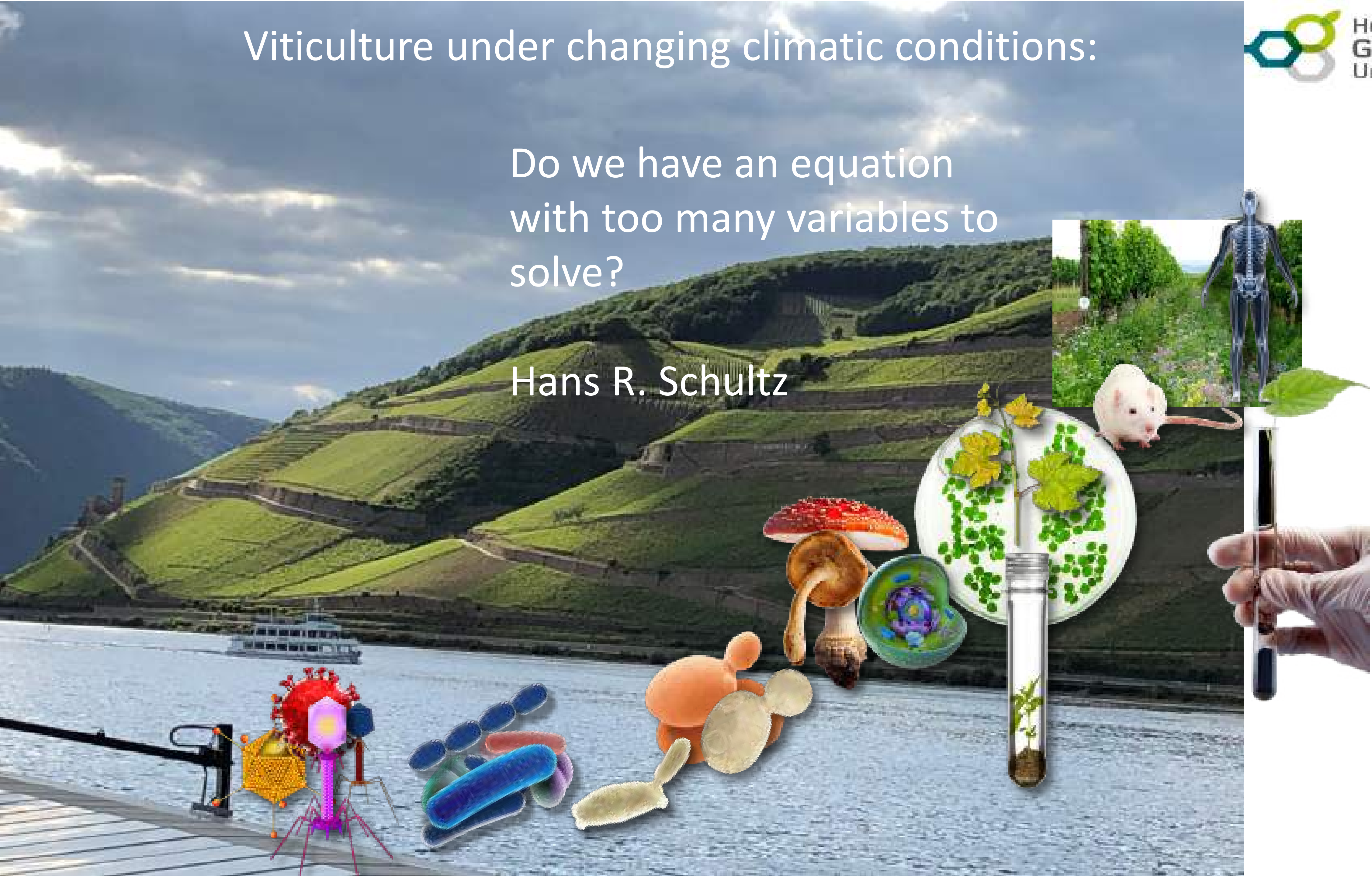
Viticulture under changing climatic conditions:

Do we have an equation with too many variables to solve?

Hans R. Schultz



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We should not miss these goals!

But can we still reach these goals?

Setting the stage

- EU green deal:
- reduce the use of chemical plant protection agents 50% by 2030
- reduce the use of fertilizers for a minimum of 20%
- reduce nutritional (fertilizer) losses by 50%
- implement a biodiversity strategy and 25% organic production systems by 2030
- turn Europe into a climate neutral continent by 2050

Outline

- some facts
- Soils, the underrated climatic factor
- biodiversity – what can we do?
- water, a big issue
- Plant protection – where to go?
- which production system for the future?
- Consequences in the discussion on CC

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some facts

- The food system contributes 19-29% of global anthropogenic GHG (CO_2, methane, CH_4, nitrous oxide, N_2O and nitric oxide, NO) emissions (9.8-16.9 Pg CO_2e) (1 Petagram = 1.000.000.000 T) CO_2e (CO_2e = total effect of all GHG (greenhouse gases) nomalised to CO_2) per year.

- Of this agriculture (+land-cover change) contributes (7.8-14.8 Pg CO_2e)
- yet these soils could have a sequestration potential of -2.7--3.2 Pg CO_2 per year

- appr. 33.4 Pg CO_2e are emitted annually from fossil fuel combustion and the cement industry

Food Security and Nutrition (2018): Challenges for Agriculture and the hidden potential of soil, A report to the G20 Agriculture Deputies, FAO, OECD, IFAD, IFPRI, World Bank, WTO

Plummer, D. (2018) Green Paper: A business case for the redesign of the food system from the ground up. Triage Limited, 29pp

