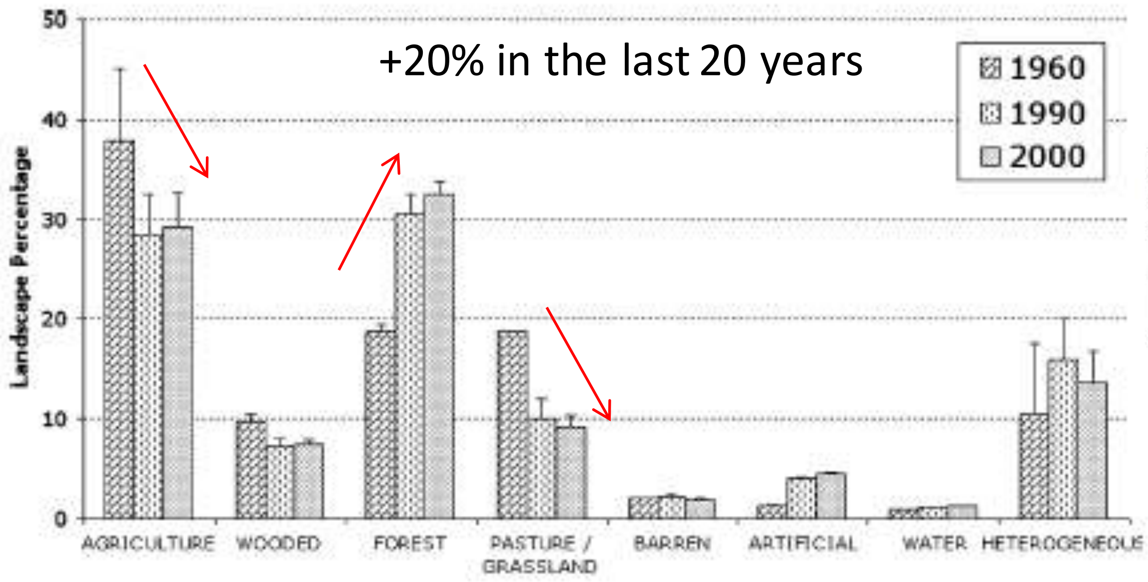
A broadened paradigm: Matters of scale

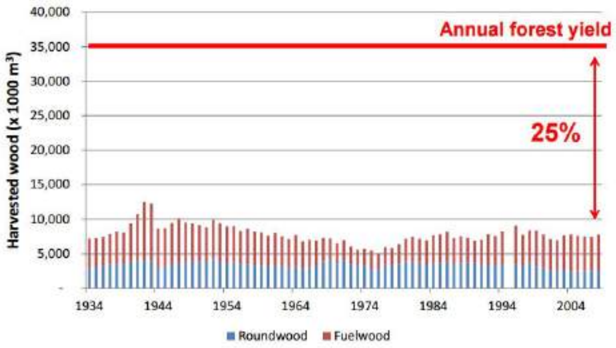
- Working on small watersheds…

- ..keeping in mind that they are part of a river basin

The Italian case: focus on mountain forests

National forest cover	36.2%
Public property	33.9%
Coppice stands	53%
Forest under protection	27.5%
Hydrogeological protection	86.6%
Forest planning	15.7%
Tourists	5.9%
Mountain forests	34.7%
Other woodlands in mountains	16.1%

