Climatic differentiation of the alien plant *Senecio inaequidens* (Asteraceae) during invasion

When evolutionary phenomena make predictions uncertain…

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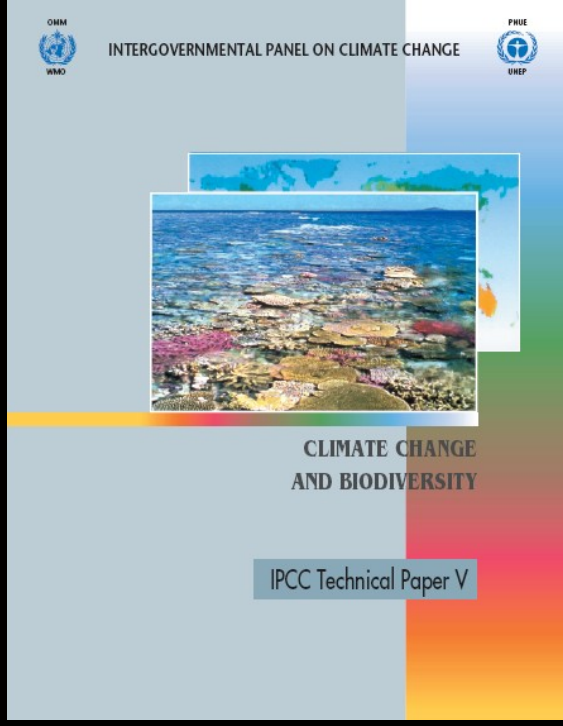
FNRS


Introduction

IPCC 2002 Technical report

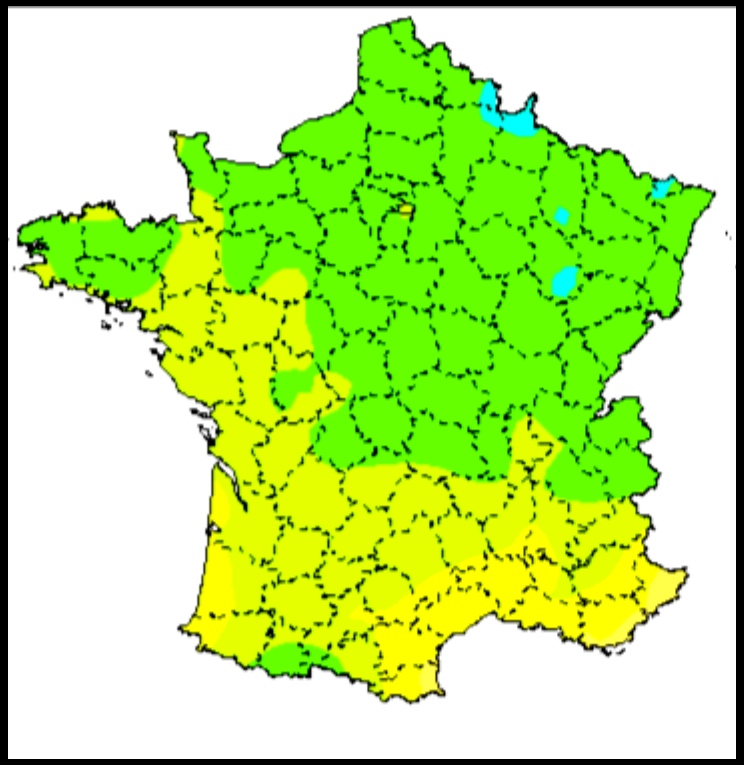
Projected impacts of changes in mean climate and extreme climatic events on terrestrial and marine ecosystems:

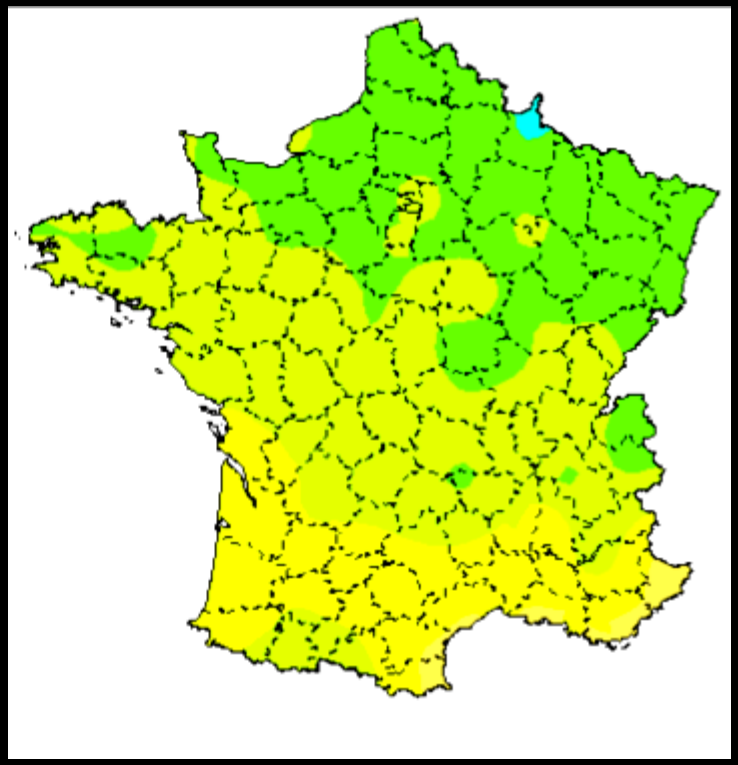


➔ « Changes in phenology are expected to occur in many species »

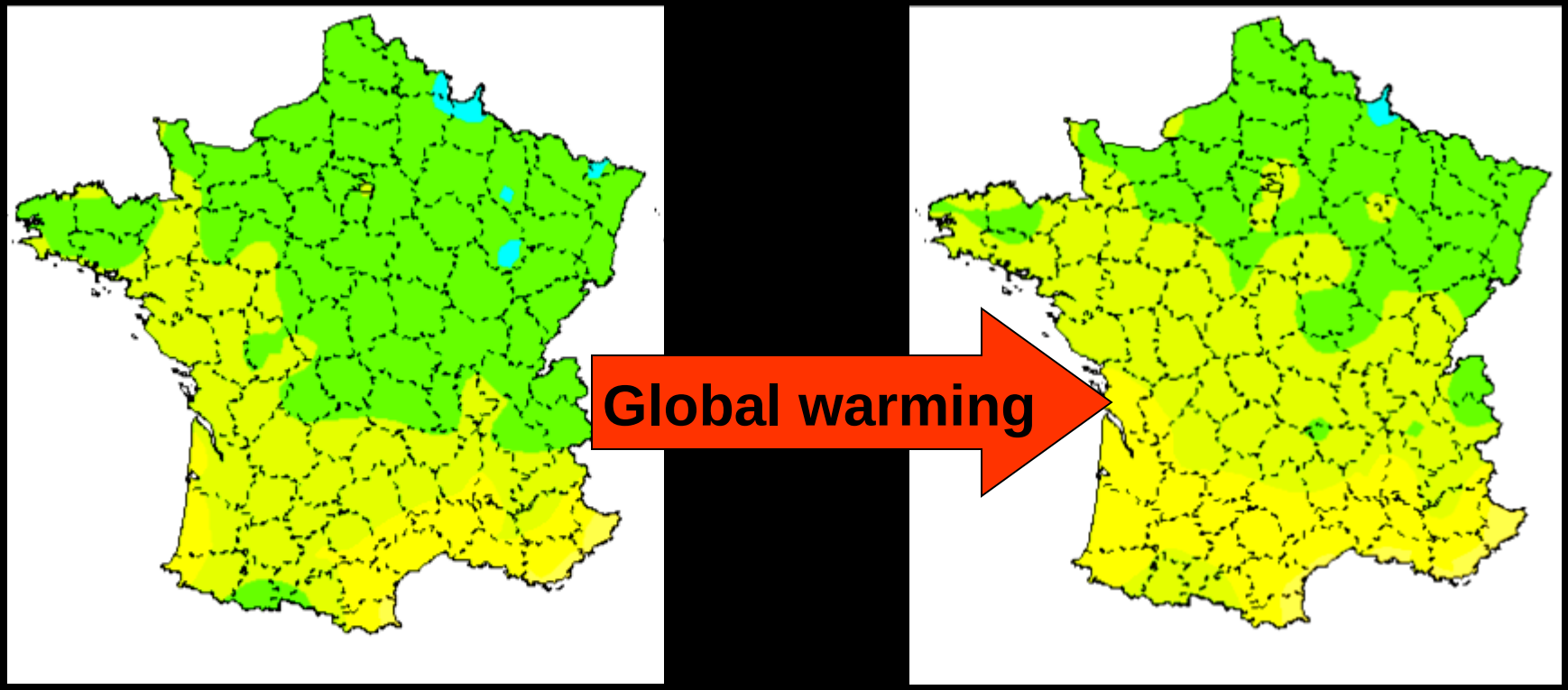
➔ « The general impact of climate change is that the habitats of many species will move poleward or upward from their current locations »