Soils, the under-rated climatic factor

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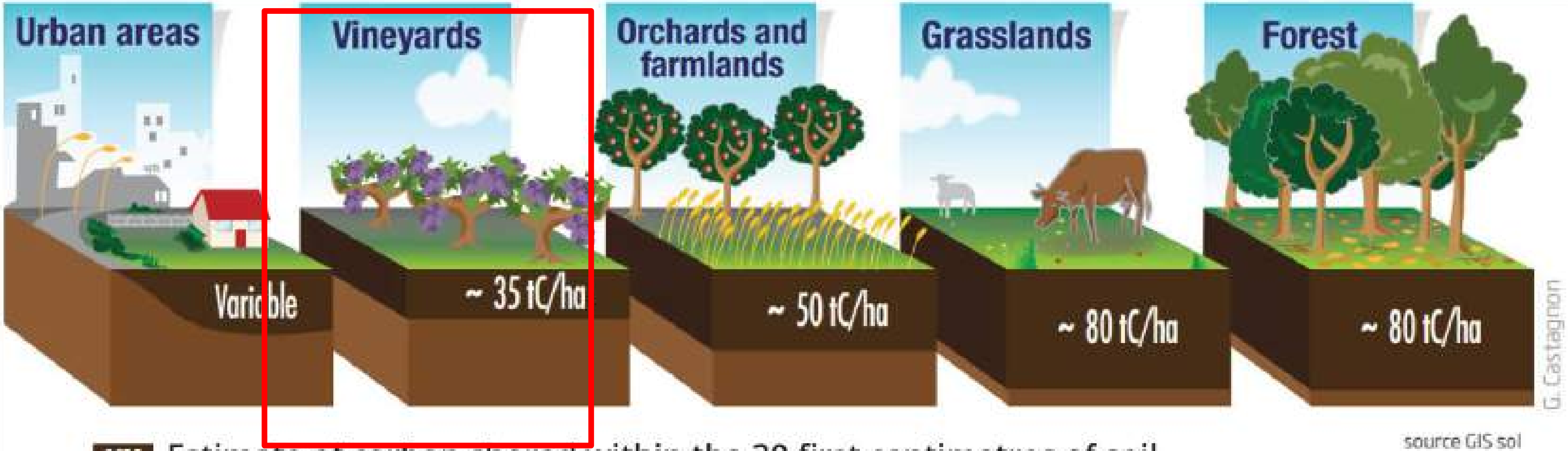
4 PER 1000
SOILS FOR FOOD SECURITY AND CLIMATE

- Soils are the key to sustainability its our most valuable resource
- Soils store about 1.500-2.500 Billion tons of carbon – more than the atmosphere (780 Billion tons) and plants (560 Billion tons) combined
- It takes 2000 years to build 10 cm of soil
- Every year we loose 24 Billion Tons of soil due to erosion (extreme events will increase this number)
- This is 3.4 tons per person and year and is equivalent to 60€ per person and year = 420 Billion € per year
- The 4 per 1000 initiative aims at an increase of 0,4% C content in soils per year to balance out global GHG emissions

Soils as a carbon storage component in different vegetation types

Figure 2 Variations in organic carbon sink depending on land use in France



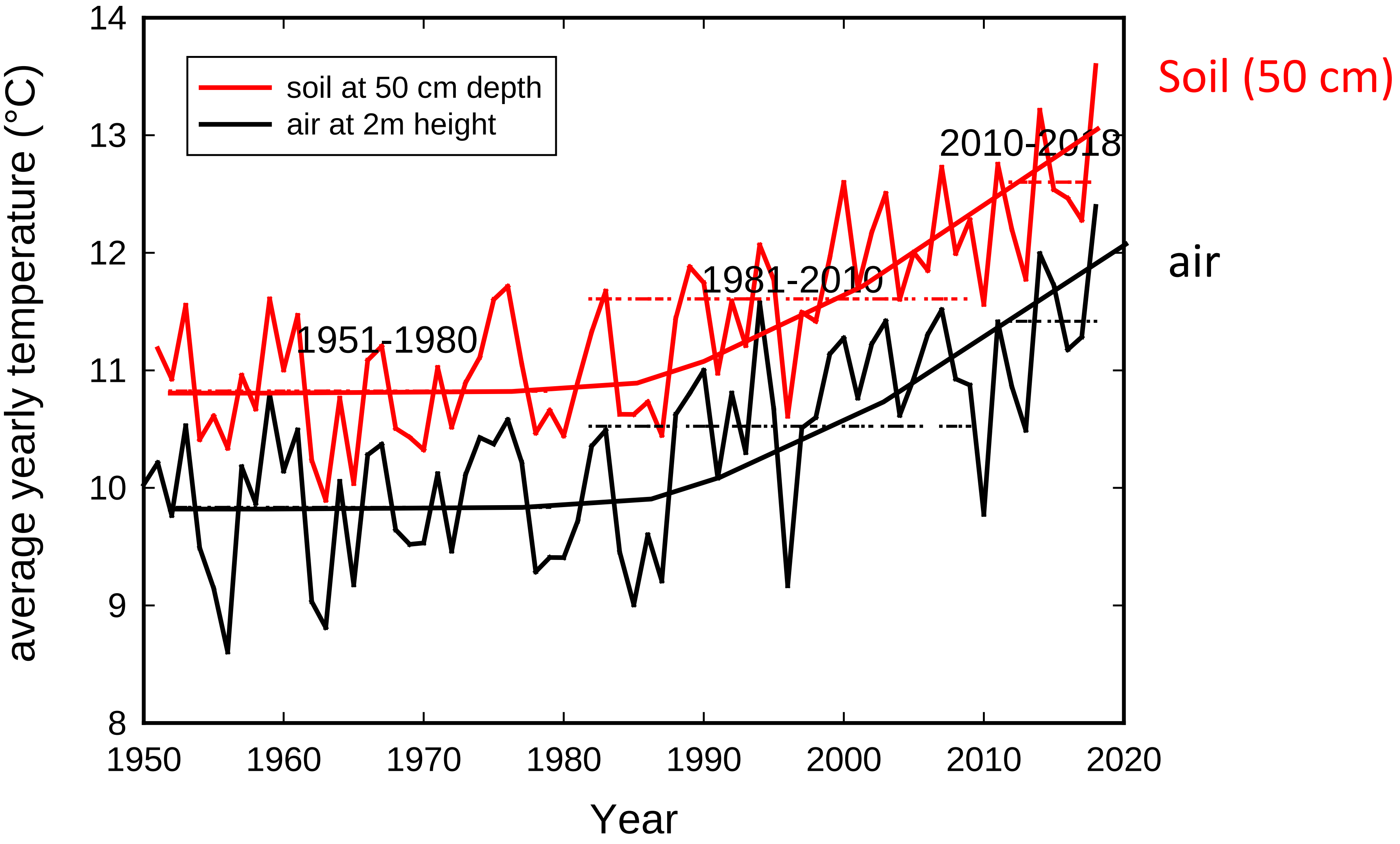
XX Estimate of carbon shared within the 30 first centimetres of soil

