The potential of in situ- and remote sensing activities to address drought effects on forest ecosystems

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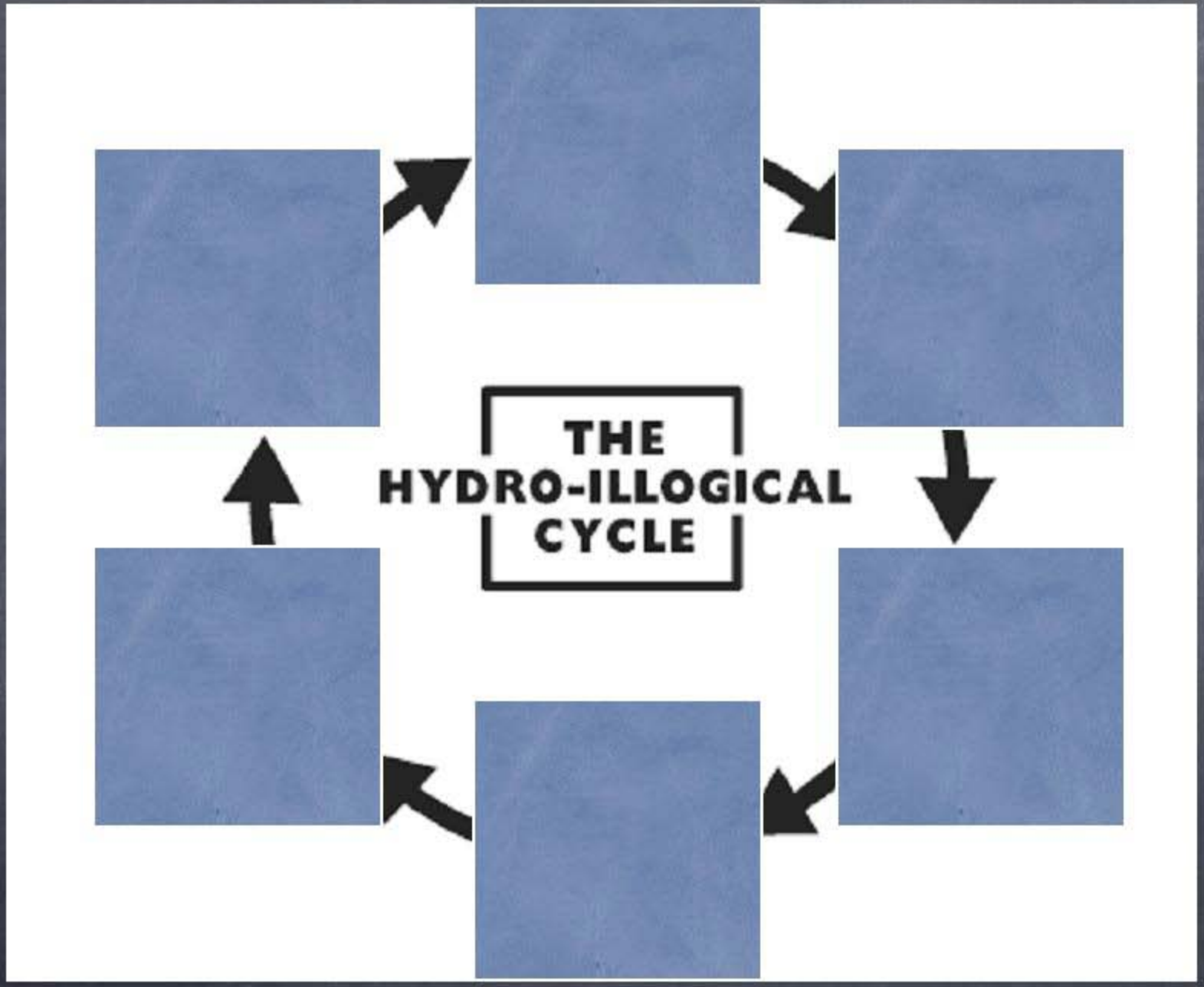
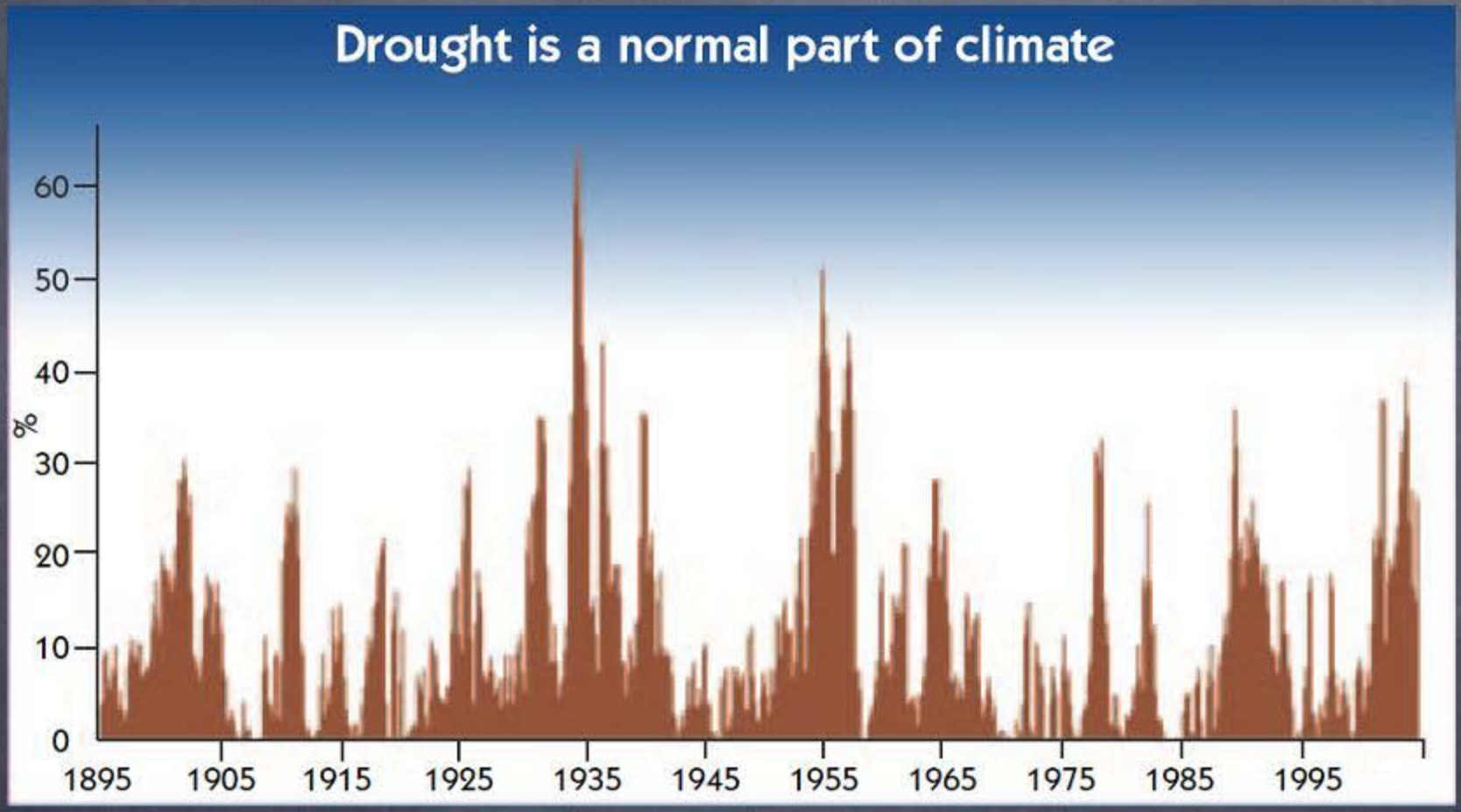
Expected output

- An overview of existing surveillance and monitoring activities, both in situ and remote sensing.
- Stimulus to a greater integration/collaboration of European research, monitoring, modelling, and remote sensing.
- A conceptual framework for a broad-scale early warning system in European forests;