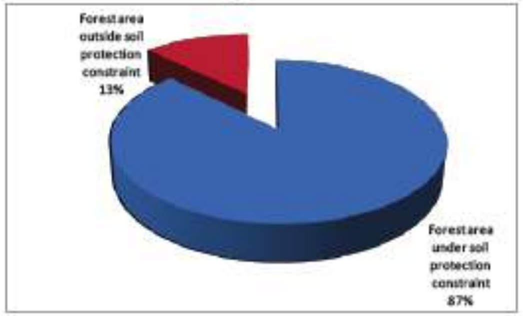




Forest focused and forest related policies

Forest relate policy: **Hydrogeological protection of national territory**

Tool: Law 3267/1923, Law 1126/1926

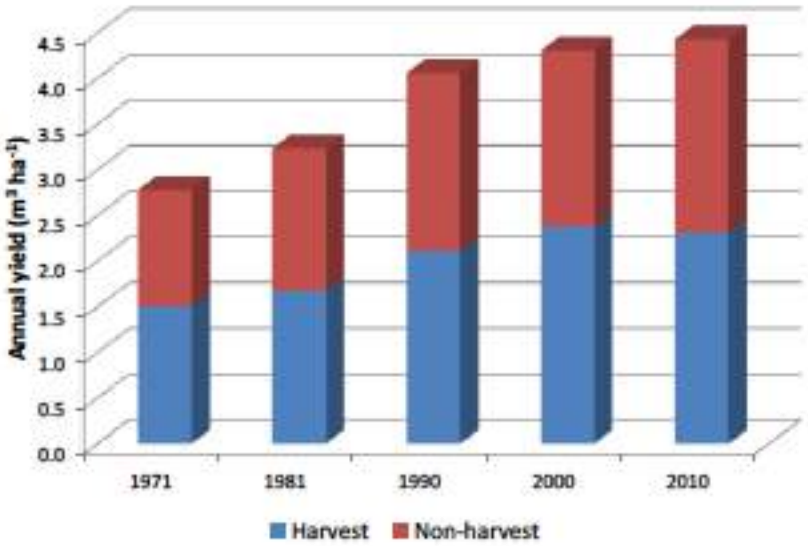


Forest and forest management are seen as tools to ensure soil protection from disaster, erosion and guarantee an orderly flow of metereological water

Terrificante documentazione della catastrofe

Main rules:
- release of plants in the cutting area;
- absolute ban for roots eradication;
- minimum age of the plant s for final cutting;
- absolute ban on the activity of grazing areas used before the natural regeneration has not been established;

Regional specificity - North



‘900

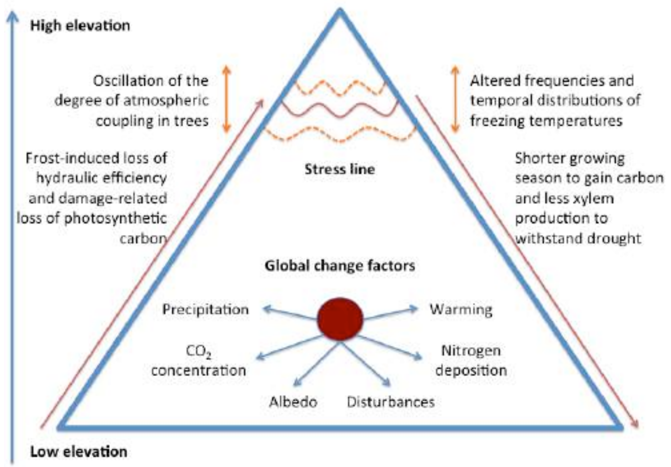
- Artificial forest composition
- Inadequate standing volume
- Poor wood quality
- Low site fertility

