Vulnerability of Grassland Systems to Climate Change in Europe

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Grassland ecosystems

In EU-27…

… grassland ecosystems are permanent for ~85%

… they cover 67 million ha, i.e. ~40% of agricultural surface (60-70% in Ireland and UK)

… they are run by ~5.4 millions of farmers

… they provide the feed basis of 78 million herbivores, producing ~25% of milk and meat

(Peyraud, 2013)

Climate change impacts on grasslands

Climatic & atmospheric changes → **Impacts**

Climatic & atmospheric changes	Impacts
CO_2 concentration ↗	Photosynthesis ↗ Water use efficiency ↗
Precipitation ↘	Plant water status ↘
Temperature ↗	Length of the cycle ↗

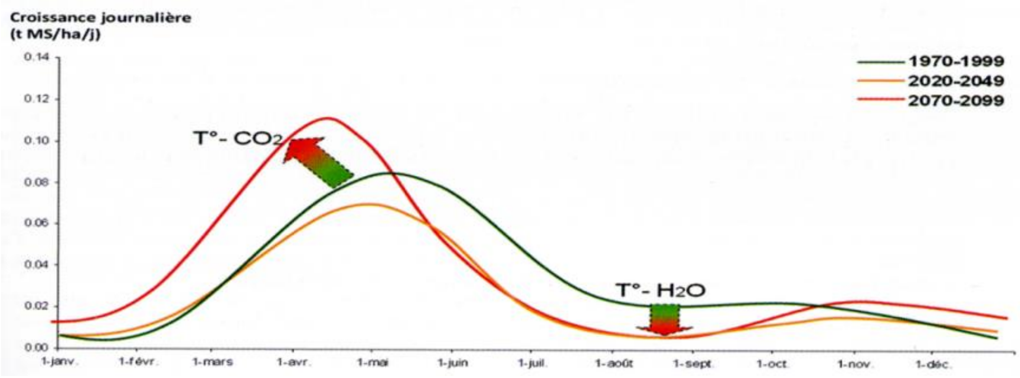
Adaptations to climate change impacts / 1

Impacts → **Adaptations**

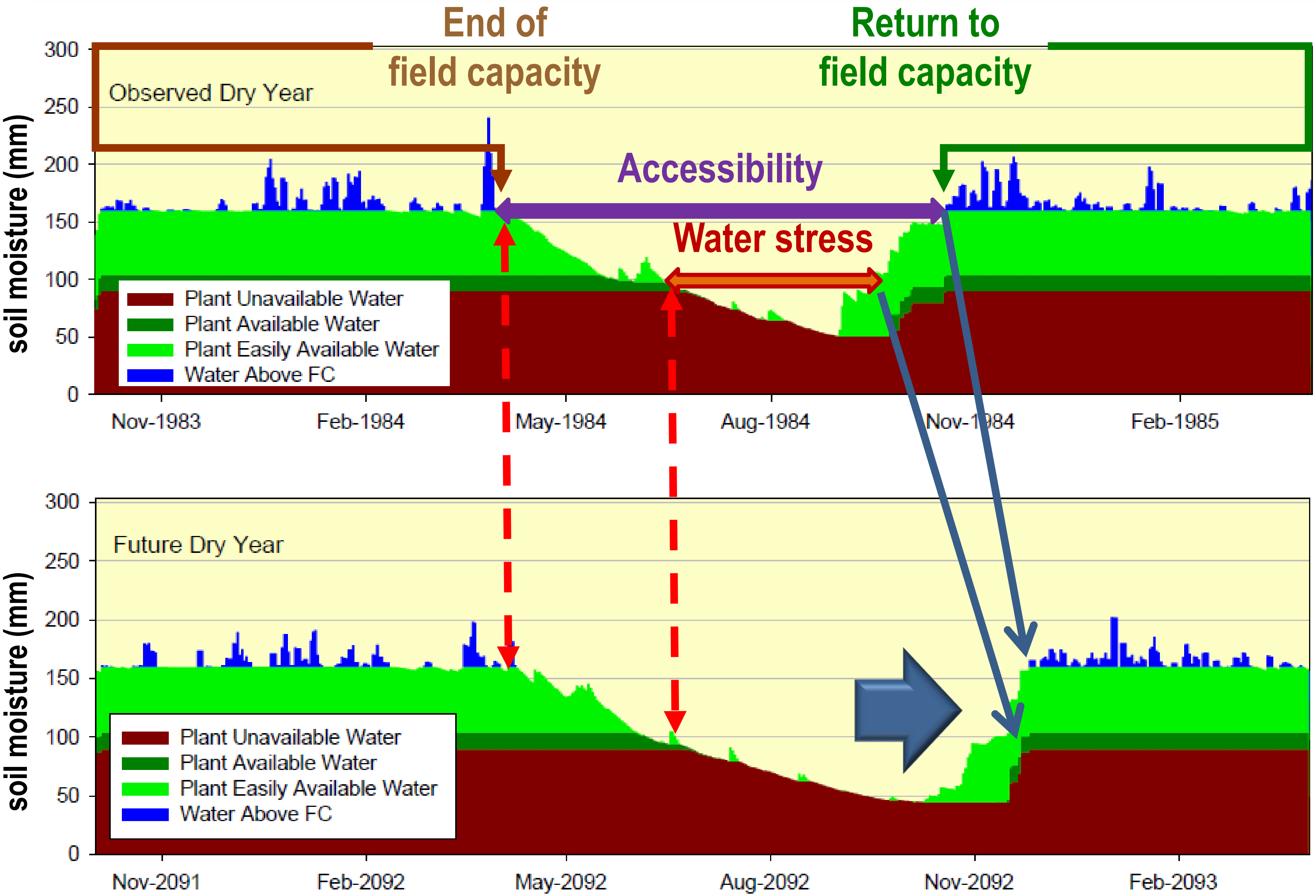
Start of grass growing season ↘ **Nitrogen input** ↗

Evolution of yearly productivity of a grassland

(Durand et al., 2010)



Soil water balance



(Rivington et al., 2013)

