

INRAE STICS LIÈGE université Gembloux Agro-Bio Tech

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Impact of climate change on the main cash crop in Belgium

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https://environnement.wallonie.be/home/gestion-environnementale/risques-climatiques.html



2020 drough year

2021 humid summer



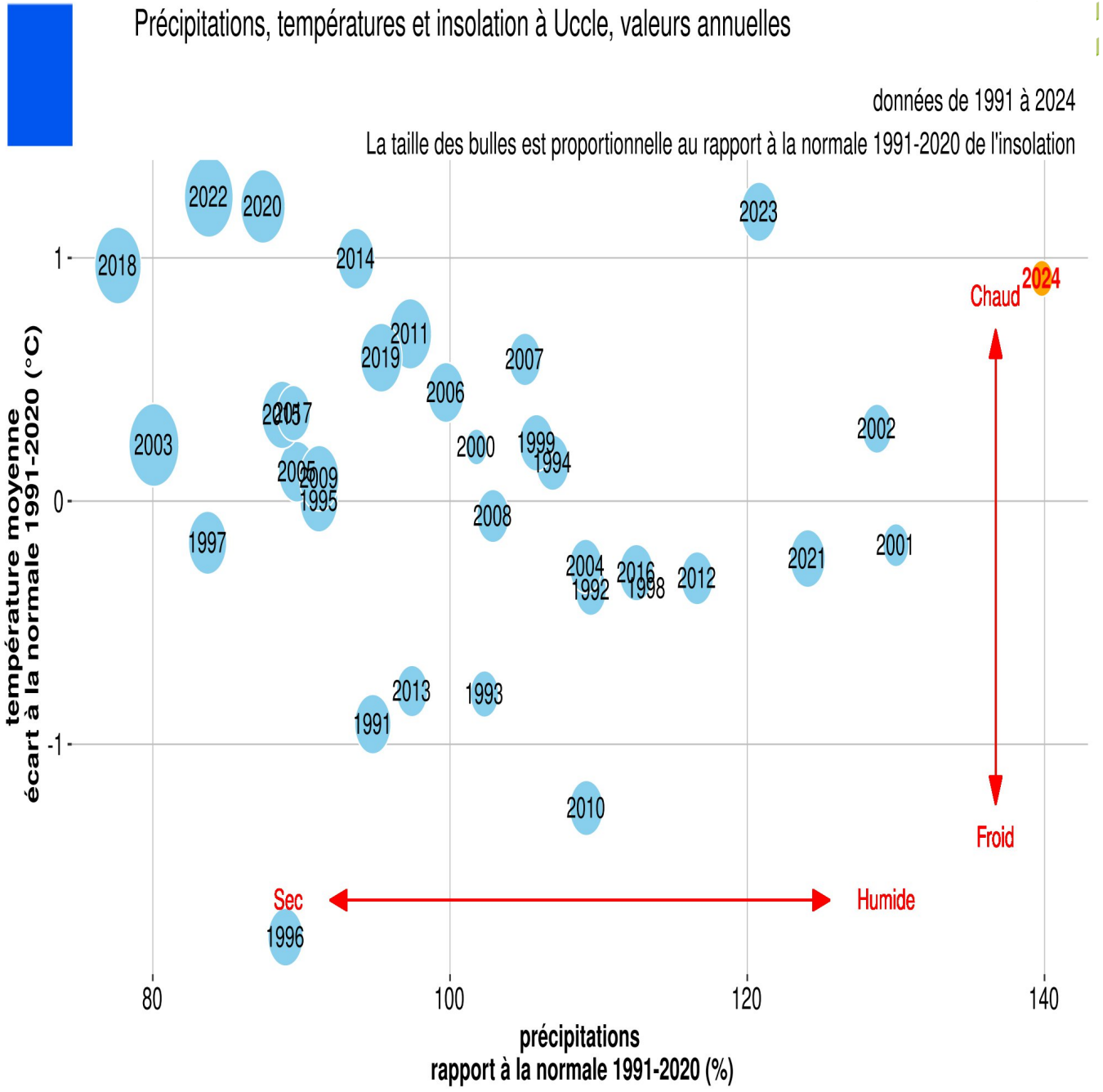


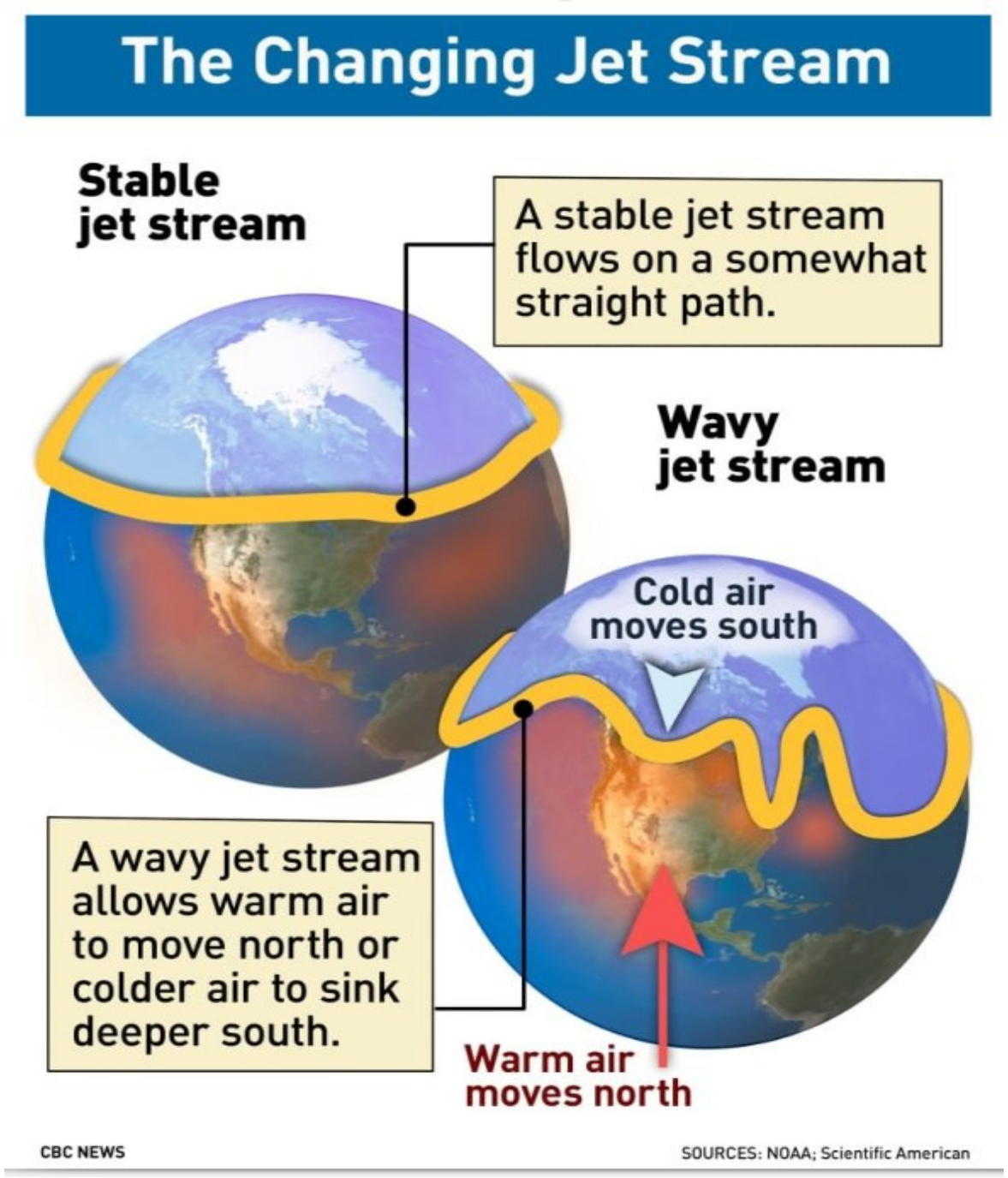
