Vulnerability of Grassland Systems in Europe to Climate Change

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Grassland ecosystems

In EU-27…

… grassland ecosystems are permanent for ~85%

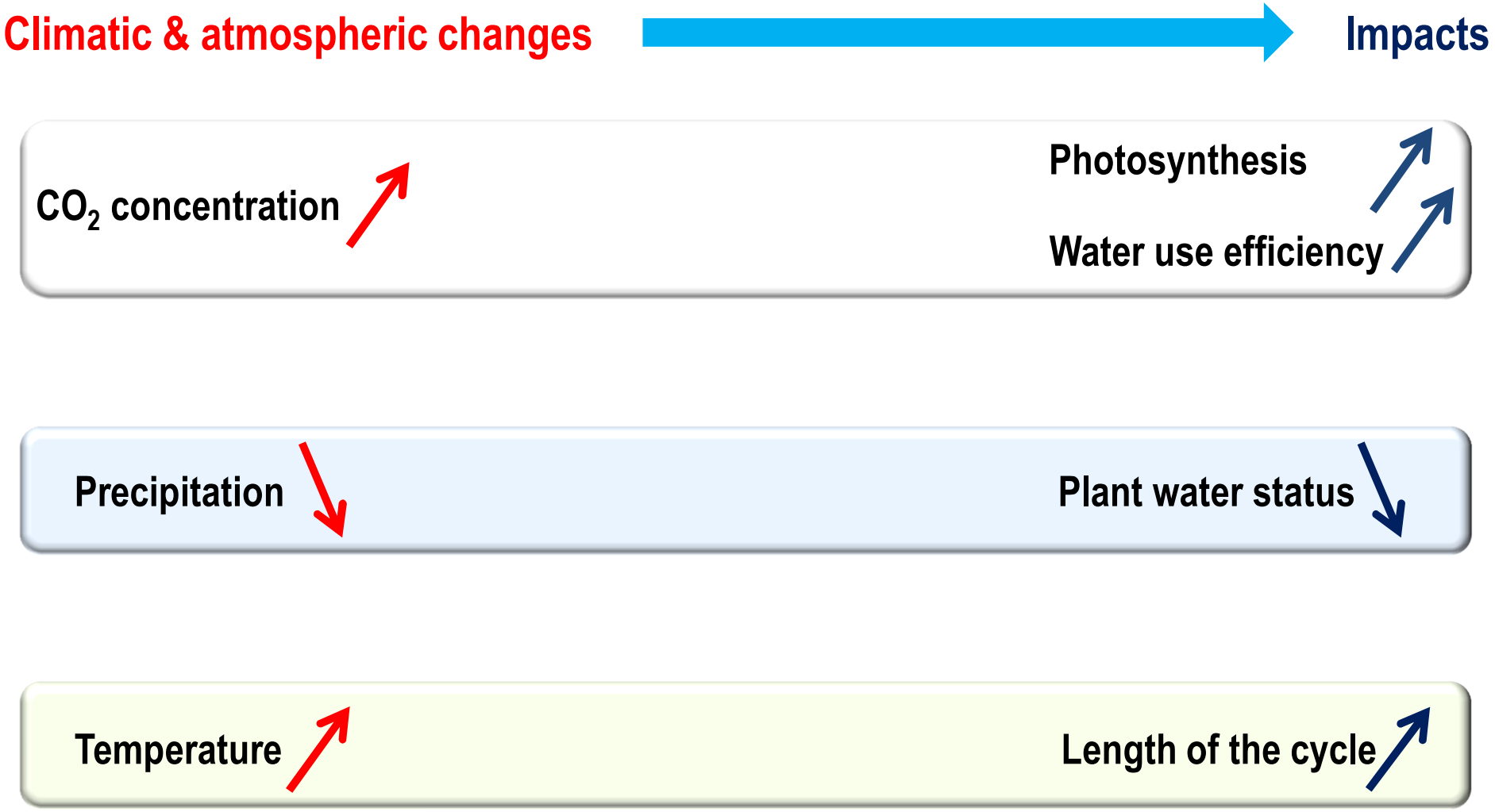
… they cover 67 million ha, i.e. ~40% of agricultural surface