Introduction

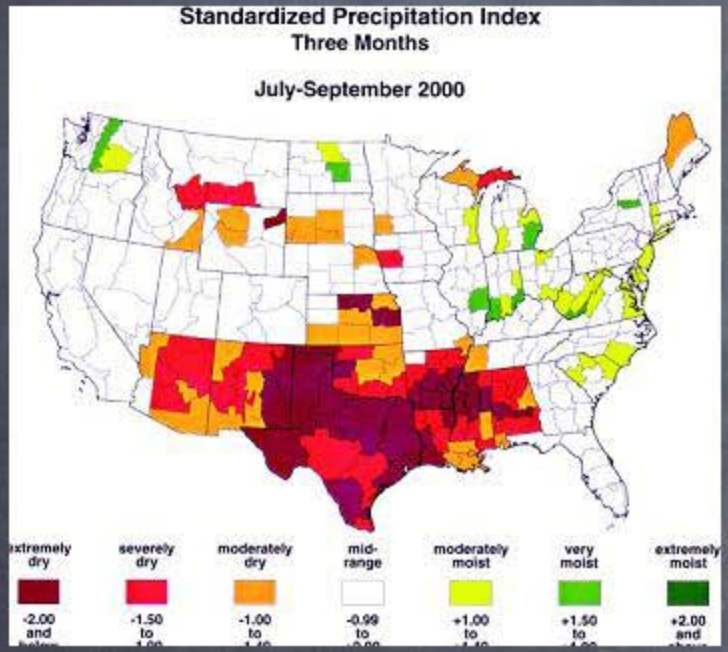


Source: National Drought Mitigation Centre



- it is impossible to make Europe drought-proof

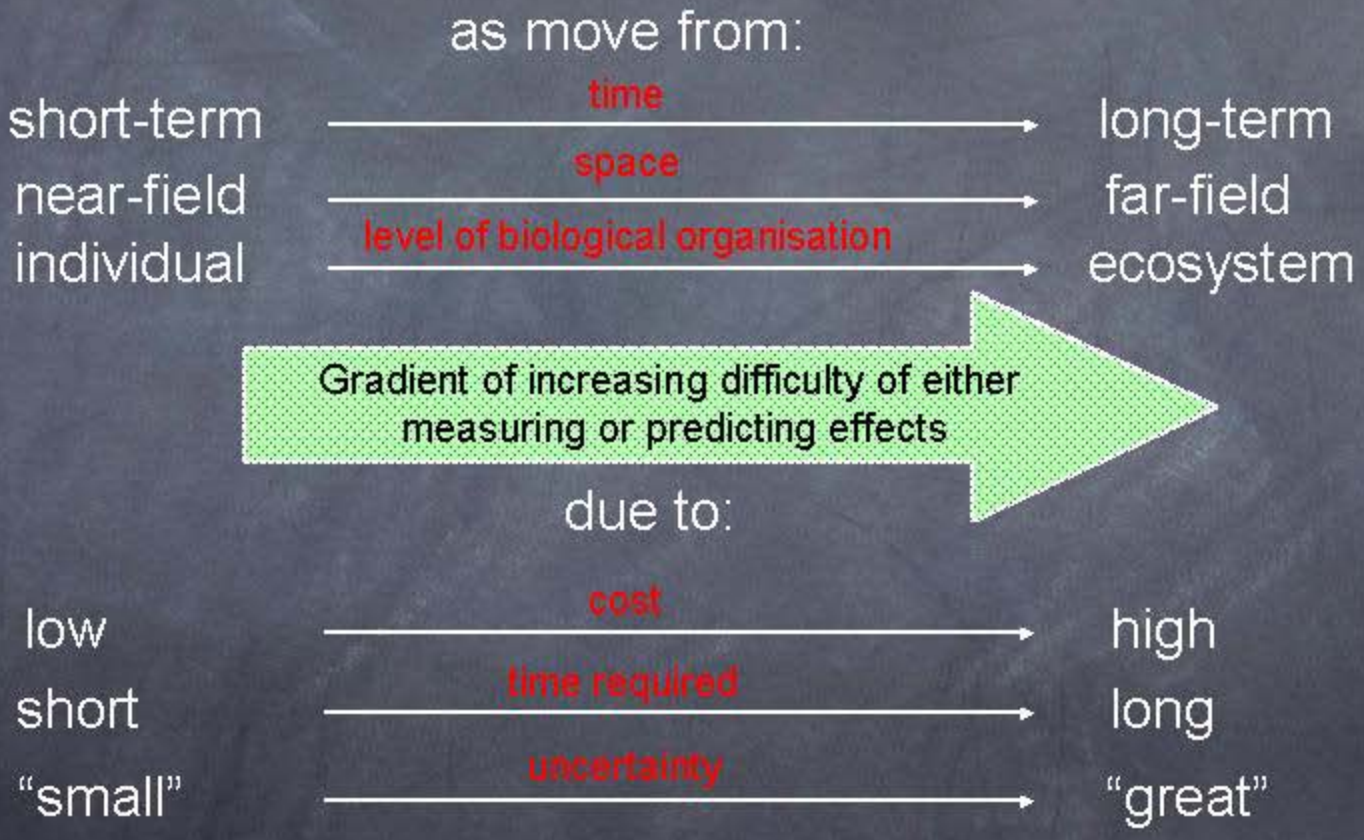
Drought indices



Heim, R.R.Jr., 2002: A Review of Twentieth-Century Drought Indices Used in the United States. Bull.Amer. Meteor. Soc., 83, 1149-1165.

- Palmer's Index (1965) Precipitation and temperature analyzed in a water balance model; comparison of meteo- and hydrological drought across space and time
- Standardised Precipitation Index (1993) Precipitation; allows measurement of droughts in terms of precipitation deficit, at multiple simultaneous timescales with potentially different behavior at all of them
- Vegetation (1995) Satellite AVHRR radiance (visible and near-IR); measures Condition Index "health" of vegetation
- Drought Monitor (1999) Integrates several drought indices and ancillary indicators into a weekly operational drought-monitoring map product (DSS)

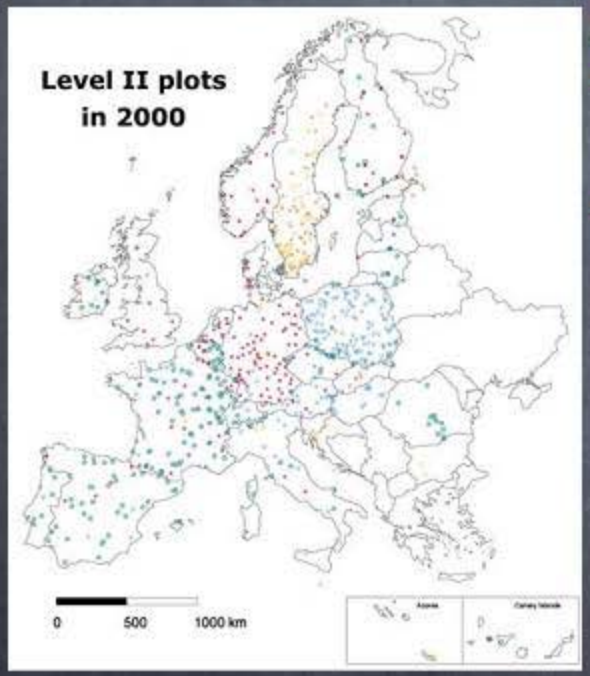
Measuring and predicting ecological effects



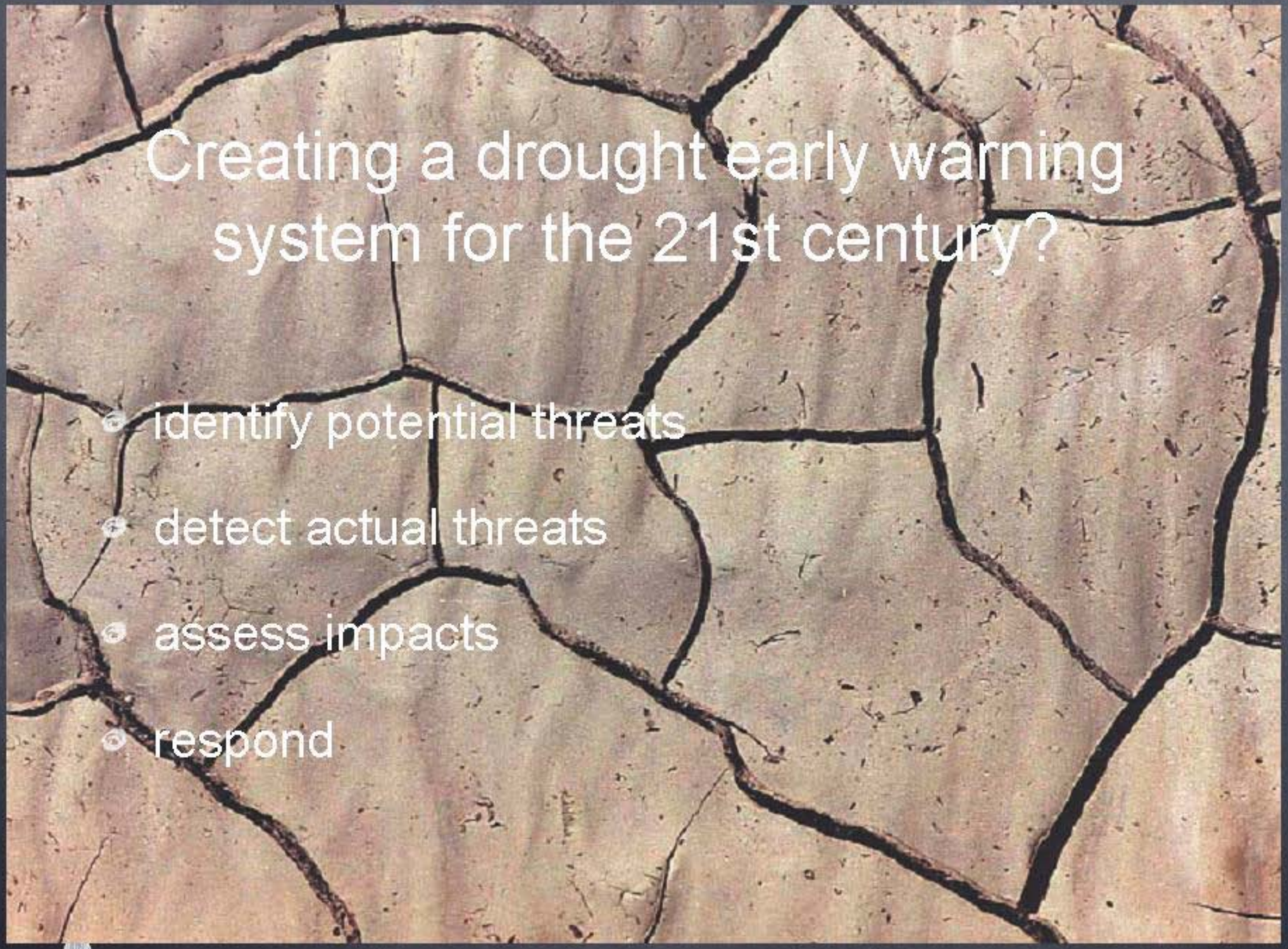
Ongoing activities in Europe

- Intensive sites (e.g., Integrated Monitoring, LTER-sites, sites ateliers) provide process understanding, (e.g., nutrient fluxes, recruitment) but are not applicable at the regional or national level;
- Networks (ICP-level I & II) are generally used for monitoring of large-scale resources such as air or soil and may (e.g., atmospheric deposition) be useful for characterizing regional scale phenomena; and
- Surveys (e.g., national forest inventories), which are often more policy oriented, provide information that can be statistically generalized to regional or national scales