2022 drought year

2024 humid year

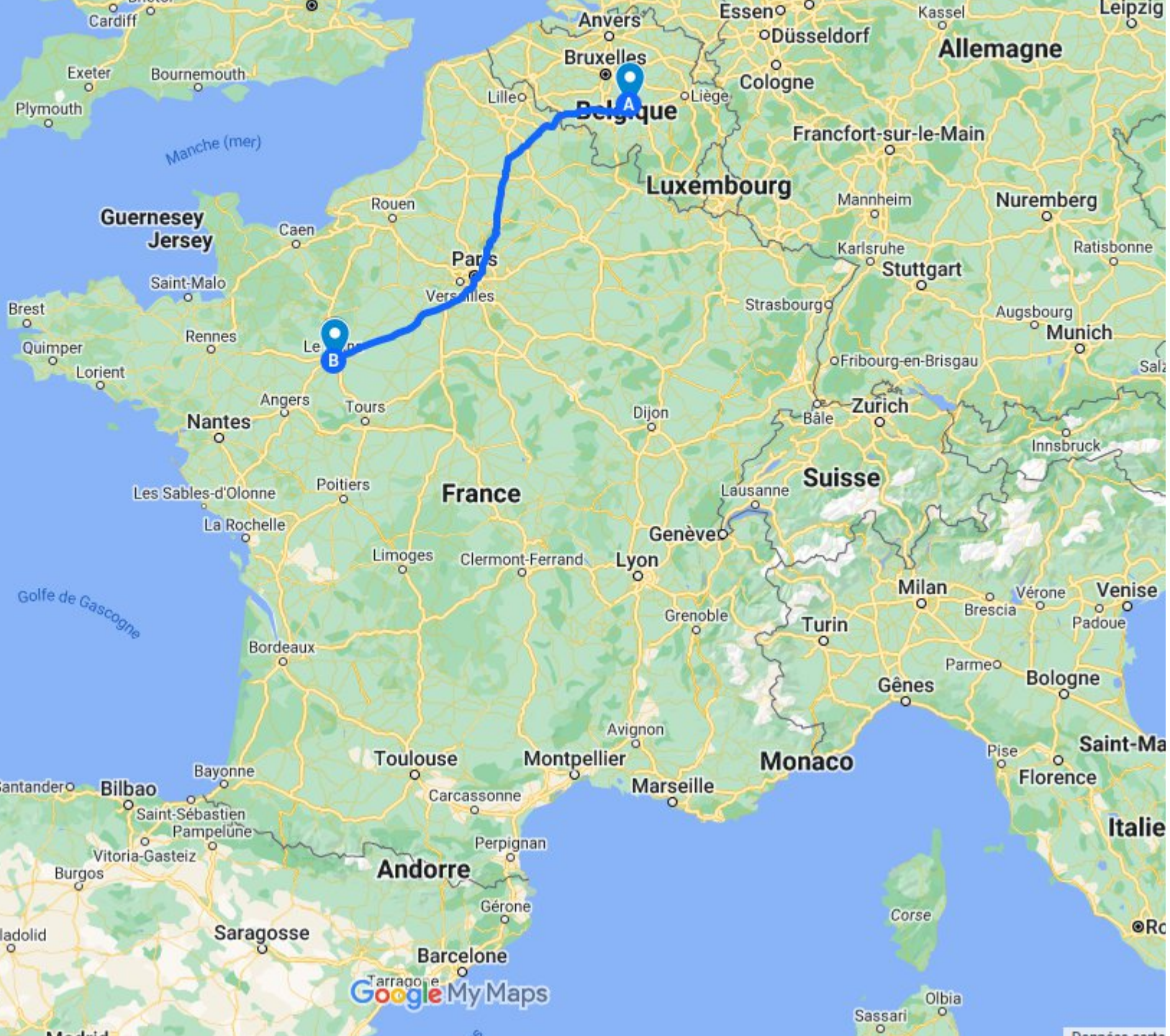






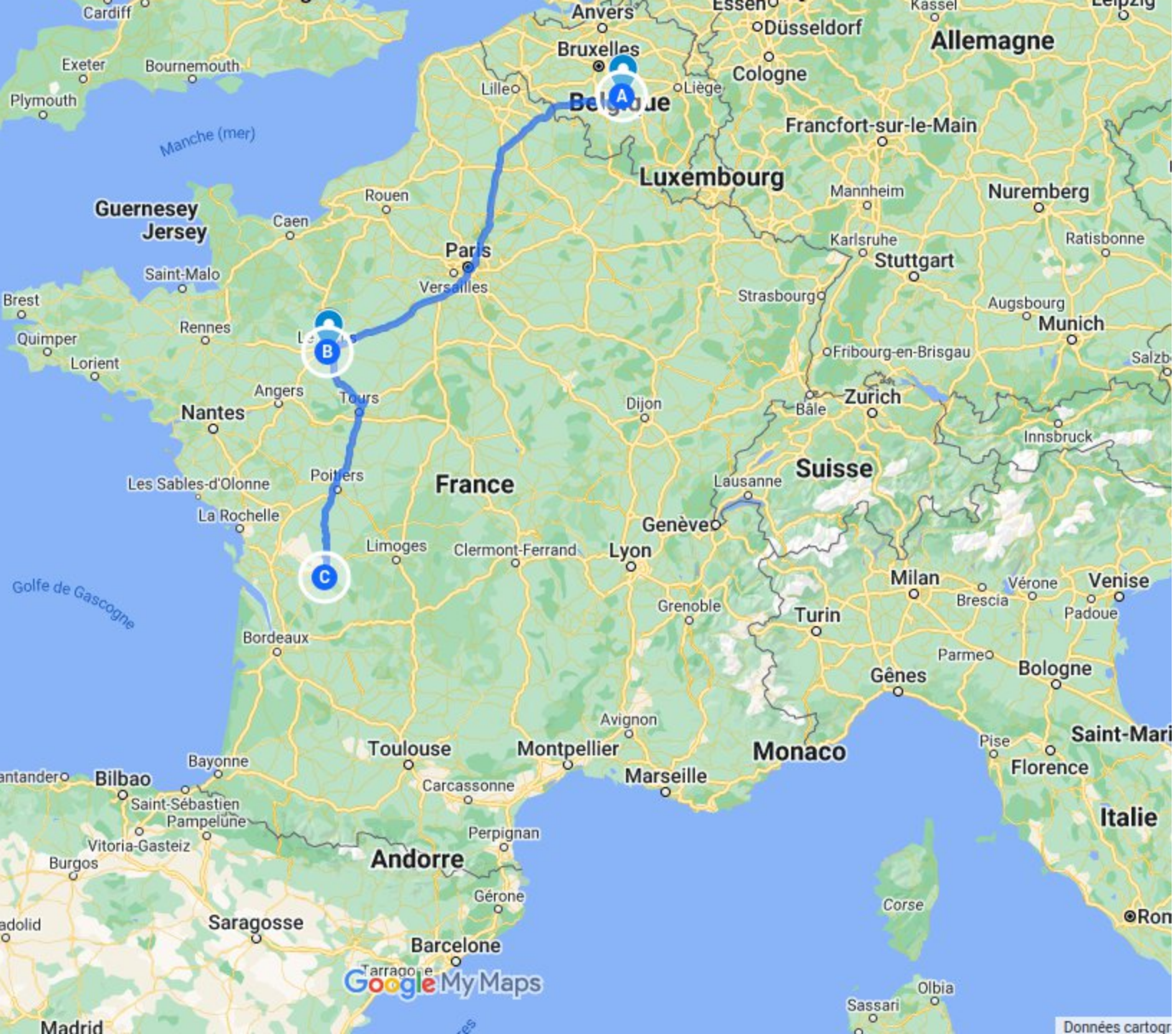


Why this contrast ?



In 2030 Gembloux will have the climate of Mans

According to Xavier Fetweys (Climatologist Uliège)



In 2030 Gembloux will have the climate of Mans

In 2070 the climate of Angoulême

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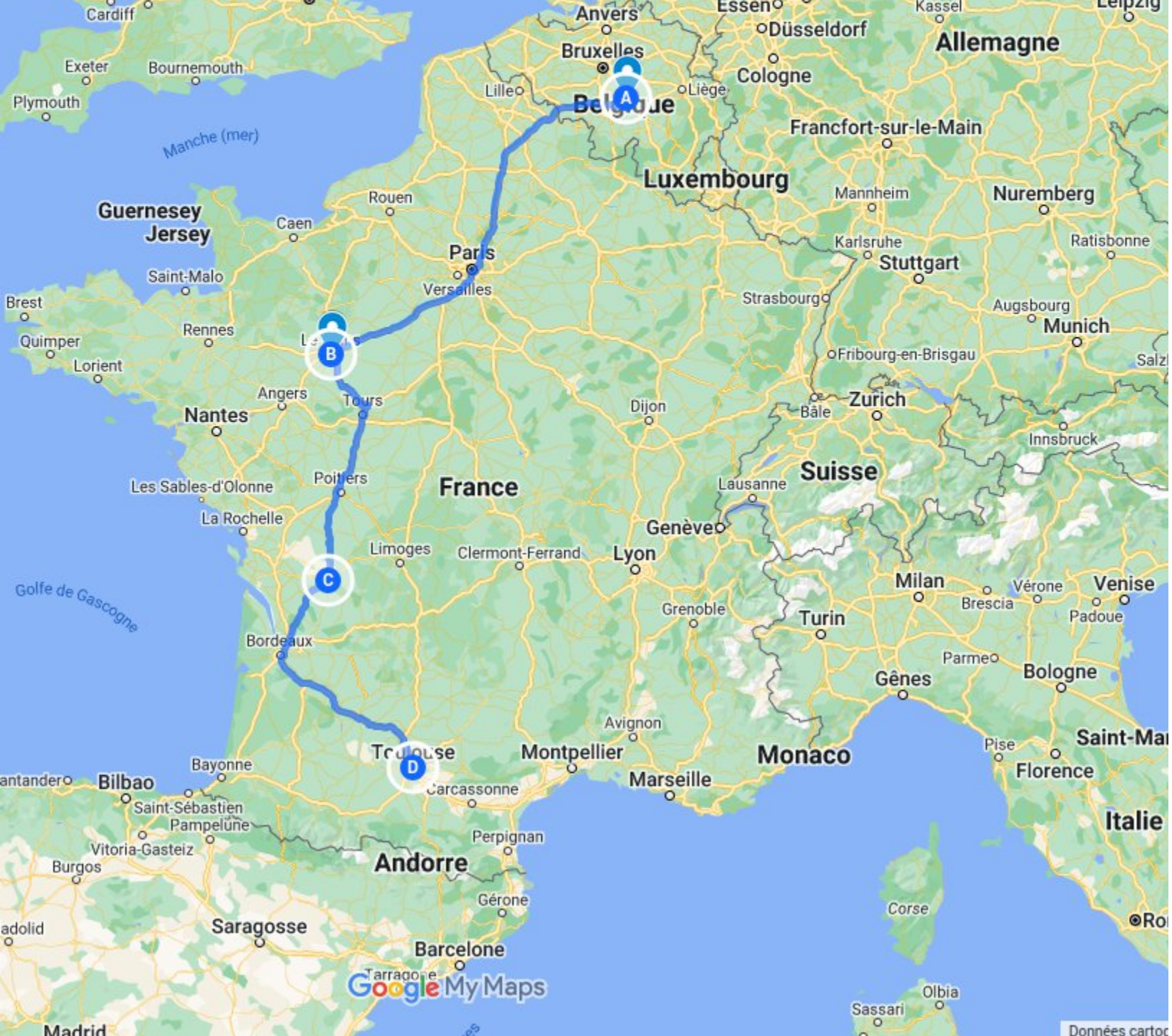