Modeling a specie’s range modification due to global warming

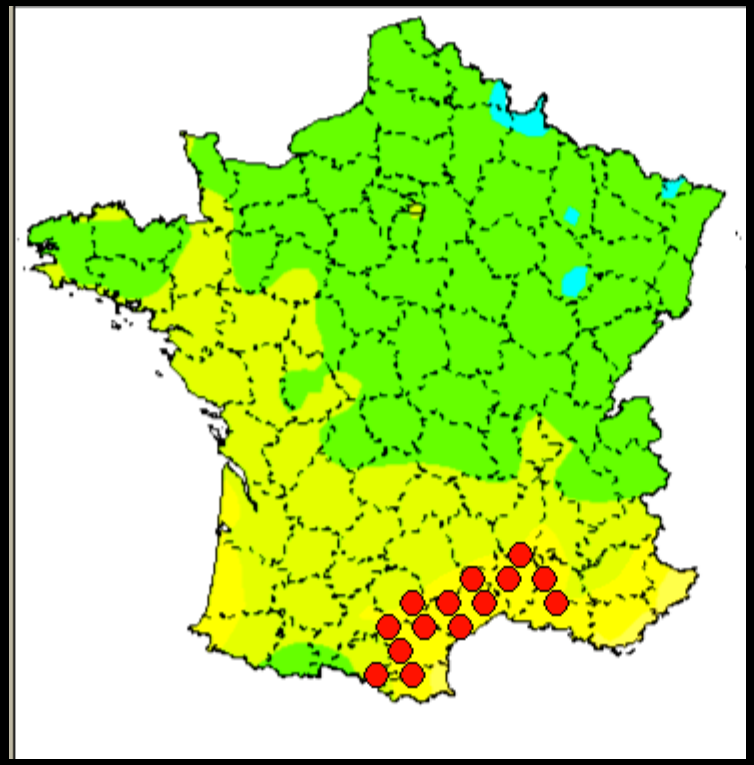


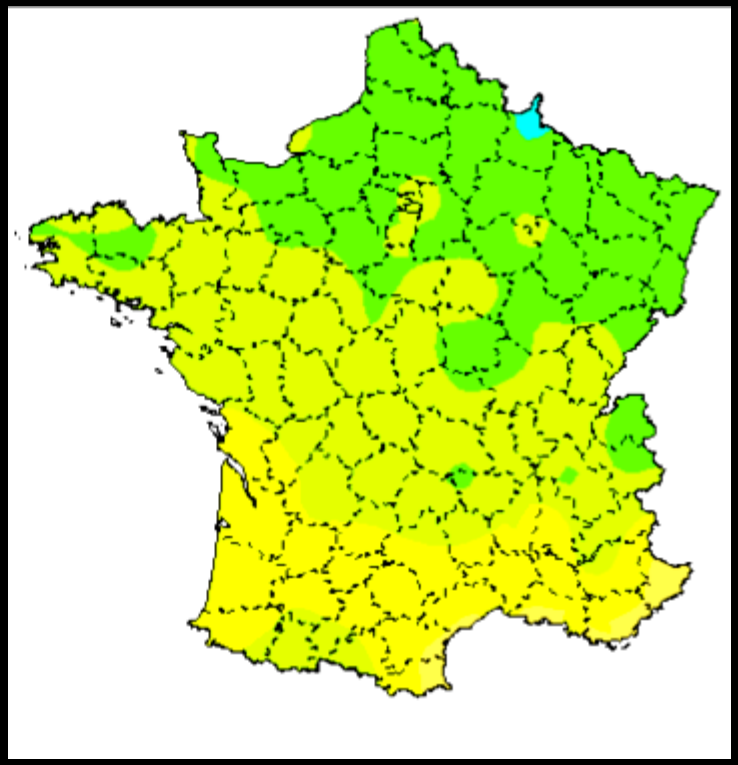


Modeling a specie’s range modification due to global warming

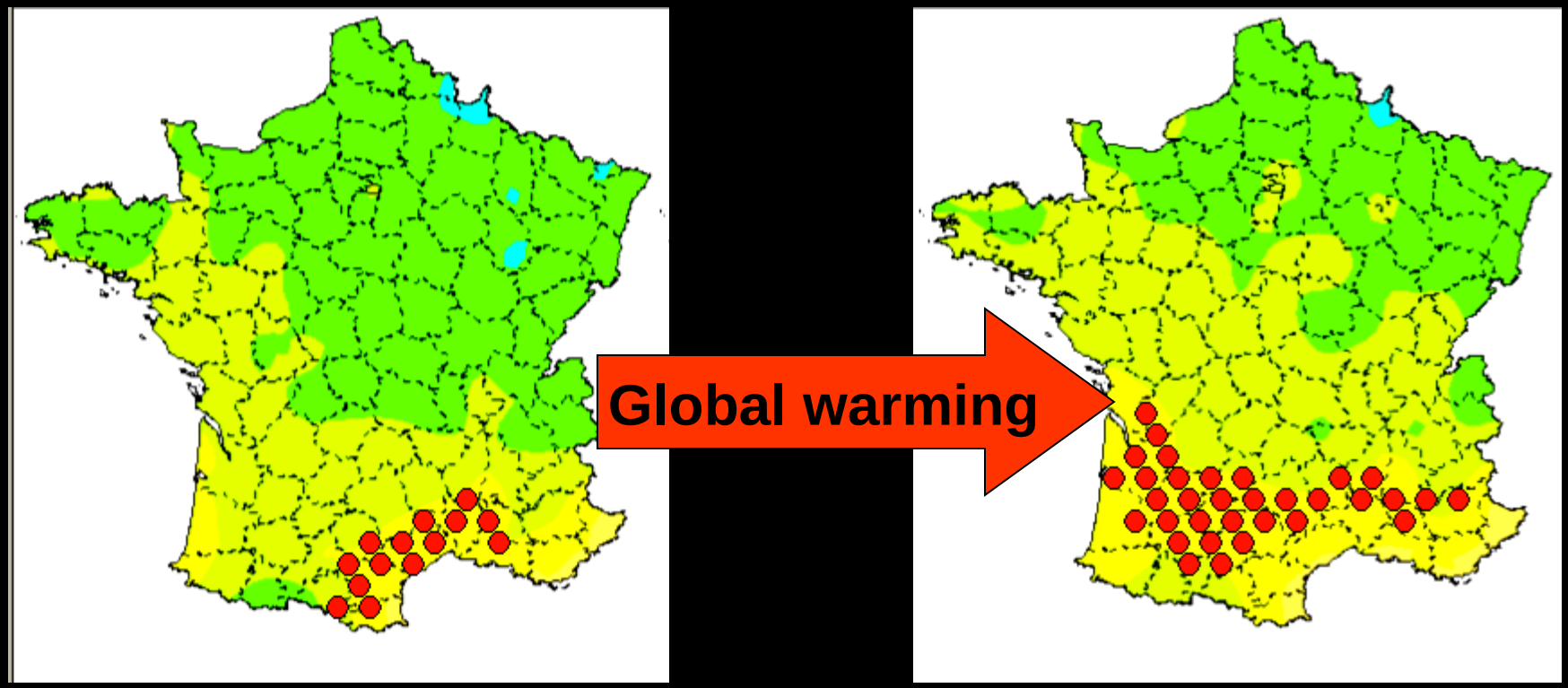


Modeling a specie’s range modification due to global warming



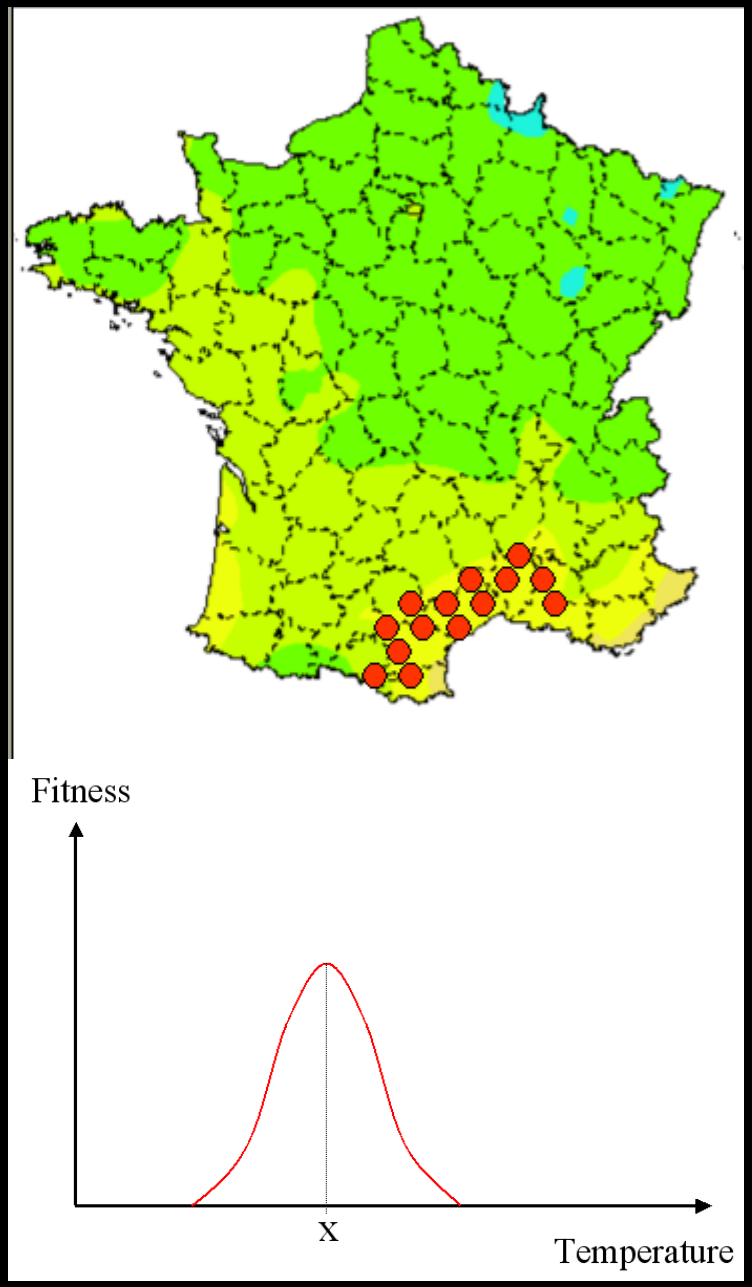


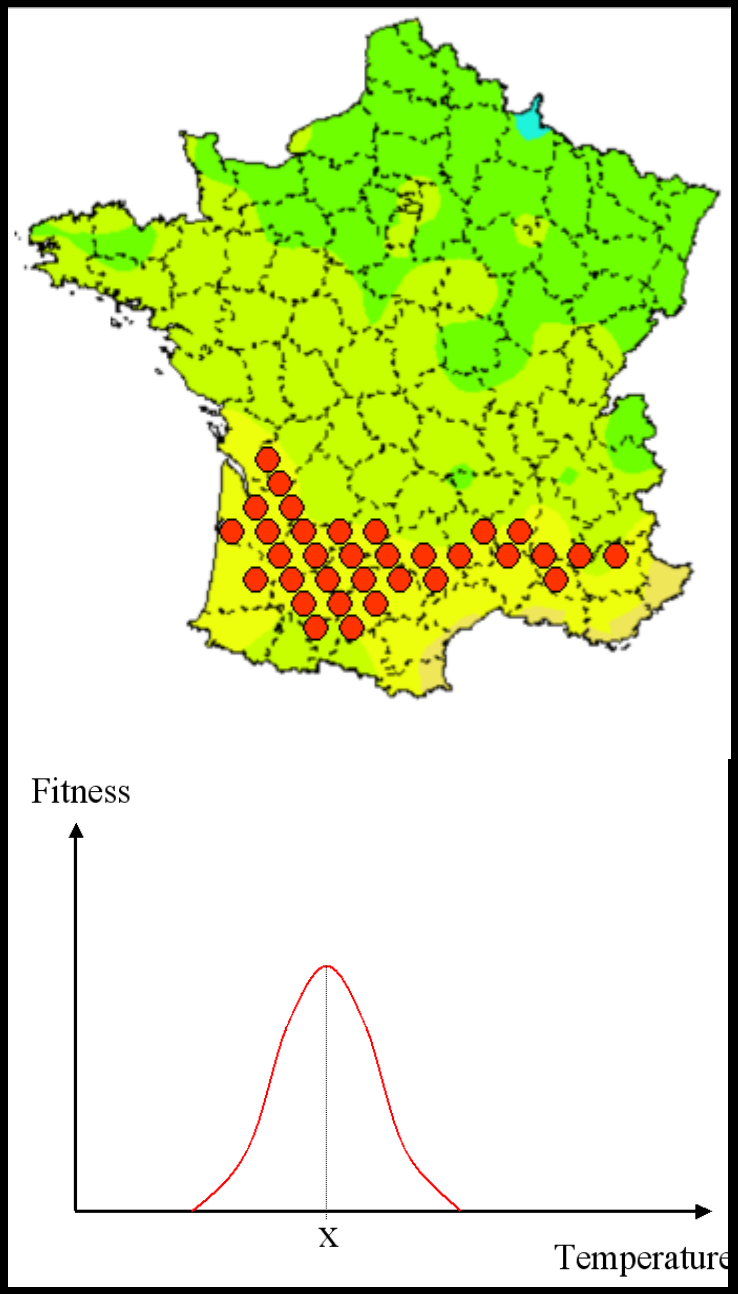
Modeling a specie's range modification due to global warming



These impacts are forecasted with the global assumption that species remain constant in their climatic optimal requirements.

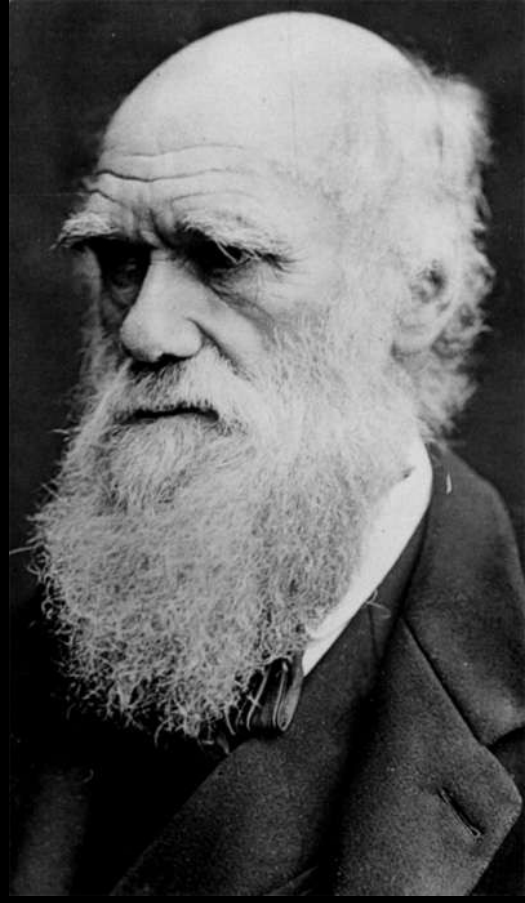
➔ Species '*follow*' their abiotic niche…


Fitness
x
Temperature

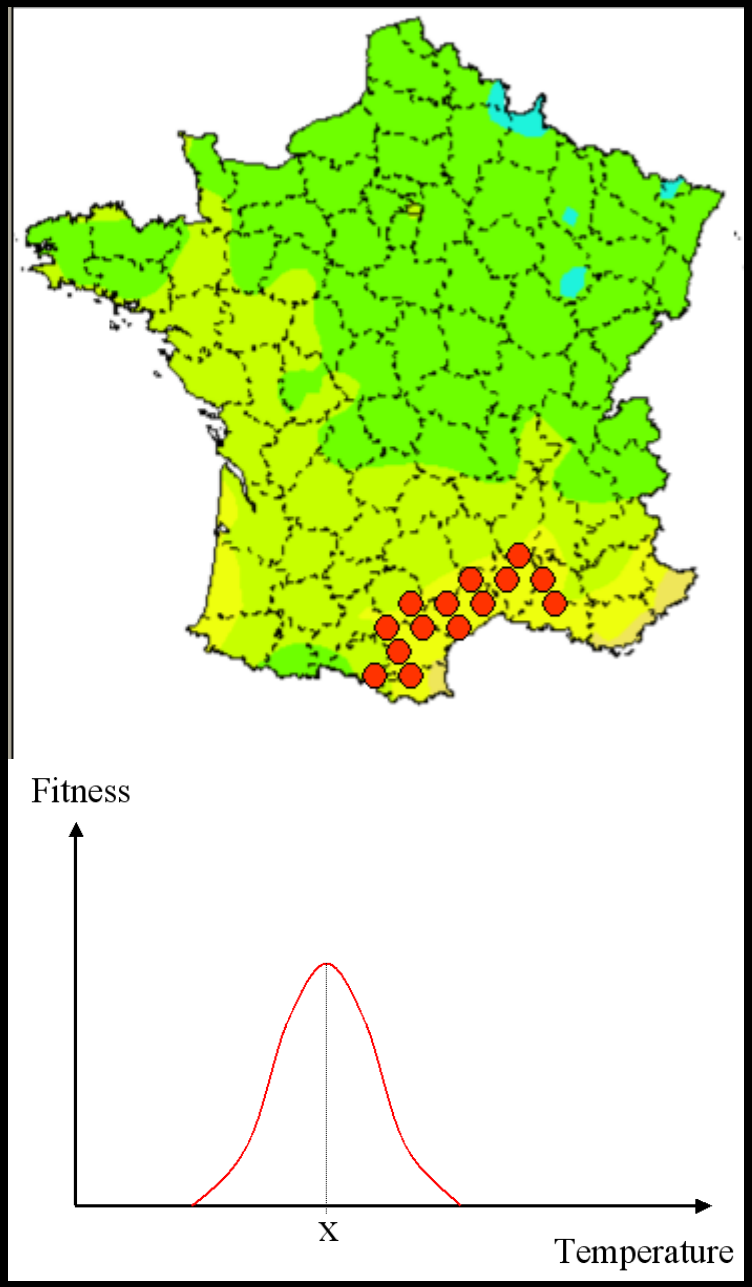

Fitness
x
Temperature

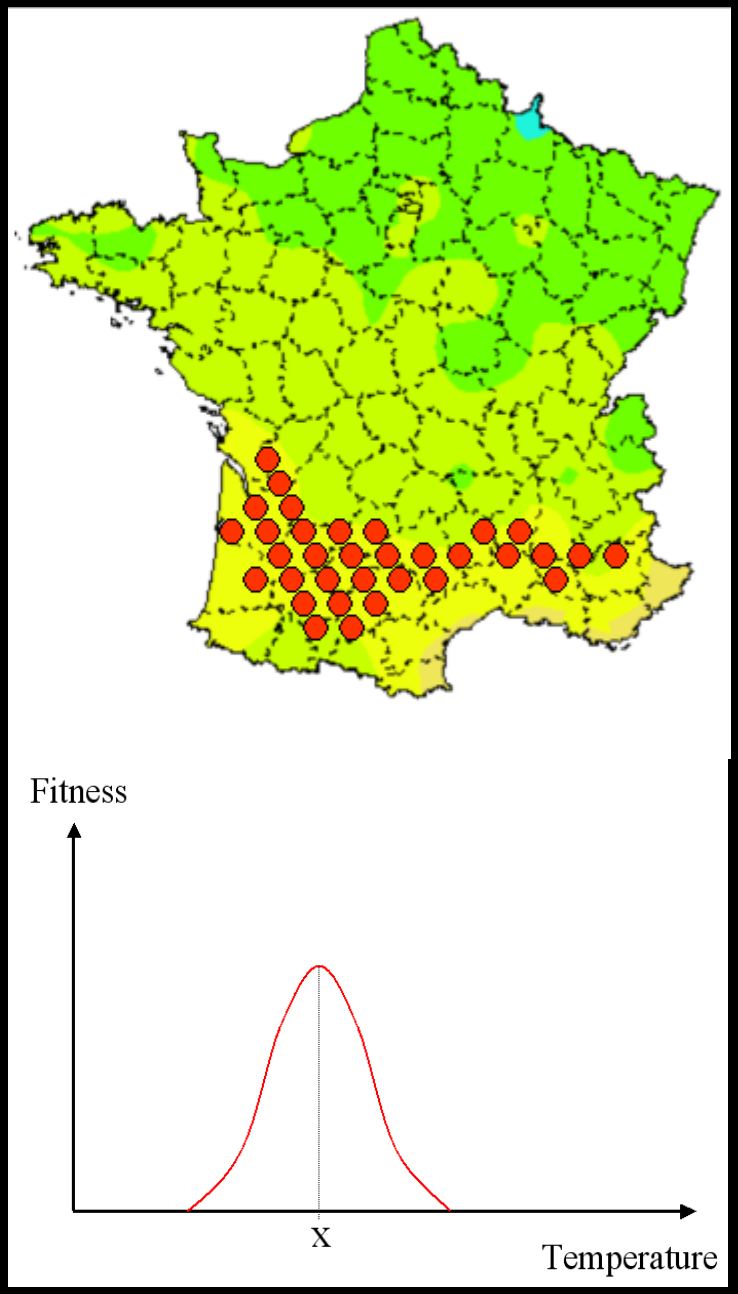
But:

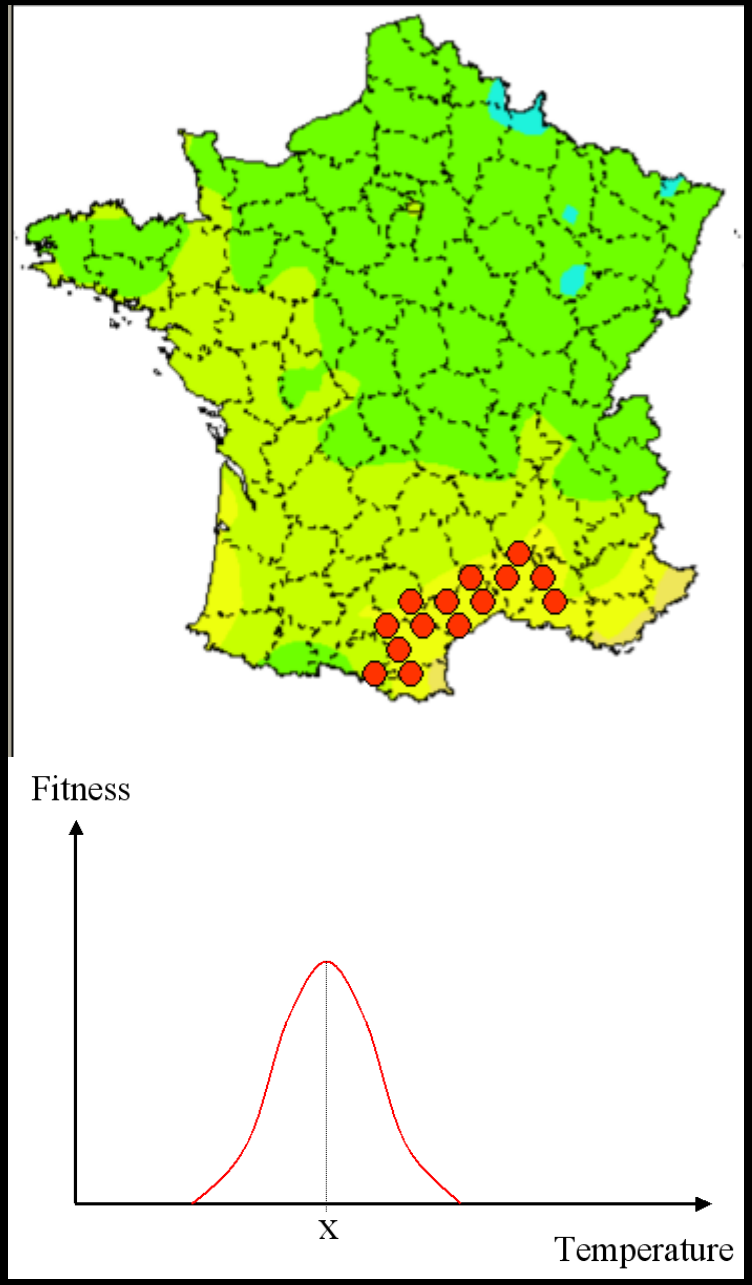
Species are not static entities: they can potentially develop adaptations in response to a changing environment !

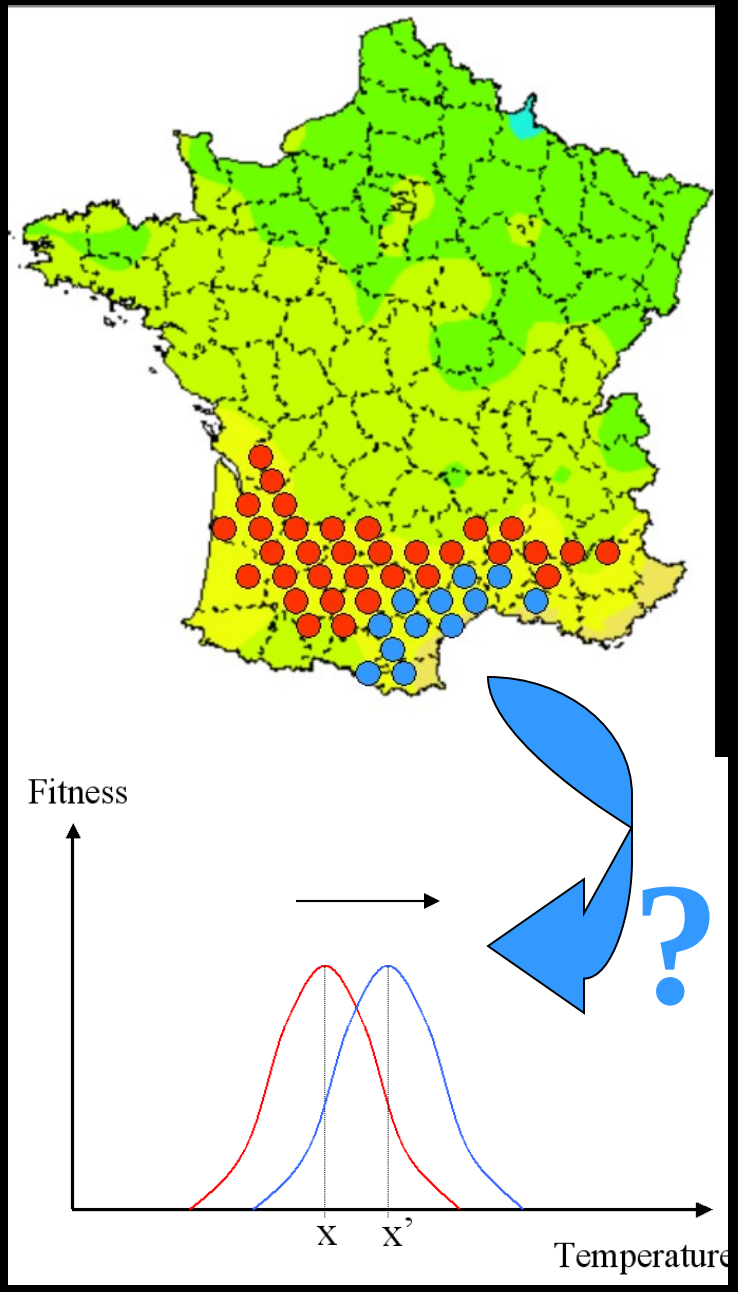


➔ **Evolutionary theory might be ‘troublesome’ when trying to forecast global warming impacts !**


Fitness
x
Temperature


Fitness
x
Temperature


Fitness
x
Temperature


Fitness
?
x
x'
Temperature

In the present study, we address the following questions:

➔ Can plant populations develop adaptative differentiations in relation to climate (*e.g.* temperature) ?

➔ Is the timescale of this potential differentiation compatible with that of global warming?

Plant invasions are an opportunity to study these questions at a large biogeographical scale


Material &
Methods

Trying to answer these questions is made possible by the study of *Senecio inaequidens* invasion…

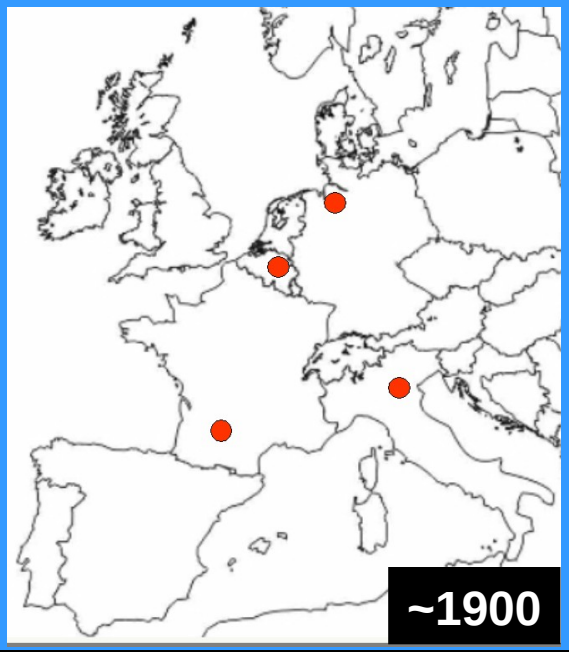
Senecio inaequidens DC. (Asteraceae):

- Perrenial herbaceous shrub from South Africa and Lesotho
- Numerous yellow capitulae; mostly self-incompatible; tetraploid
- Long flowering period (6 months)
- Pioneer species, invading mainly roadsides and railways

Trying to answer these questions is made possible by the study of *Senecio inaequidens* invasion…

Invasion History :

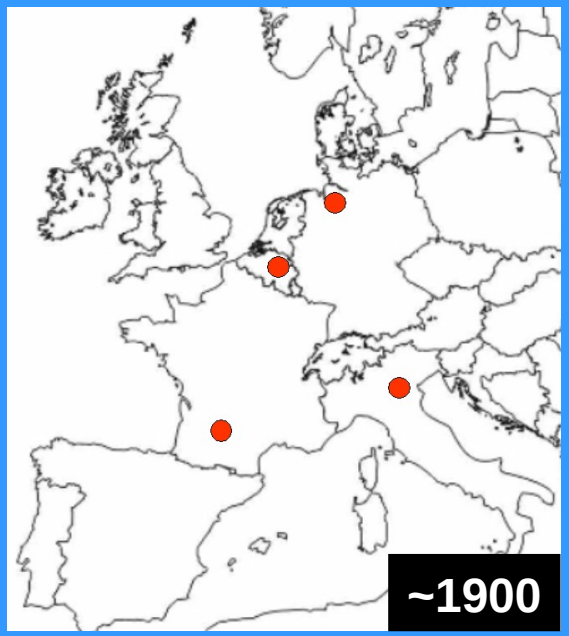
- The species was introduced to Europe as a wool alien in several locations linked to wool industries:
  - Verviers (Belgium) : 1892
  - Bremen (Germany) : 1896
  - Mazamet (France) : 1936
  - Verona (Italy) : >1940

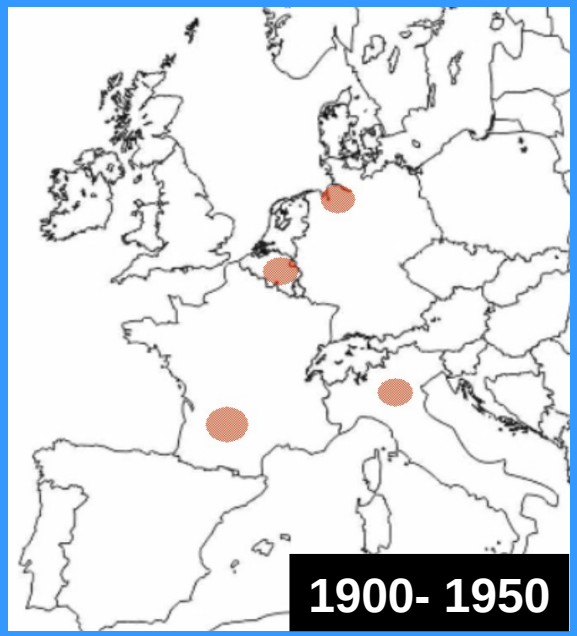


Trying to answer these questions is made possible by the study of *Senecio inaequidens* invasion…

Invasion History :

- During several decades, it was only found in the vicinity of wool processing areas



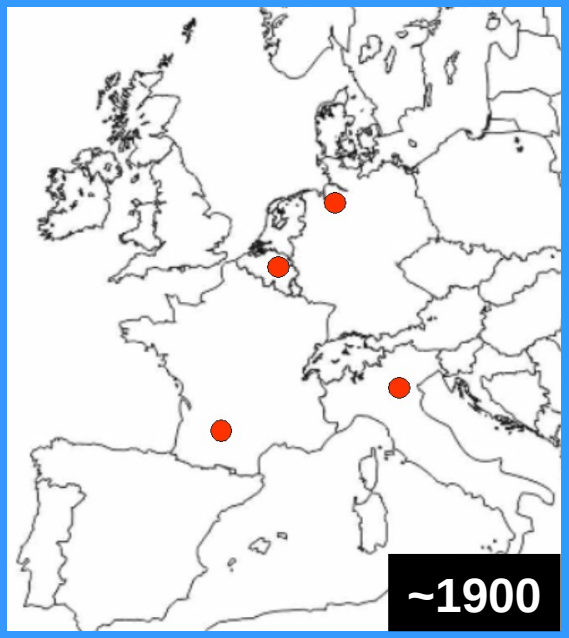


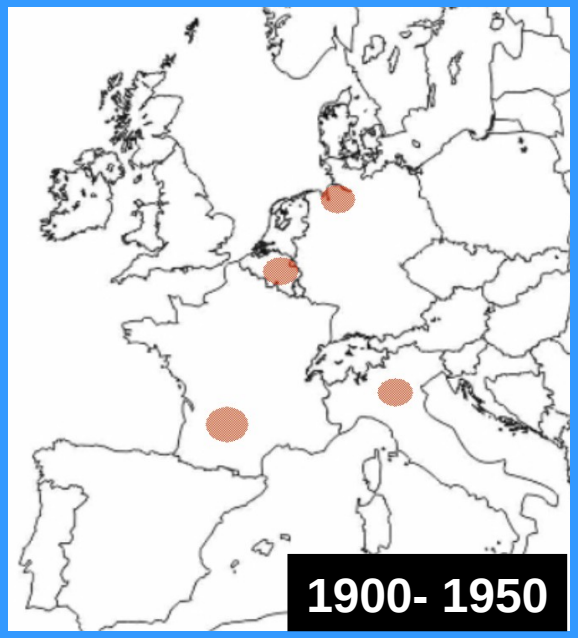
Trying to answer these questions is made possible by the study of *Senecio inaequidens* invasion…

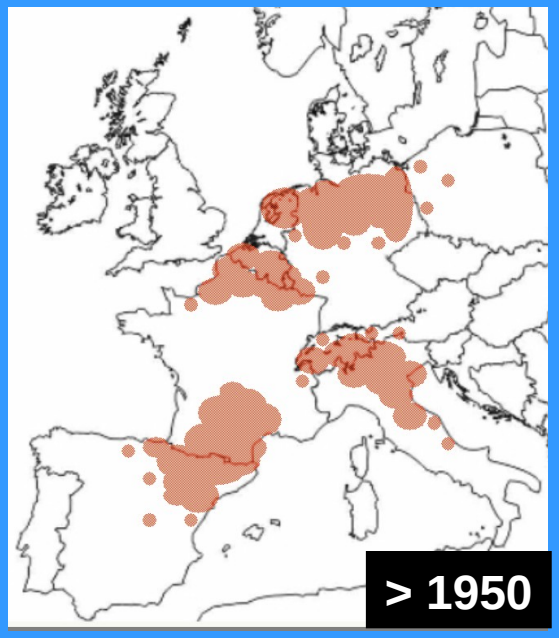
Invasion History :

- From 1950-1970, it started to spread throughout Europe, it **climatic contrasted zones…**