Adaptations to climate change impacts / 2

Impacts → **Adaptations**

End of grass growing season

Length of grazing time

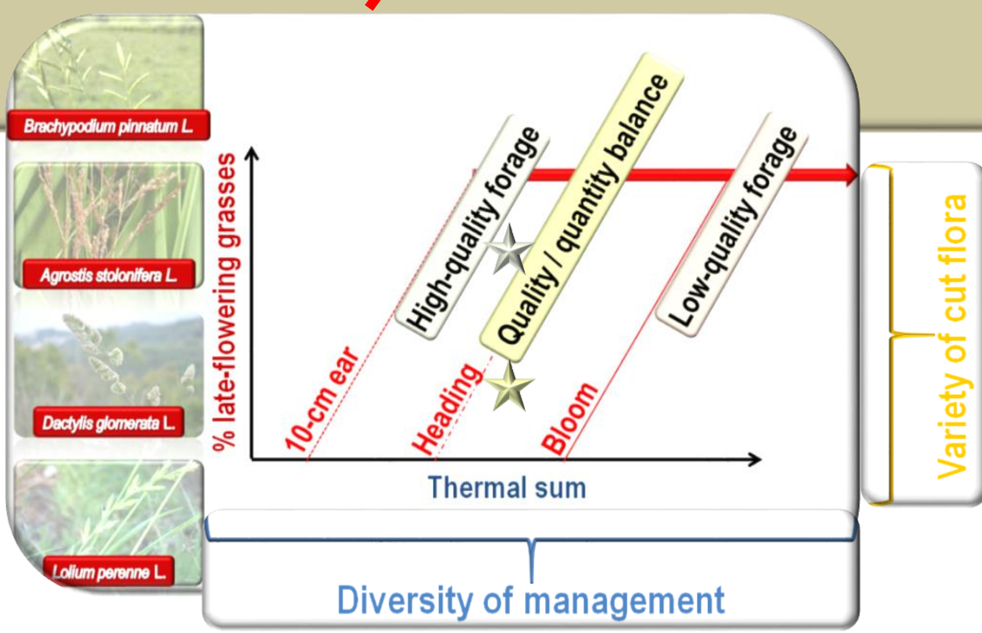
Number of cuts

Summer water deficit

Forage stocks

Irrigation requirements

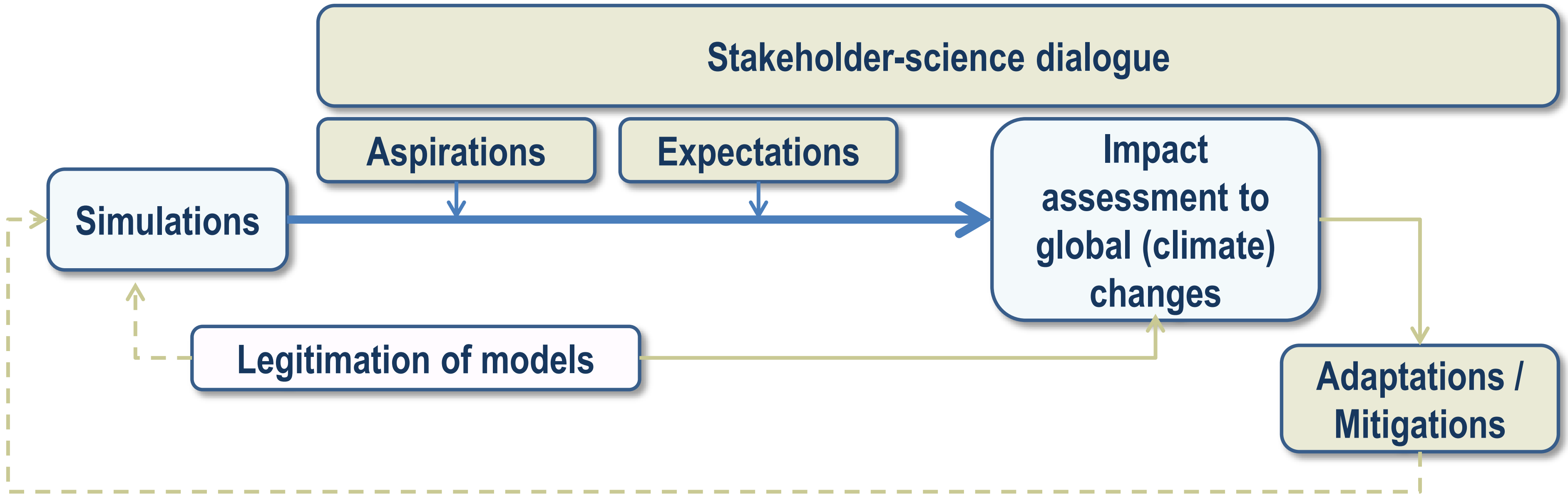
Plant diversity



(Theau et al., 2010)

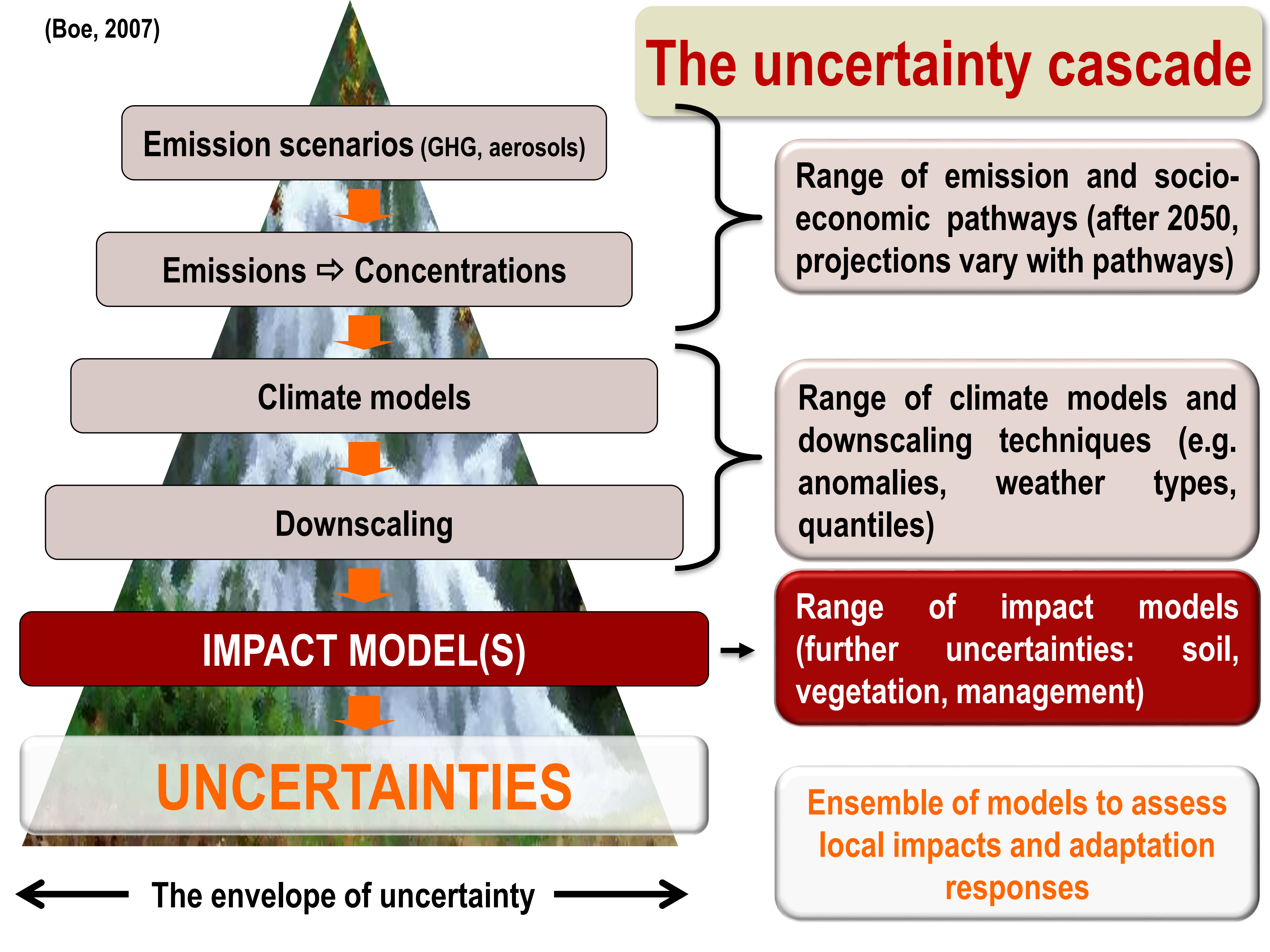
+ Lignin
+ Cellulose
- Crude protein
- Nonstructural carbohydrates