ICP Forests level II monitoring network



- 860 plots
- major forest ecosystems
- surveys:
  - crown condition
  - soil matrix
  - soil solution
  - foliage
  - deposition
  - ambient air quality
  - meteorology
  - forest growth
  - ground vegetation
  - phenology
  - remote sensing


Creating a drought early warning system for the 21st century?
identify potential threats
detect actual threats
assess impacts
respond

Identify potential threats

- identify potential threats to forest ecosystems so that detection activities may be planned
- includes gathering, analyzing and organizing pertinent information to facilitate awareness and detection of potential threats

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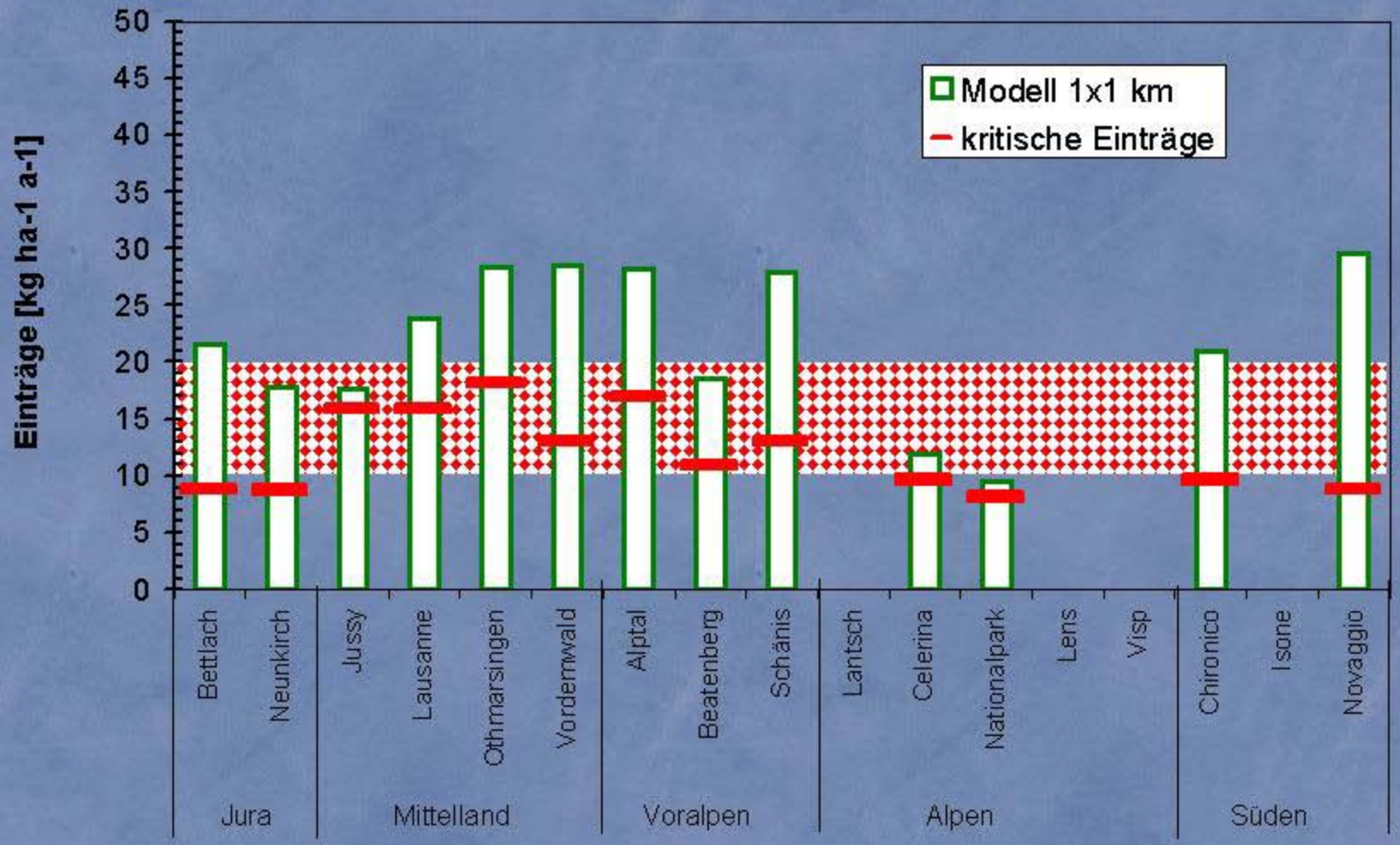
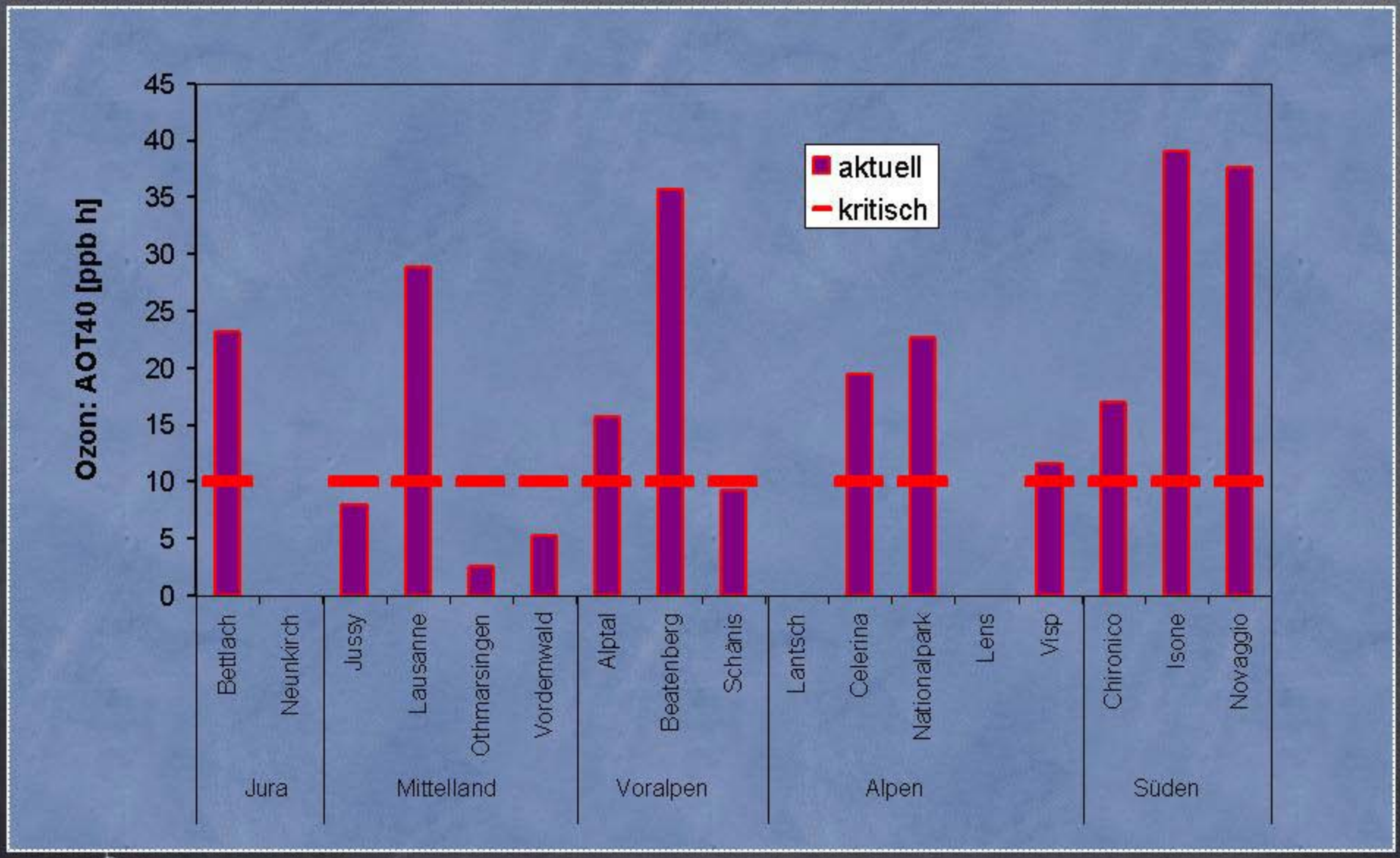
sensitive areas: nitrogen deposition



source: Thimonier et al., 2004

sensitive areas: ozone (AOT40)