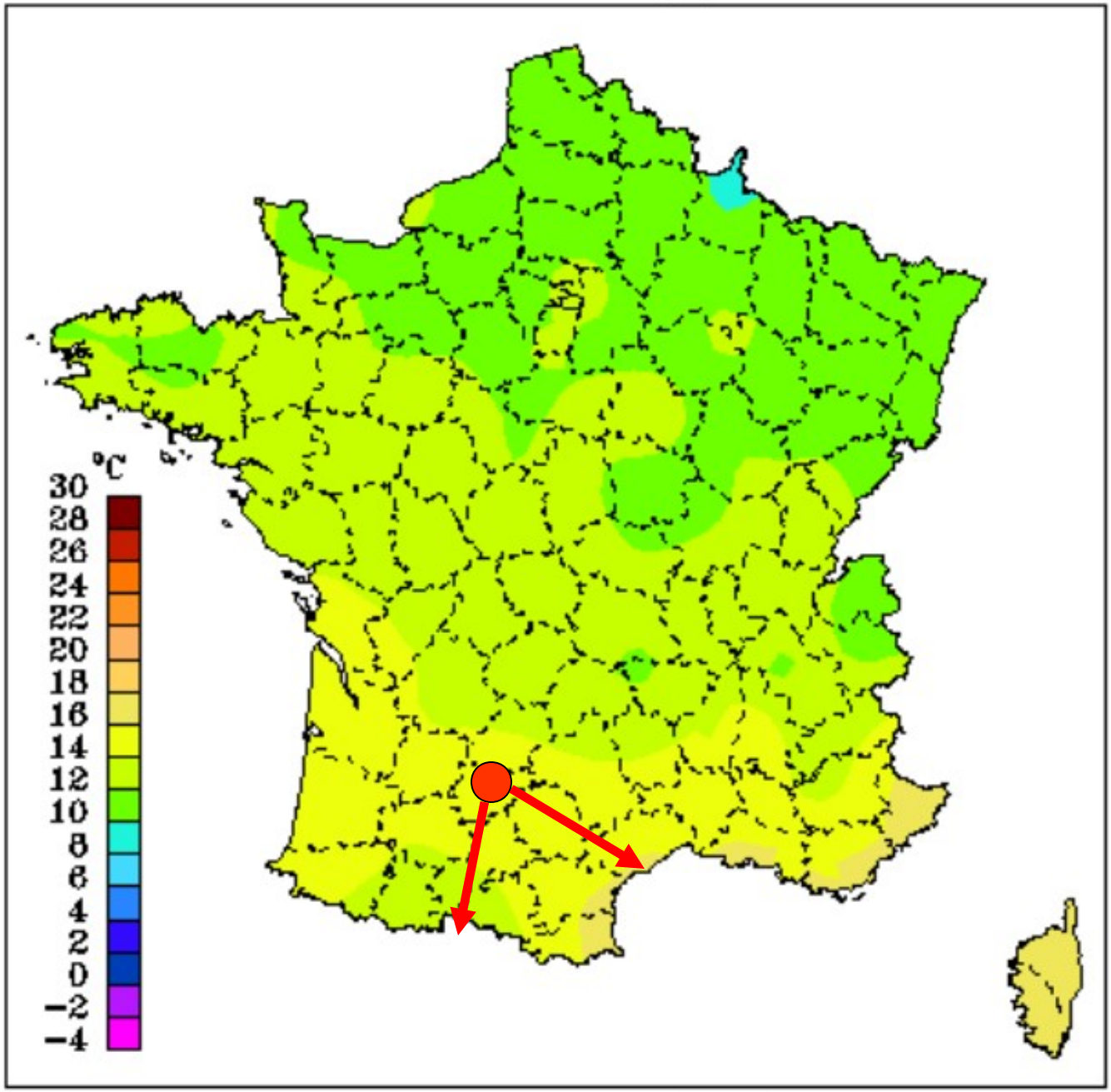
  ➔ **During ~ 50 years, *Senecio* encountered increasing and decreasing temperatures during invasion, while colonizing different altitudinal zones !**





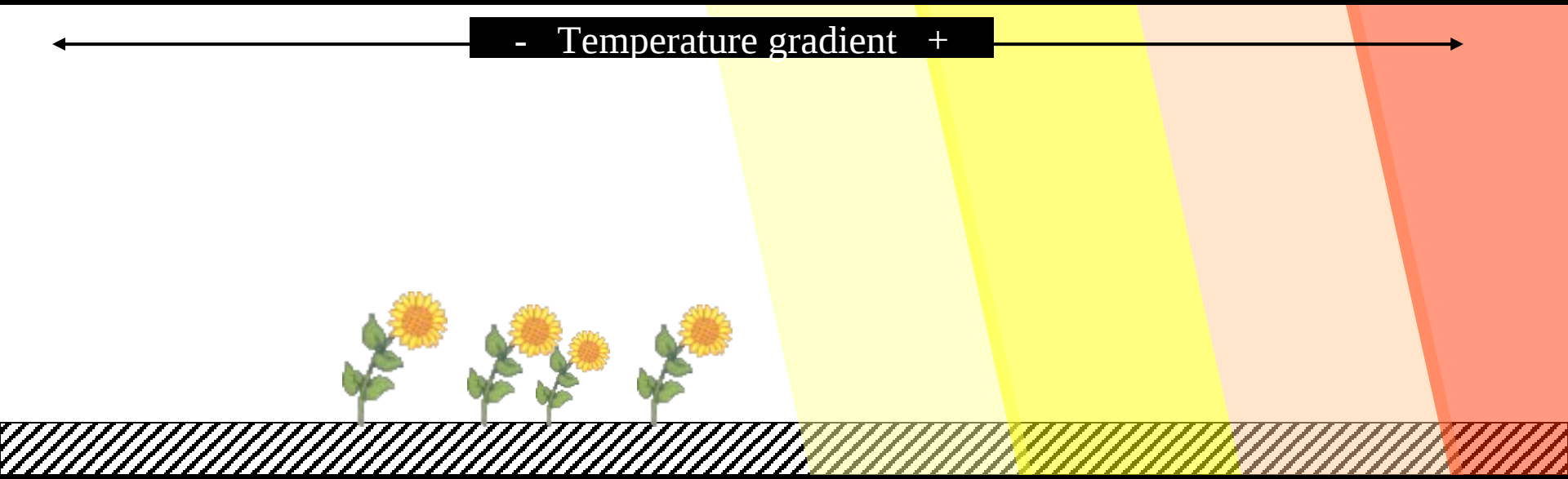


TEMPERATURE MOYENNE (°C)
MEAN TEMPERATURE (°C)