Model-based climate change studies

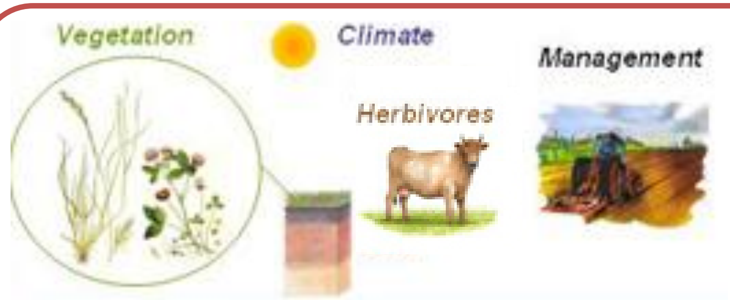


Bellocchi et al., 2006, 2015

Rivington et al., 2007


(Boe, 2007)
The uncertainty cascade
Emission scenarios (GHG, aerosols)
Emissions ⇨ Concentrations
Climate models
Downscaling
IMPACT MODEL(S)
UNCERTAINTIES
The envelope of uncertainty
Range of emission and socio-economic pathways (after 2050, projections vary with pathways)
Range of climate models and downscaling techniques (e.g. anomalies, weather types, quantiles)
Range of impact models (further uncertainties: soil, vegetation, management)
Ensemble of models to assess local impacts and adaptation responses

Systemic approach to grassland vulnerability



Agro-ecosystem

Plot scale

Modelling

Inputs
(climate, soil, management)

Initial values

Parameters

Grassland specific	Crop generic	Dynamic global vegetation
PaSim	STICS	Biome-BGC MuSo
SPACSYS	EPIC	LpJmL
AnnuGrow	ARMOSA	CARAIB
		ORCHIDEE

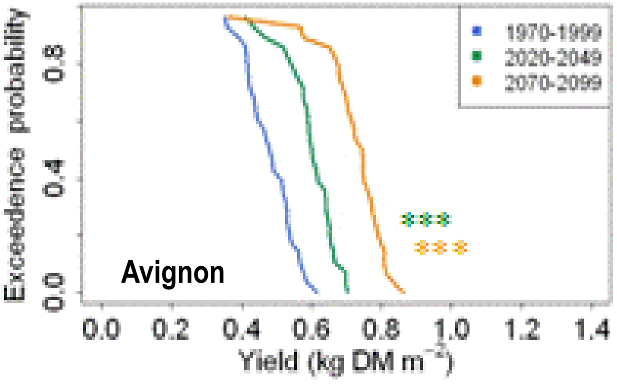
Outputs
(GHG, GPP, yield, ...)

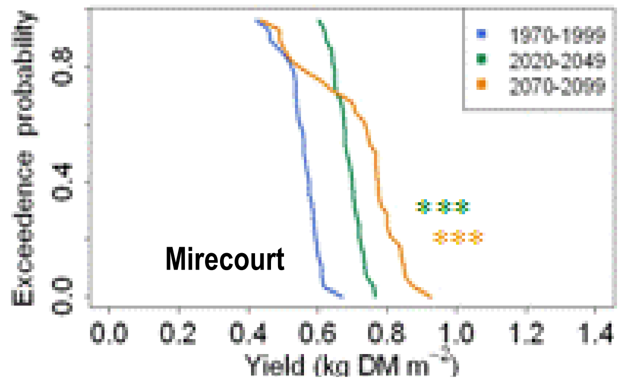
Vulnerability indicators
exposure, sensitivity, adaptive capacity

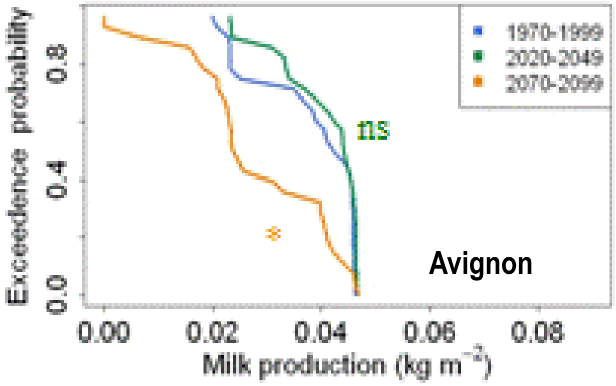
(Lardy et al., 2014)