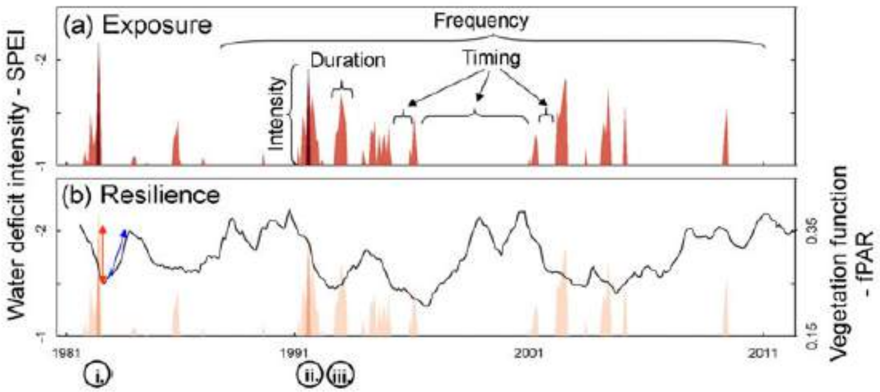
‘000

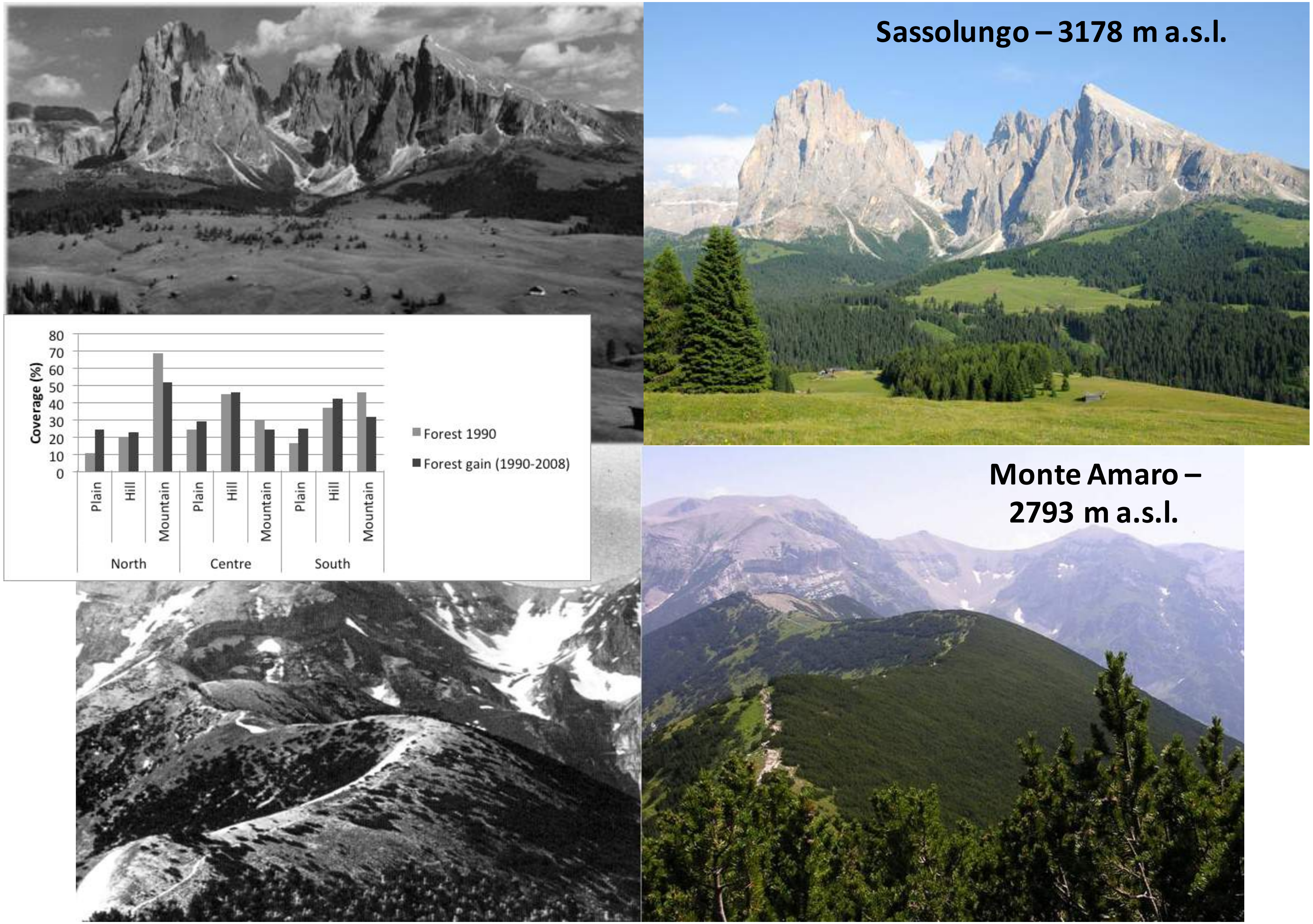
- Innovative forest management
- Increased mixed forests
- Decreased clear cutting
- More natural composition
- Effective forest roads
- Grazing regulation changes