Detect actual threats

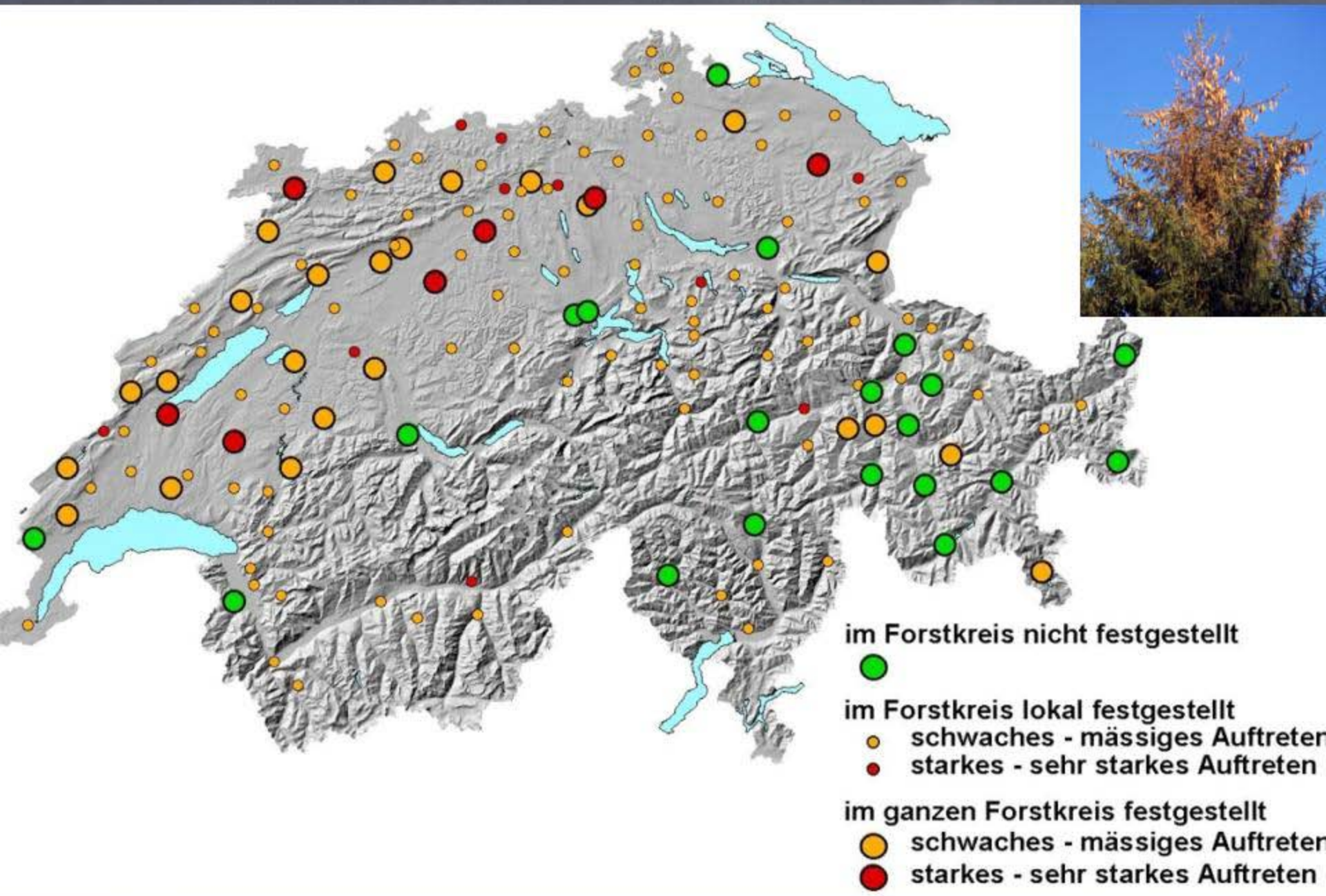
- early detection of any disturbance phenomenon that threatens forest ecosystem functioning

im Forstkreis nicht festgestellt

im Forstkreis lokal festgestellt
- schwaches - mässiges Auftrete
- starkes - sehr starkes Auftreten

im ganzen Forstkreis festgestellt
- schwaches - mässiges Auftrete
- starkes - sehr starkes Auftreten

source: PBMD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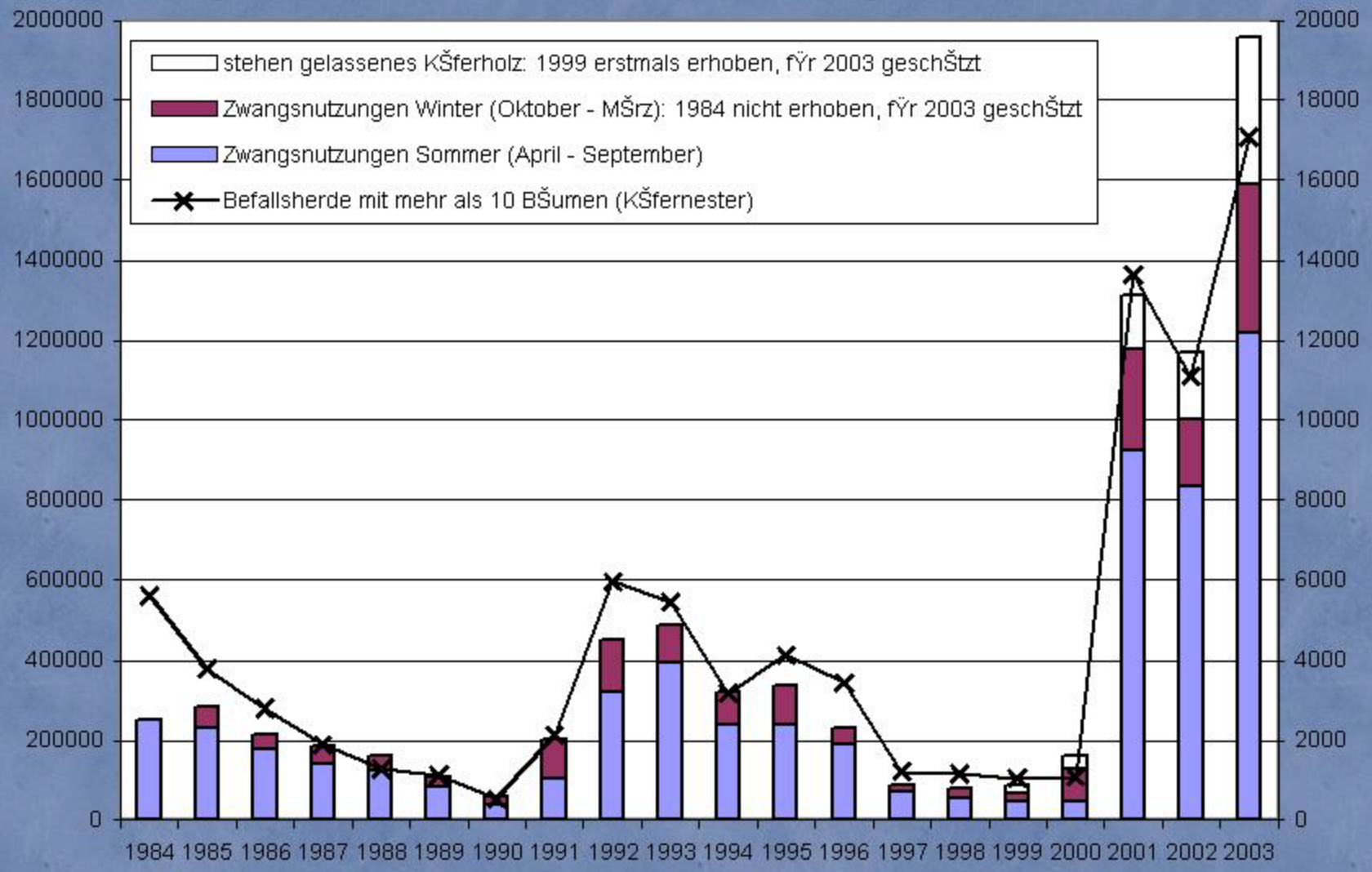
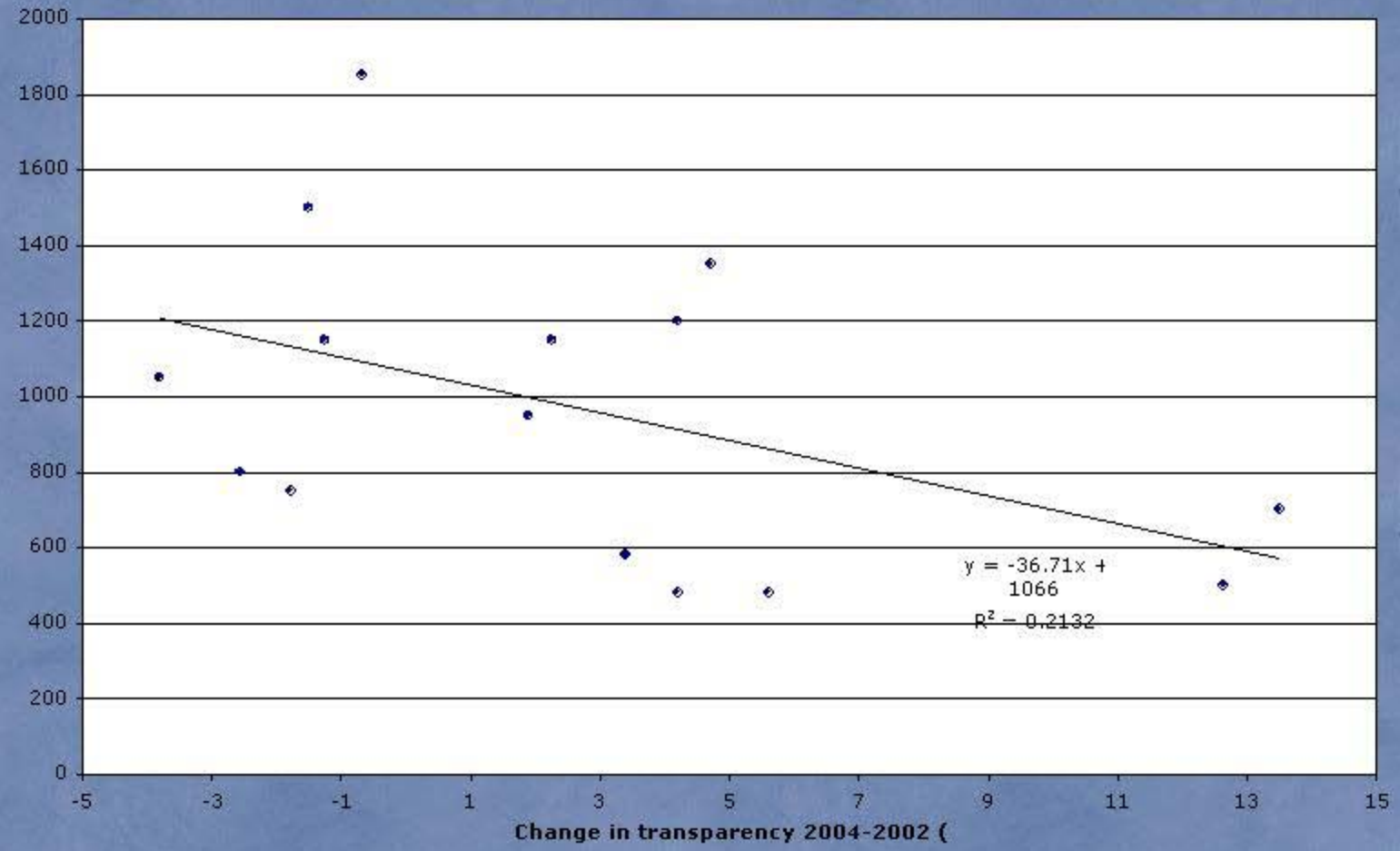
assess impacts