Organic matter stocks in forests, grasslands and low vegetation growing in highlands are large, whereas stocks are quite low in vineyards, farmlands and Mediterranean zones. Quantifying stocks is difficult in urban areas; nevertheless, a significant amount of carbon could be stored under green spaces. carbon stored in forest litter is not taken into account.

Source : GIS sol; (ADEME, 2014)

What do we observe?

Strong temperature increase in the soil (the Geisenheim time series, annual avg.)



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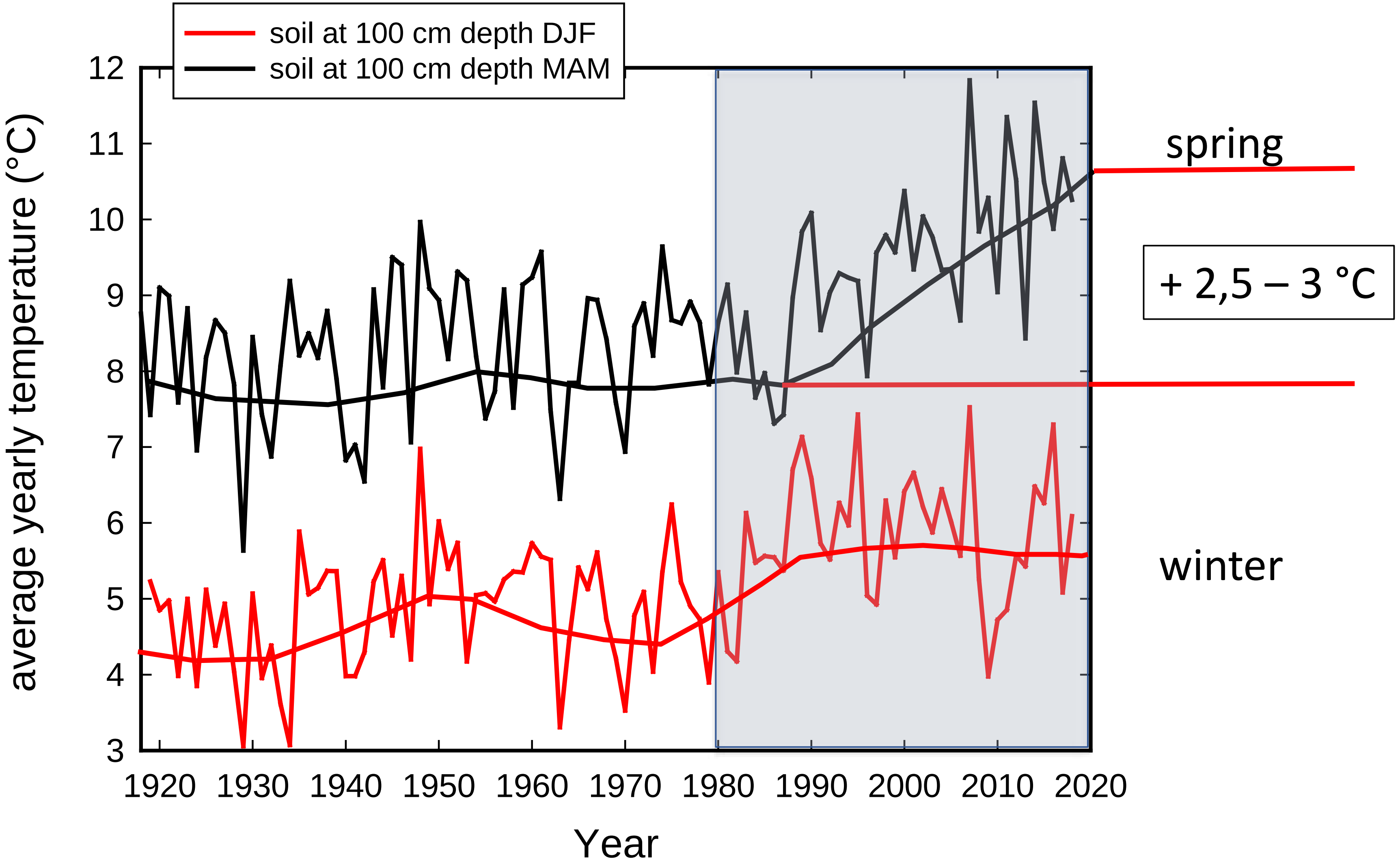
Data: adapted from Deutscher Wetterdienst, Geisenheim

Temperature increase in winter (December, January, February; DJF, as compared to spring, March, April, May; MAM) 1 Meter soil depth 100 years!