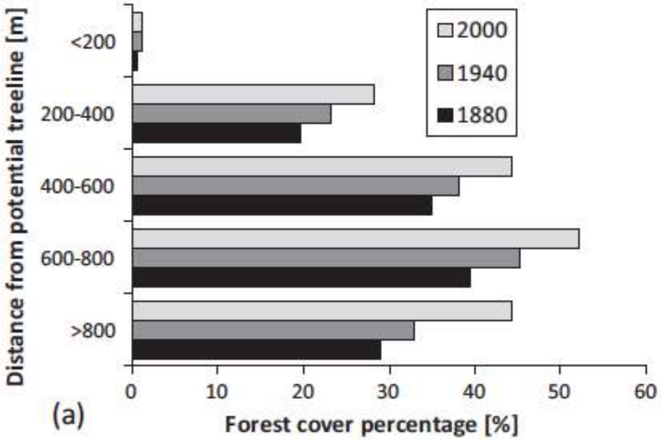
Regional specificity - South

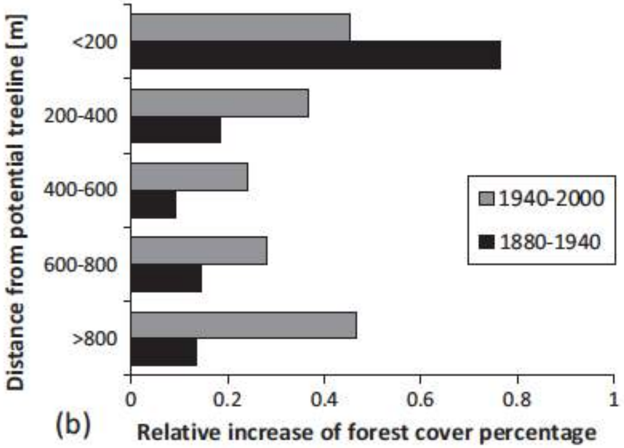
Year	Heavy grazing (transhumance and pastoralism) and cutting	Moderate grazing (pastoralism) and cutting	Low grazing (pastoralism) and cutting	Mountain pine forest cover (ha)	Forest cover class (% of total)
Provinces of Pescara – Chieti – L'Aquila					
1880	Sheep n. > 500000 Inhabitant n. 800000 (126620*)				
1890					
1900					
1910					
1920		300000 < Sheep n. <500000 Inhabitant n. 943000 (125585*)			
1930					
1940					
1950				685 (1954)	I, 24%; II, 37%; III, 39%
1960					
1970					
1980			Sheep n. < 300000 Inhabitant n. 978000 (92521*)		
1990				1196	I, 6%; II, 7%; III, 87%
2000				1327	I, 13%; II, 22%; III, 65%
2010				1409 (2006)	I, 13%; II, 23%; III, 64%
Municipalities of the Majella National Park					
1982			30116		
1990			41143		
2000			31352		
2005			17769		
2008			23081		
2009			14715		