- includes all processes and programmes needed to evaluate potential impacts caused by environmental threats

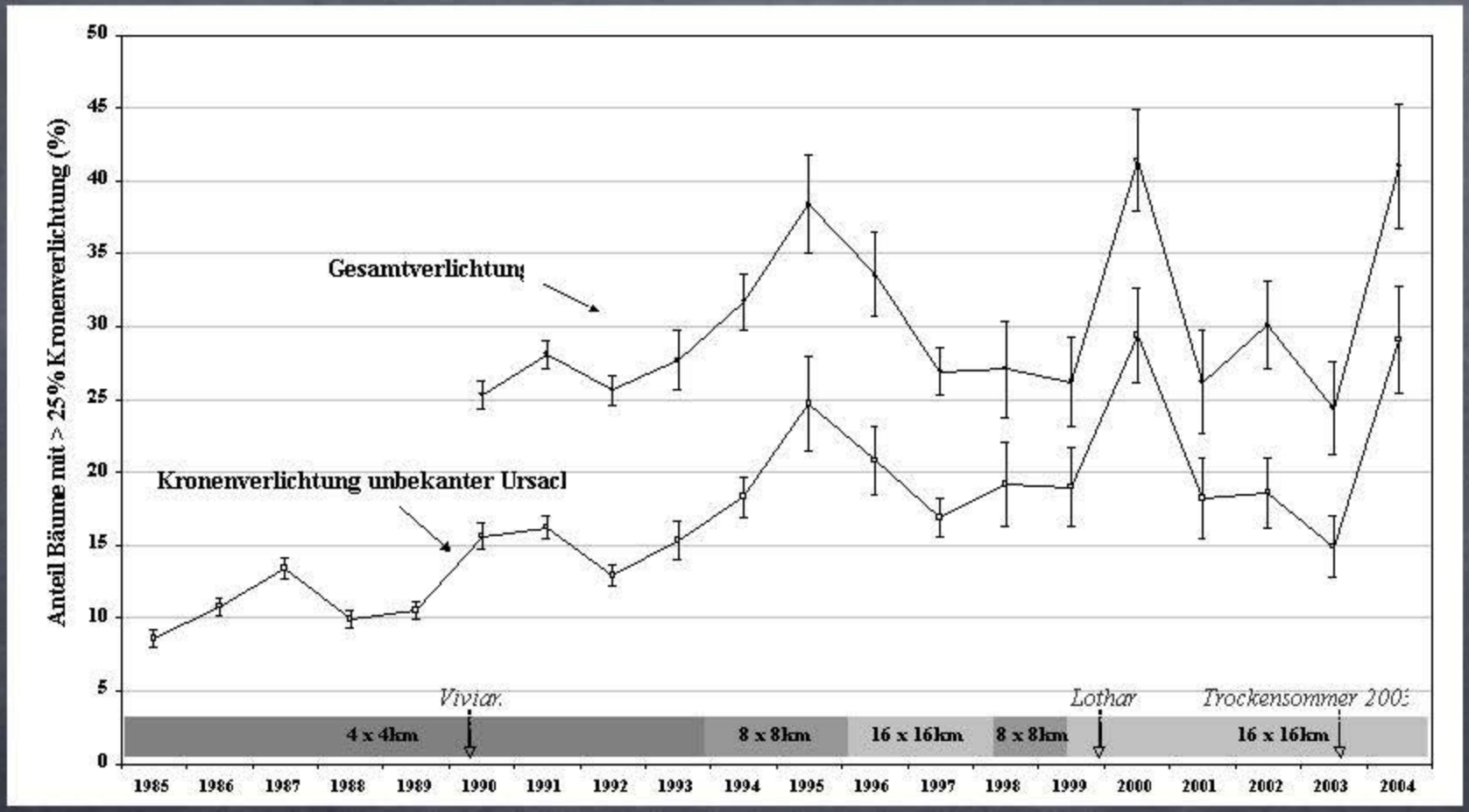

stehen gelassenes KŠferholz: 1999 erstmals erhoben, fŸr 2003 geschŠtzt
Zwangsnutzungen Winter (Oktober - MŠrz): 1984 nicht erhoben, fŸr 2003 geschŠtzt
Zwangsnutzungen Sommer (April - September)
Befallsherde mit mehr als 10 BŠumen (KŠfernester)
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