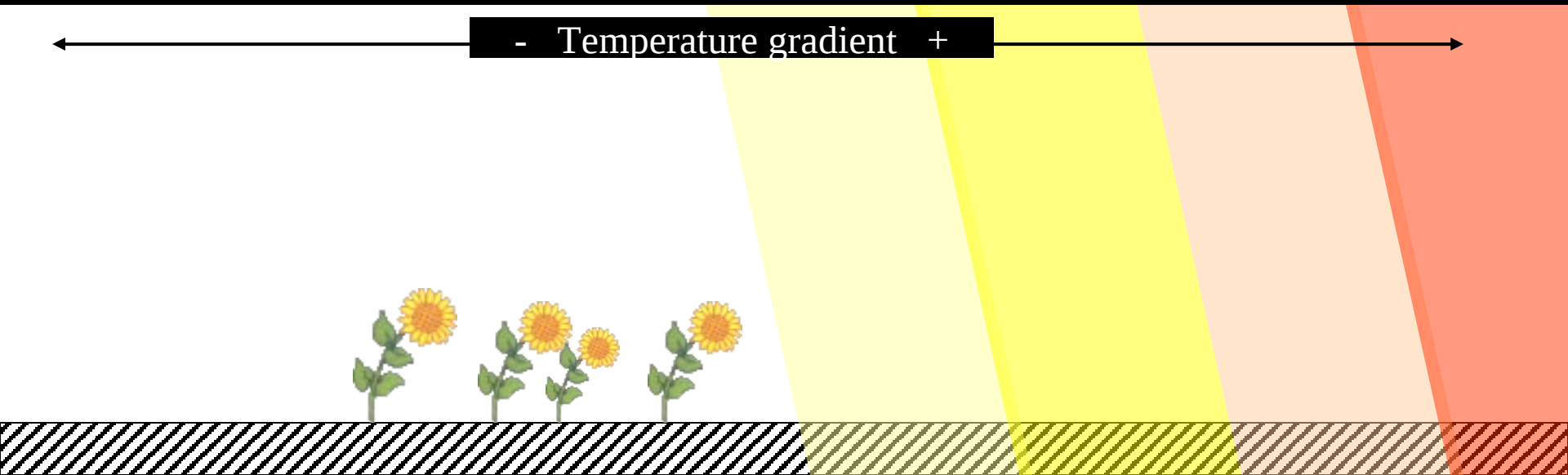


ANNEE–YEAR 2003

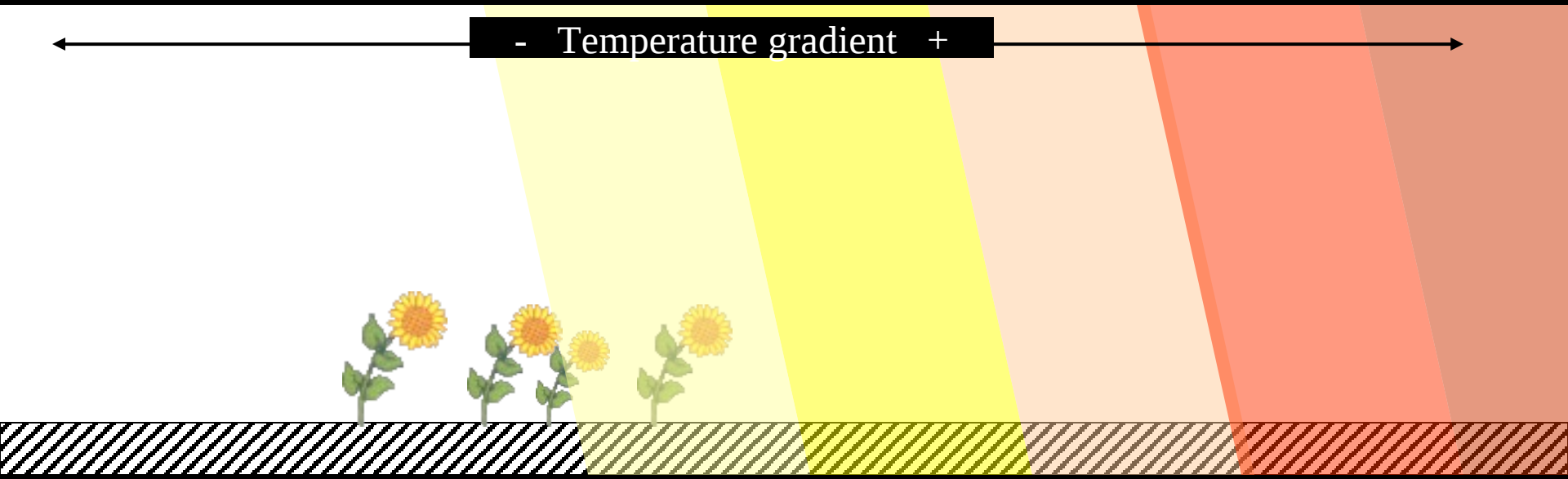
Global warming



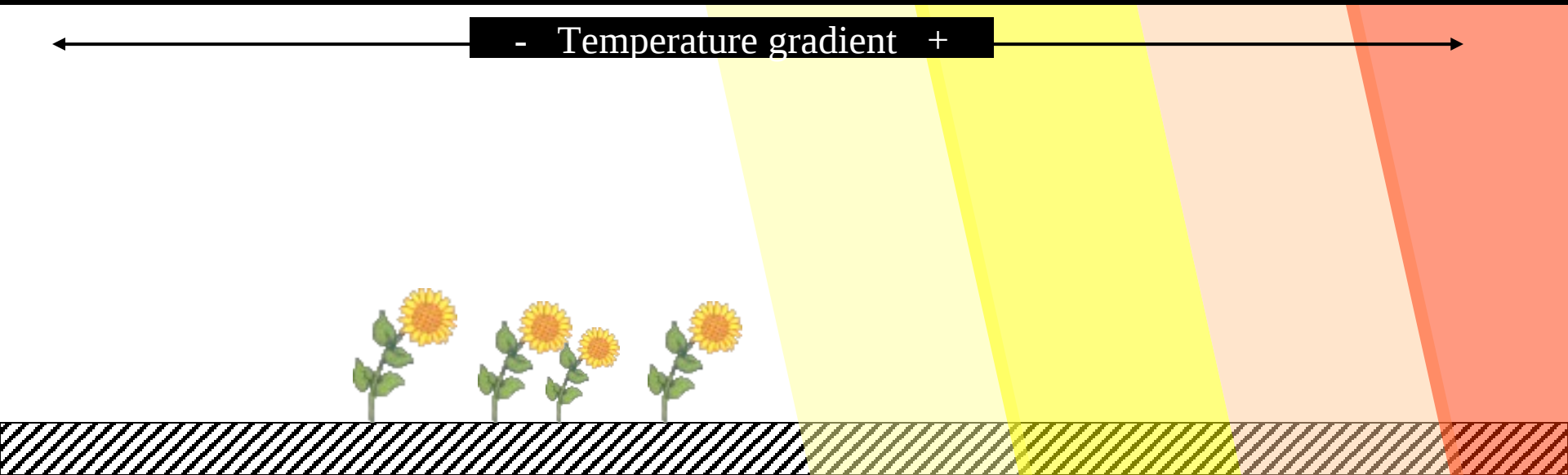
Senecio invasion



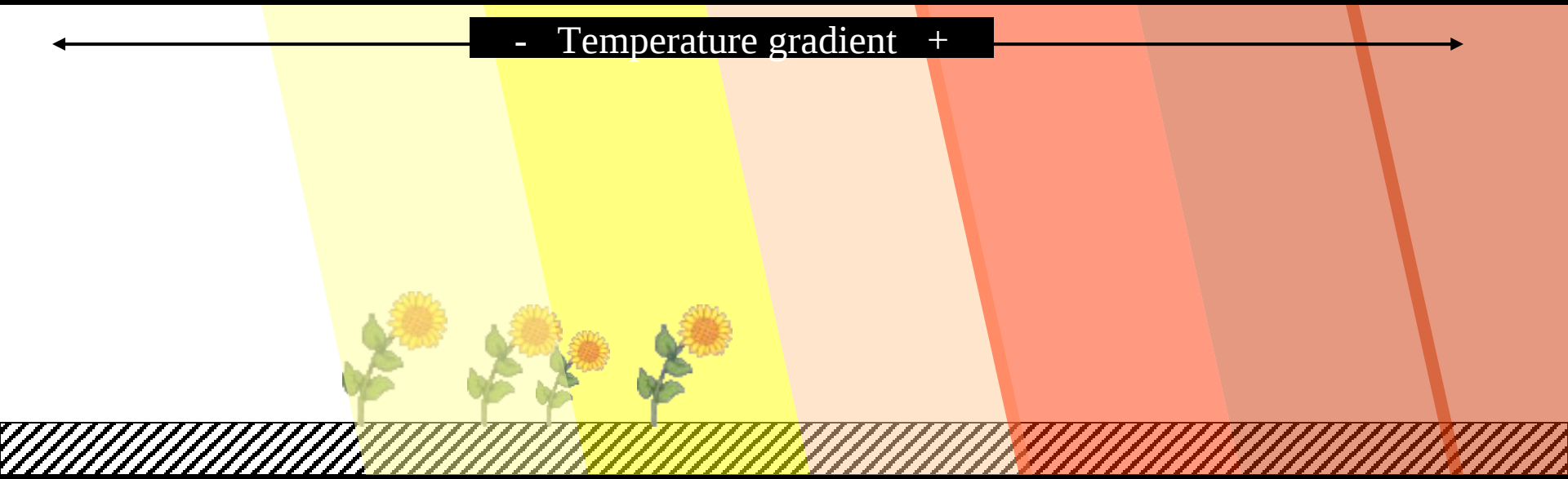
Global warming



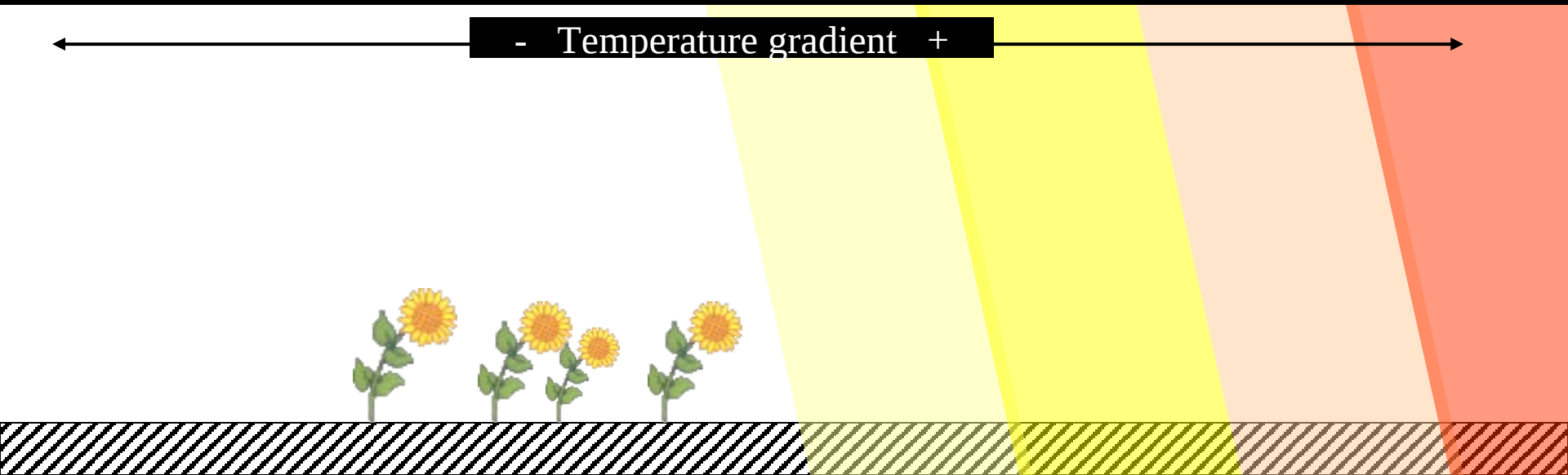
Senecio invasion



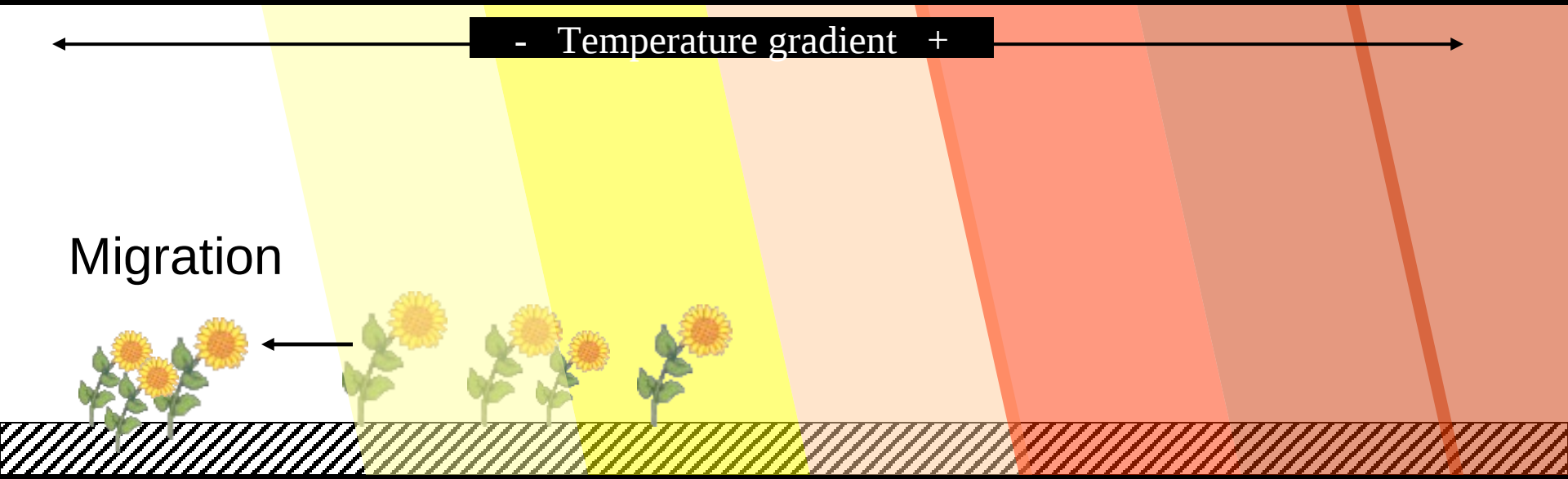
Global warming



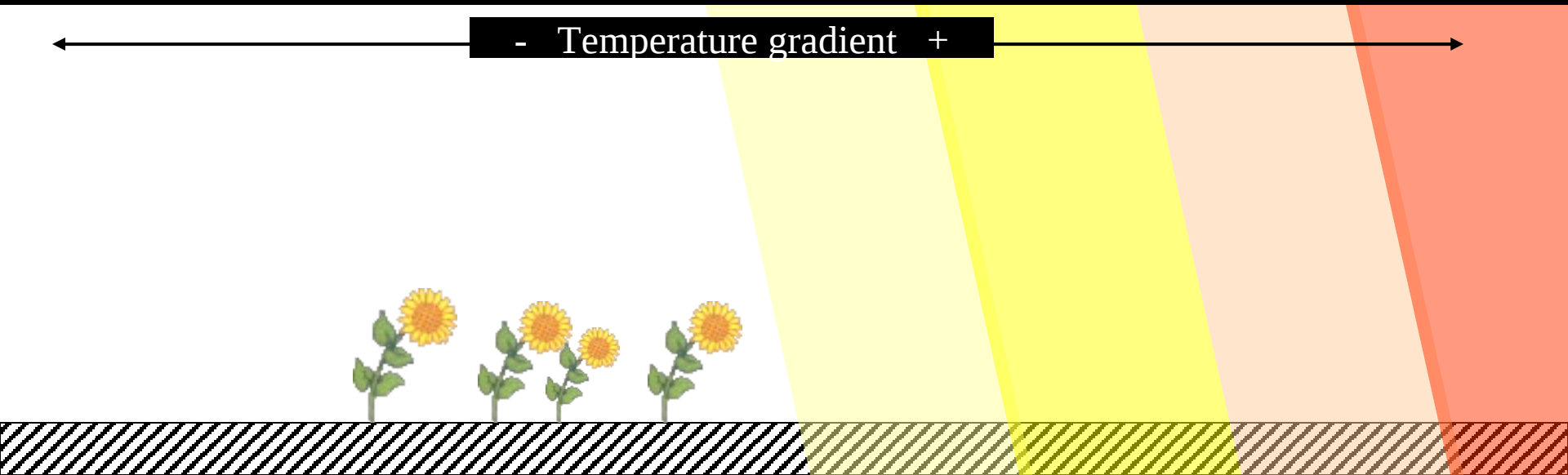
Senecio invasion



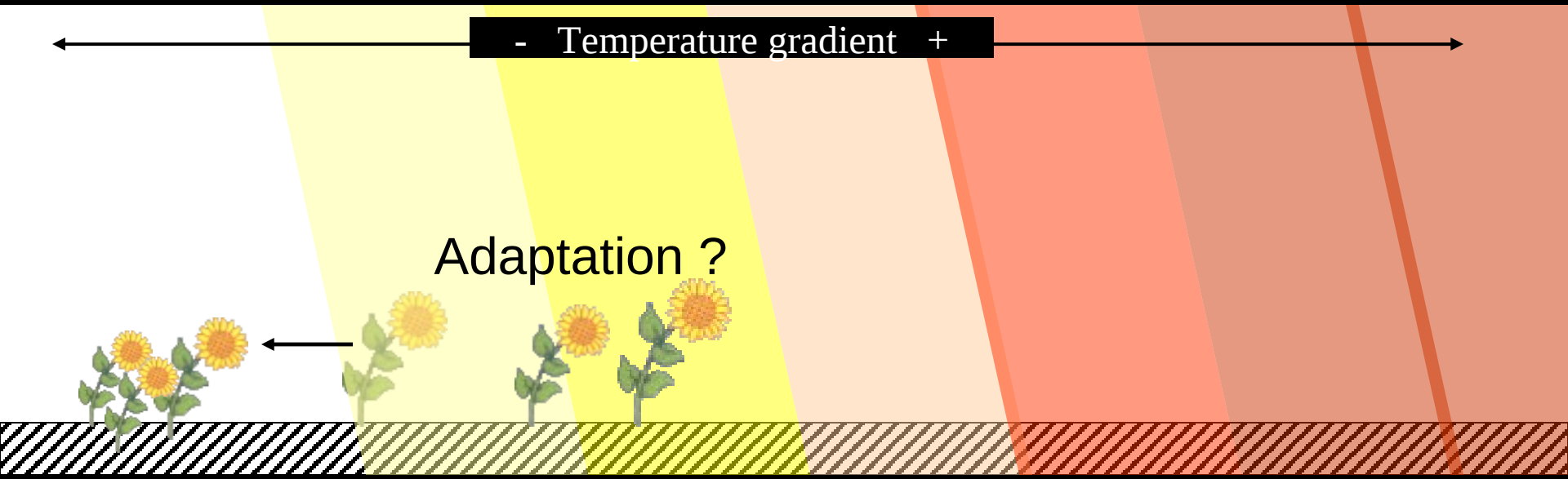
Global warming



Senecio invasion



Global warming



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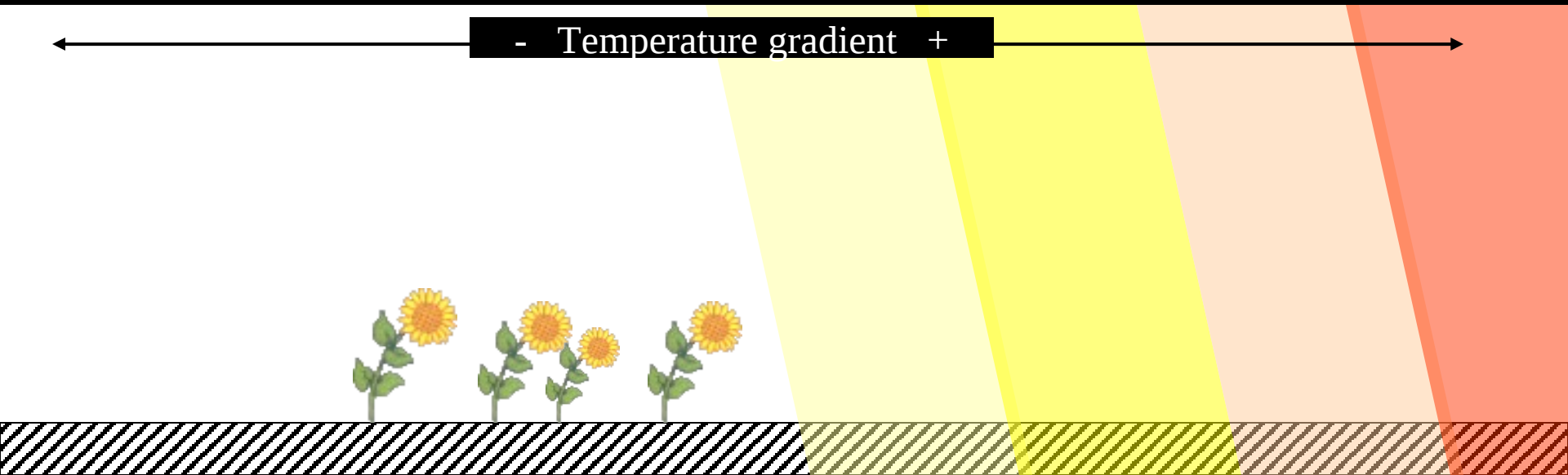
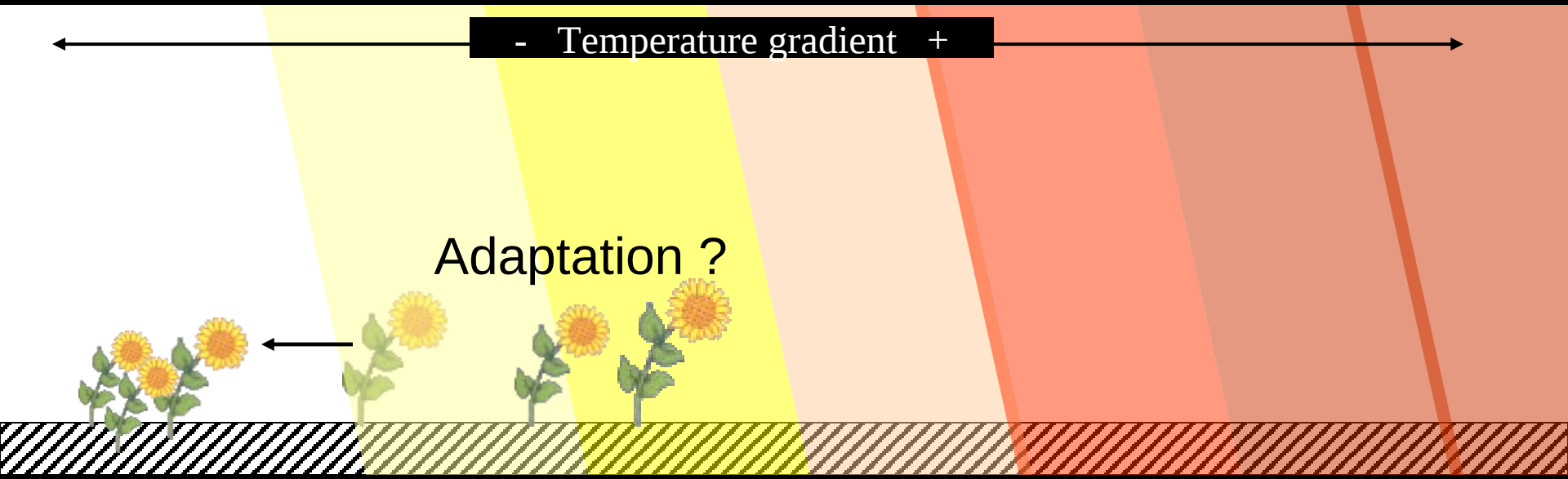
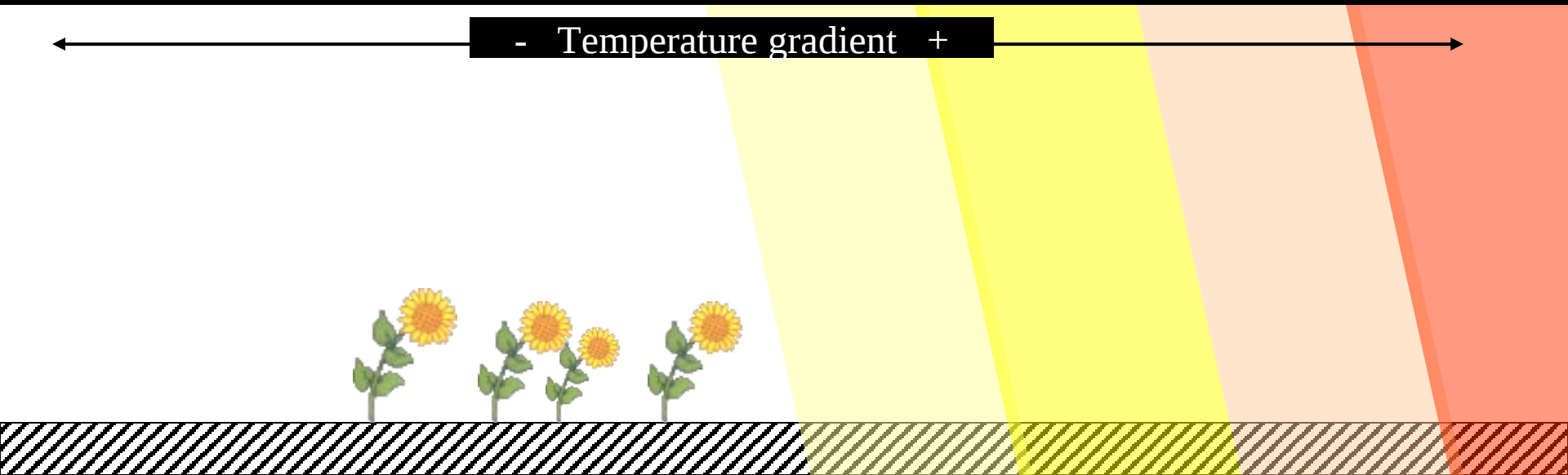