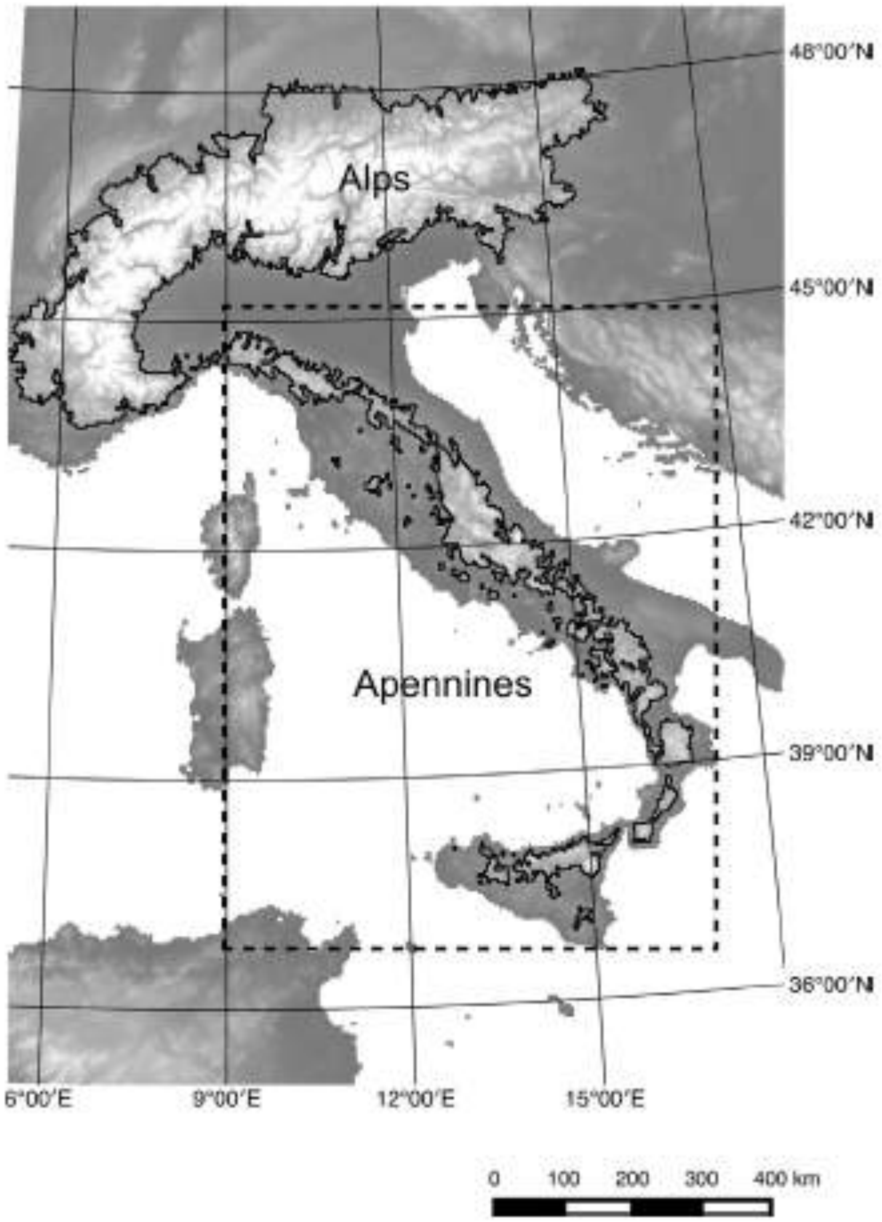




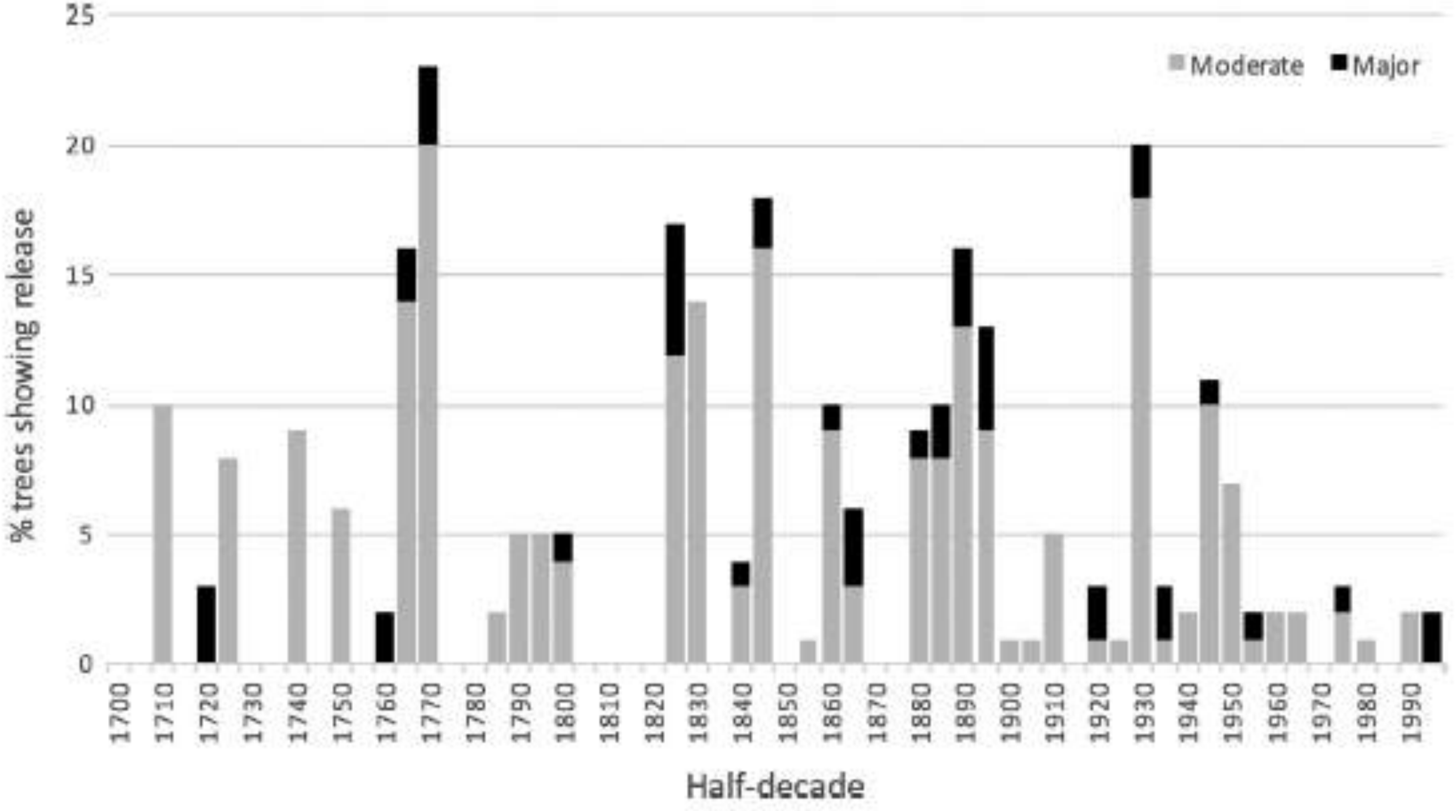

Sassolungo – 3178 m a.s.l.
Monte Amaro – 2793 m a.s.l.
Coverage (%)
80
70
60
50
40
30
20
10
0
Plain
Hill
Mountain
North
Centre
South
Forest 1990
Forest gain (1990-2008)


Distance from potential treeline [m]
<200
200-400
400-600
600-800
>800
2000
1940
1880
0
10
20
30
40
50
60
(a)
Forest cover percentage [%]


Distance from potential treeline [m]
<200
200-400