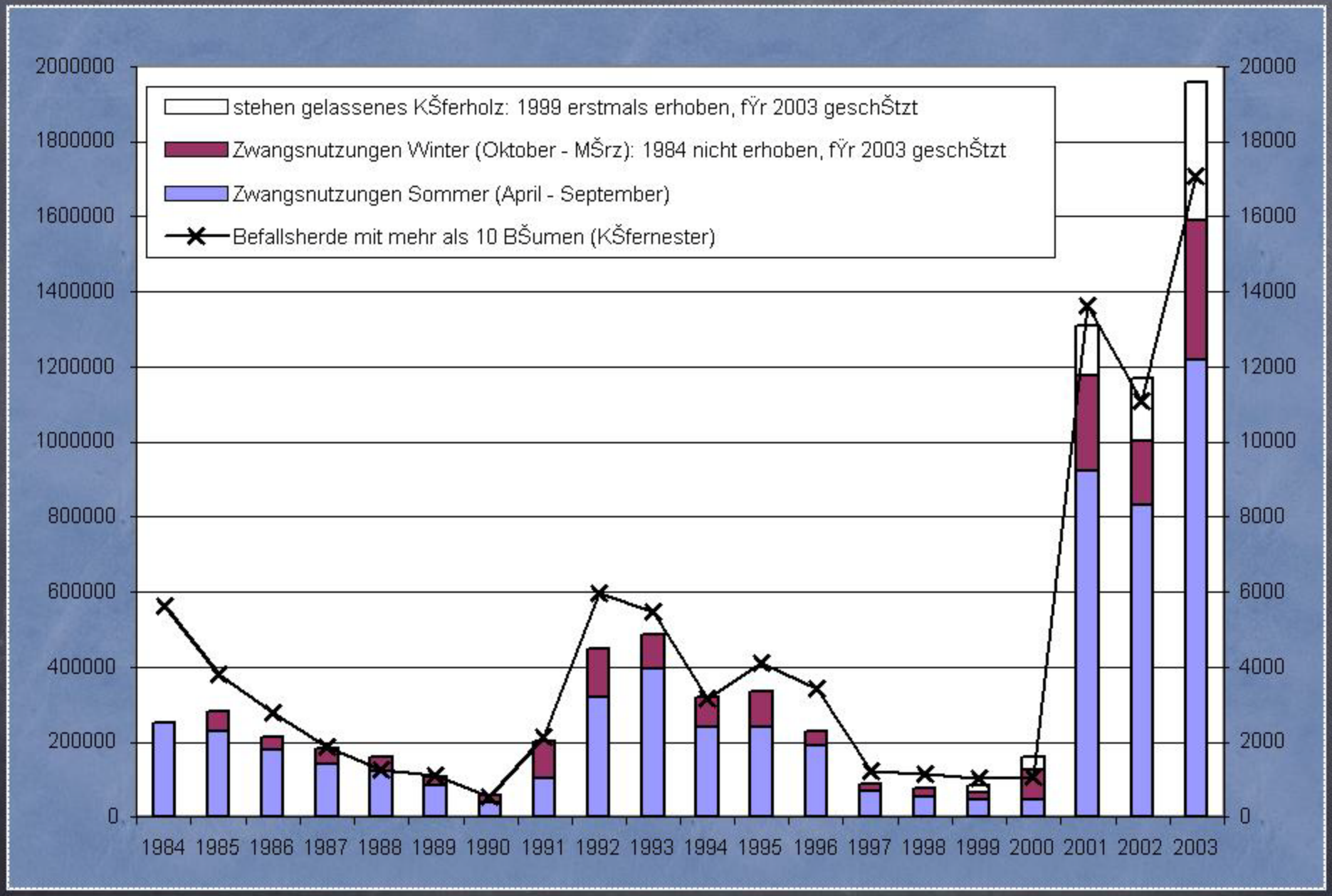
source: PBMD



source: Dobbertin (pers. comm.)

Forest Condition in Switzerland





source: Cherubini et al., 2003

Respond

- timely response and follow up is crucial to prevent or ameliorate unacceptable environmental damage from environmental threats.

Remote sensing

Observation strategy from space for impact monitoring

Observation of forests by remote sensing

- Observation means by remote sensing
  - Air-borne sensors (aerial photography) : analogical or digital data
  - Space-borne sensors (satellite sensors) : digital dataset
  - Remote sensing data need ground-based measurements !
    (for validation, model assimilation, error mitigation…)
- What can we measure from airplane and satellite ?
  - Monitoring indicators on crown conditions
    - Chlorophyll content, foliage deficit, crown structure, mortality…
  - Monitoring indicators on canopy functioning
    - Phenology, water stress, soil moisture, biogeochemical cycles, energy and water fluxes with atmosphere

Monitoring forest indicators on crown conditions from remote sensing

Spectral domain

Visible, Near Infrared (NIR), Short Wave Infrared (SWIR)

Observation mean

Large scale aerial photography Very High Resolution Spatial Sensors	>1:10,000 < 1 m		Tree
Medium scale aerial photography	<1:10,000		
High Resolution Spatial Sensors (SPOT/HRV-HRVIR-HRG, Landsat TM+,...)	5-30m		Stand

Monitoring forest indicators on crown conditions from remote sensing

- Region to Europe
  - Intensification of extensive monitoring ground networks (ICP Level I, …):
    - Spatial interpolation: Improvement of forest inventory accuracy
    - harmonisation of nomenclature, sampling optimisation: regional compatibility
- Local (forest stand) to region
  - Spatial damage assessment at stand scale : exhaustive or sampling scheme
    - Information on spatial processes of forest health
    - Optimisation of ground forest inventory methods
    - Integration in processes models of forest stands
    - Improvement of forest planning and risk management

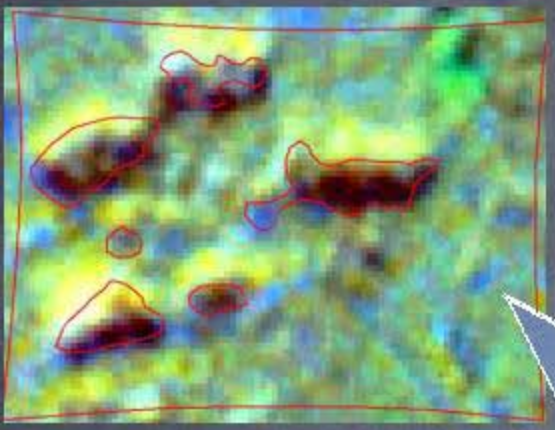
High resolution spatial remote sensing

1m – 30m resolution

- forest condition assessment (chlorophyll or foliage deficit)

Less favourable	More favourable
Weak alteration	Strong alteration
Diffuse damage	Concentrated damage
Coniferous	Broadleaved
Mixed stands	Pure stands
Young / low density	Mature / dense
Fragmentation - uneven aged	Closed – even aged
Mountainous	Flat
One image (date) available	Several images available
	A priori knowledge of the physical context (Digital Elevation Model, Species composition…)

Use of HR satellite data : an example
1999 storm damage assessment



Change index
derived from SPOT
Dark brown colour indicates
severe loss of trees

Zur Anzeige wird der QuickTime™ Dekompressor „TIFF (Unkomprimiert)“ benötigt.

Aerial photographs
taken after the storm
Red contours are delineated
by visual interpretation

Monitoring forest indicators on canopy functioning from remote sensing

- Spectral domain
  Visible, Near Infrared (NIR), Short Wave Infrared (SWIR), thermal IR, microwave

- Observation mean
  Low Resolution Spatial Sensors (500 m – 30 km)
  (VEGETATION/Spot, MODIS/Terra-Aqua, AVHRR/Noaa, SMOS, ...)

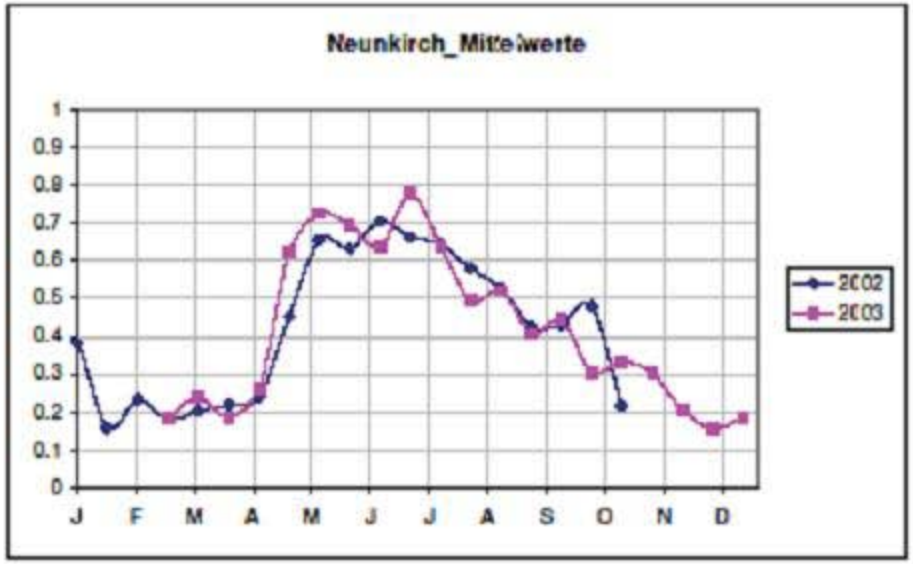
Stand

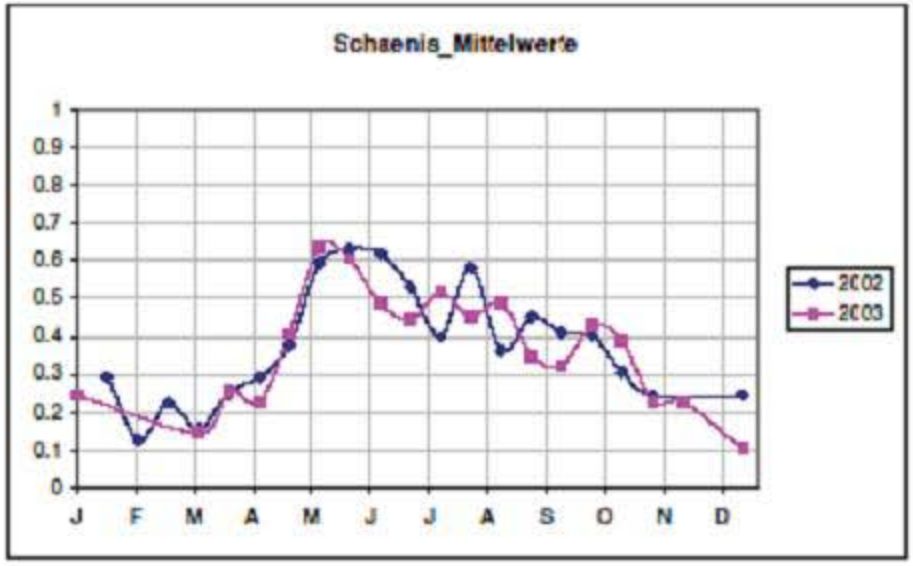
- Revisit frequency
  15 minutes (Geostationary satellite)
  to 1 day (VEGETATION, MODIS, NOAA)

What are the variables of canopy functioning ?