… 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



Adaptations to climate change impacts / 1

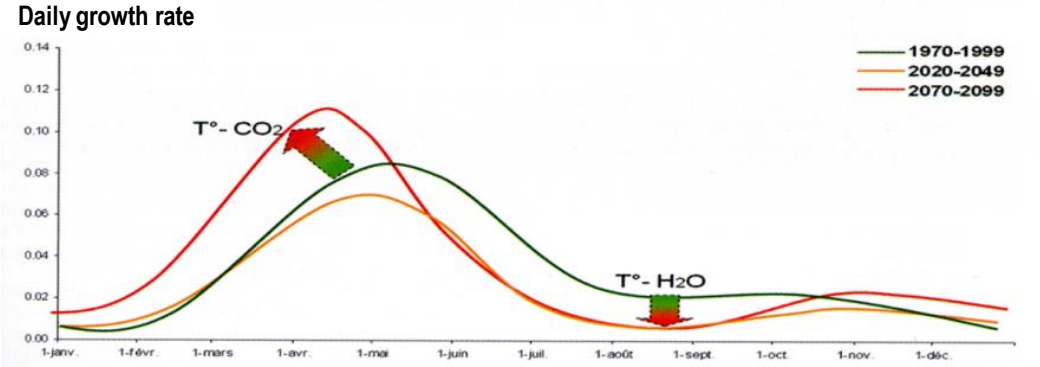
Impacts → Adaptations

Start of grass growing season ↘

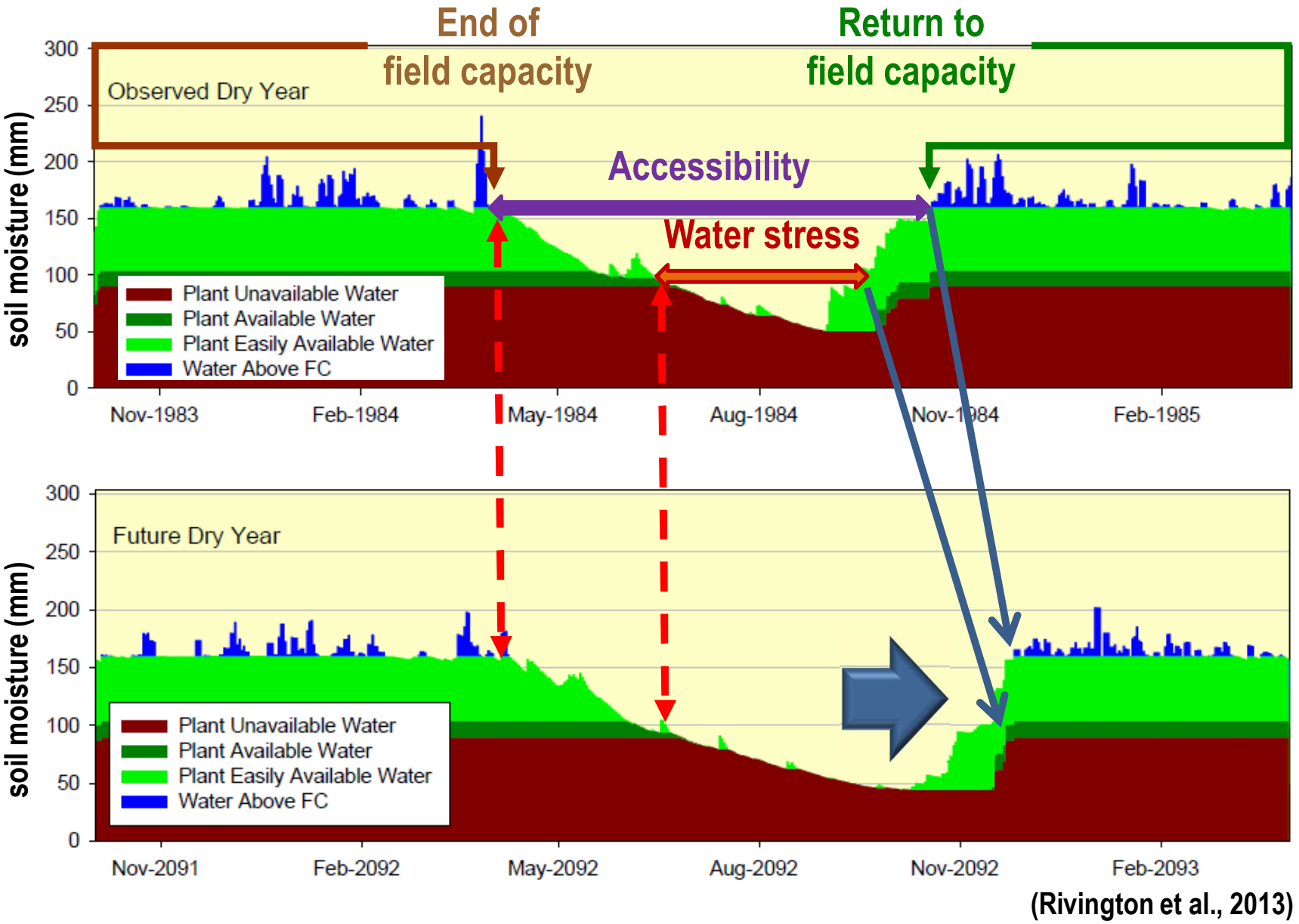
Nitrogen input ↗

Evolution of yearly productivity of a grassland

(Durand et al., 2010)



Soil water balance



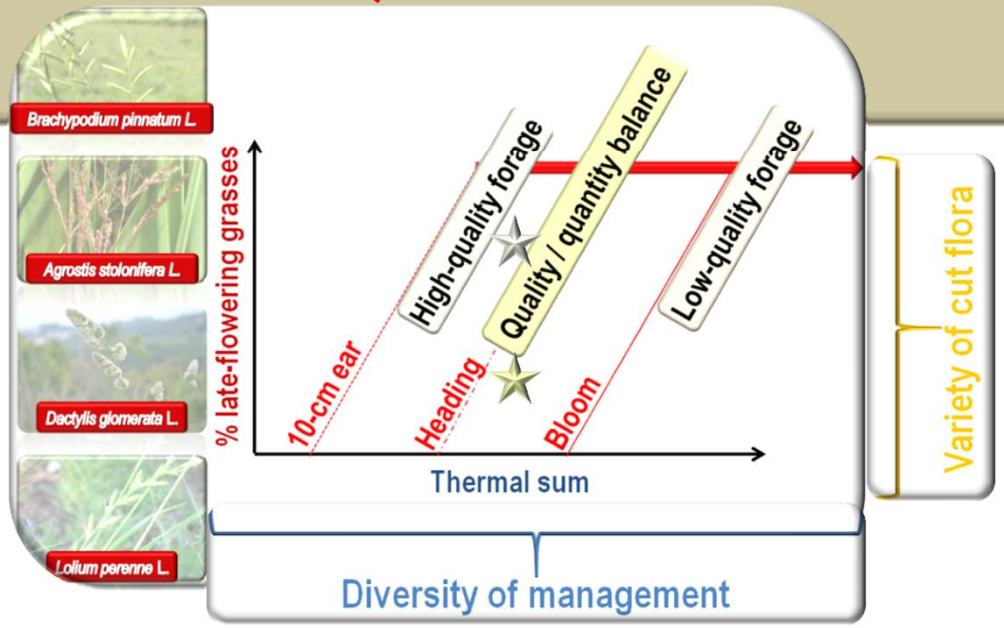
(Rivington et al., 2013)