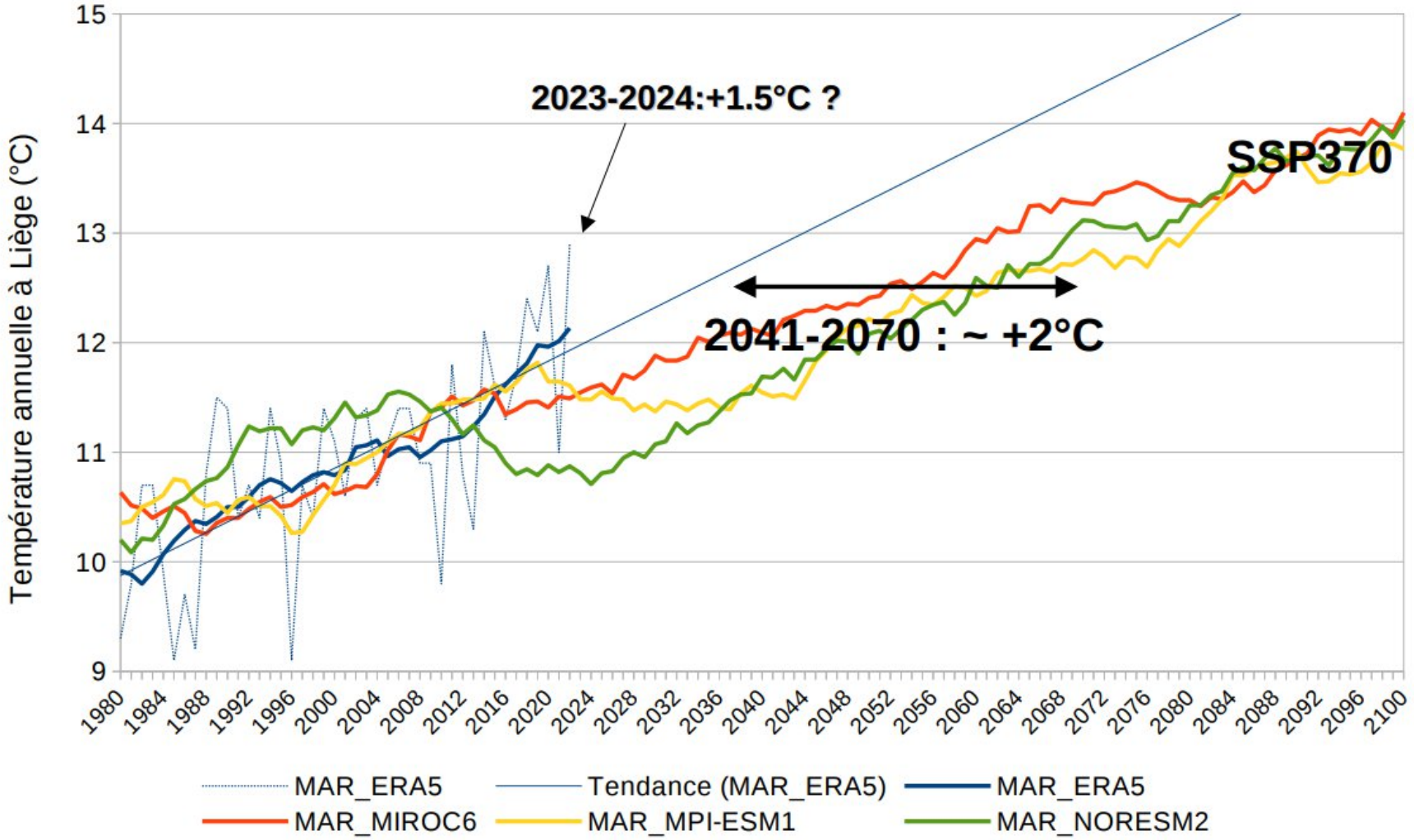
In 2030 Gembloux will have the climate of Mans

In 2070 the climate of Angoulême

In 2100 the temperature of Toulouse

According to Xavier Fetweys (Climatologist Uliège)

Where are we going?



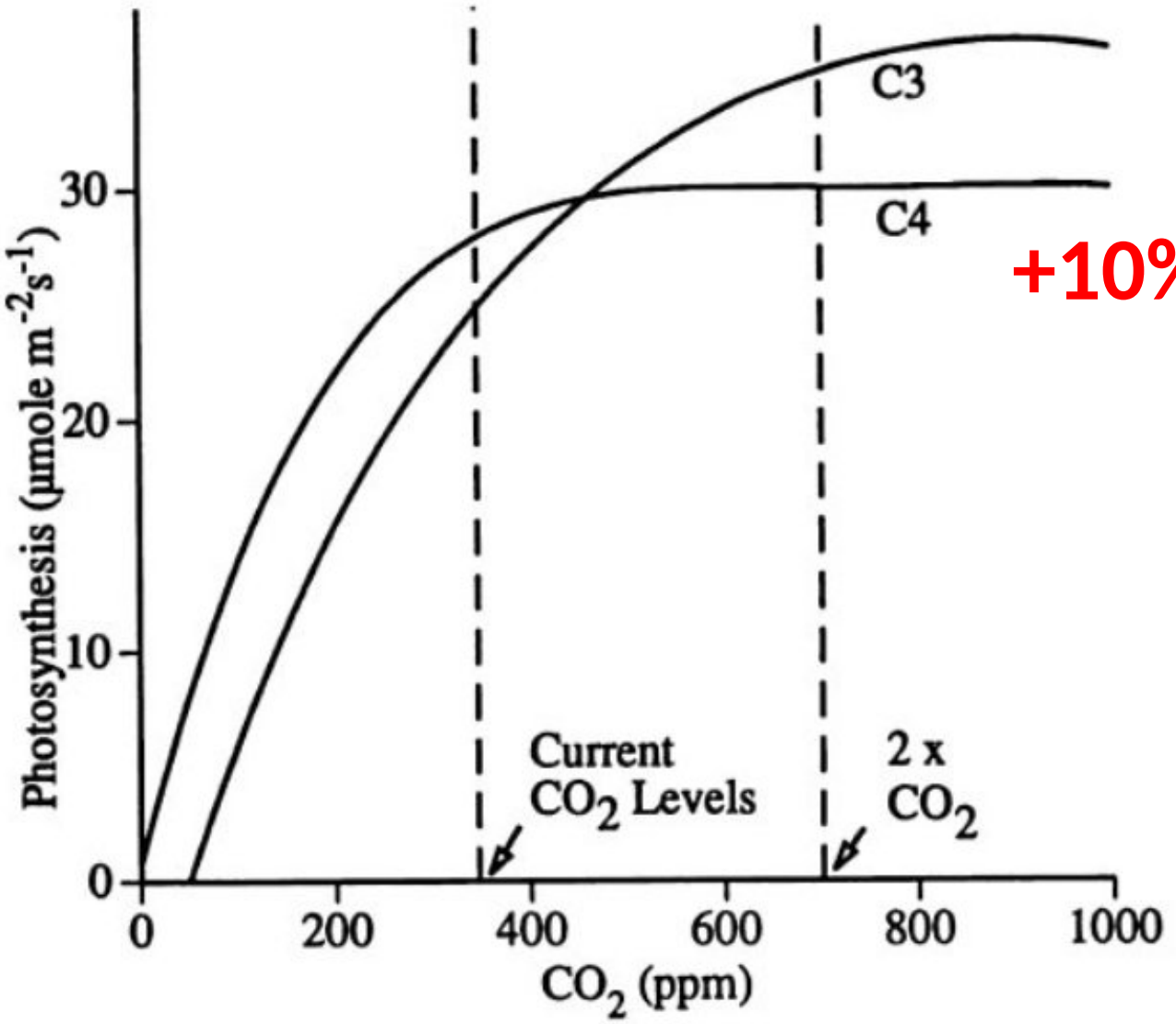
Different Global Circulation Model (GCM):

- CMCC
- MIROC
- MPI
- …

One direction!

Effect of CO2

Don’t forget the CO2 fertilizer effect !



Kaiser, 1997

Predicting the impact of climate change with crop models

Main inputs

Daily climatic conditions
- Solar radiation
- Temperature : minimum and maximum
- Rainfall
- Air humidity
- Wind speed
- CO_2 concentration

Management itinerary
- Sowing : date, depth & density
- Soil tillage
- Residue & organic matter restitution
- Irrigation & fertilization : date, amount & type
- Special techniques : pruning, cutting, …
- Harvest

Cultivated plants
- Species and cultivars
- Ecophysiological properties
- Initial status

Soil permanent and initial properties
- Soil depth
- Bulk density
- Water content at wilting point & field capacity
- Stone content
- Initial water and N contents
- Clay content, organic N, pH, $CaCO_3$, etc.
- …

STICS modules

Ecophysiology of aerial parts
- Phenological and aerial development
- Above- and belowground growth
- Yield elaboration

Crop microclimate
- Soil temperature
- Crop temperature



Plant, soil & management interactions
- Water demand and management
- Nitrogen demand, fixation and management
- Organic matter cycling and management

Soil – root interactions
- Root density profile
- Water balance
- Nitrogen balance
- Water, nitrogen and heat transfer

Main outputs

Plant development
- Phenological development
- Leaf area index
- Plant/tiller density
- …