400-600
600-800
>800
1940-2000
1880-1940
0
0.2
0.4
0.6
0.8
1
(b)
Relative increase of forest cover percentage

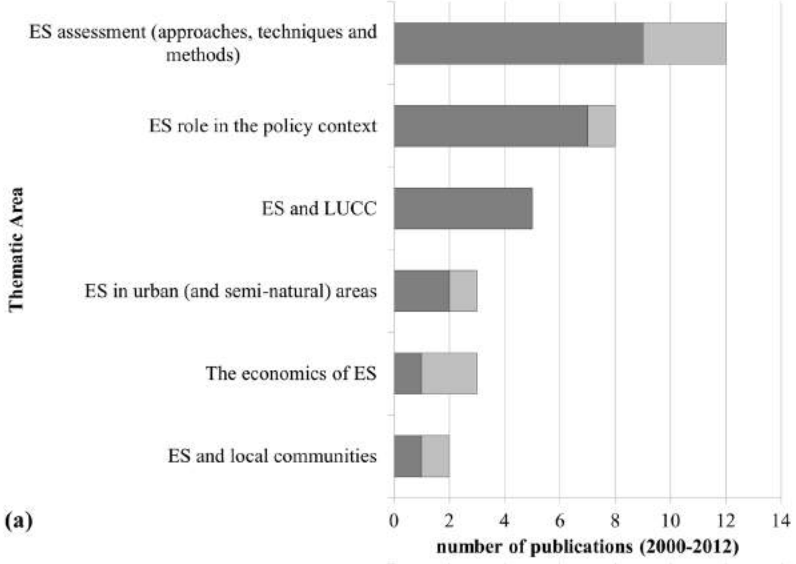


48°00'N
45°00'N
42°00'N
39°00'N
36°00'N
6°00'E
9°00'E
12°00'E
15°00'E
Alps
Apennines
0 100 200 300 400 km



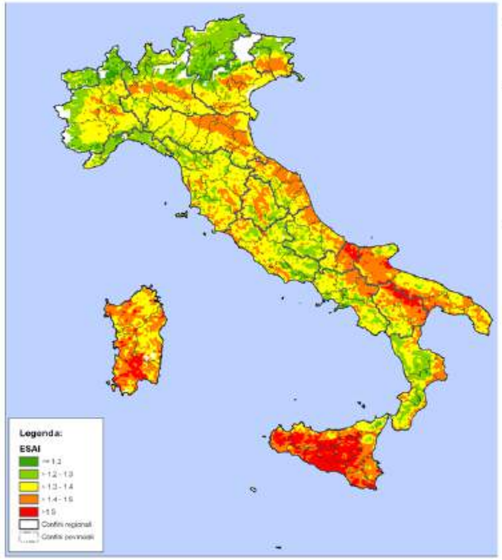
Moderate
Major
% trees showing release
Half-decade
0
5
10
15
20
25
1700
1710
1720
1730
1740
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990