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 ↗

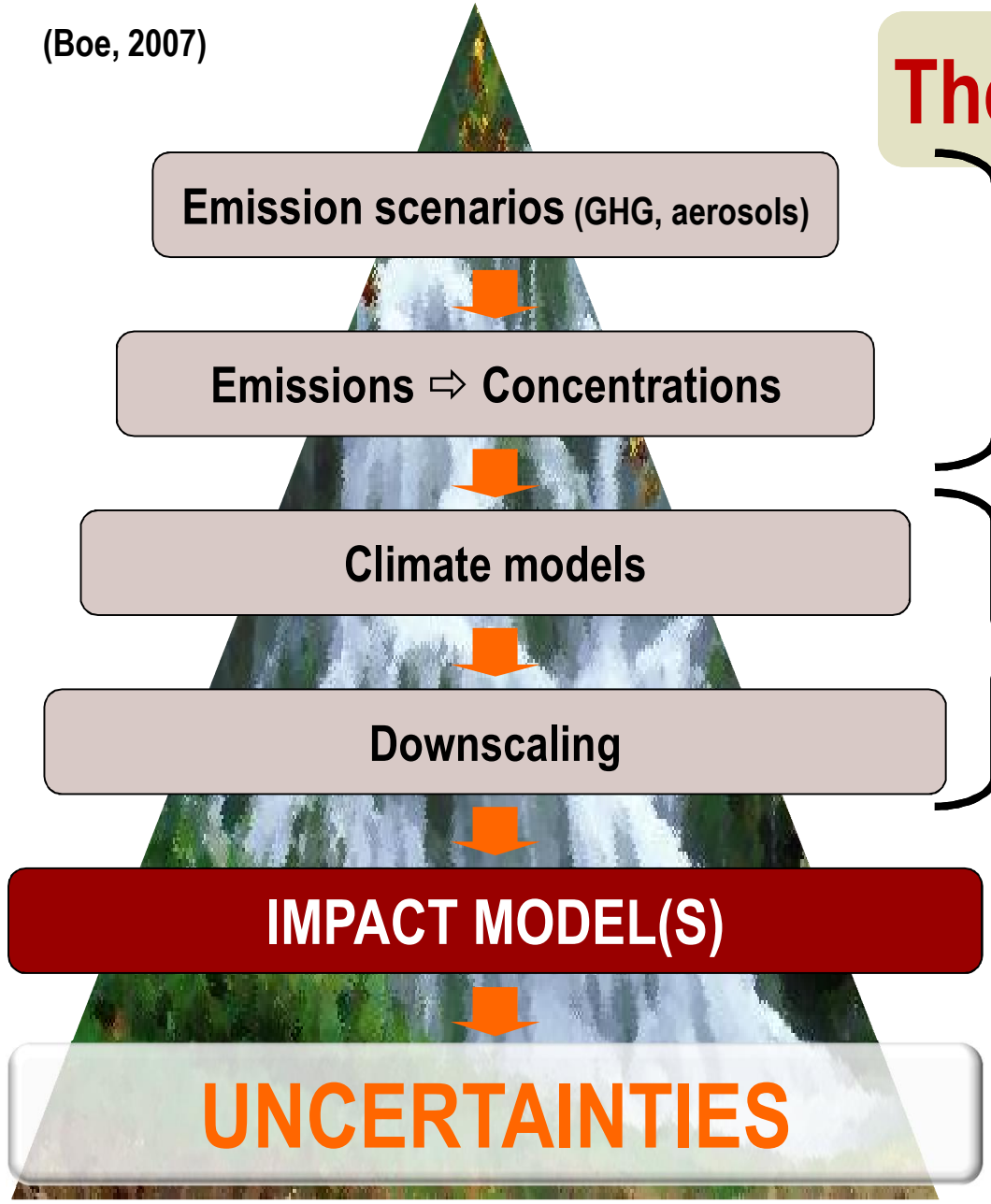


(Theau et al., 2010)

+ Lignin
+ Cellulose
- Crude protein
- Nonstructural carbohydrates

(Boe, 2007)

The uncertainty cascade



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

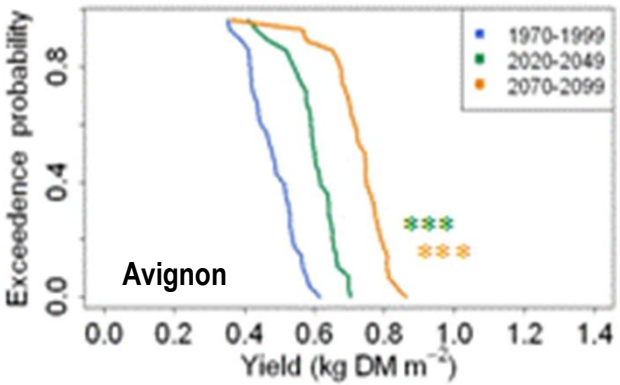
Outputs
(GHG, GPP, yield, …)

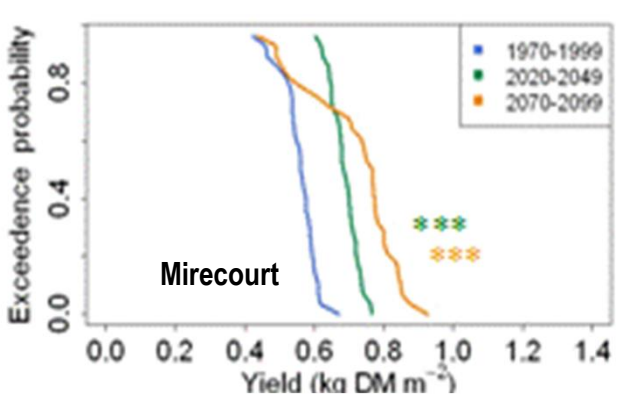
Vulnerability indicators
exposure, sensitivity, adaptive capacity

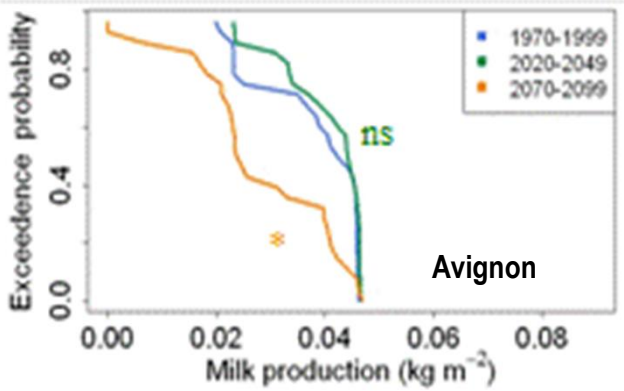
(Lardy et al., 2014)