Root system growth
- Root front growth
- Root density profile

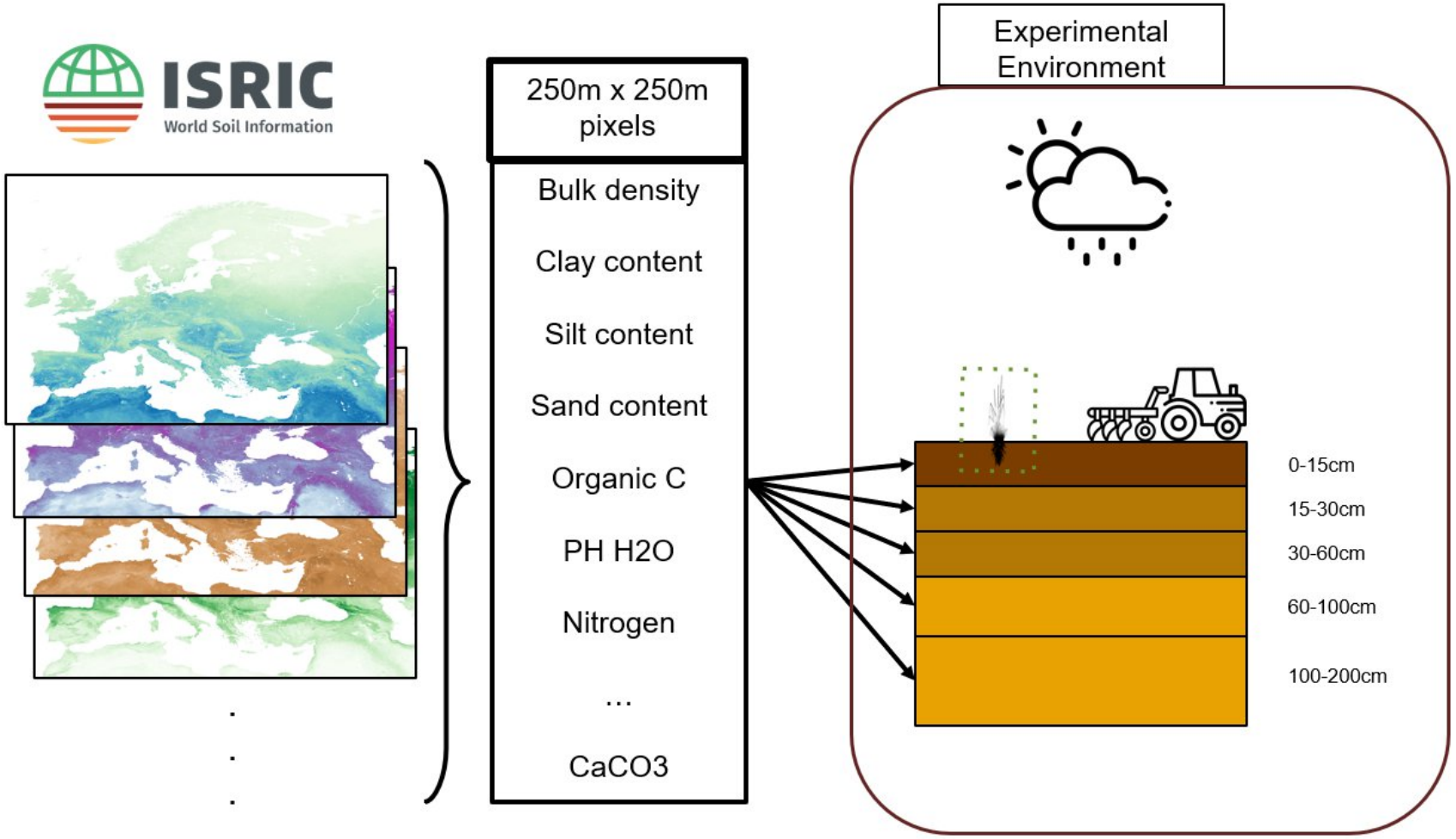
Aboveground growth
- Aboveground biomass & organs' repartition
- Yield components
- Yield quality (water, protein, oil, …)
- Plant N uptake & grain N content

Plant sensed stresses
- Water (deficit and anoxia) stress indices
- Nitrogen stress index
- Frost and high temperature stress indices

Soil water & nitrogen balances
- Soil water content, soil/mulch evaporation and plant transpiration
- Soil mineral N content, soil organic C and N content, soil CO_2 and N_2O emissions
- Water deep infiltration & N leaching

Soil structure
- Soil organic C and N dynamics
- Compaction and fragmentation

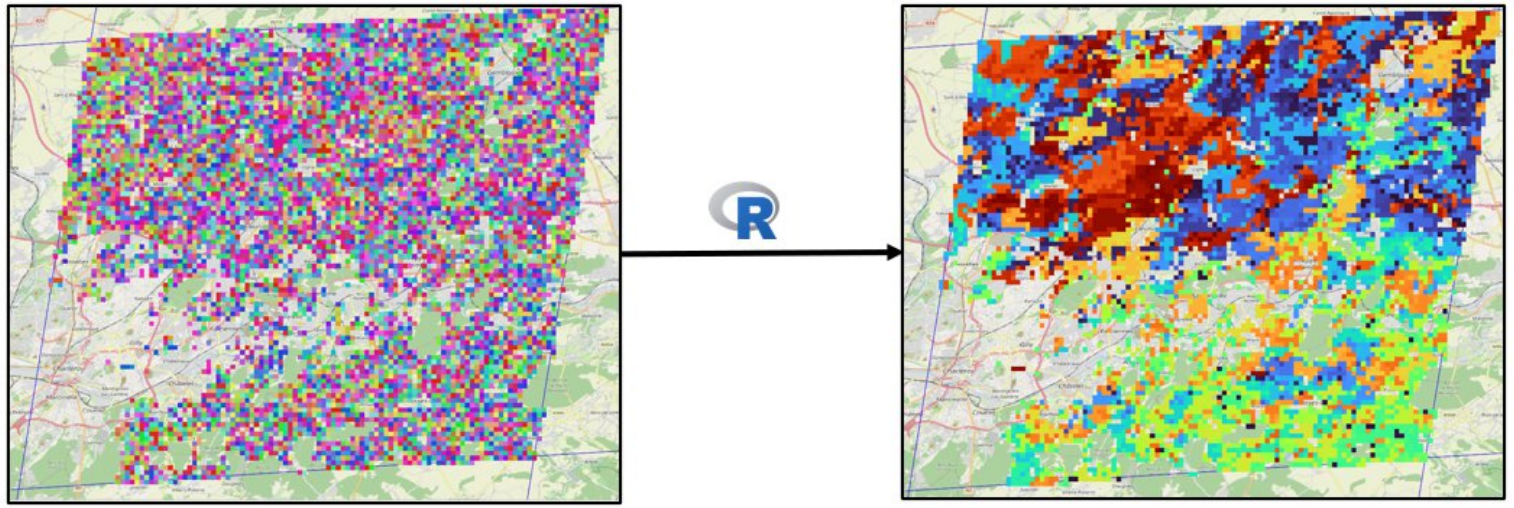
Predicting the impact of climate change with crop models



Soil data : 250*250m
Climate Data : 5*5 km

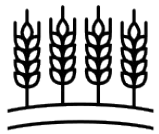
Predicting the impact of climate change with crop models

Soil data : 250*250m
Climate Data : 5*5 km
aggregation by similar soil within climatic tiles using unsupervised X-means clustering



Predicting the impact of climate change with crop models

5 crops studied :

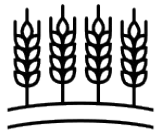
- Winter wheat 
- Rapeseed 
- Sugar beet 
- Potato 
- Maize 

3 GCMs and 3 global warming scenario's (+ the historical period 1980-2010)

GCMs		*+2°C*	*+3°C*	*+4°C*
CMCC-CM2_SR5	**Years**	2024-2053	2048-2077	2060-2079
	[CO_2]	429	605	741
MIROC6	**Years**	2030-2065	2066-2095	2081-2100
	[CO_2]	545	722	1005
MPI-ESM1-2-HR	**Years**	2045-2074	2071-2100	2081-2100
	[CO_2]	592	757	1005

Predicting the impact of climate change with crop models

5 crops studied :