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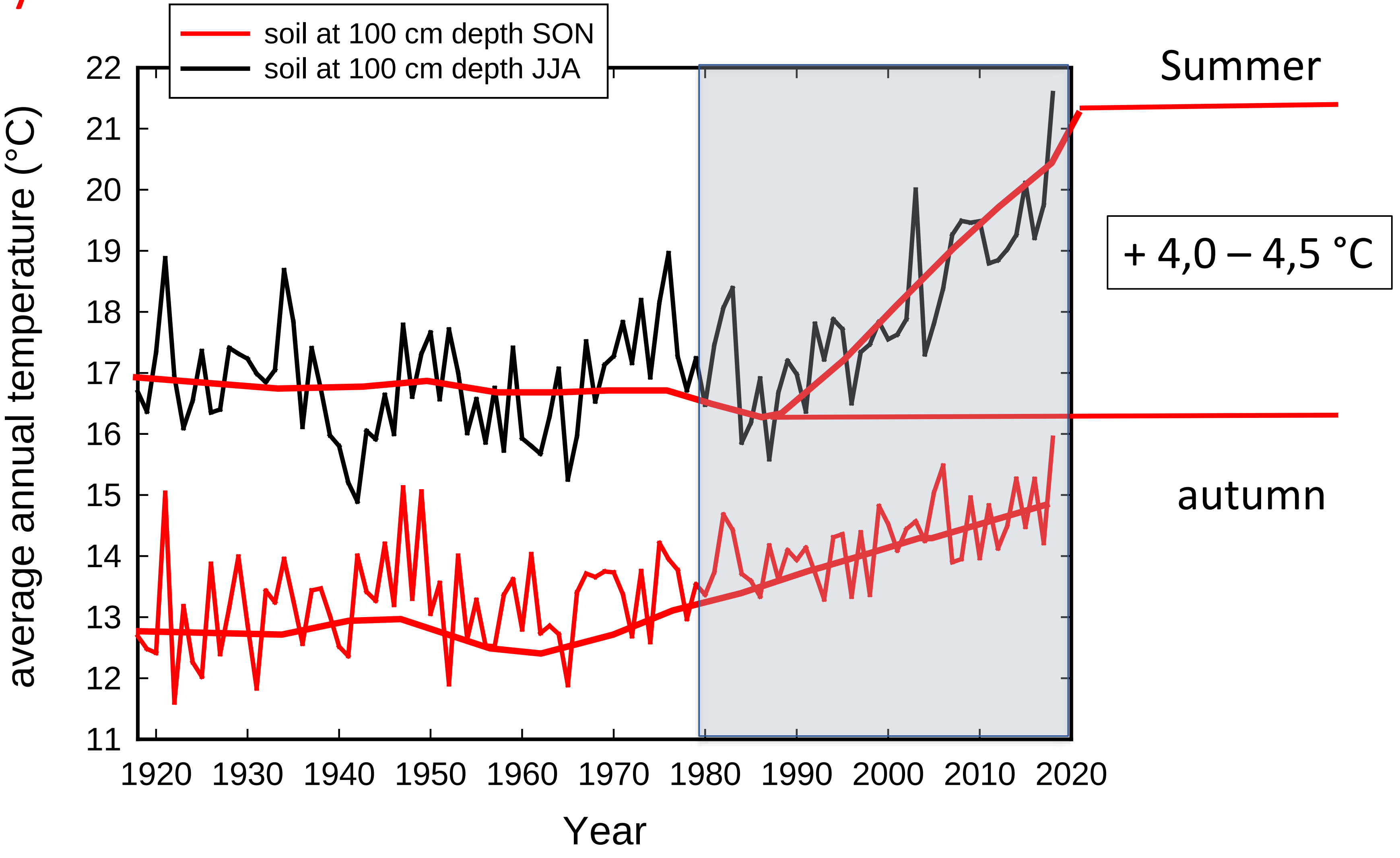
Data adapted from: Deutscher Wetterdienst, Geisenheim

Temperature increase in summer (June, July, August; JJA, as compared to autumn, September, October, November; SON) 1 Meter soil depth 100 years!



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Data adapted from: Deutscher Wetterdienst, Geisenheim

Are there consequences for the sink activity of soils. Especially for carbon?

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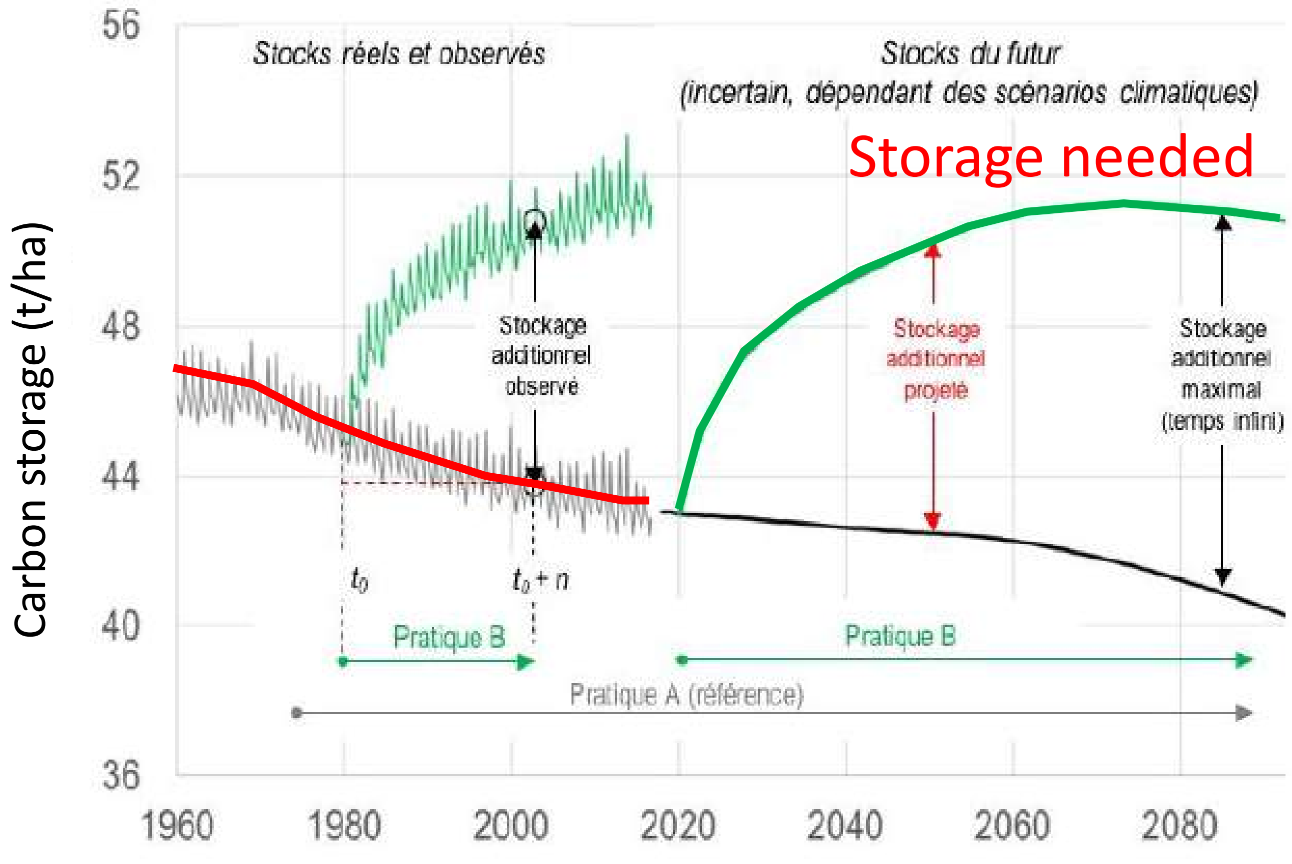