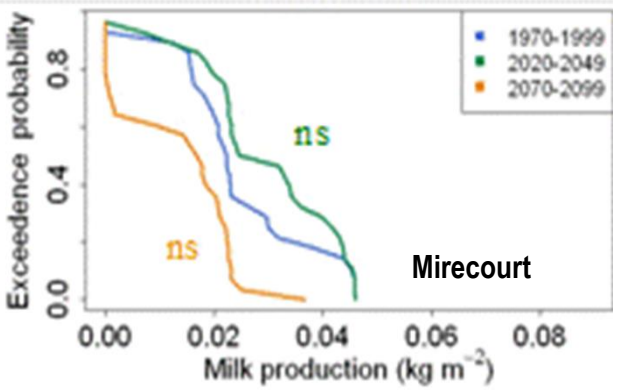
Impact projections in France / 1

Extensive permanent grasslands





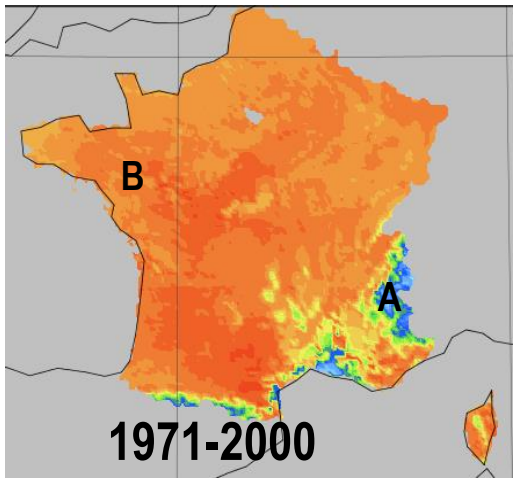


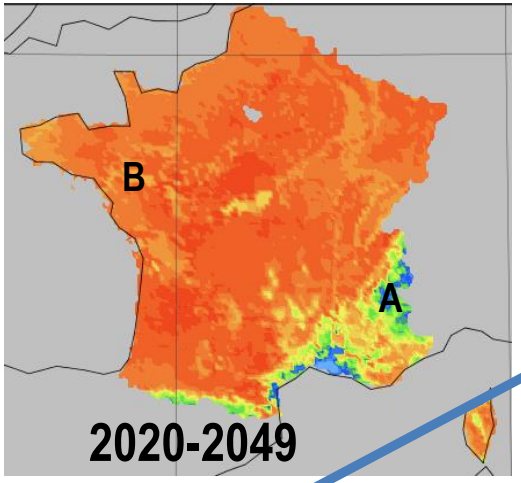


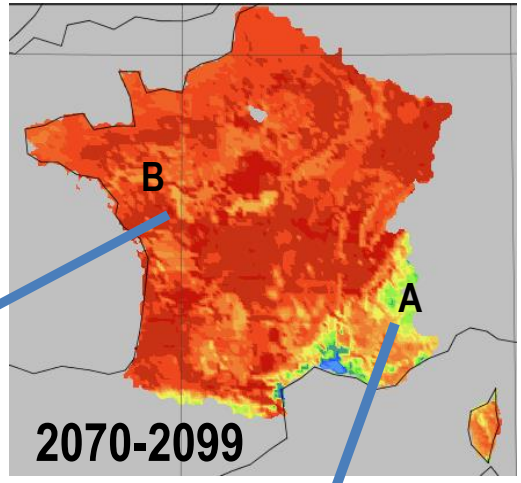
New opportunities for annual forage production with risks of forage losses in summer (and risks of milk production losses in summer-autumn)

(Graux et al., 2013)

Impact projections in France / 2



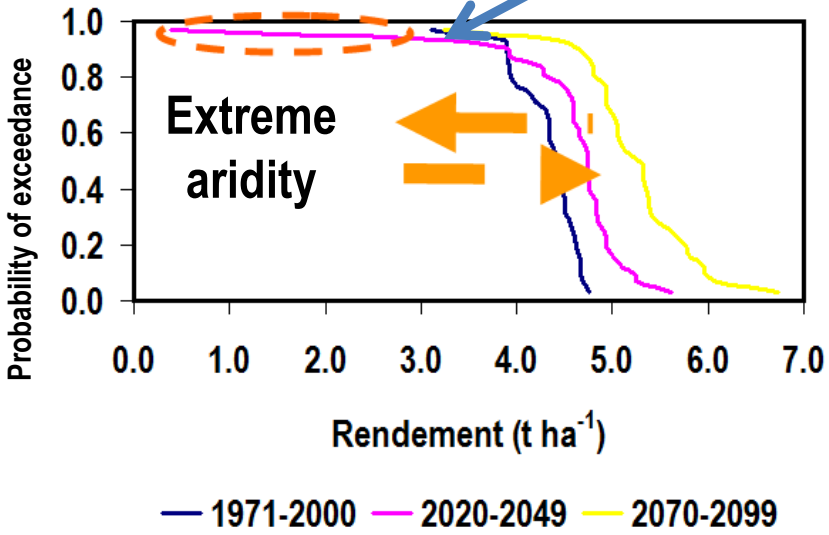


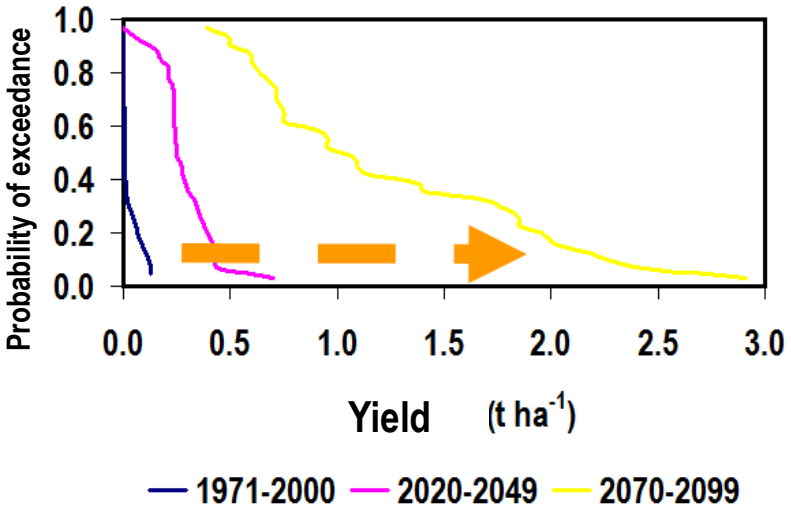


Simulated grassland yield (kg DM m^{-2} yr^{-1})