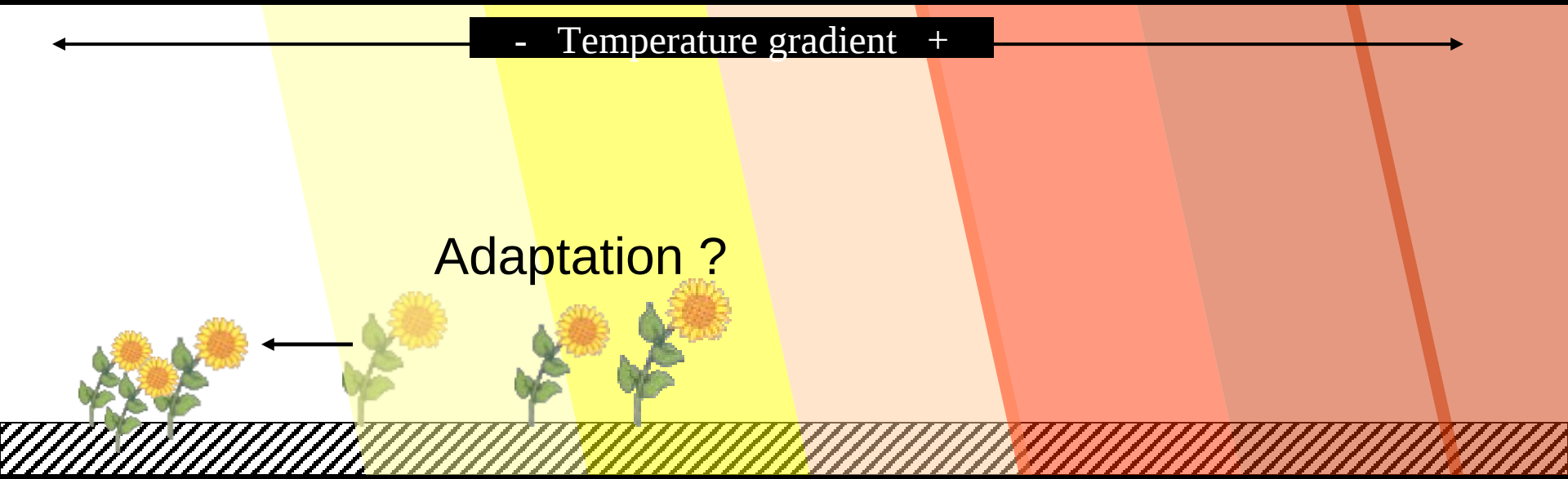
Global warming



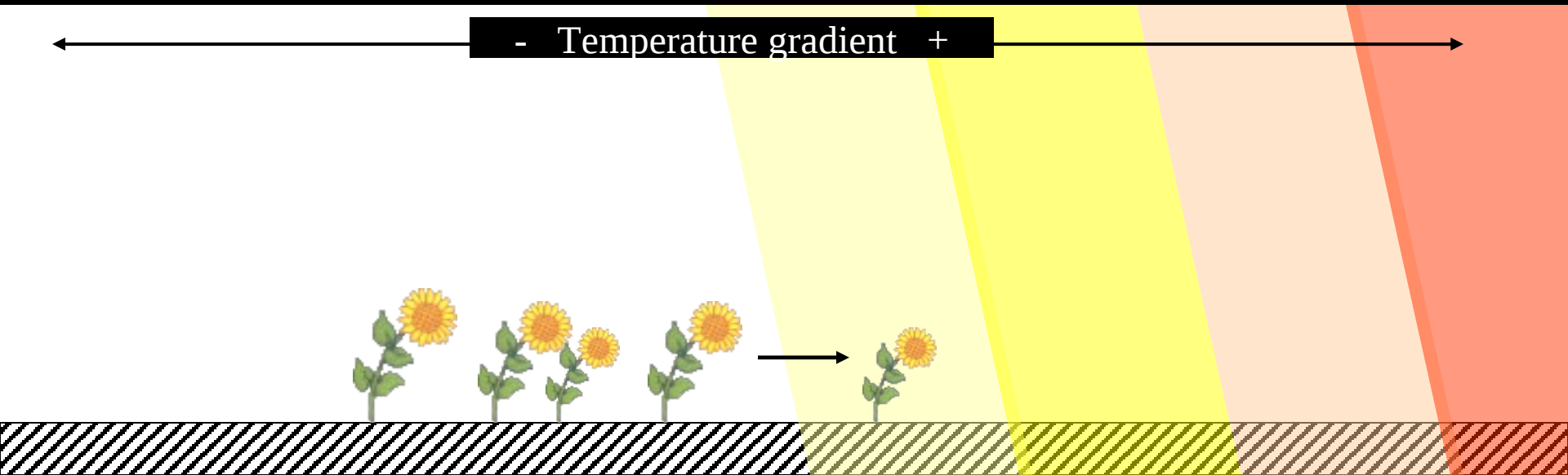
Senecio invasion



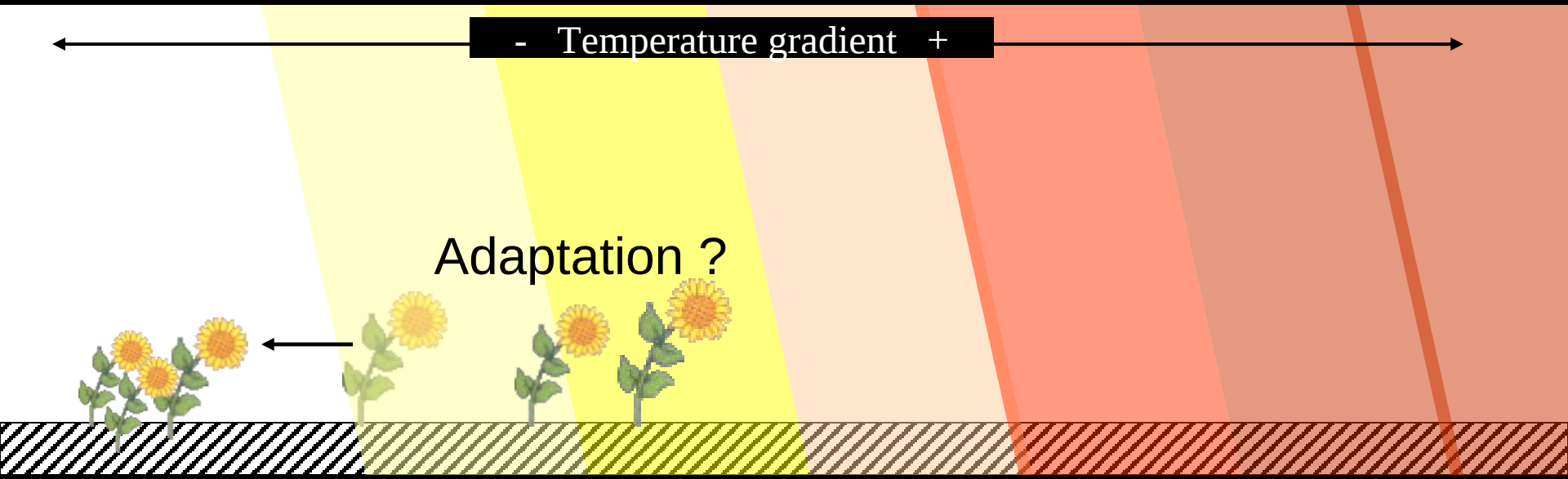
Global warming



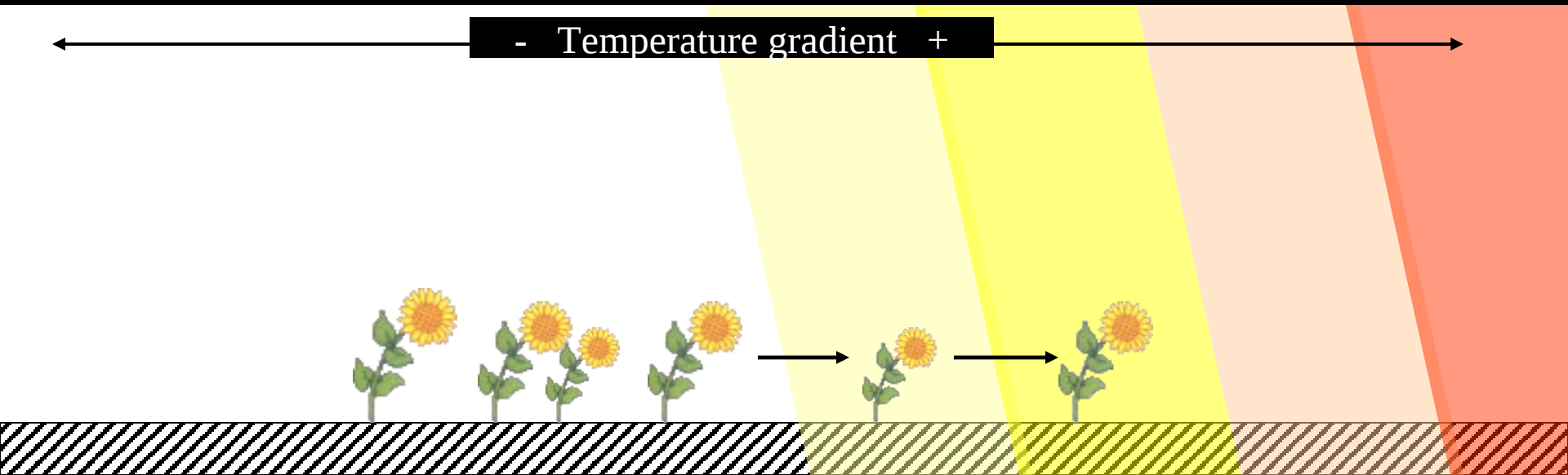
Senecio invasion



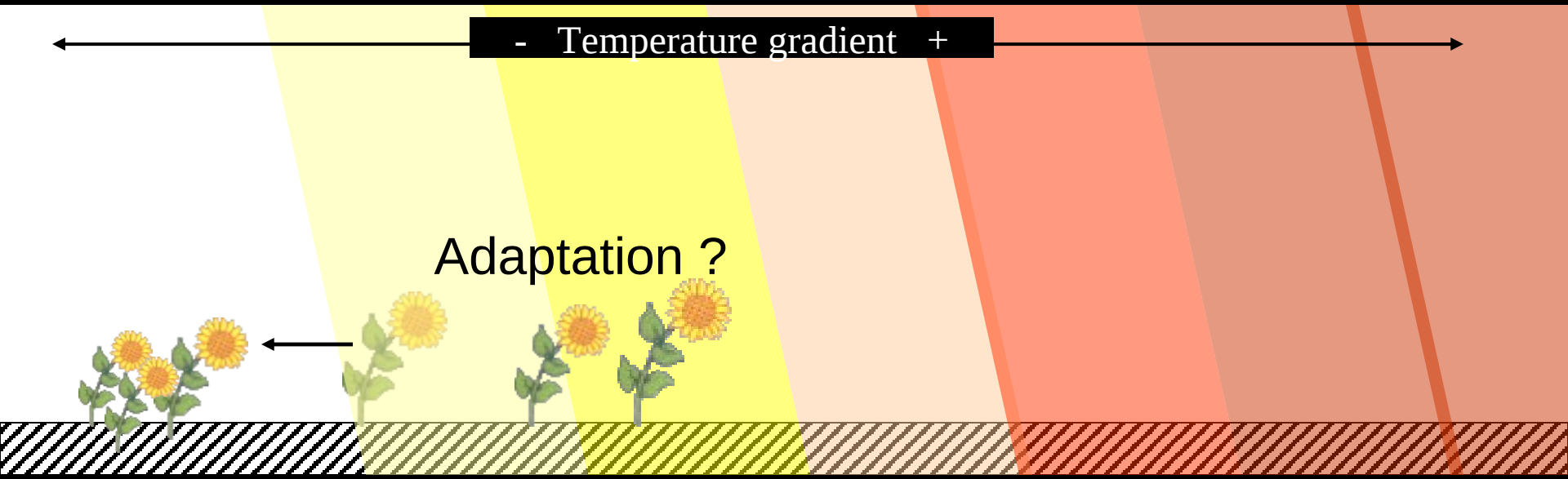
Global warming



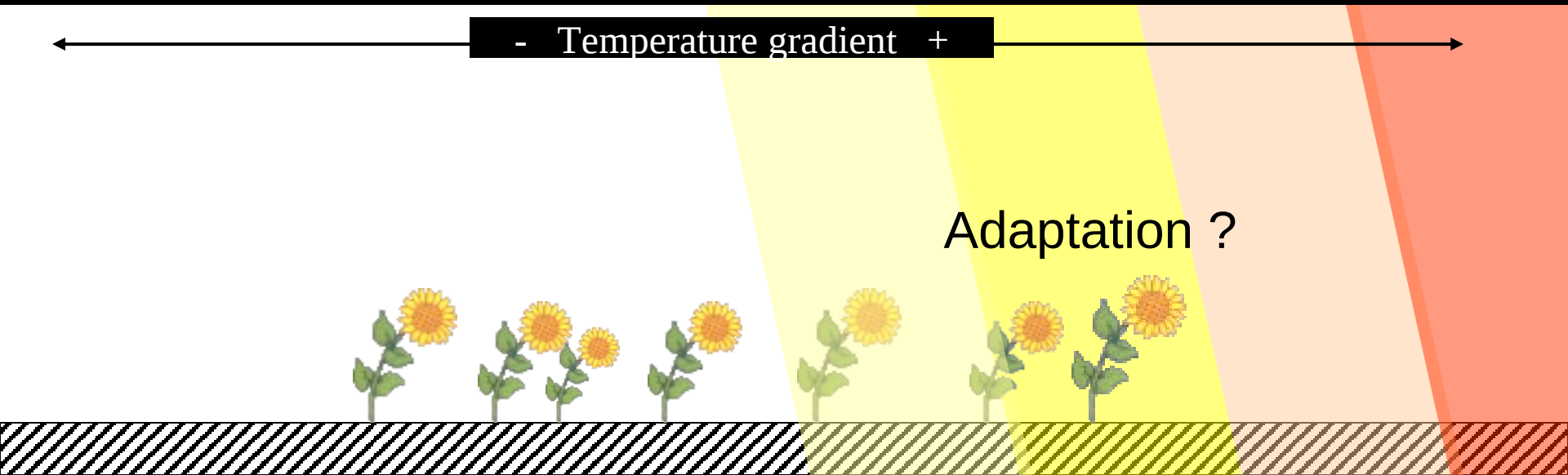
Senecio invasion



Global warming



Senecio invasion



Seeds collection and population characterization along altitudinal gradients

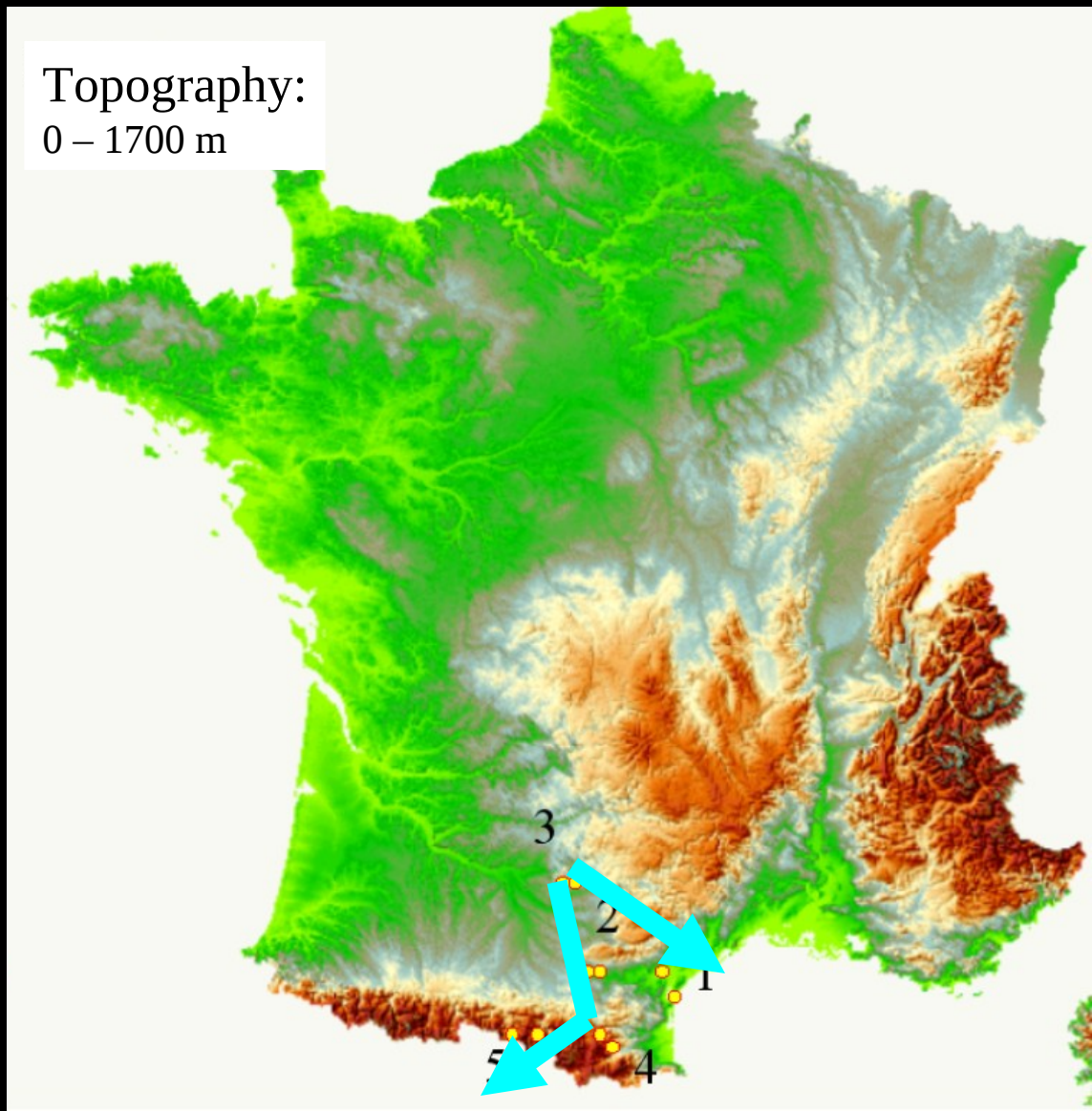
French transect:

•5 altitudinal-climatic zones x 2 populations x 10 individuals

• Temperature and summer drought gradient

• Mean annual T° : 16.1 to 6.3 °C

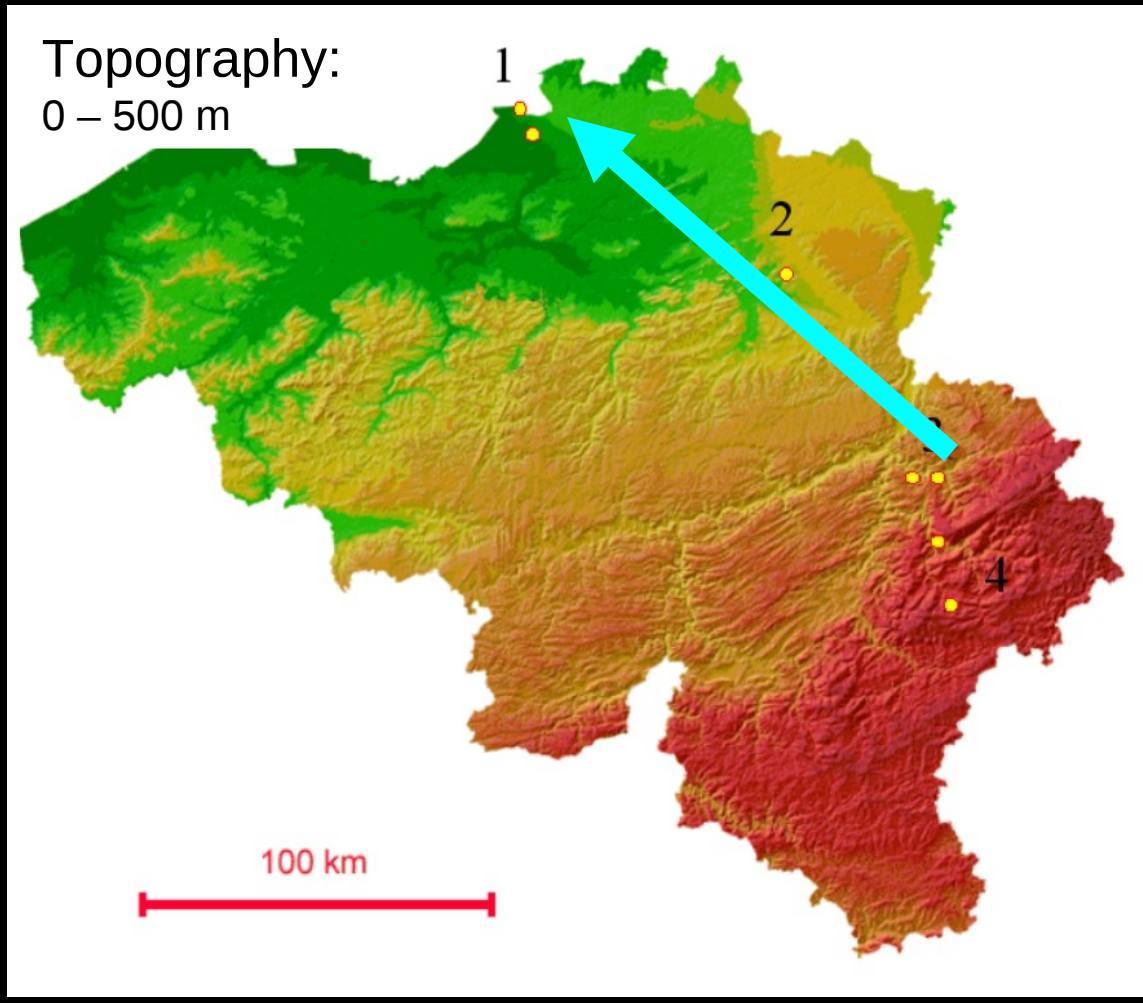
• Downward invasions: + 3.4°C
• Upward invasions : - 6.4°C



Seeds collection and population characterization along altitudinal gradients

Belgian transect:

- 4 altitudinal-climatic zones x 2 populations x 10 individuals
- Temperature and rainfall gradient
- Mean annual T° 9.6 to 5.7 °C