Figure 4. Représentation schématique des cinétiques de stockage associées à l'adoption de pratiques en un lieu donné : stockage additionnel observé (à gauche), stockage additionnel projeté (à droite).

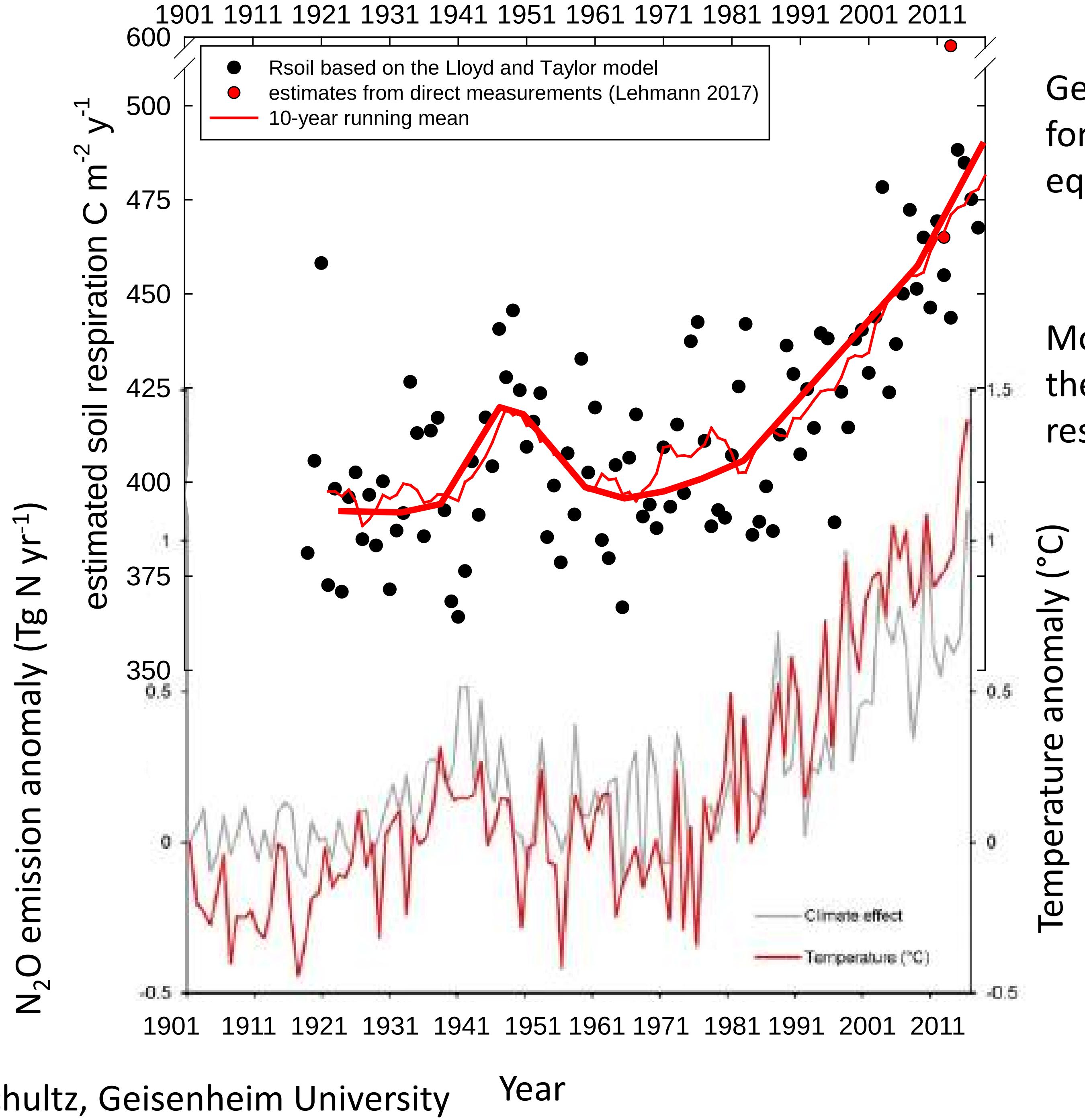
These french data suggest, that during the last 60 years about 3-4 T C (= 11-14,5 T CO_2)/ ha were lost over the entire agricultural surface area (for example ag. surface Germany about 22.Mio ha)

Soils as a source for GHG emissions?