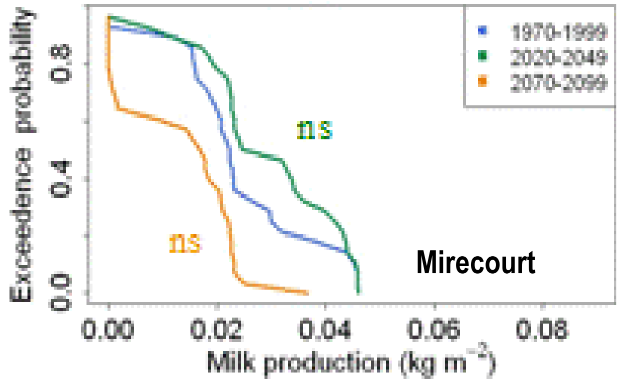
Impact projections in France / 1

Extensive permanent grasslands





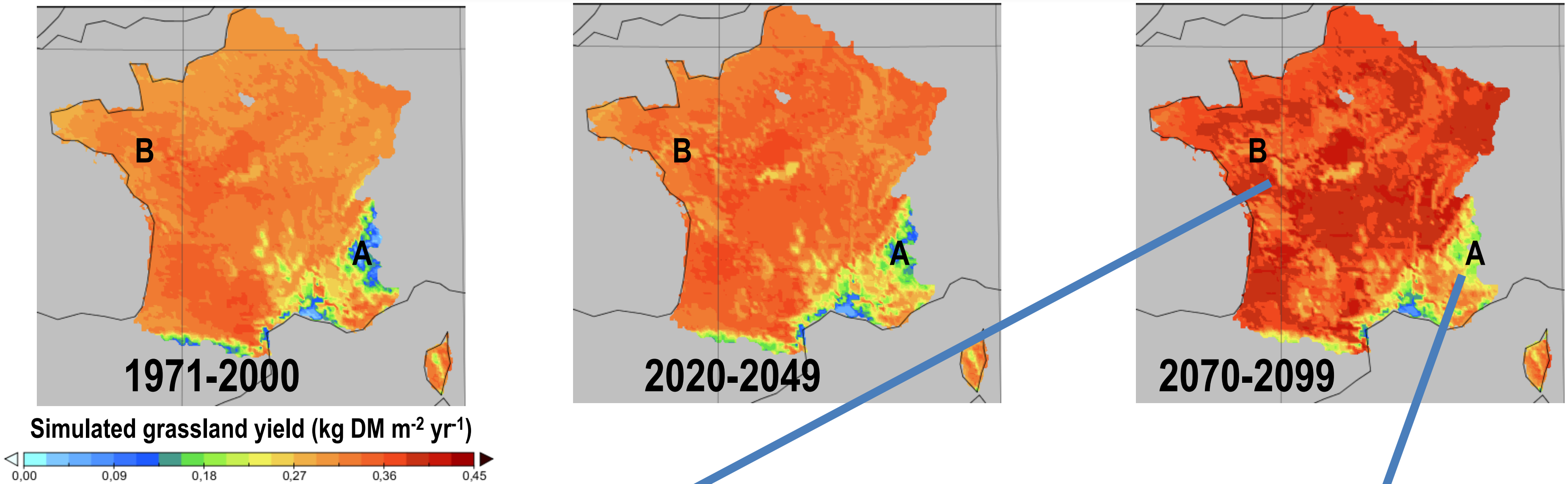




New opportunities for annual forage production with risks of forage losses in summer (and risks of milk production losses in summer-autumn)

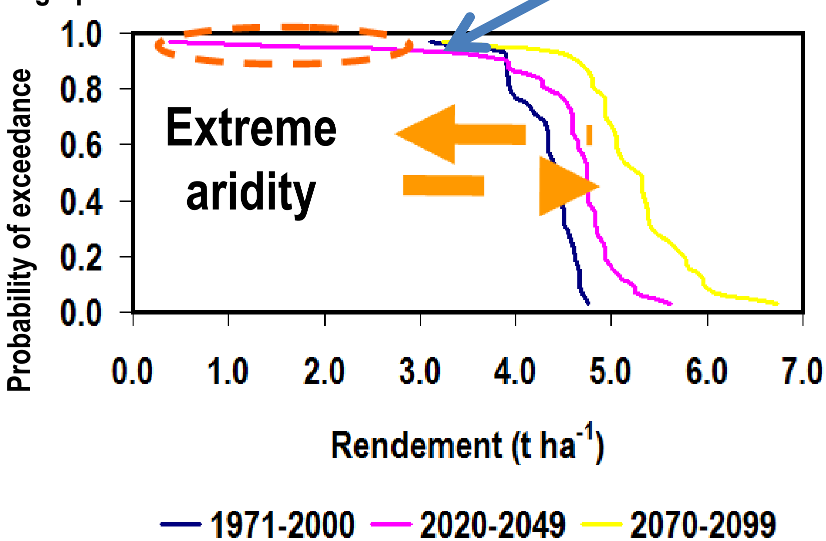
(Graux et al., 2013)

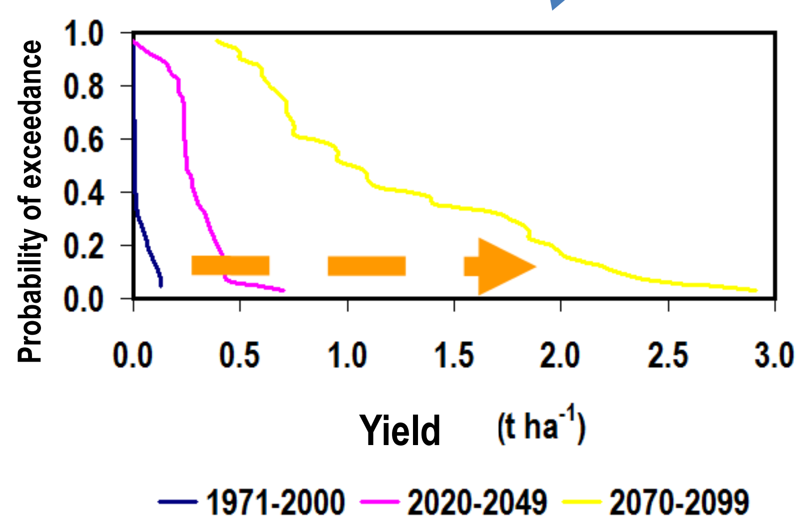
Impact projections in France / 2



A: low-production area (Vital et al., 2013)