- Winter wheat 
- Rapeseed 
- Sugar beet 
- Potato 
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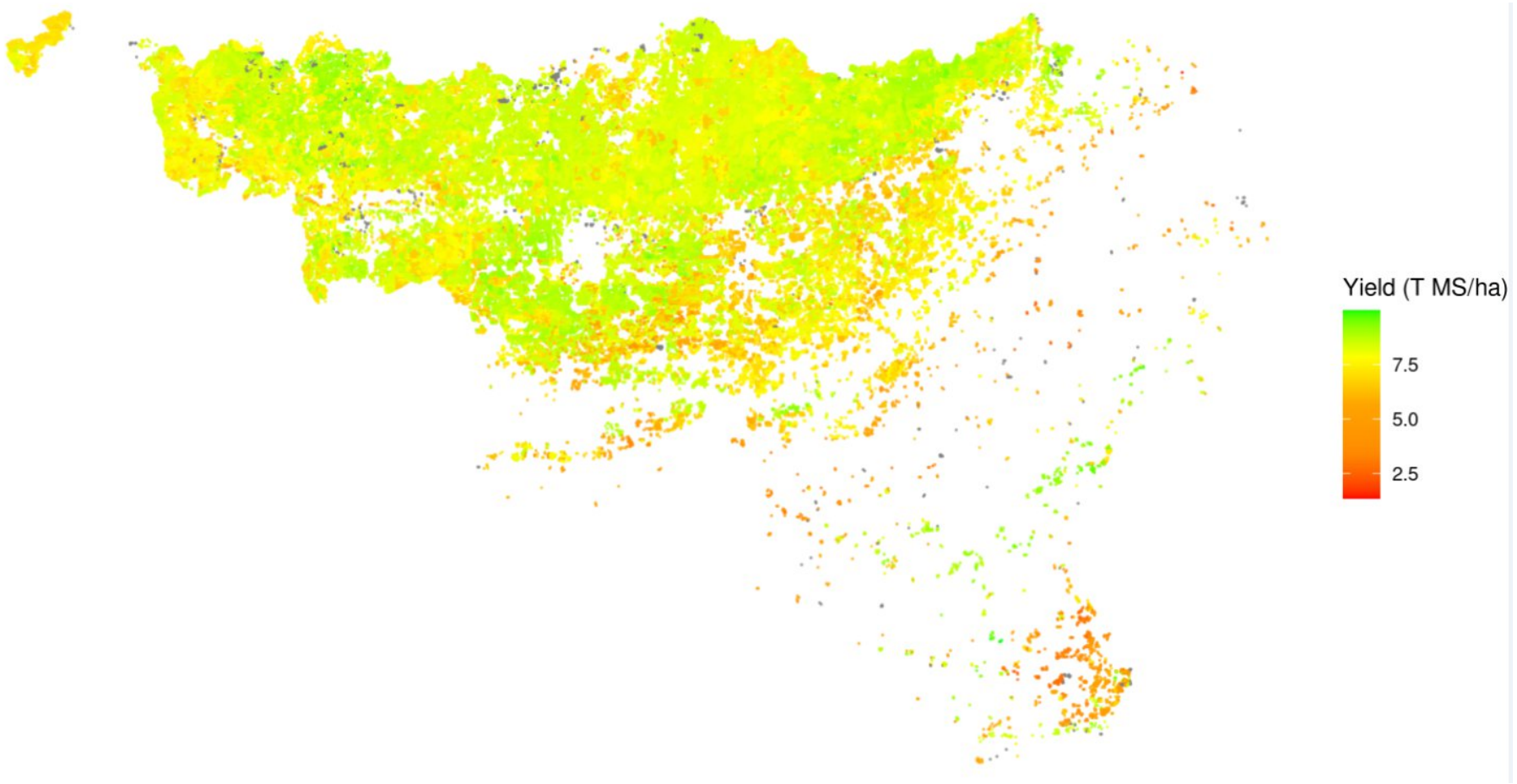
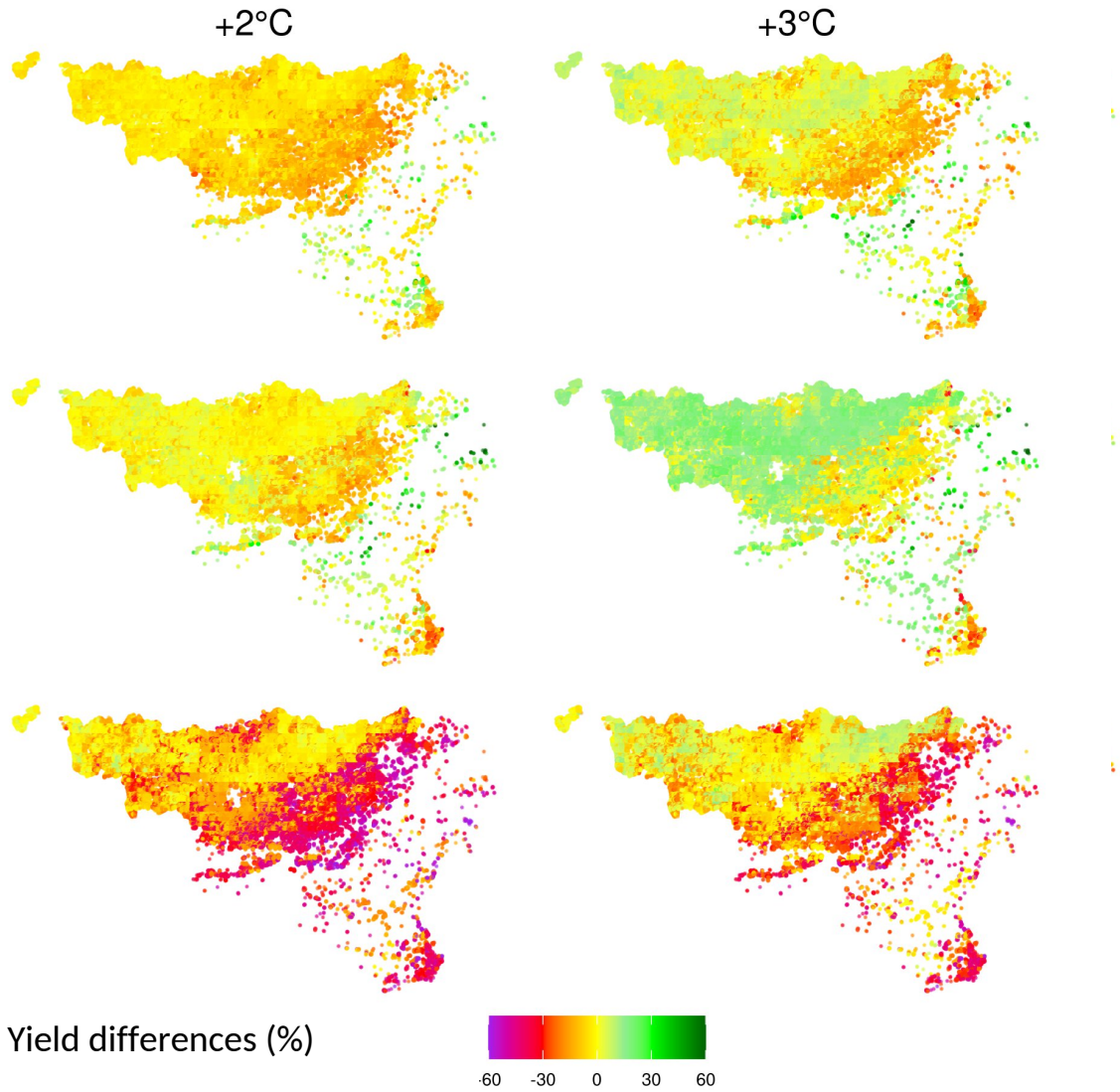
==>Calibrations of crop parameter file developed for Belgium by Delandmeter et al. (2023, 2024) and Lenoir (2024).

Winter wheat

Historical



Winter wheat

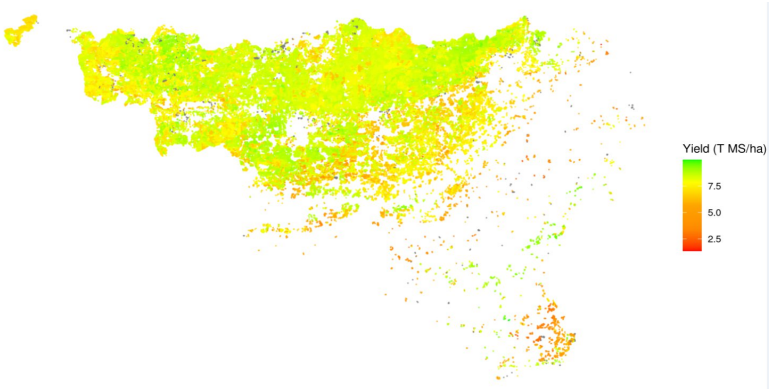


Spatial response is different

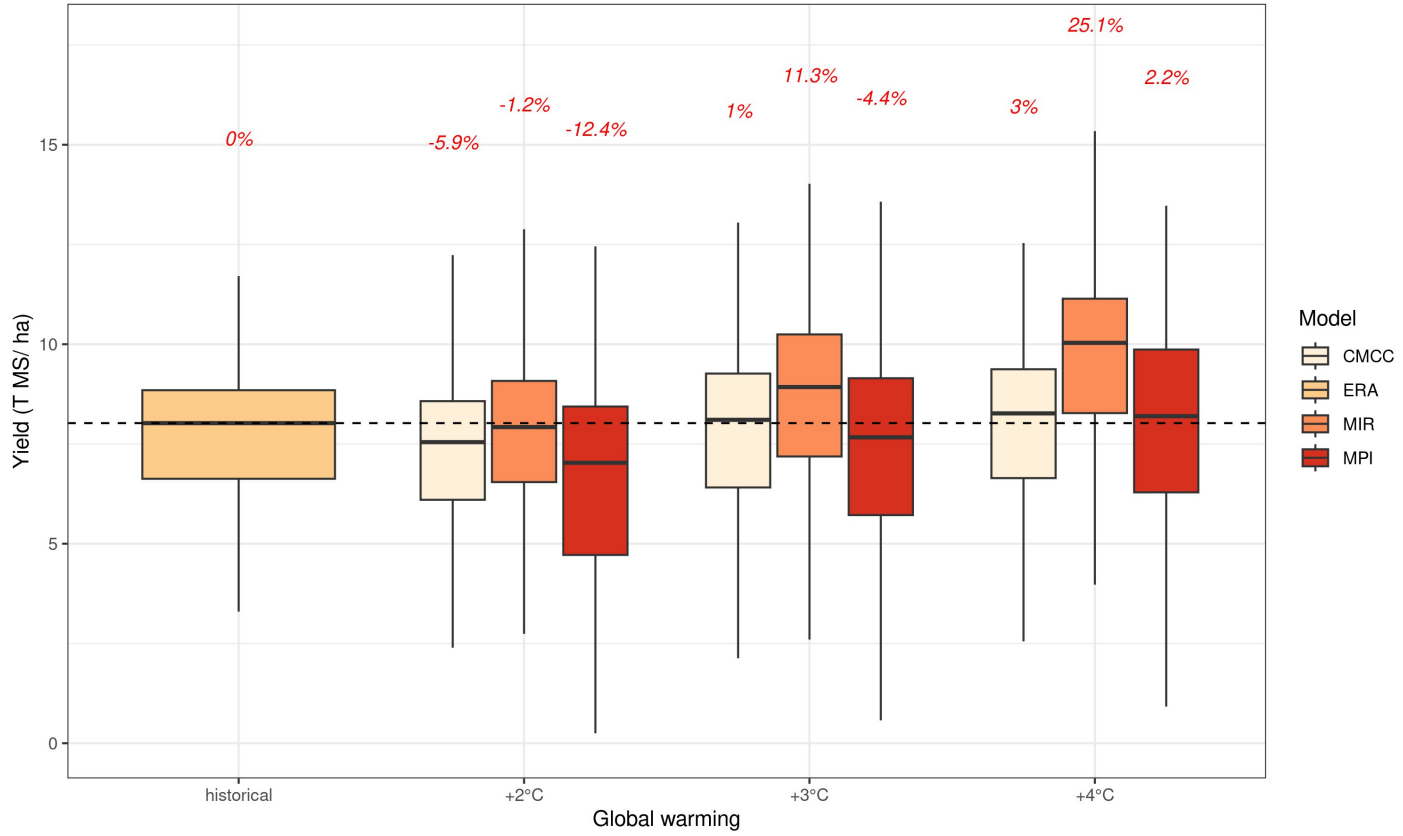
Yield differences (%)= median yield changes relative to the historical period