In situ population characterization

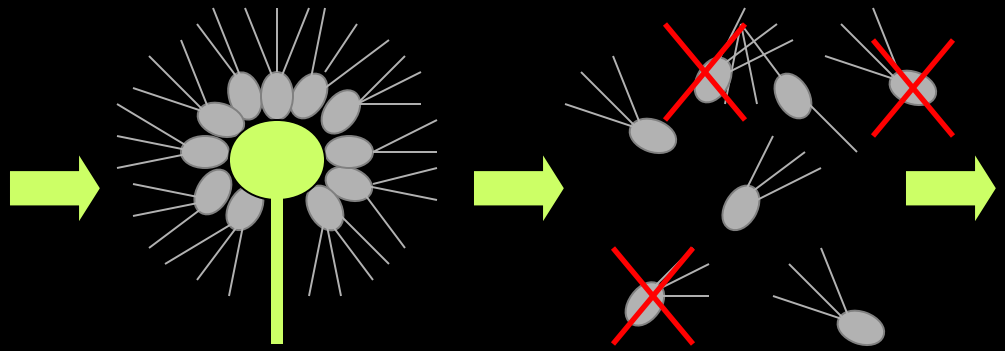
10 biggest individuals

MEASUREMENTS:

- *Plant height*
- *Plant volume*
- *Plant above-ground biomass*

Seed collection and elimination of intra-maternal effects

Parent individual (random)



Capitulae collected

Sorting of achenes

10 biggest achenes without anomaly

Sowing and measurements

10 biggest achenes without anomaly

Sown in one pot

1 plant was kept

One plant per parent individual

Germination study
(n = 2400)

Phenology and growth study
(n = 240)

Sowing and measurements

10 biggest achenes without anomaly

Sown in one pot

1 plant was kept

One plant per parent individual

MEASUREMENTS:

- *Germination delay*

- *Flowering delay (since germination)*
- *Height at first flowering*
- *Final height*
- *Final above-ground biomass*
- *Reproductive allocation*

Common garden experiment: *randomized bloc design*

Statistical analysis

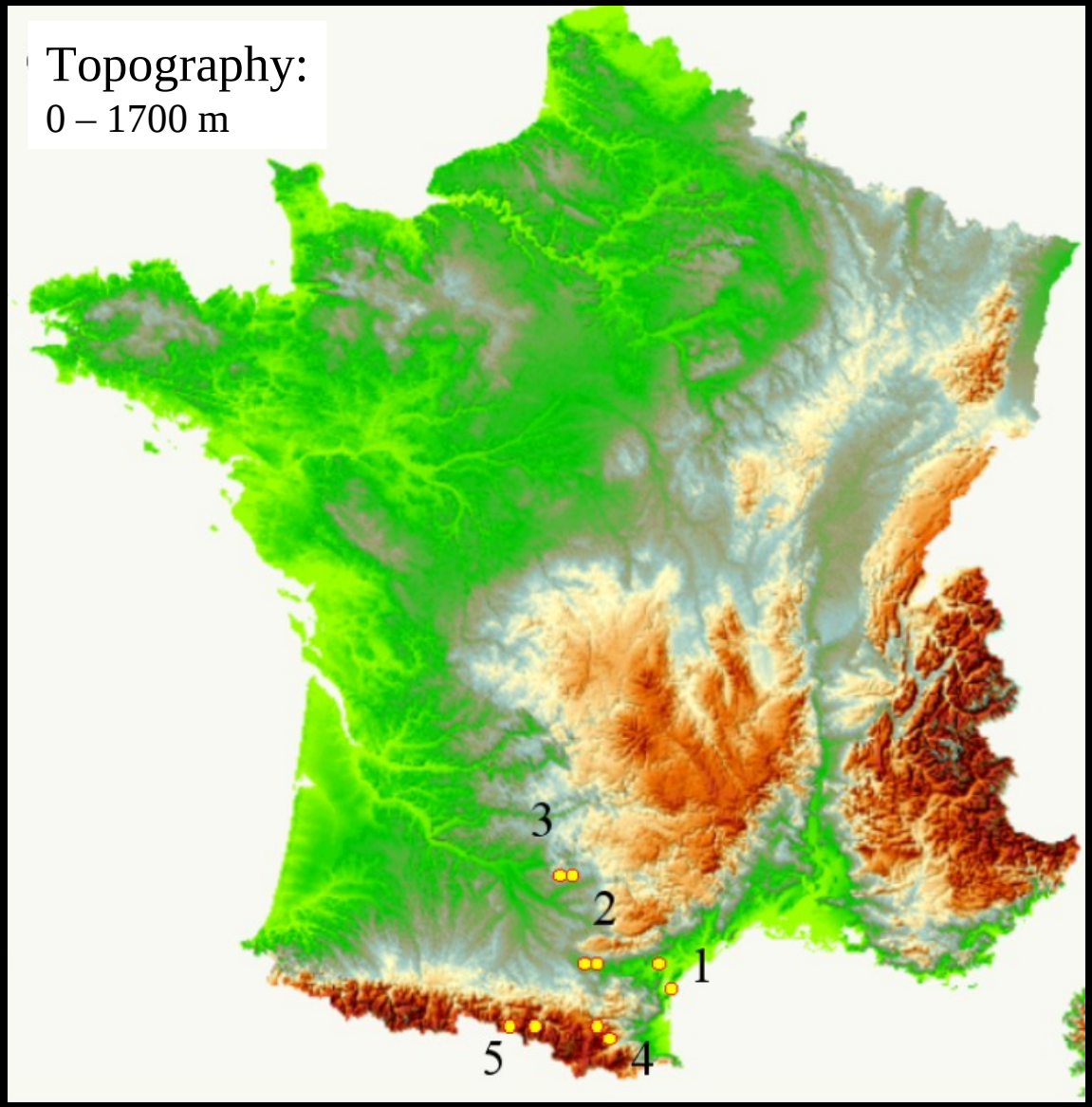
For each transect separetely:

Comparisons of transect zones → ***ANOVAs***

Linear correlation → ***Population trait means <u>vs</u> Altitude***


Main results

French transect



In situ population characterization

- ***Plant height***
- ***Plant volume***
- ***Above-ground biomass***

In situ population characterization

- ***Plant height***
- ***Plant volume***
- ***Above-ground biomass***

Significant differences between transect zones (ANOVA)

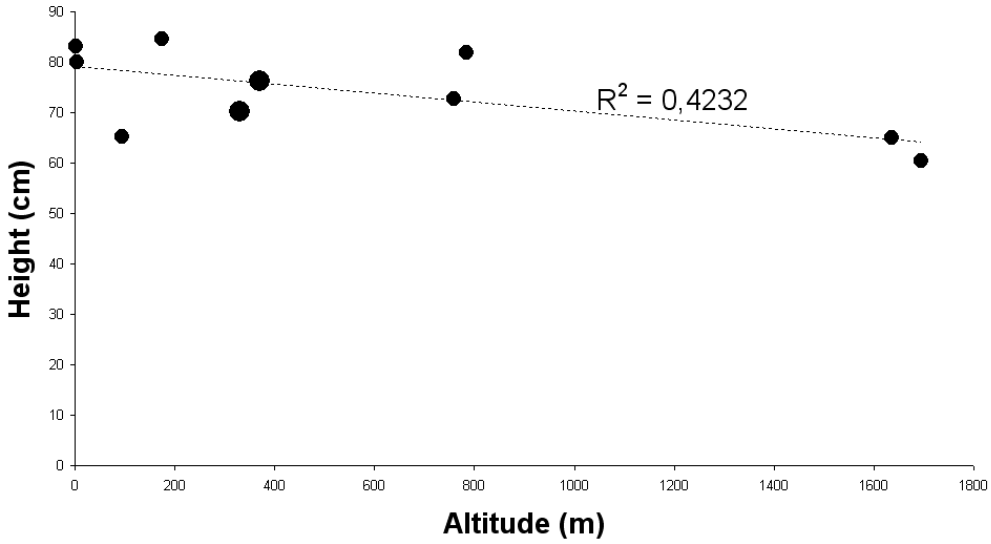
In situ population characterization

- ***Plant height***
- ***Plant volume***
- ***Above-ground biomass***

In situ population characterization

- ***Plant height***
- ***Plant volume***
- ***Above-ground biomass***

Significant decrease with altitude



In the field, plants from lower elevations grow larger

Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering***
- ***Final height***
- ***Final above-ground biomass***
- ***Reproductive allocation***

Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering*** →
- ***Final height*** →
- ***Final above-ground biomass***
- ***Reproductive allocation***

Significant differences between transect zones (ANOVA)

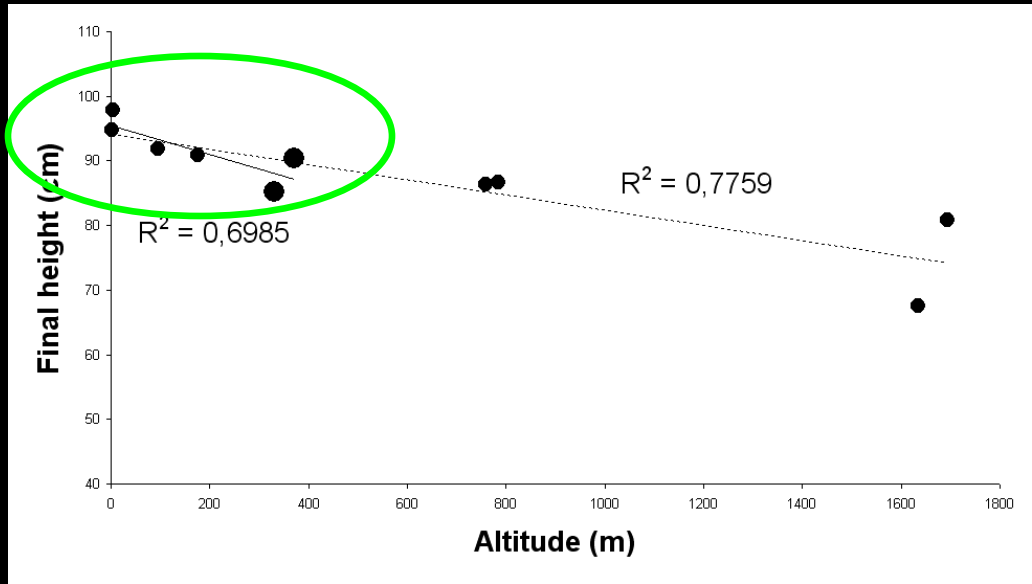
Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering***
- ***Final height***
- ***Final above-ground biomass***
- ***Reproductive allocation***

Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering***
- ***Final height***
- ***Final above-ground biomass***
- ***Reproductive allocation***

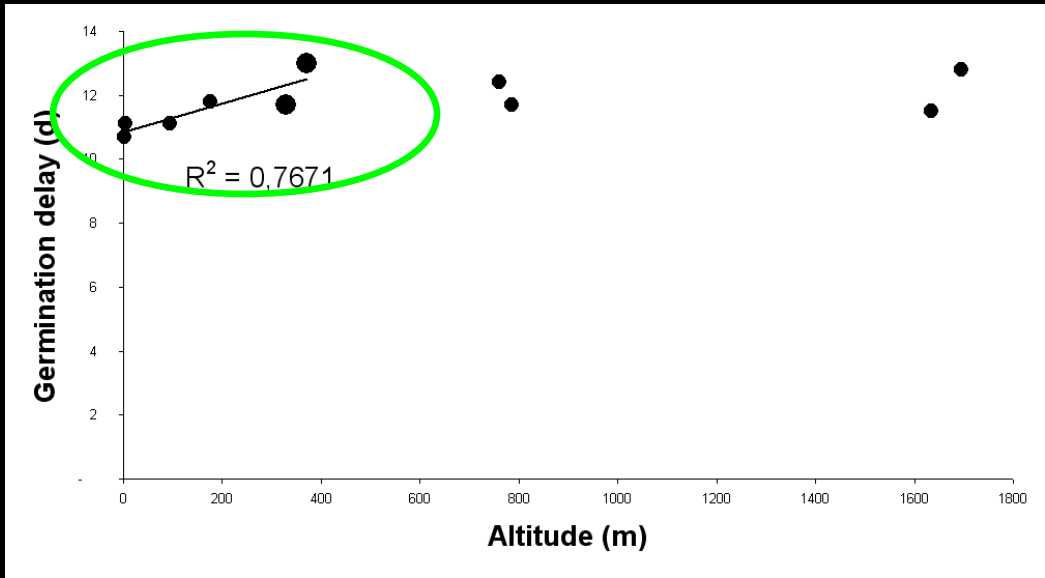
Significant decrease with altitude,
(especially along downward invasion)



Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering***
- ***Final height***
- ***Final above-ground biomass***
- ***Reproductive allocation***

Significant **increase** with altitude, along **downward invasion** only



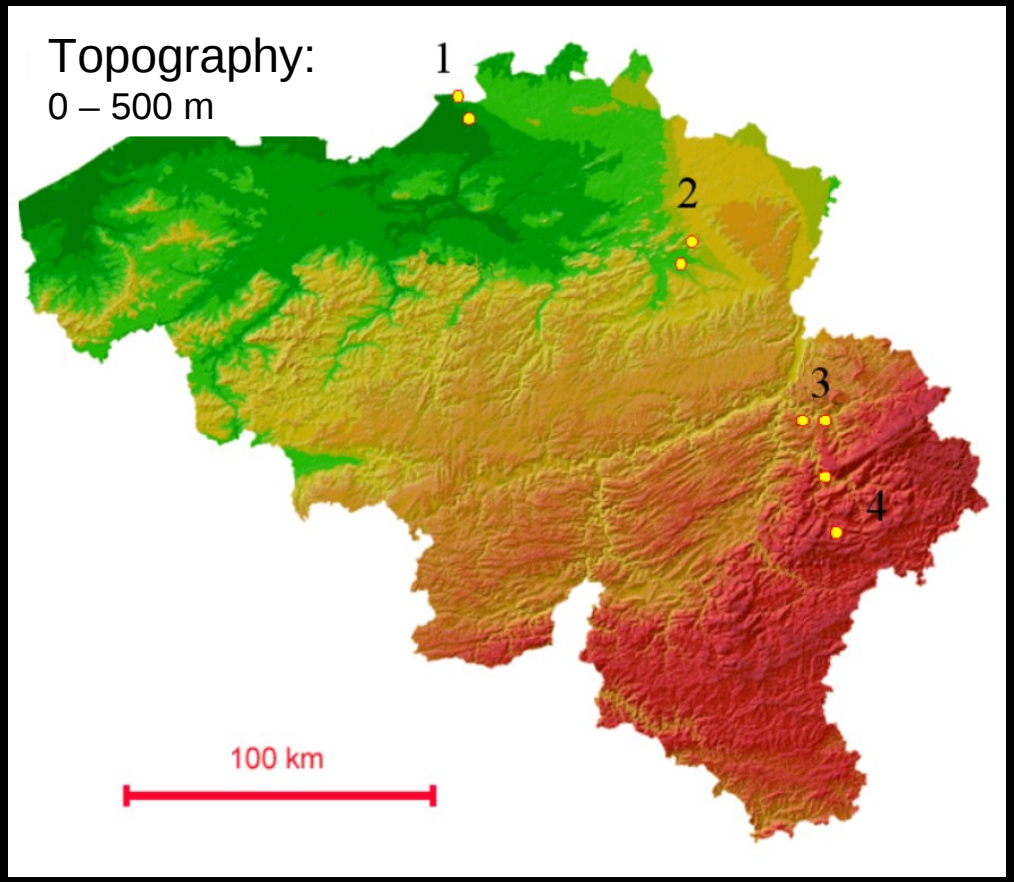
Common garden

- ***Germination delay***
- ***Flowering delay (since germination)***
- ***Height at first flowering***
- ***Final height***
- ***Final above-ground biomass***
- ***Reproductive allocation***

Significant **increase** with altitude, along **downward invasion** only

In the common garden, plants from lower elevations tend to germinate earlier, grow larger and allocate more ressources to growth than to reproduction

Belgian transect



Same altitudinal pattern for growth traits in the common garden… whereas less marked !


Conclusion

➔ This study reports a **species differentiation in relation to a spatial climatic variation**… what about a **temporal** climatic variation (global warming)?

➔ Plants from lower elevations tend to germinate earlier, to bloom at a greater age and to allocate more ressources to growth (Changes in germination, phenology and growth allocation!)

➔ Differentiation was steeper while the species encountered an **increase in temperature** (downward invasion)

➔ The differentiation is most likely adaptative for:

- Typical clinal variation
- Same pattern along both independent gradients

➔ Adaptative differentiations took place in a **timescale of less than one century…**

➔ Other studies reported adaptative differentiation in relation to climate for invasive species
(*Tamarix* sp.; *Solidago* spp.; I*mpatiens glandulifera*)

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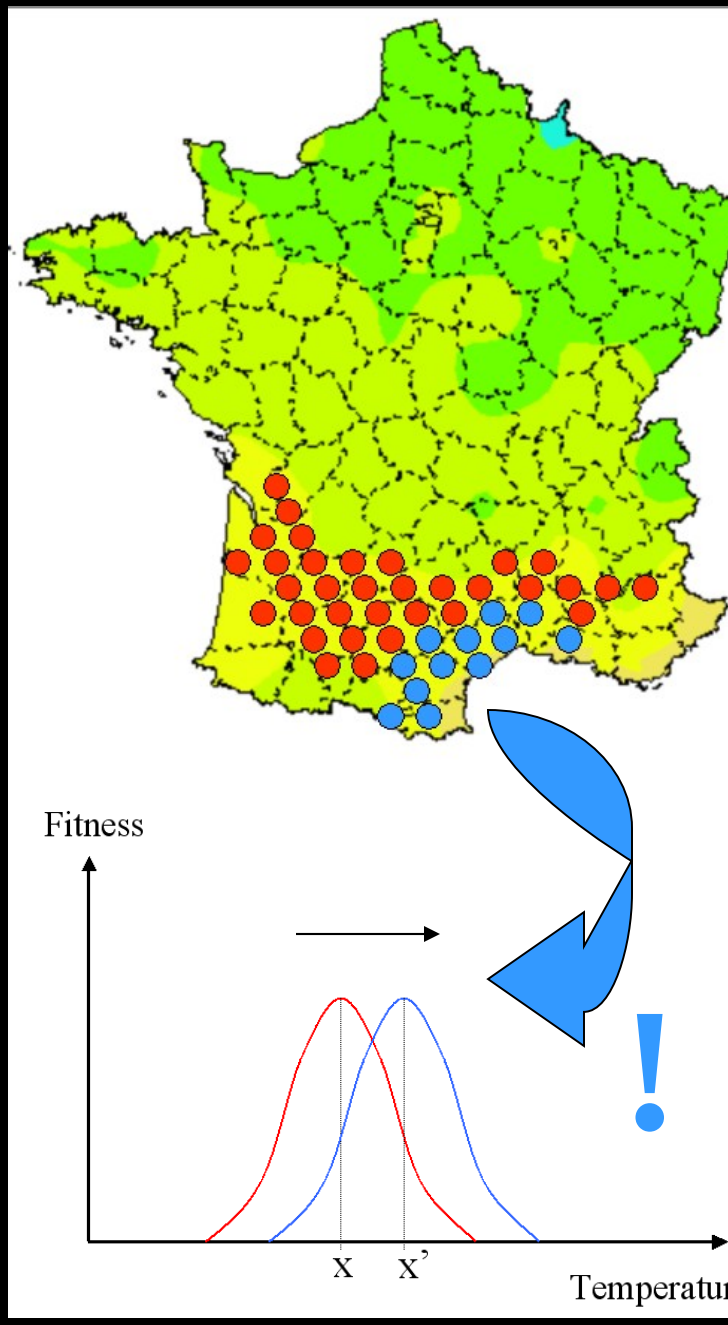
(*Tamarix* sp.; *Solidago* spp.; I*mpatiens glandulifera*)

➔ In this point of view, **global warming can force evolution of species**…

But are all species able to adapt ?

If not, global warming would favour some species (*e.g.* **invasive species**) through diversification while disadvantaging others!



Take-home messages:

➔ **Species are not static entities**: increasing research suggests that adaptations (*e.g*. in relation to a changing climate) can appear **faster** than previously thought.

➔This makes species distribution models even **more uncertain:** need to quantify the differentiation to include it in models…

➔ Global warming can force the irreversible differentiation of species. In the case of **alien invasive** species, a great adaptation potential is likely to induce a positive reaction to global warming…

Thank You

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