B: high-production area





Vulnerability to climate change

- **IPCC definition (IPCC, 2001)**

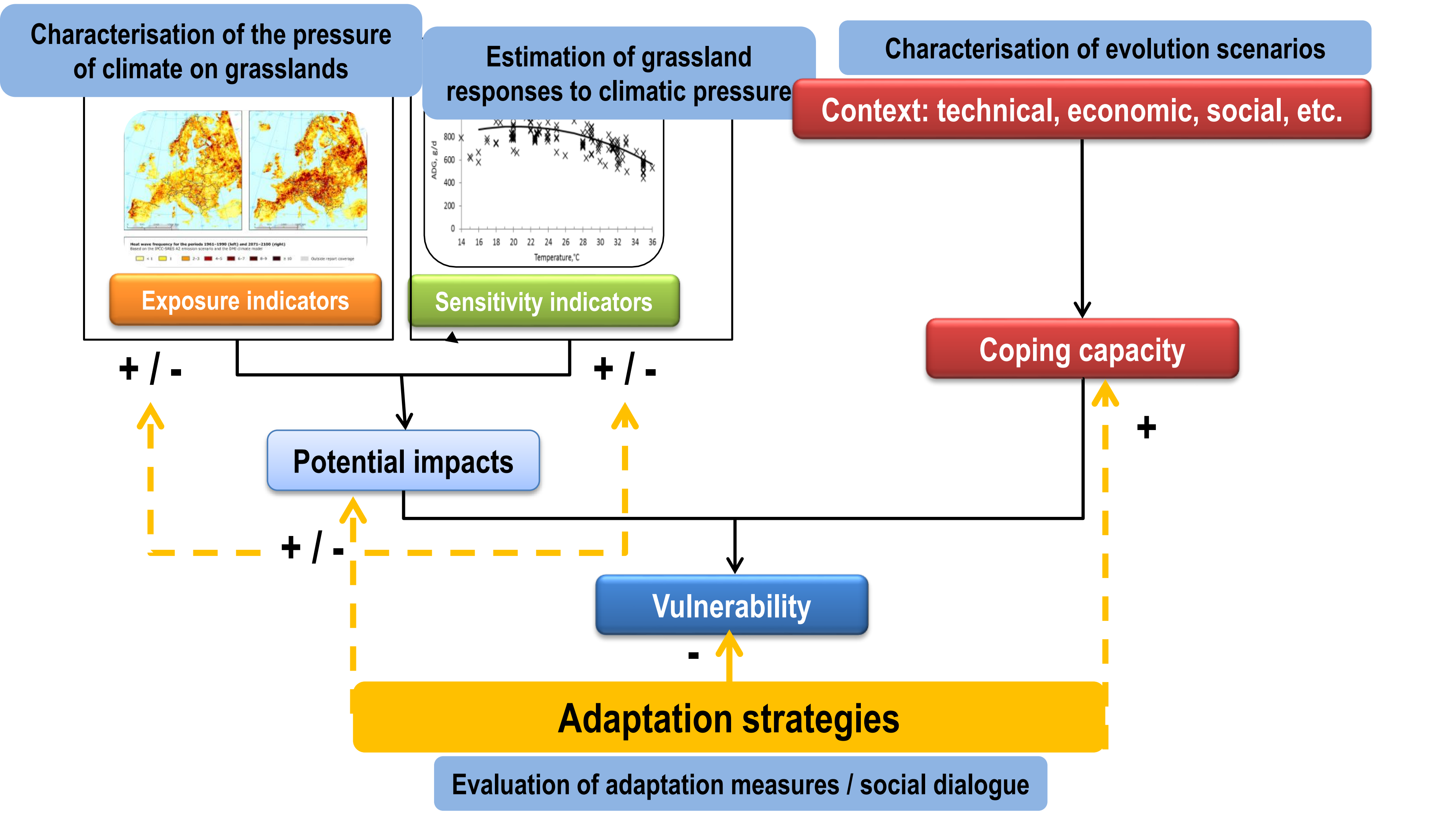
  The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes

  Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is **exposed**, its **sensitivity** and its **adaptive capacity**

- **Conceptualisation of vulnerability for climate change research**

  The definition accounts for the ***long-term nature of the climate problem*** (by including the adaptive capacity) and for the ***heterogeneity and complexity of the hazard*** (by including an exposure factor)

Vulnerability assessment



Exposure metrics

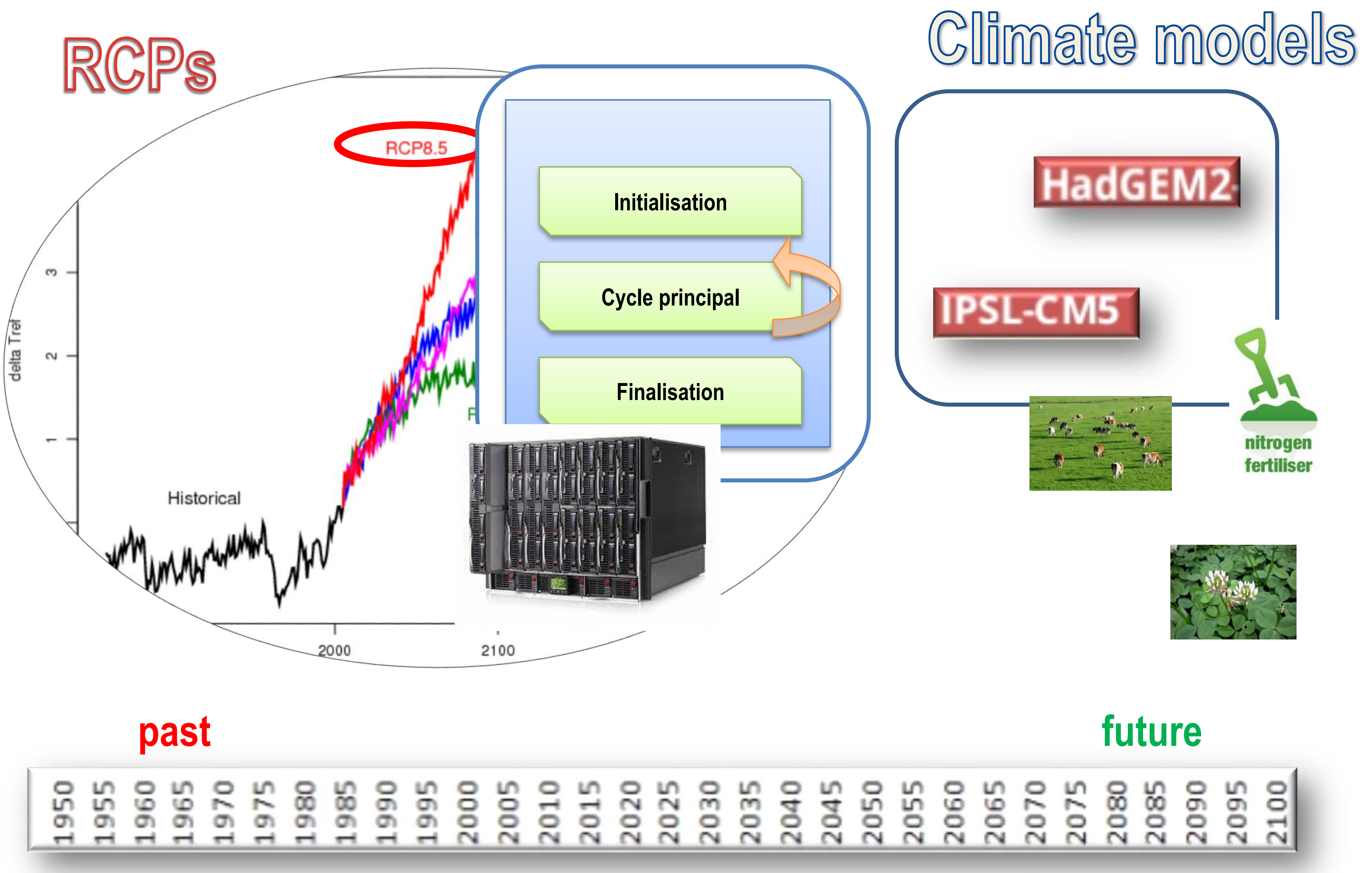
Indicator	Quantile	Metric
Dry spell length	25%	Maximum number of consecutive dry days in a year
Number of heat waves	75%	No. of >six consecutive days when $T_{max} > T_{max}$ (baseline) + 3 °C
Aridity index	25%	$\boxed{b = \frac{1}{2} \cdot \left(\frac{P_Y}{T_Y + 10} + 12 \cdot \frac{p_a}{T_a + 10} \right)}$ $b < 5$: extreme aridity … $b > 59$: strong humidity