Winter wheat

Historical



Under climate change

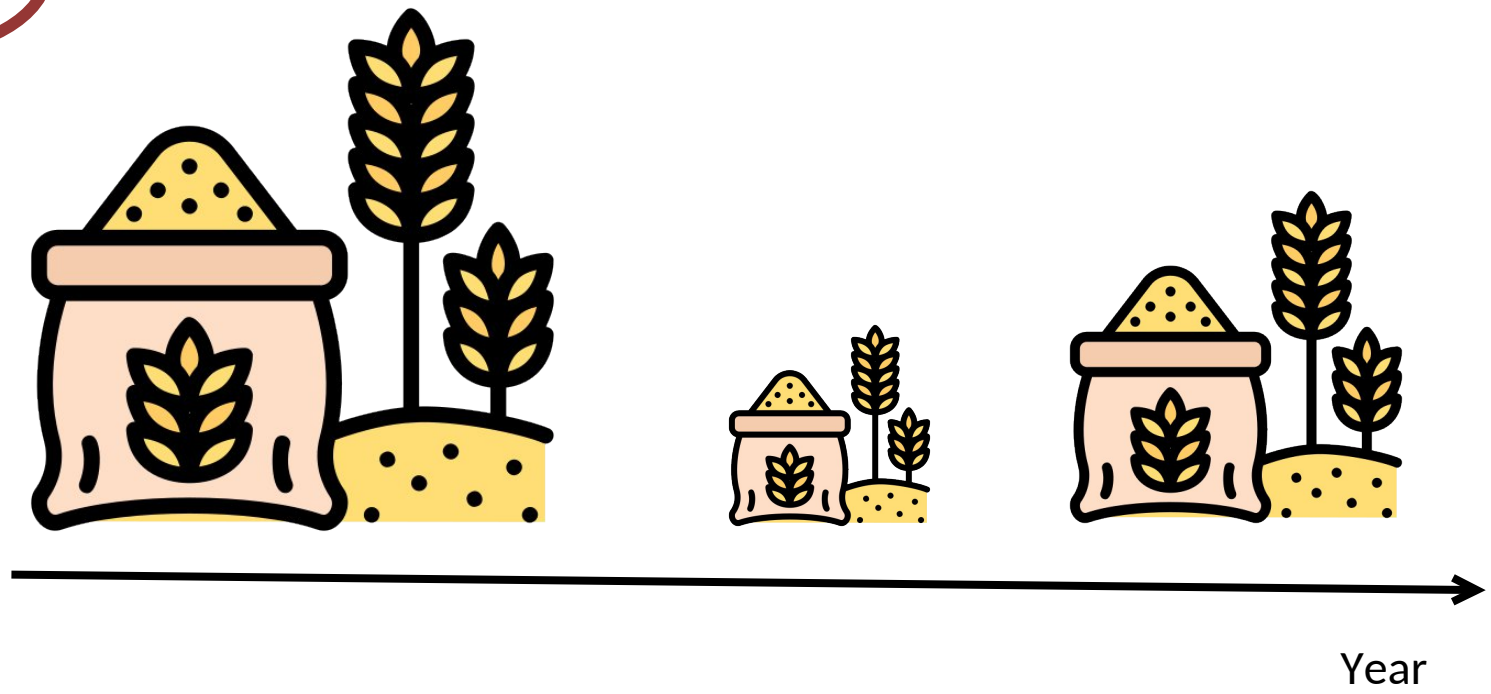


==>Yield at the short term will tend to decrease !

Winter wheat

How does my yield fluctuate from year to year?

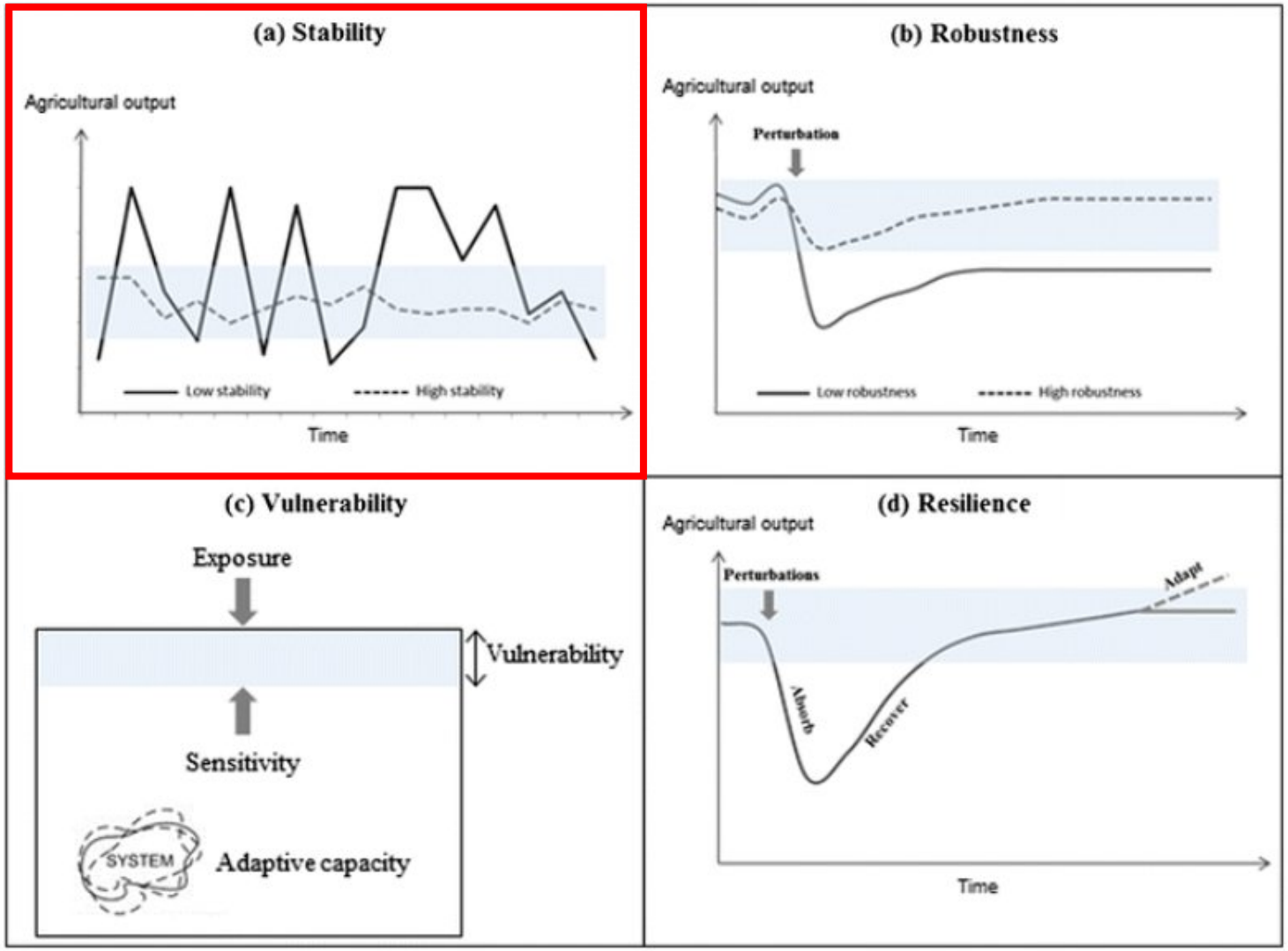




Median yield is not enough. Yield stability is also important for farmers.