Pellerin, S. et al. (2019) Stocker du carbone dans les sols francais, quel potentiel au regard de l'objectif de 4 pour 1000 er à quel coût? Synthèse du rapport d'étude, INRA (France), 114 S.

Potential C losses from a vineyard soil (example Geisenheim)

Analogy to global N_2O-emission rates



Geisenheimer soil temperaturer series used for modelling soil (+ root) respiration equivalent to potential C losses

Model applied: Lloyd, J., Taylor, J.A. (1994) On the temperature dependence of soil respiration. Functional Ecology, 8, 315-323.

Tian, H. et al. (2020) A comprehensive quantification of global nitrous oxide sources and sinks. Nature 586, 248-256

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Conclusion

- apparently, both GHG, CO_2 and N_2O follow the same pattern of potential emissions
- What do we need to do, to invert this

Soil management is the key!

… bio-organic or conventional systems have to be further developed?

Good **production measures** is not equivalent to good **climate protection measures**!

How can we turn vineyard soils into a GHG sink?

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Practise to increase C storage	Additional C/ha (kgC/ha/y)	CO_2-extracted from atmosphere for additional storage (kg CO_2/ha/y)	CO_2e-extracted from atmosphere taking GHG emissions into account (kgCO_2e/ha/y)	Tot. vineyard surface area (ha)	CO_2e-extracted from atmosphere for France taking GHG emissions into account (t CO_2e/ha/y)
Permanent cover crop	- 464	-1701	- 1541	150.000	- 230.000
Winter cover crop	- 300	- 1100	- 1087	410.000	- 450.000

Pellerin, S. et al. (2019) Stocker du carbone dans les sols francais, quel potentiel au regard de l‘objectif de 4 pour 1000 er à quel coût? Synthèse du rapport d‘étude, INRA (France), 114 S.

How can we turn vineyard soils into a GHG sink?

An example from California (warm and dry summers)

Net global warming potential (GWP) kg CO_2-eq ha^{-1} a^{-1}	Min Till + cover crop (dwarf barley)	Tillage (1 x autumn, 1 x spring + 1x mulch) + cover crop (dwarf barley)
Changes in soil organic carbon (- = uptake)	-1.123	-172
N_2O	+62,6	+75,5
CH_4	-5,1	+10,1
Fuel Carbon	+192,5	+234,7
Net GWP	-873,6	+472,9
Yield (grape fresh wt. kg/ha) (9 x irrigated)	4.369	6.477

Wolff et al. (2018) Minimum tillage of a covercrop lowers net GWP and sequesters soil cabon in a California vineyard. Soil & Tillage Research, 175: 244-254.

We need to pay more attention to the C/N ratio of cover crops because of GHG emission potential!

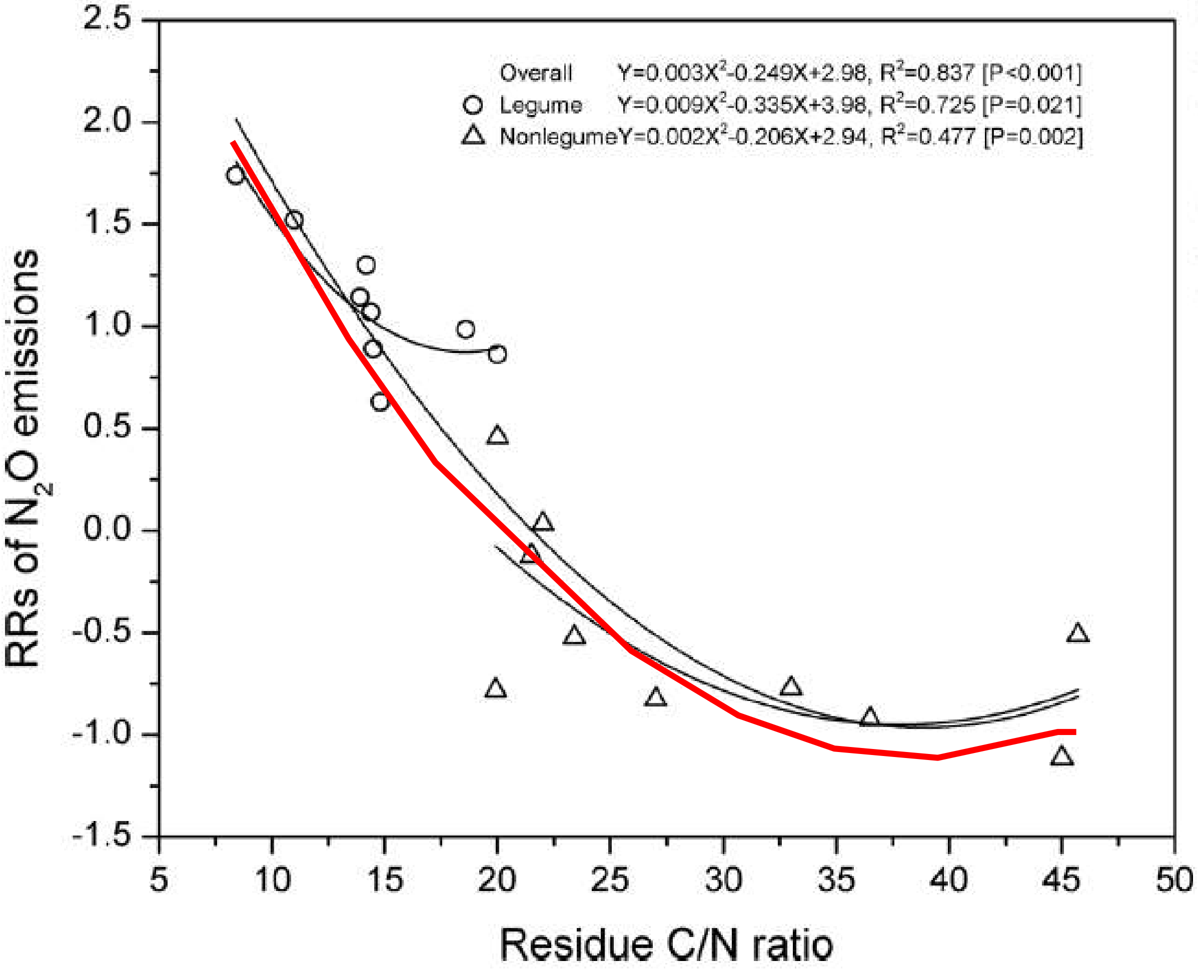
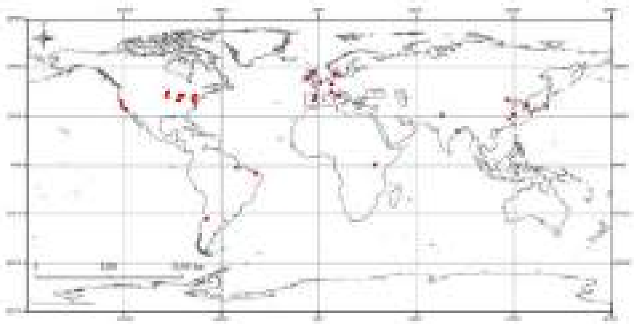