- Phenology : reflectance, vegetation index (e.g. NDVI), Dates of vegetation start and senescence
- Seasonal variations : Leaf Area Index, cover fraction
- Evaporation / water cycle : thermal IR (Surface Temperature)
- Soil moisture : passive microwave
- Surface temperature: water cycle, indicator of stress for coniferous forest
- Drought : expected long term impact on phenology, water fluxes

Fagus sylvatica





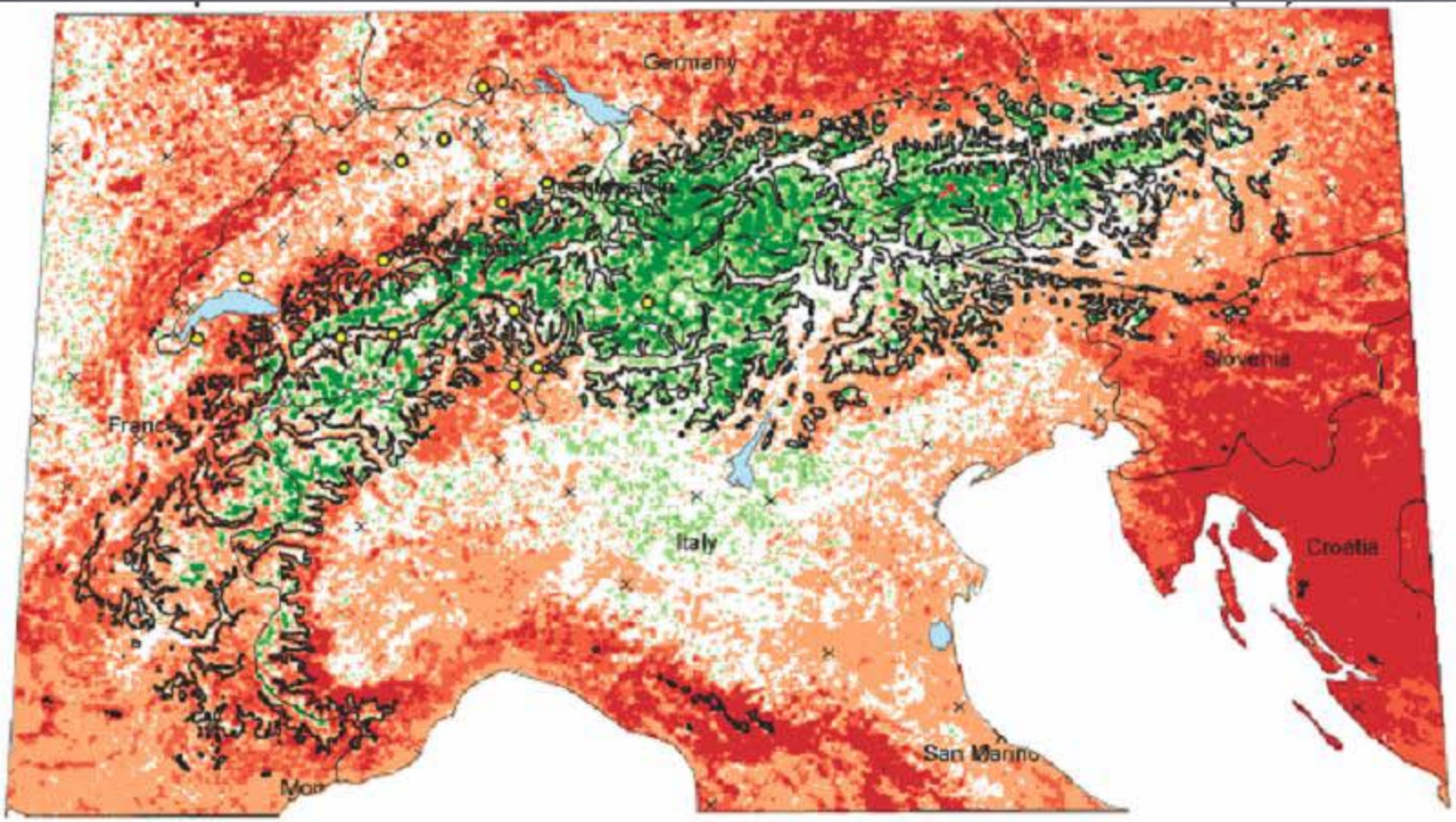
Observation strategies from space

- Systematic and comprehensive coverage of Earth continents at low spatial resolution (300 m – 1 km) with high revisit frequency (daily)
  - Wide field of view sensors : NOAA/AVHRR, (ADEOS) PARASOL/POLDER, SPOT4/VGT-1 & SPOT5/VGT-2, TERRA&AQUA/MODIS, ENVISAT/MERIS, MSG/SEVIRI, SMOS
  - Applications: meteorology (cloud cover, land surface temperature…), vegetation mapping, phenology, biosphere modelling, carbon and water cycle
- Coverage limited to target areas at higher spatial resolution (1 m – 30 m) but with lower revisit frequency
  - High resolution sensors : LANDSAT, SPOT, IRS, IKONOS, ORBVIEW, ERS-SAR, RADARSAT, ASTER…
  - Applications: land surface process models, validation of global models, land cover mapping, land cover change, natural hazards

Drought 2003 : what we can do

	Regional monitoring	Local monitoring
Geographical coverage	European territory	1 – 10,000 km², selected sites
Data source	use of wide field of view sensors (e.g. VEGETATION, MERIS, MODIS)	use of high resolution sensors (e.g. SPOT) with high revisit frequency
Activity	to derive monthly vegetation indices (NDVI) and to compare the 2003 and 2004 situations with “normal”, to assimilate vegetation parameters into models for CO^2 and water fluxes	to derive temporal vegetation profiles. Assimilation of parameters (fAPAR, LAI) into vegetation models.
Advantages	data quickly and easily available, free of charge. Global snapshot of Europe. Temporal profiles of vegetation behaviour.	analysis of vegetation reaction at stand level. Better discrimination between forest and other vegetation types.
Disadvantages	aggregation problem due to the spatial low resolution, difficult to go down to small forest stands.	limited to sites. No archive as reference !

Calculated Net Primary Productivity differences from MODIS data between 2003 and 2002



NPP Proportion (%) < 75 | 75.1 - 85 | 85.1 - 95 | 95.1 - 105 | 105.1 - 115 | 115.1 - 125 | > 125

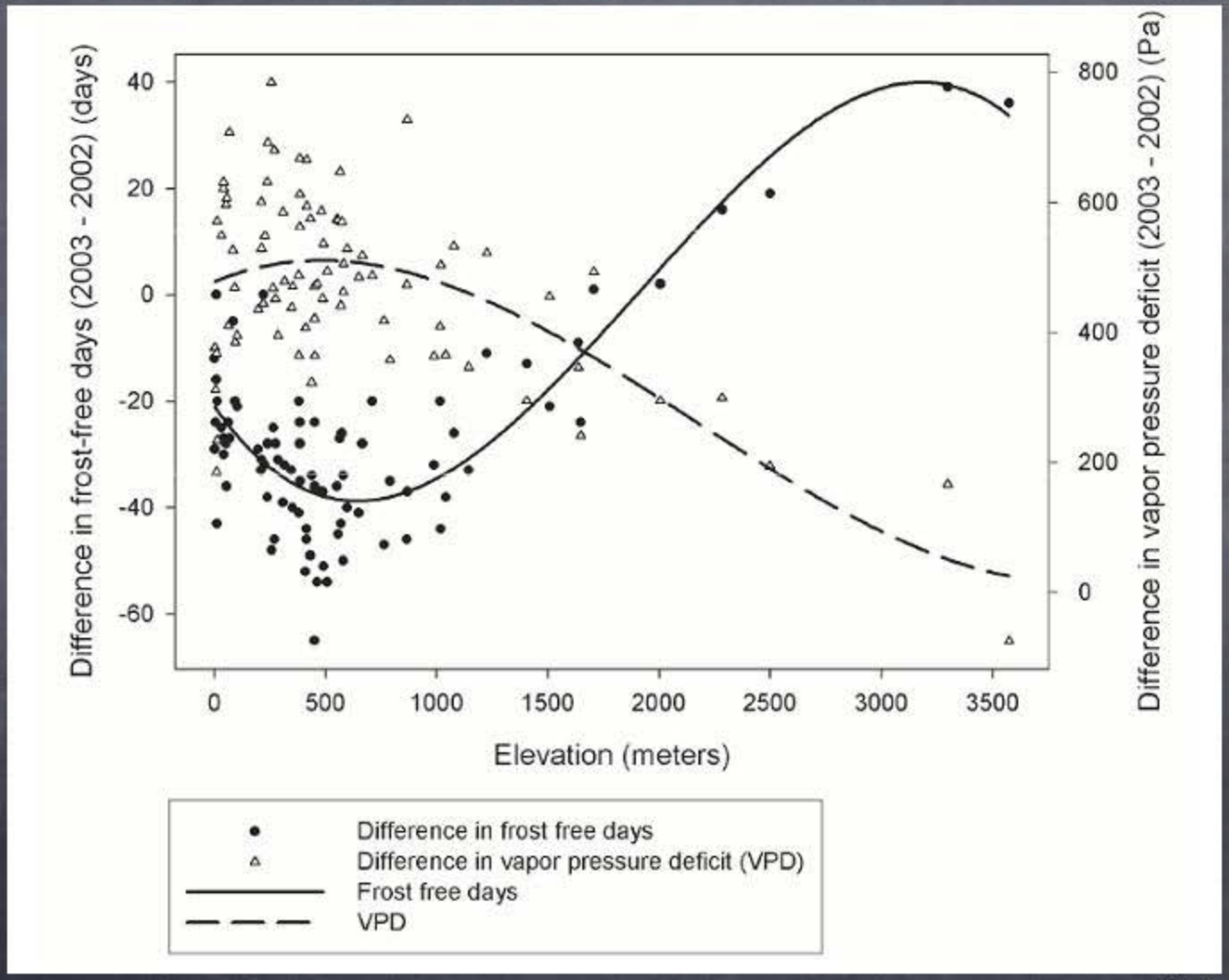
× WMO weather stations

○ Long Term Forest Ecological Research Sites

1500 meter contour

source: Jolly et al. (submitted)