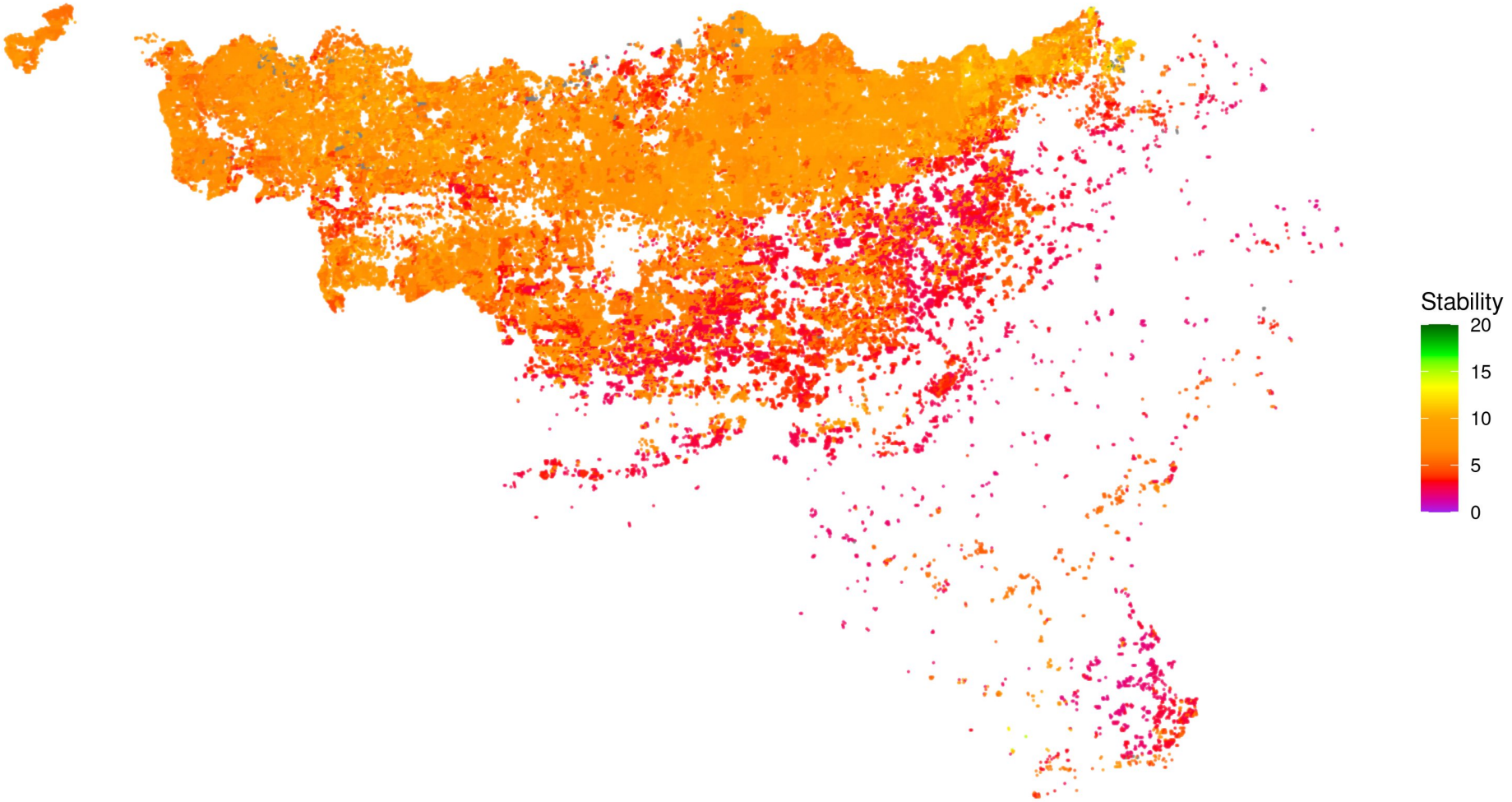
Stability

Stability = μ/σ

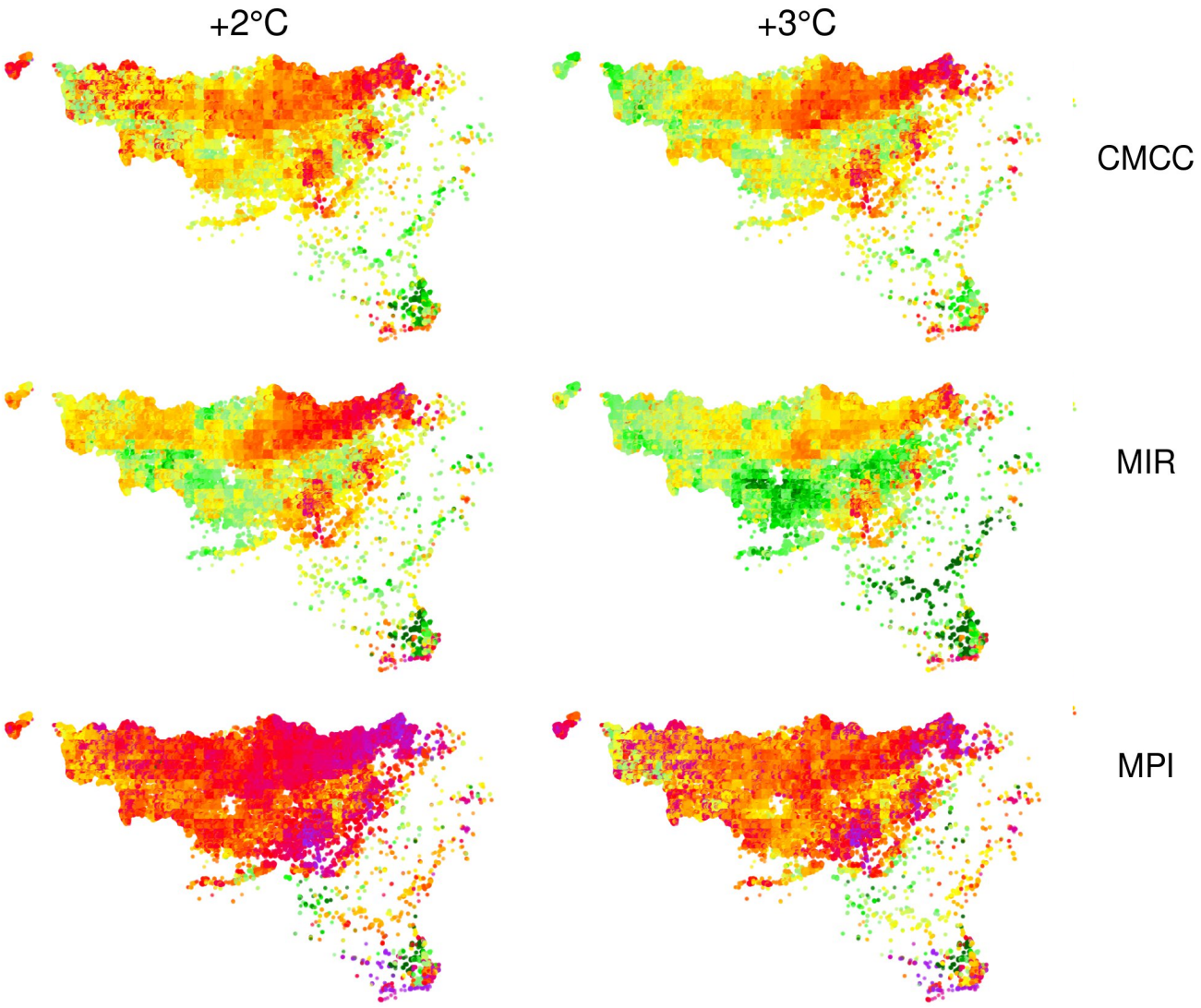


Urruty et al., 2016

Winter wheat



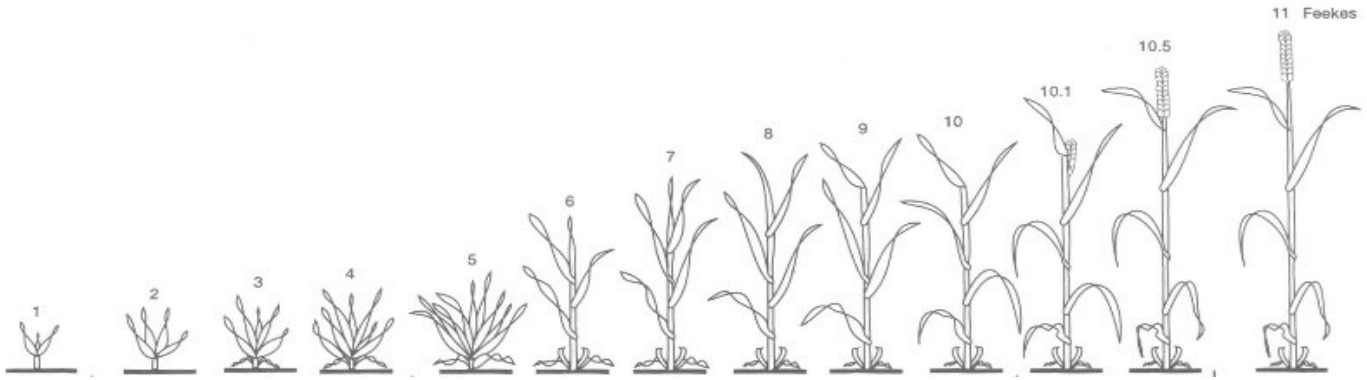
Winter wheat



In the north of Wallonia: decrease of the stability.

MPI GCM induces high unstability

Winter wheat

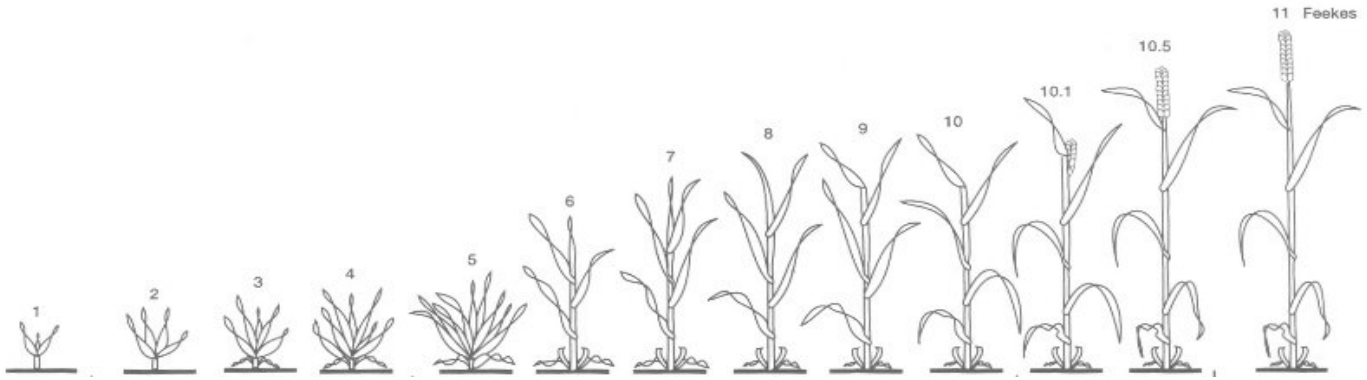




https://www.yahoo.com/entertainment/speedy-gonzales-animated-movie-in-development-at-212251939.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAEOaLuNrm3Ju-TY3sU-240_y5w8000g4CLeQlb1rhkUJPFE5cr-5KVyiB71w6TwsaefiTEhyFDwbuOlpNIEegbCKLJ7qOXTM5ZmChGpdqByAZmC1EgpfVNBJ364ogqr3SZZYMEC055pKXcmwNrIqPdjZMGesnUr1GDpe8HiD6Lyg

Physiological maturity
historical : 24 Juillet

Winter wheat





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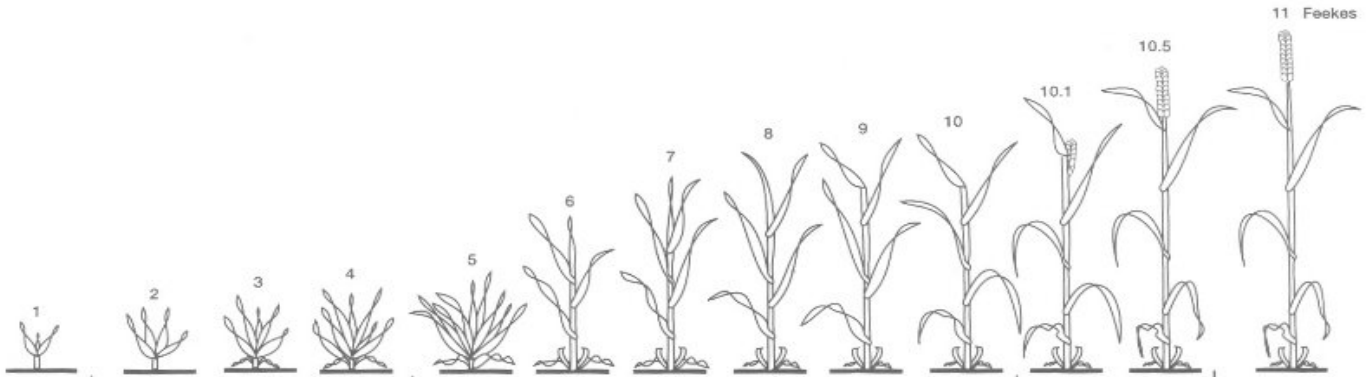
Physiological maturity
historical: 24 Juillet
+2°C :16 Juillet

– **8 days**

Winter wheat





https://www.yahoo.com/entertainment/speedy-gonzales-animated-movie-in-development-at-212251939.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAEOaLuNrm3Ju-TY3sU-240_y5w8000g4CLeQlb1rhkUJPFE5cr-5KVyiB71w6TwsaefiTEhyFDwbuOlpNIEegbCKLJ7qOXTM5ZmChGpdqByAZmC1EgpfVNBJ364ogqr3SZZYMEC055pKXcmwNrIqPdjZMGesnUr1GDpe8HiD6Lyg