Fig. 5. Relationships between response ratios (RRs) of N_2O emissions and residue C/N ratio for various cover crop species. The RR was calculated by dividing N_2O emissions from the cover crop treatment by that from the no cover crop treatment.



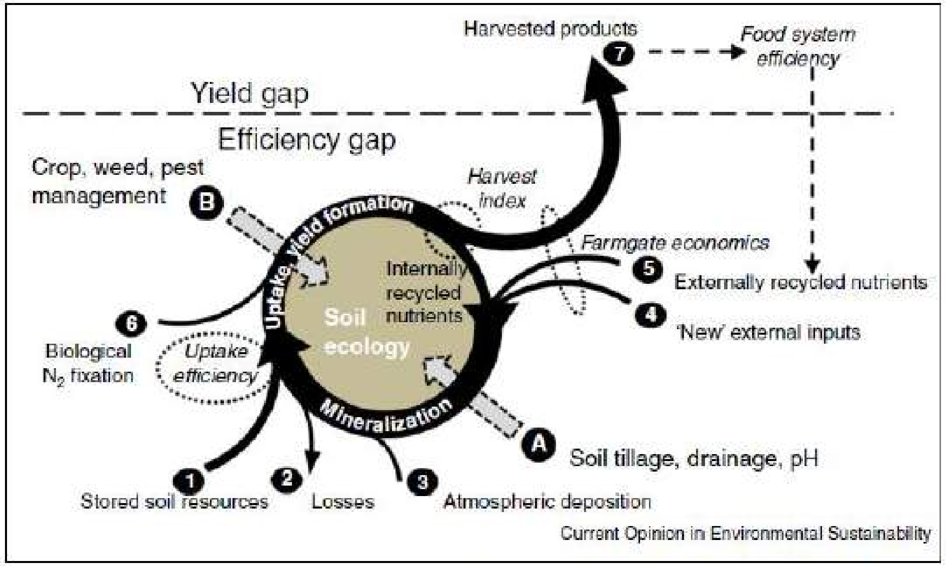
Muhammad et al. (2019) Regulation of soil CO_2 and N_2O emissions by cover crops: A meta-analysis. Soil & Tillage Research, 192: 103-112

- both CO_2 and N_2O emissions decrease strongly with increased cover crop biomass C/N ratio
- All cover crops increase carbon sequestration into the soil
- legume and non-legume cover crop mixtures and placing the residues at the surface instead of incorporating into soil reduces GHG emissions

Muhammad et al. (2019) Regulation of soil CO_2 and N_2O emissions by cover crops: A meta-analysis. Soil & Tillage Research, 192: 103-112

Some facts bio-organic/bio-dynamic against conventional from general agriculture

- C-sequestration potential ↑ +0,99 t CO_2e/ha
- N_2O reduction potential ↓ -0,49 t CO_2e/ha
- CH_4 reduction potential ↓ -0,03 t CO_2e/ha



Nordwijk and Brussard. 2015, Curr Op Environ Sus

Important is the functional unit!