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

B: high-production area





Vulnerability to climate change

- **IPCC definition (IPCC 3rd AR)**

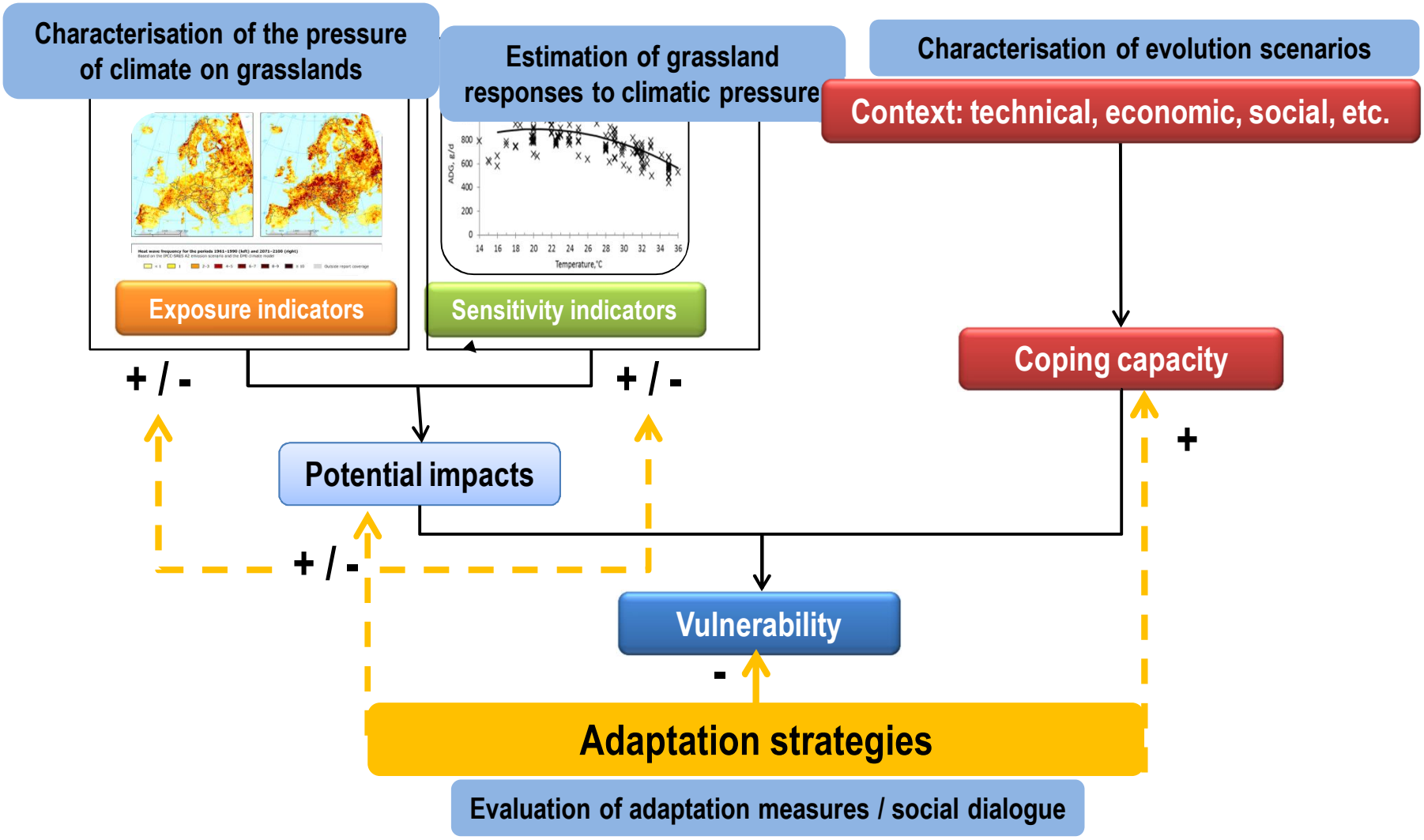
  The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes

  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%	$b = \frac{1}{2} \cdot \left(\frac{P_m}{P_m + 10} + 12 \cdot \frac{P_m}{P_m + 10} \right)$ $b < 5$: extreme aridity … $b > 59$: strong humidity

(Confalonieri et al., 2010)

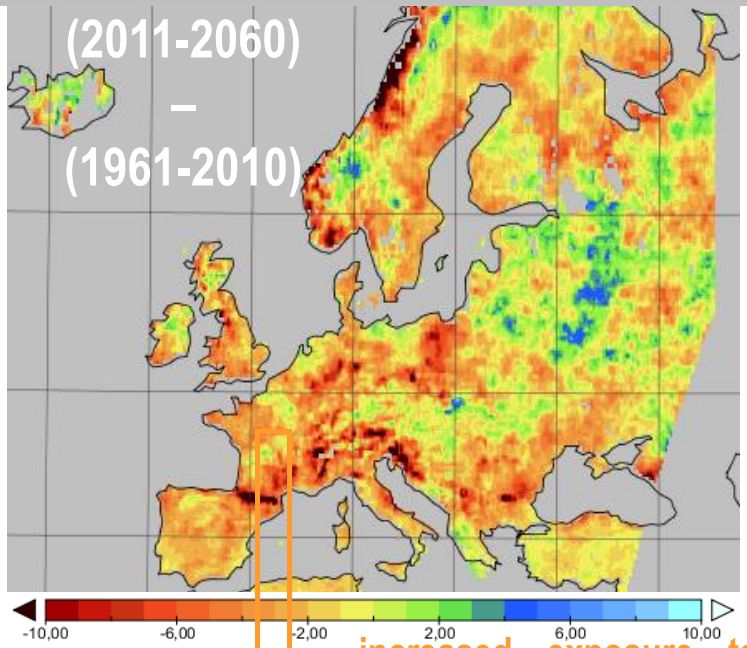
Sensitivity metrics

(Bellocchi et al., 2012; Lardy et al., 2013)