Physiological maturity

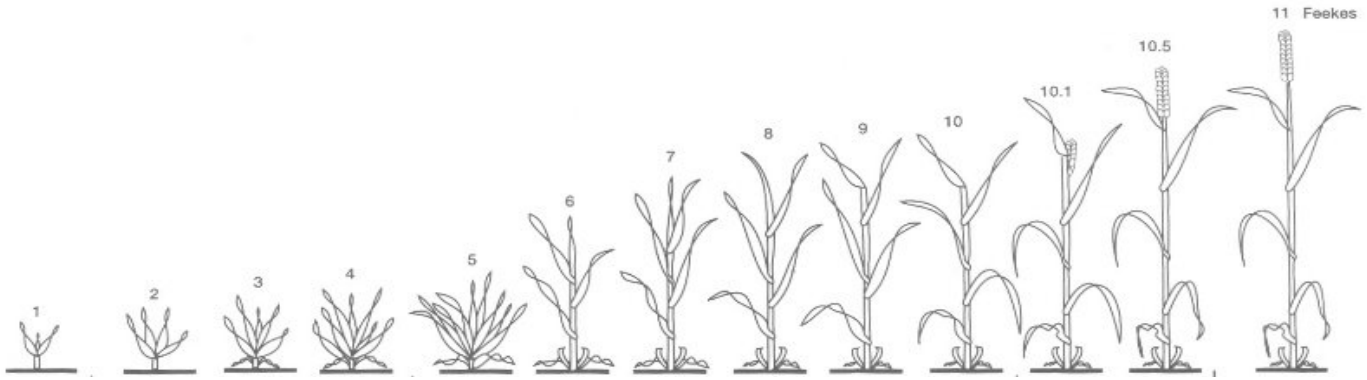
historical: 24 Juillet

+2°C :16 Juillet

+3°C-> 8 juillet

– **16 days**

Winter wheat





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Physiological maturity

historical: 24 Juillet

+2°C :16 Juillet

+3°C :8 juillet

– **16 days**

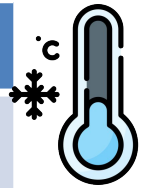
==> Avoid a part of summer heat stress !

Winter wheat

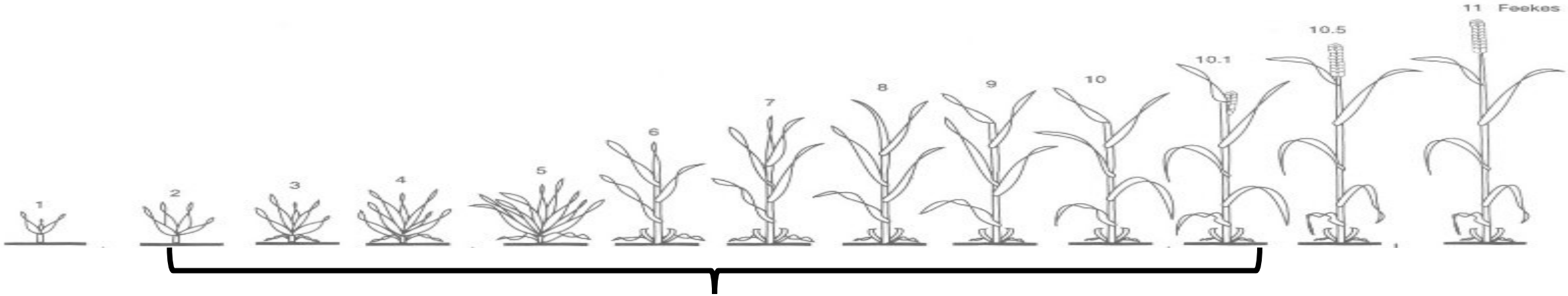


juvenile stage

	+2°C	+3°C
Thermal stress	-28%	-41%
Water logging	≃	≃



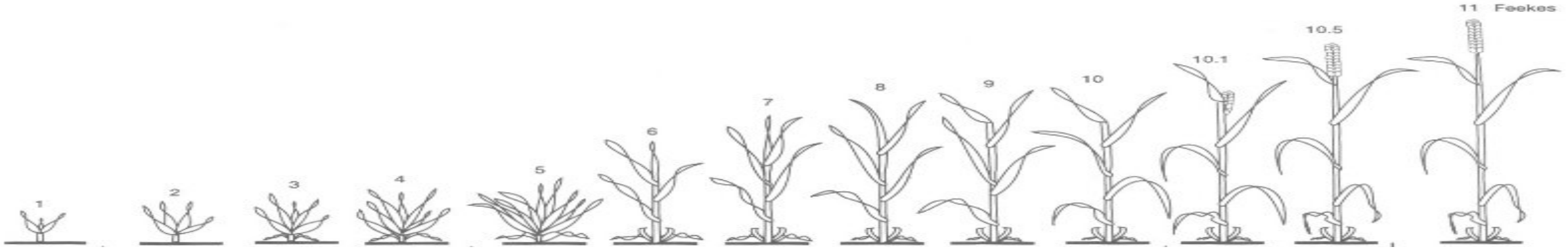
Winter wheat



	+2°C	+3°C
Thermal stress	2 out of the 3 GCMs ↘	2 out of the 3 GCMs ↘
Water logging	+460%	+470%

/ !\ Huge inter-annual variability

Winter wheat



	+2°C	+3°C
Thermal stress	+121%	+140%
Water logging	2 out of the 3 GCMs ↘	2 out of the 3 GCMs ↘
Water stress	2 out of the 3 GCMs ↗	2 out of the 3 GCMs ↗



/ !\ Huge variability

For other crops

	Global warming					
	+2°C			+3°C		
	CMCC	MIROC	MPI	CMCC	MIROC	MPI
Winter wheat	↘	↘	↘	≃	↗	↘
Rapeseed	≃	↗	↘	↘	↗	≃
Sugar beet	↗	↗	↗	↗	↗	↗
Potato	↘	↘	↘	↘	↗	↗
Maize	↘	↘	↗	↘	↘	↗

The response is inconsistent between crops.

Response depends on GCM

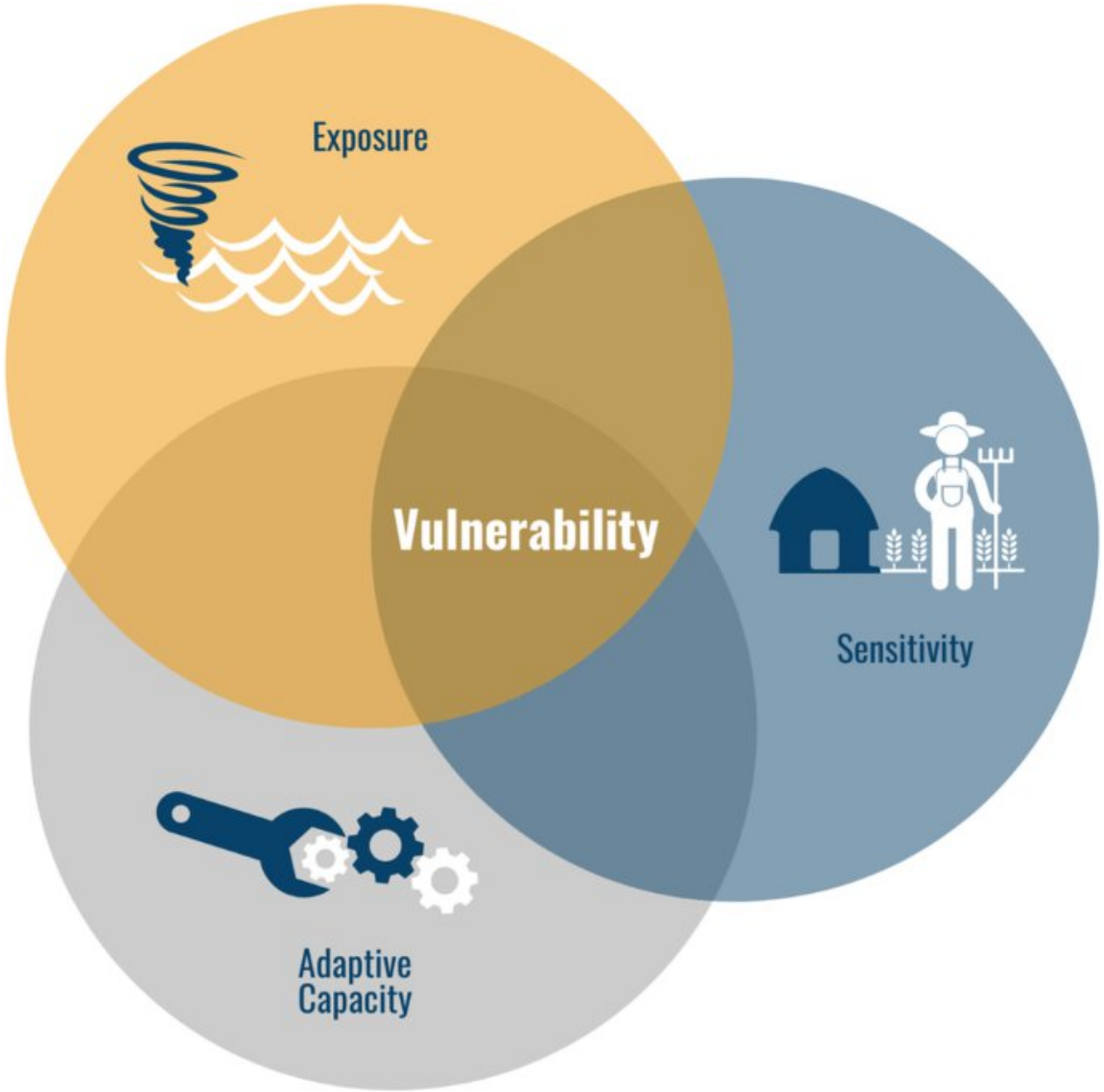
Under a +2°C warming scenario, most crops tend to show a decrease in mean yield.

/!\ Don’t forget the limitations of the predictions

Modelling

- First study assessing crop responses to climate change spatialized at the scale of Wallonia.
- Some hypothesis could be involve with scientific knowledge
- The results depend on the quality of calibration
- ==> Continued improvement

The next step ?



- Studying the changes of technical management (adaptability) to reduce the vulnerability of crop productions

Nawrotzki et al.,2023

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Thank you for your attention

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