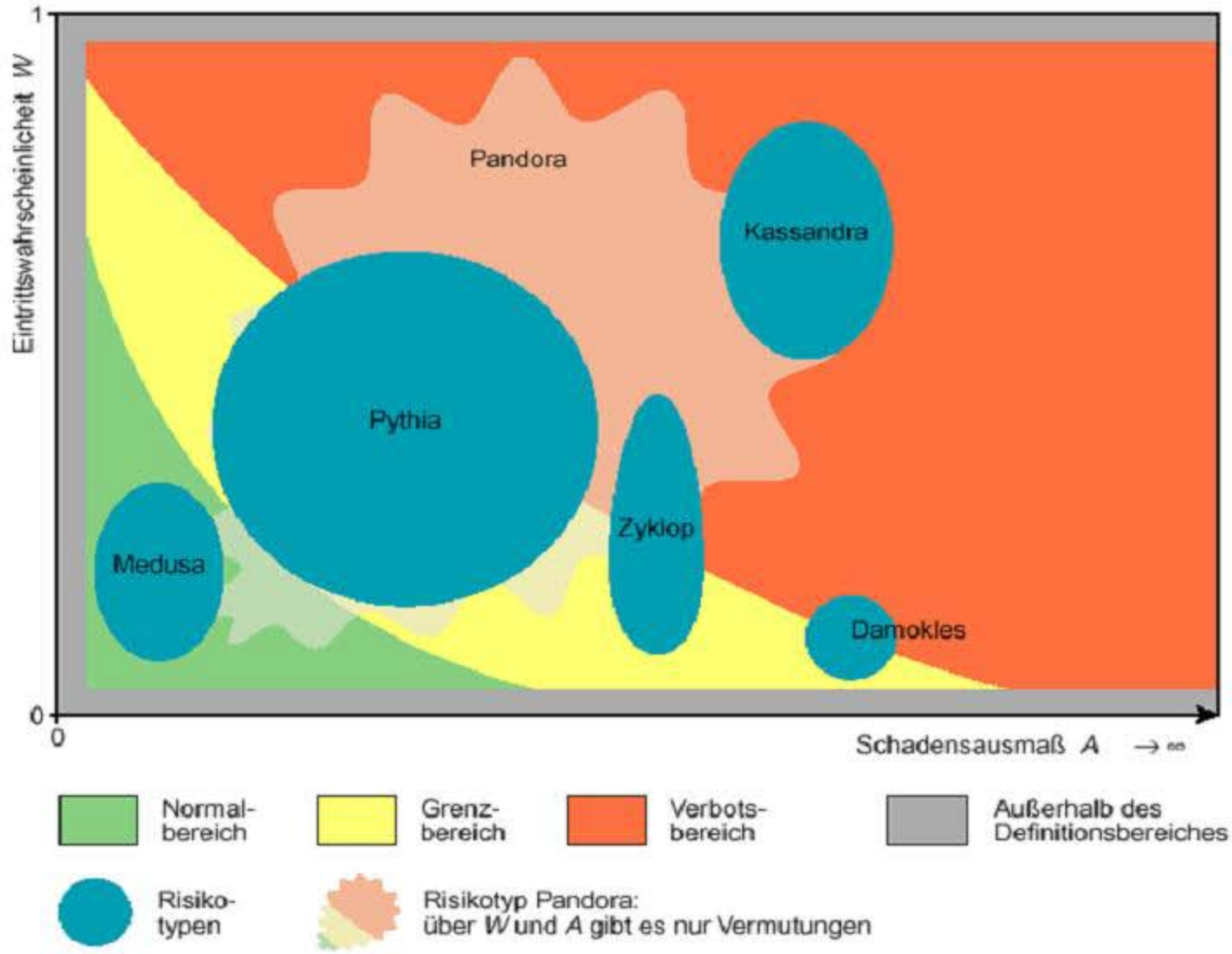
Differences in frost free days and vapor pressure deficit, a measure of evaporative demand, between 2002 and 2003



source: Jolly et al. (submitted)

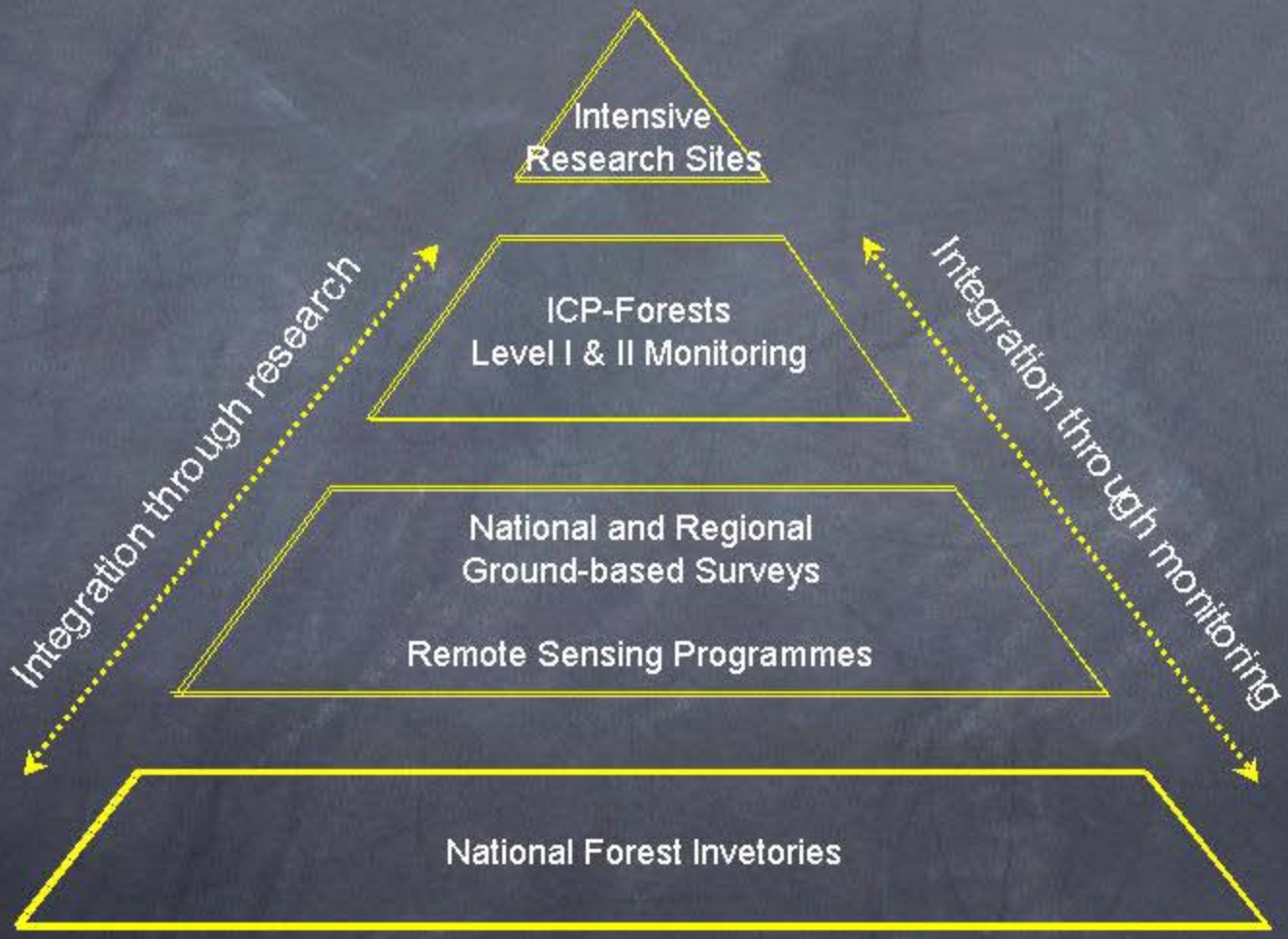
Outlook

ecological risks



Source WBGU, 1999

Potential setup of monitoring activities as a basis for a sound decision support system



contact: peernet@wsl.ch

7th Framework programme

- risk assessment; comm… management
- on the bas… …und truth data (inven… …itoring activities & fi…
- …remote sensing tools -->
- …ainable impact assessment tools for a European knowledge-based bio-economy

Pan-European Ecological Risk NETwork PEERNET