Category	Output
Productivity	Gross primary production
Carbon stocks	Total soil carbon
Nitrogen fluxes	Nitrogen leaching

Exposure to aridity

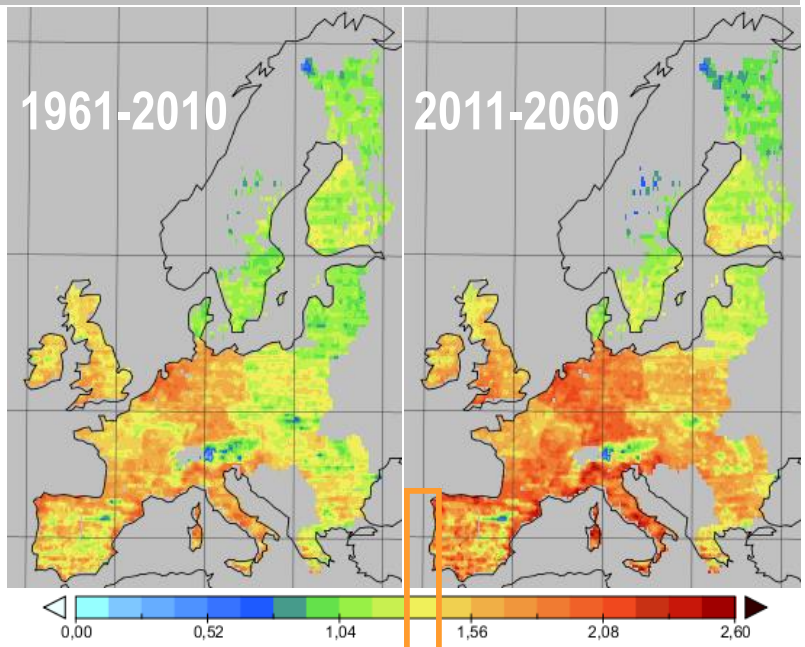
Difference between the mean values of the aridity index (*b*,) calculated for years of P2 (2011-2060) and P1 (1961-2010) with *b* < 25th percentile, as represented by the scenario A1B.



increased exposure to heat and drought stress

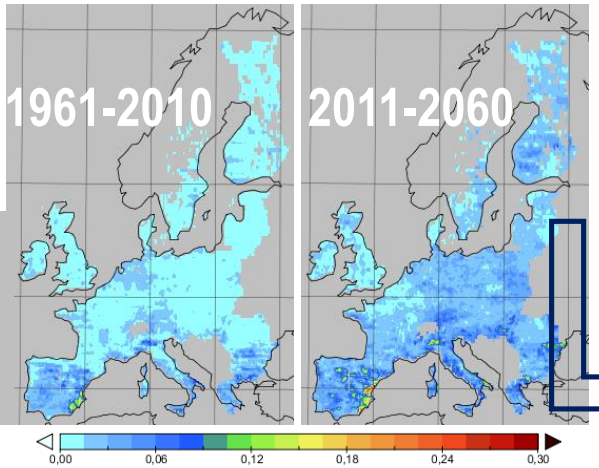
Sensitivity to aridity

PaSim-simulated grasslands: average values of gross primary productivity (kg C m^{-2}) for years experiencing conditions of aridity (*b* < 25th percentile).



increased average gross primary productivity

PaSim-simulated grasslands: variances of gross primary productivity (kg C m^{-2}) for years experiencing conditions of aridity (*b* < 25th percentile), represented by the scenario A1B.



quite general increase in the year-to-year variability

Vulnerability metrics

Index	Equation	Comments
Proportional vulnerability	$V_0 = \frac{n}{N}$	Proportion of vulnerable years in a series of years
Vulnerability gap	$V_1 = \frac{1}{N} \cdot \sum_{y:\, x_y < x_c} \left(x_c - \frac{x_y}{x_c} \right)$	Mean deficit in vulnerable years
Vulnerability severity	$V_2 = \frac{1}{N} \cdot \sum_{y:\, x_y < x_c} \left(x_c - \frac{x_y}{x_c} \right)^2$	As V_1, with more weight given to the most vulnerable years
Most vulnerable individual	$V_3 = 1 - \frac{\min(x_y)}{x_c}$	Distance to threshold of the most vulnerable year
Luers-based index	$V_4 = f\left(\frac{\delta x_y \, / \, x_y}{\delta x_c \, / \, x_c} \right)$	Explicit account of the sensitivity of the system

(Lardy et al., 2014)

Luers-based metric: vulnerability maps in Europe

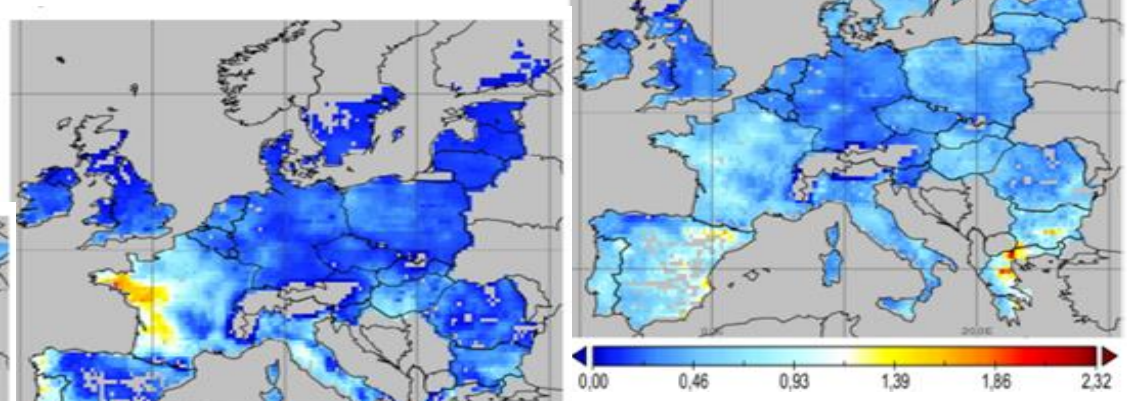
$$V_L = f\left(\frac{|\partial w/\partial x|}{w/w_0}\right)_{future} \Big/ f\left(\frac{|\partial w/\partial x|}{w/w_0}\right)_{past}$$