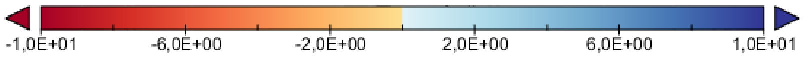
(Confalonieri et al., 2010)

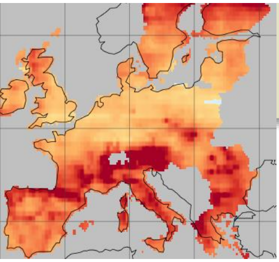
Sensitivity metrics

Category	Output
Productivity	$\boxed{\text{Gross primary production}}$
Carbon stocks	Total soil carbon
Nitrogen fluxes	Nitrogen leaching

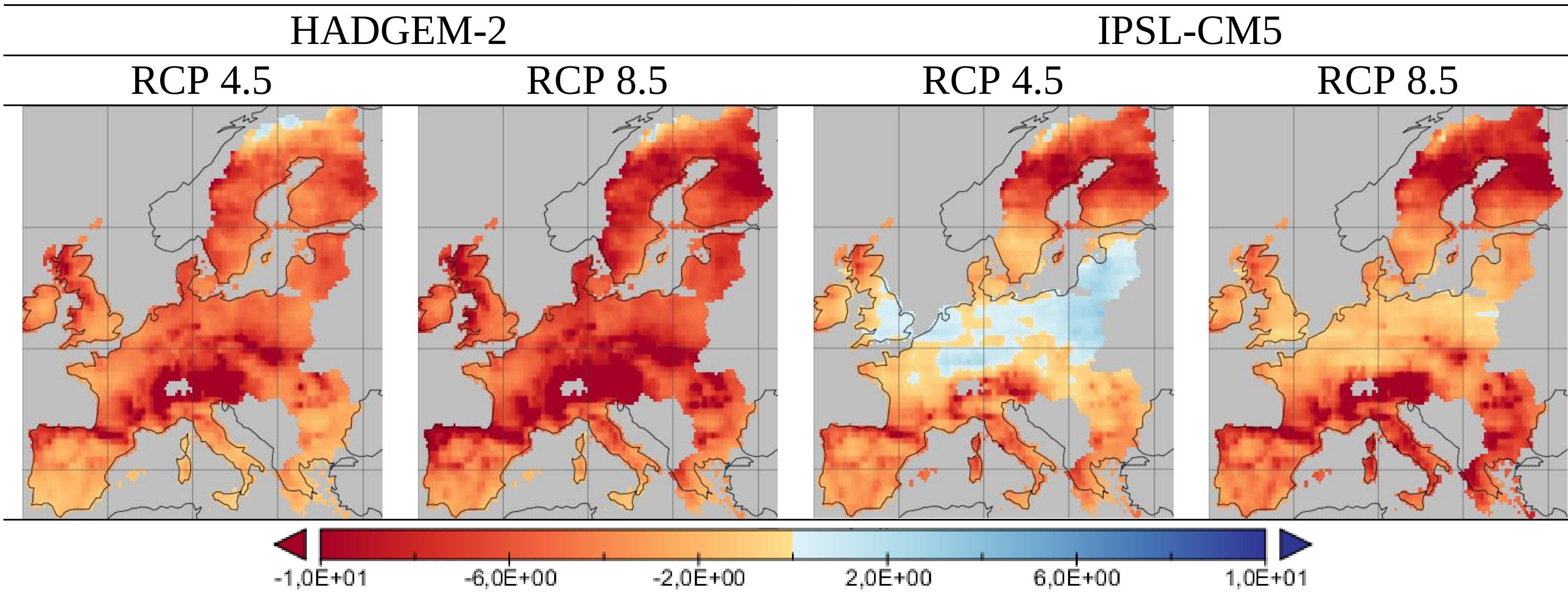
Climate scenarios / vulnerability maps





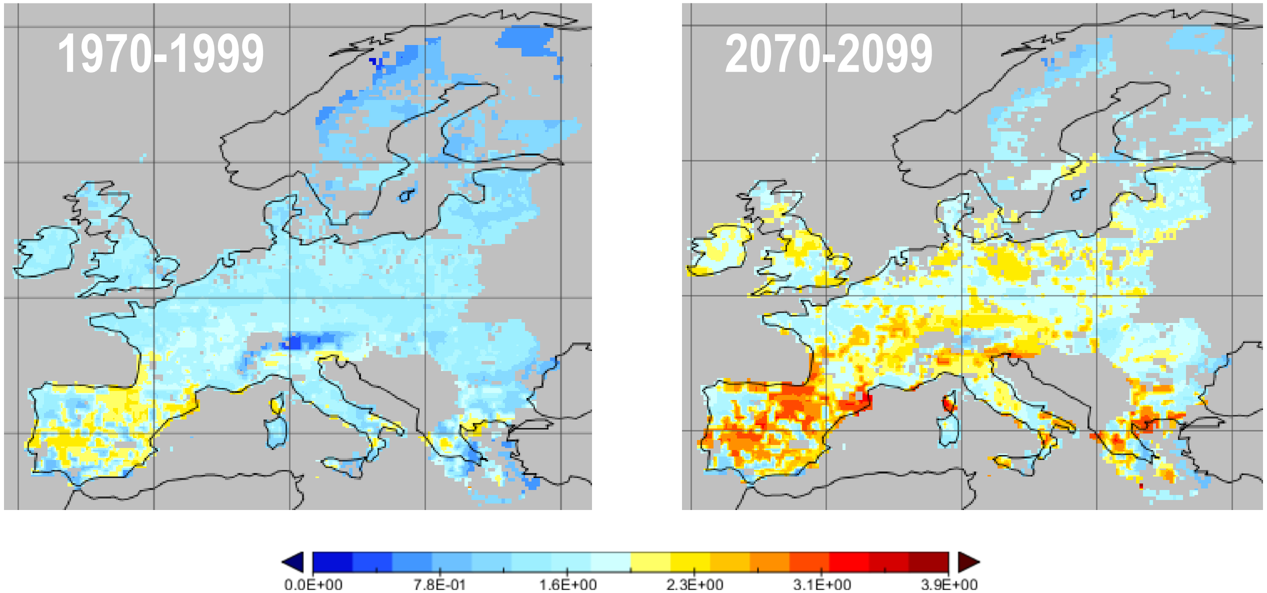


Aridity conditions



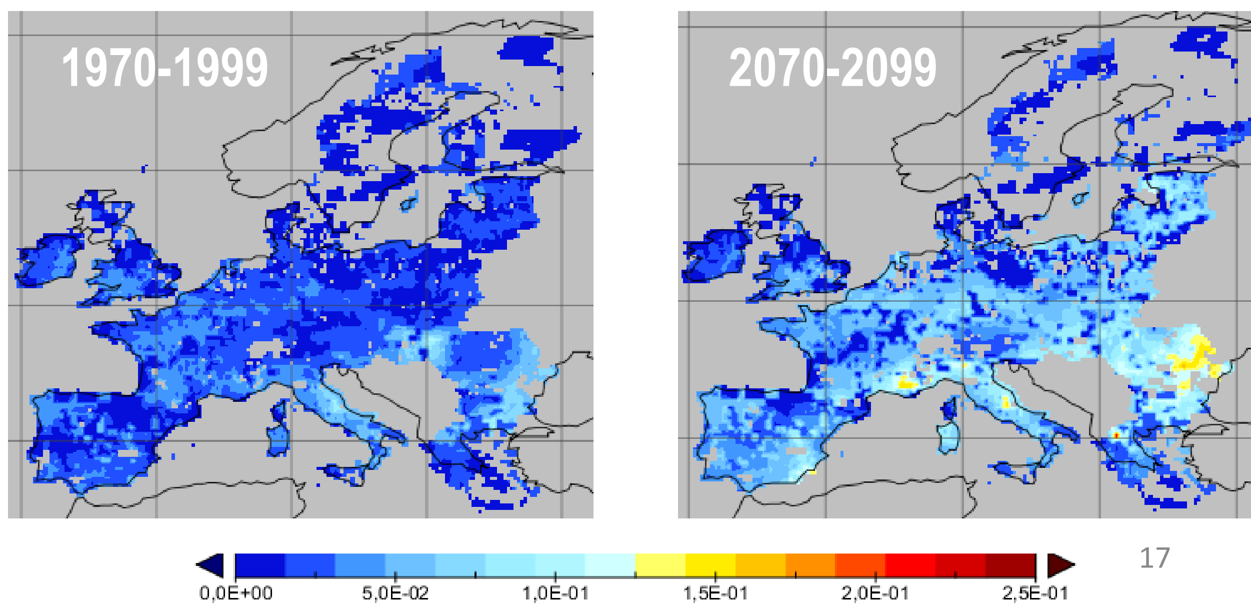
Towards increased exposure to arid conditions

Gross primary production (GPP)