Italy: a territory at risk



Sensitivity to land degradation and desertification in Italy

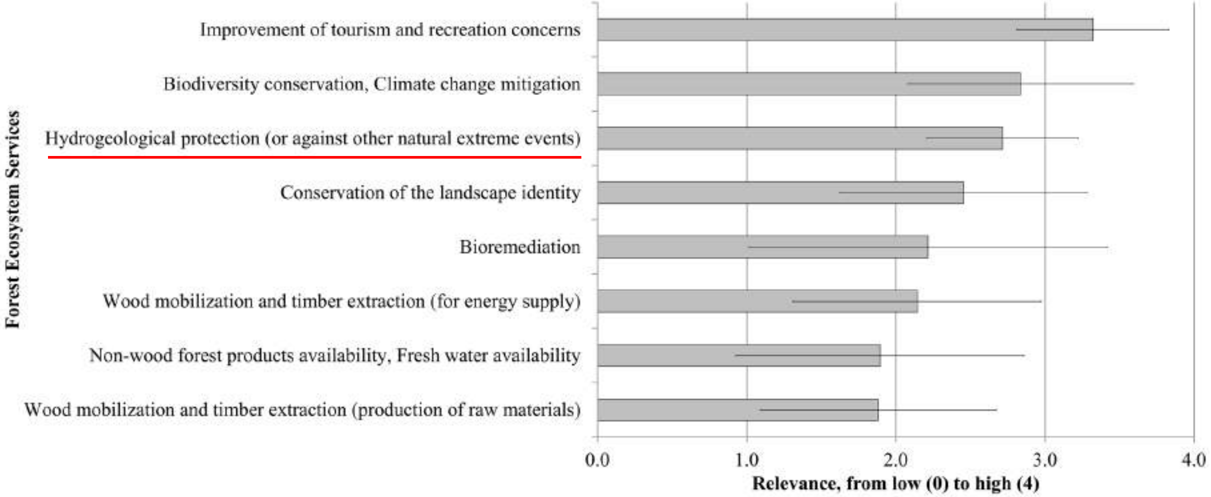
ESAI (Environmental Sensitive Areas Index)



Indice ESAI	Superficie territorio nazionale: ha x 1000	%	Variazione vs. 1990
< 1.2	1865	6	-1.0%
1.2 - 1.3	5968	20	-0.4%
1.3 - 1.4	8083	27	-0.4%
1.4 - 1.5	6754	22	0.7%
> 1.5	3056	10	0.8%
non valutabile	4477	15	-

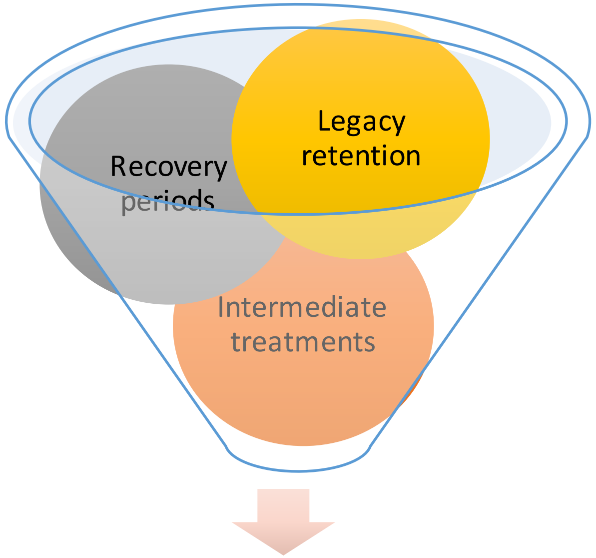
Degradation system	weight
Climate	0.184
Agriculture	0.205
Urbanization	0.144
Erosion	0.185
Pollution	0.140
Salinization	0.142
total	1.000

(Source: L Perini et al., in press)



How to adapt to changes in forest cover and atmospheric circulation?

1. Conservation of forest structures – “reactive”, “no change”
   low adverse impacts of climatic changes, high stand resistance to climatic change, high likelihood to improve stability by silvicultural measures, increasing risk of catastrophic loss
2. Active adaptation – “forward looking”, “proactive”
   introduction of new species/provenances (‘assisted migration’), change of rotation times, stand structure (e.g., tree density), disturbance management, high costs and efforts
3. Passive adaptation – “do nothing”
   no active interventions, use of spontaneous adaptation processes (succession), for forests of low economic (ecological) importance, no measures with better cost-benefit relation



ECOLOGICAL FORESTRY
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http://www.ecogeofor.unimol.it