sensitivity

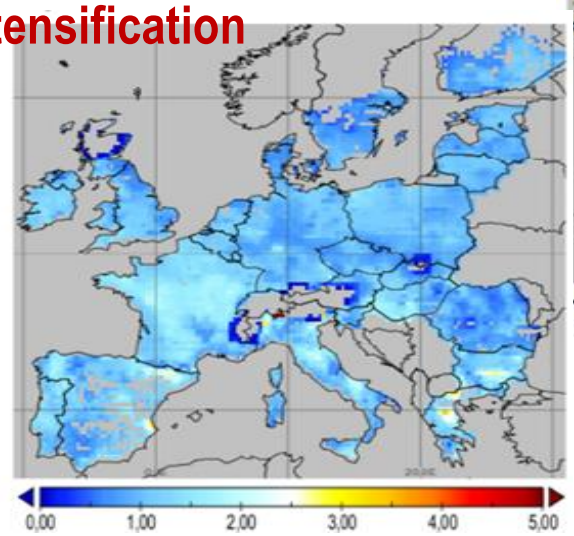
state

threshold

intensification

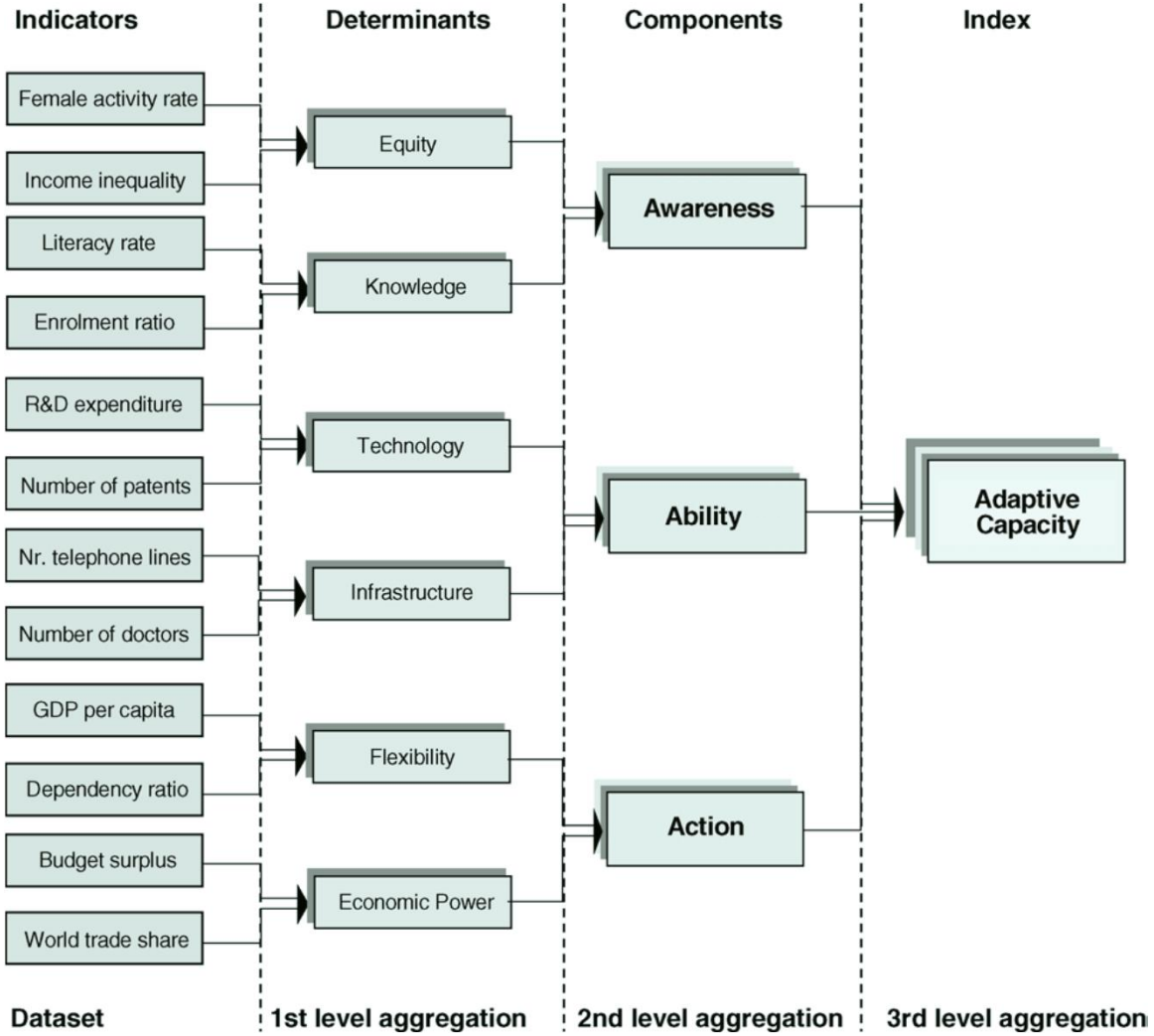


extensification



(Lardy, 2013)