increased average gross primary productivity

increased year-to-year variability



PaSim
HadGEM2
RCP 8.5

Luers-based vulnerability index

sensitivity

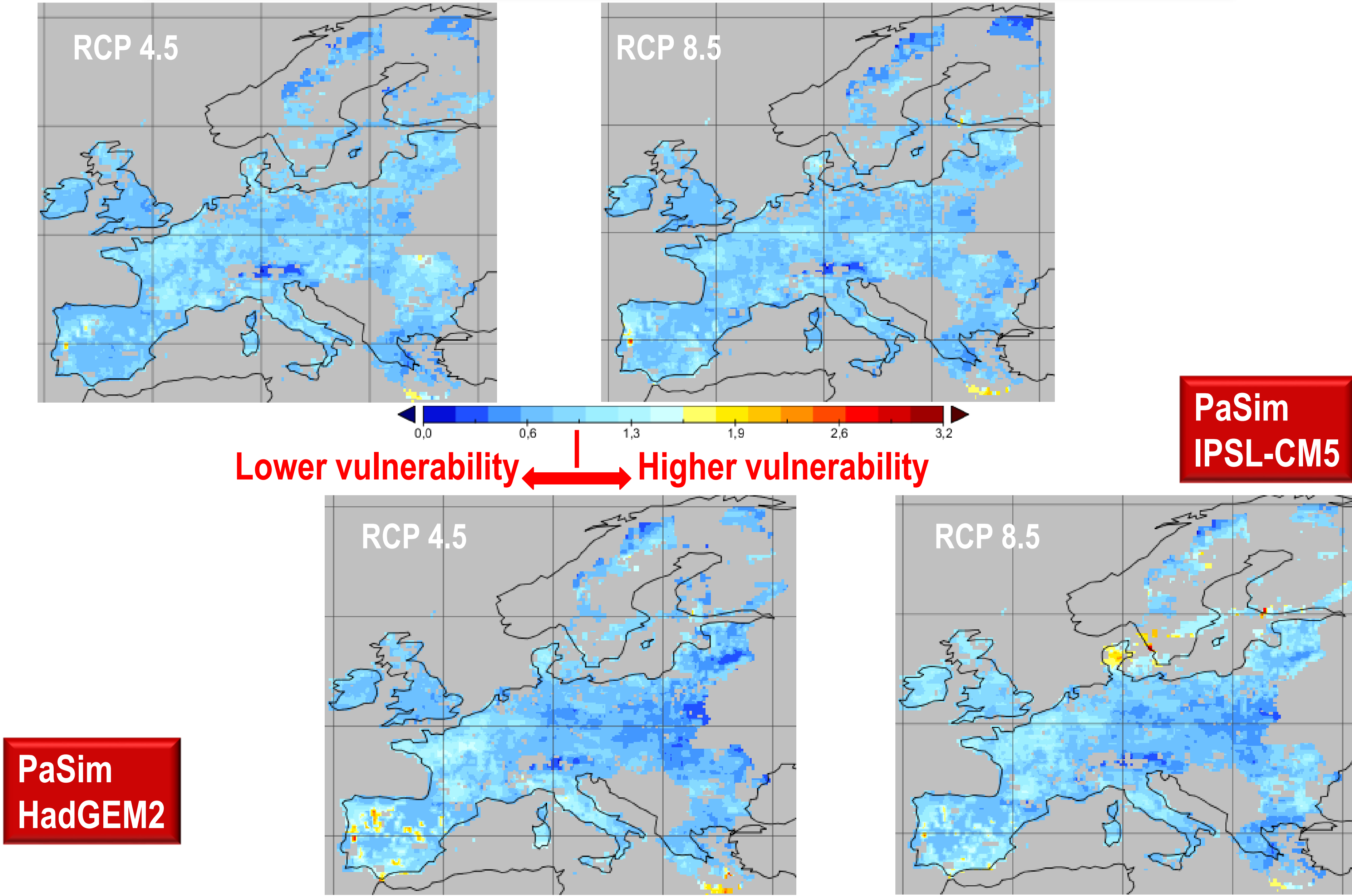
$$V_L = f\left(\frac{\boxed{|\partial W/\partial X|}}{W/W_0}\right)_{\text{future}} \Big/ f\left(\frac{|\partial W/\partial X|}{W/W_0}\right)_{\text{past}}$$

state

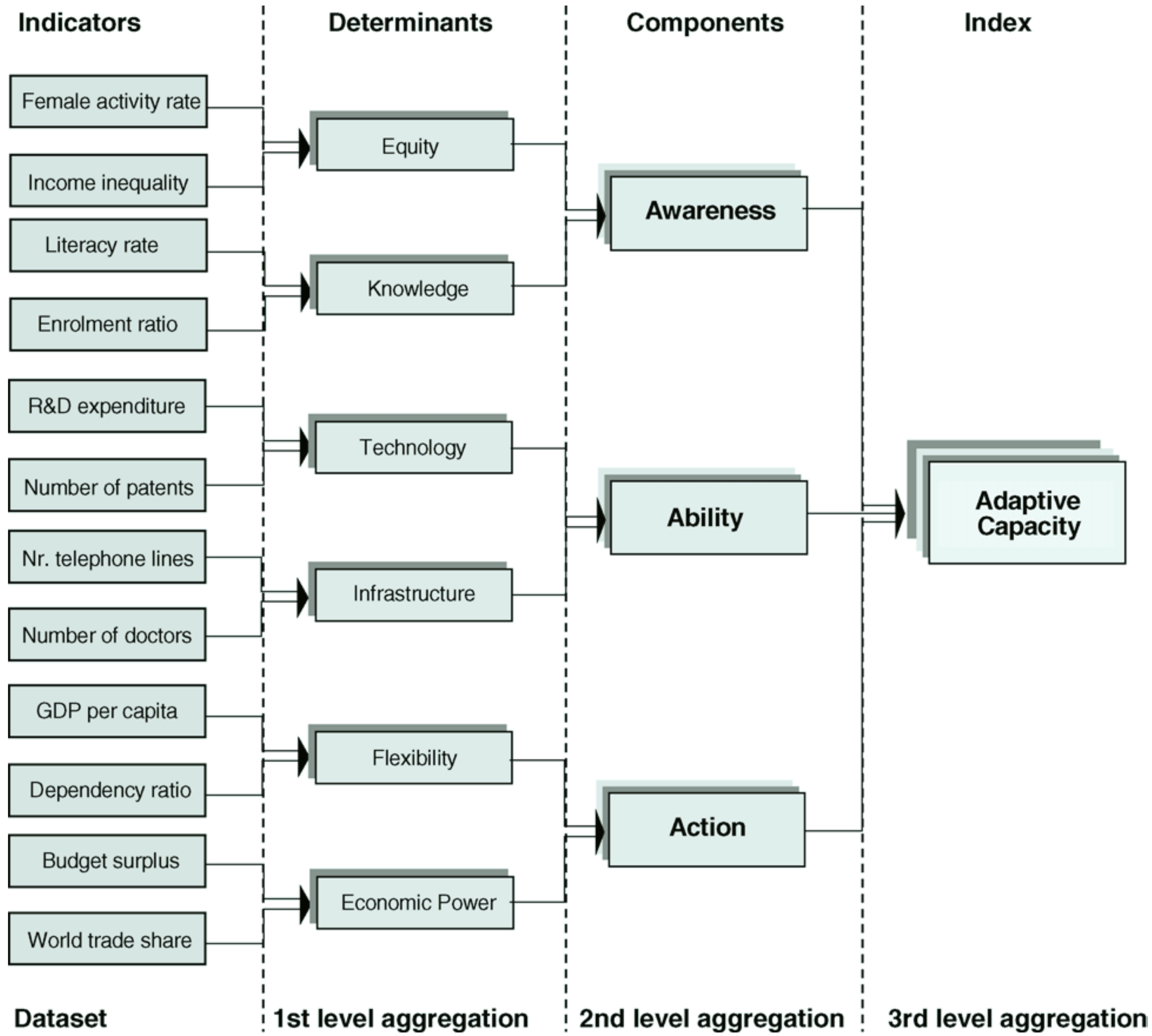
threshold

(Lardy, 2013)

Vulnerability index



Adaptive capacity



(Metzeger et al., 2006)

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Thank you!