Adaptive capacity

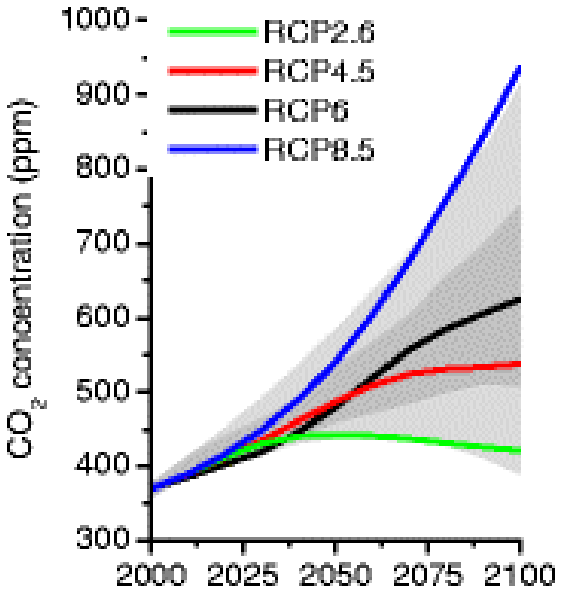


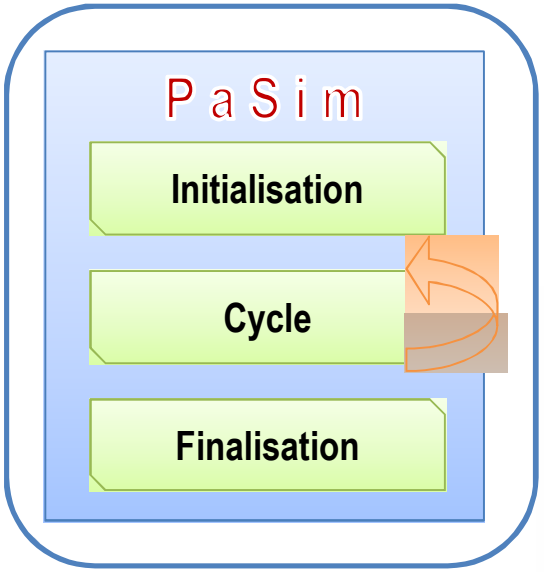
(Metzeger et al., 2006)

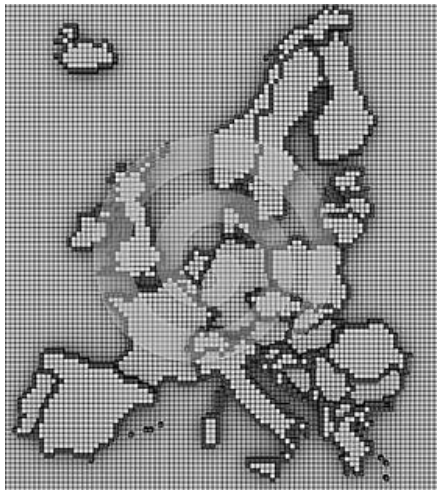
New vulnerability maps…

Management

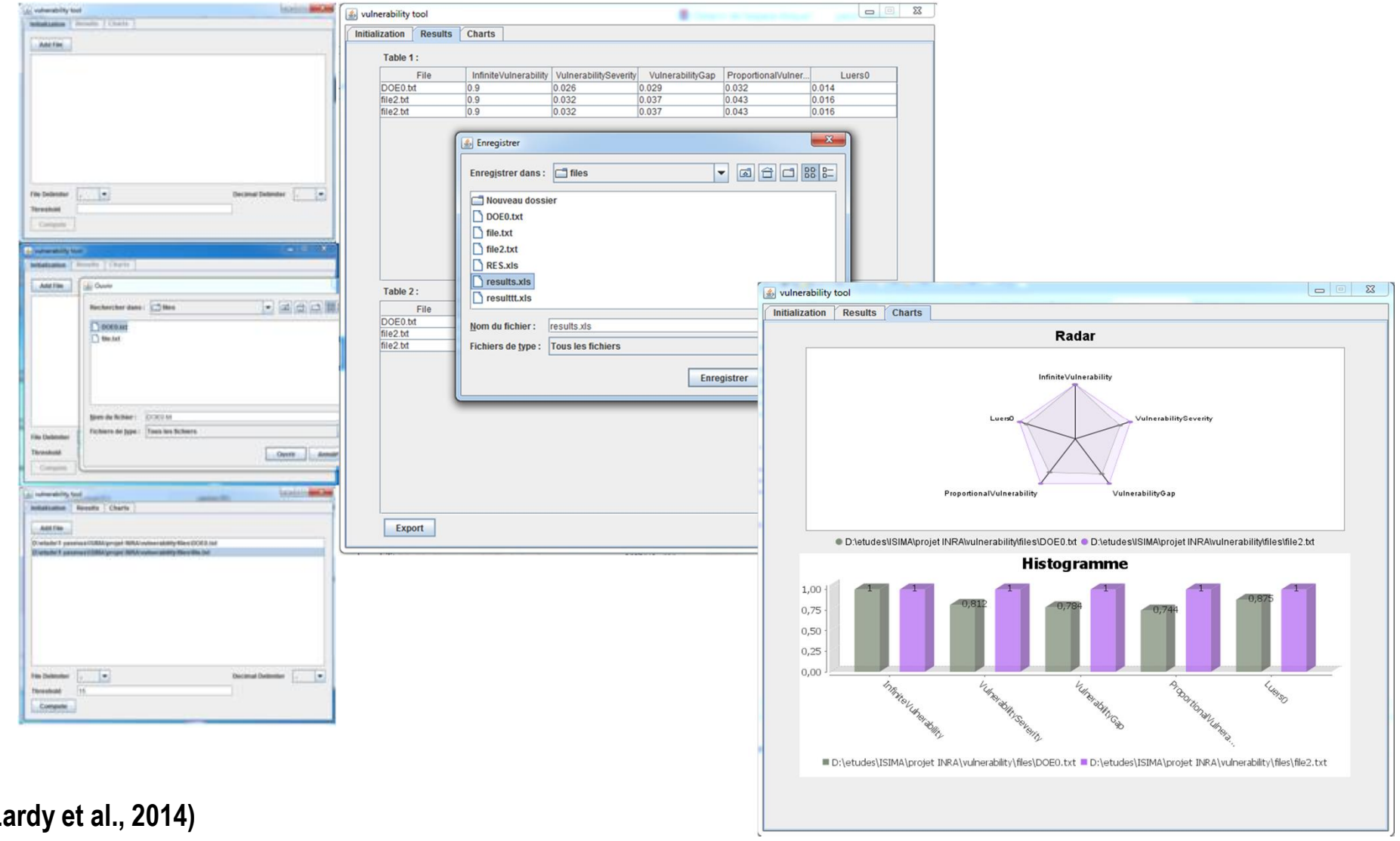
Climate







Vuln-Indices:
software to assess vulnerability to climate change



(Lardy et al., 2014)

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ANIMAL CHANGE
An integration of mitigation and
adaptation options for sustainable
livestock production under climate change


SEVENTH FRAMEWORK
PROGRAMME

Thank you!