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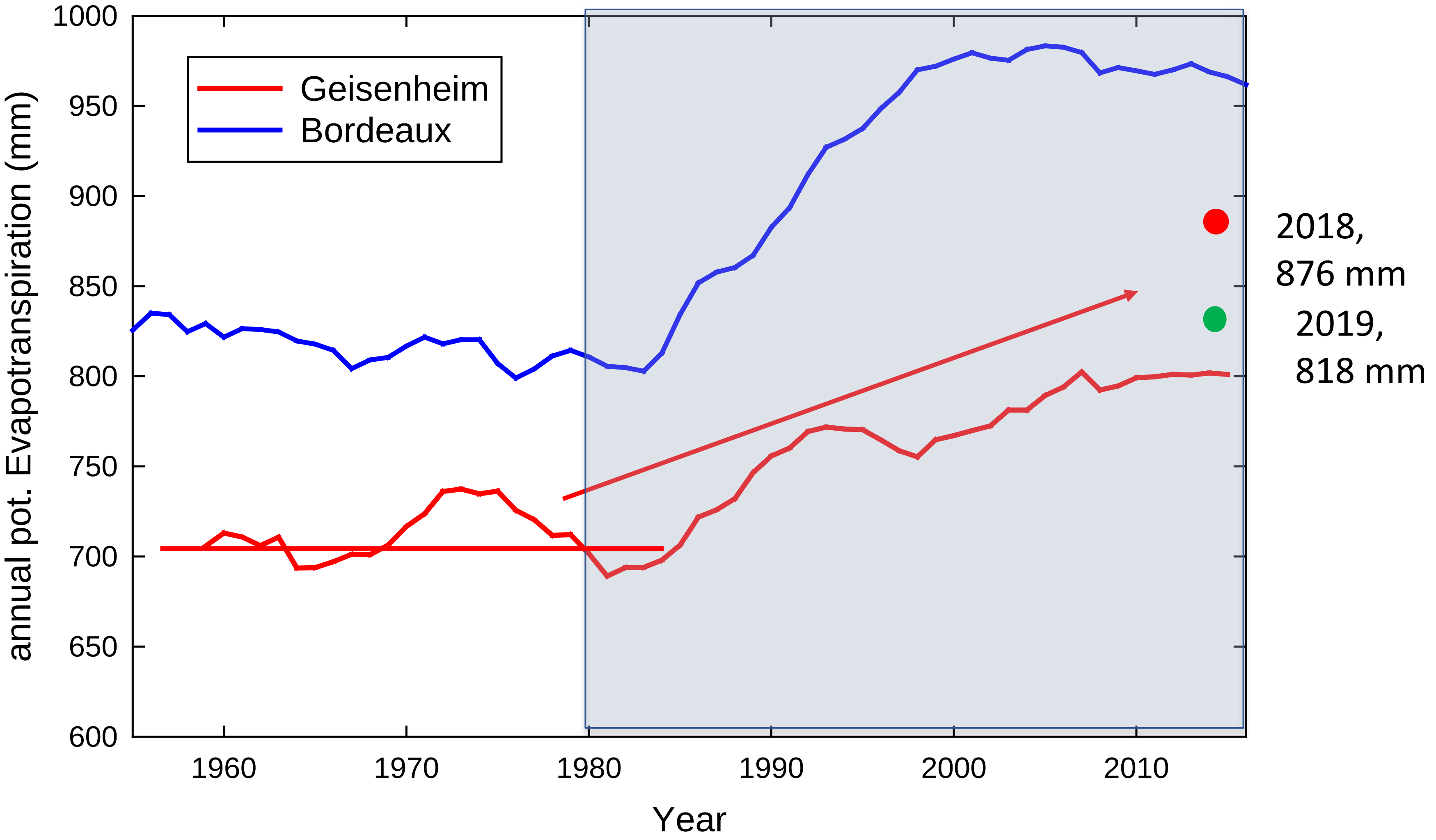
Expl. Skinner et al. (2019) The impact of long-term organic farming on soil-derived greenhouse gas emissions. Scientific reports, 9: 1702

Conclusion

- We need to study our management systems more with respect to their GHG emission potential
- What role does water availability play?

Warming increases Evapo-transpiration!



French data: DB, CLIMATIK, Agroclim, INRA; German data: Deutscher Wetterdienst, Geisenheim

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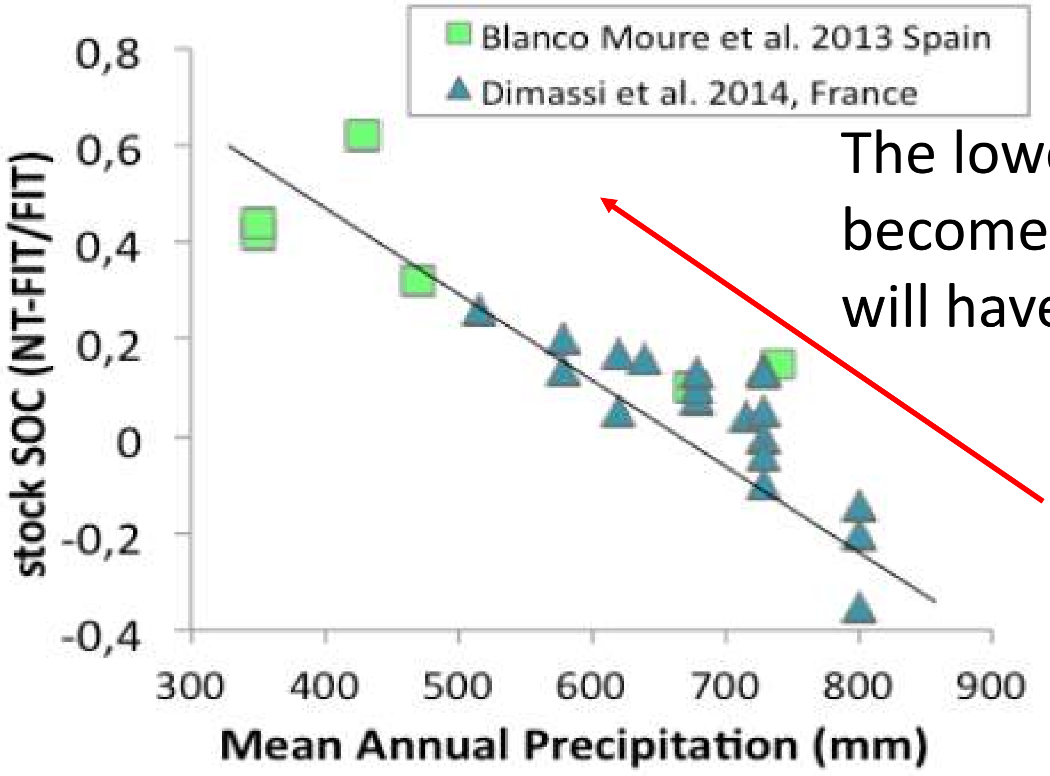
Carbon storage capacity also depends on water availability

This example shows the combined effects of soil management (NT = no tillage, FIT, tillage) and available water on C storage capacity



The lower water availability becomes the more NT systems will have an impact on C storage

Figure 4-21. Effet du climat sur la variation de stock de COS quand on passe du labour (FIT) au non-labour (NT) (Source : Dimassi *et al.*, 2014)

Pellerin, S. et al. (2019) Stocker du carbone dans les sols francais, quel potentiel au regard de l'objectif de 4 pour 1000 er à quel coût? Synthèse du rapport d'étude, INRA (France), 114 S.

What else does increased soil temperature mean?

Rootstocks:

Increased conductance?

Increased root surface?

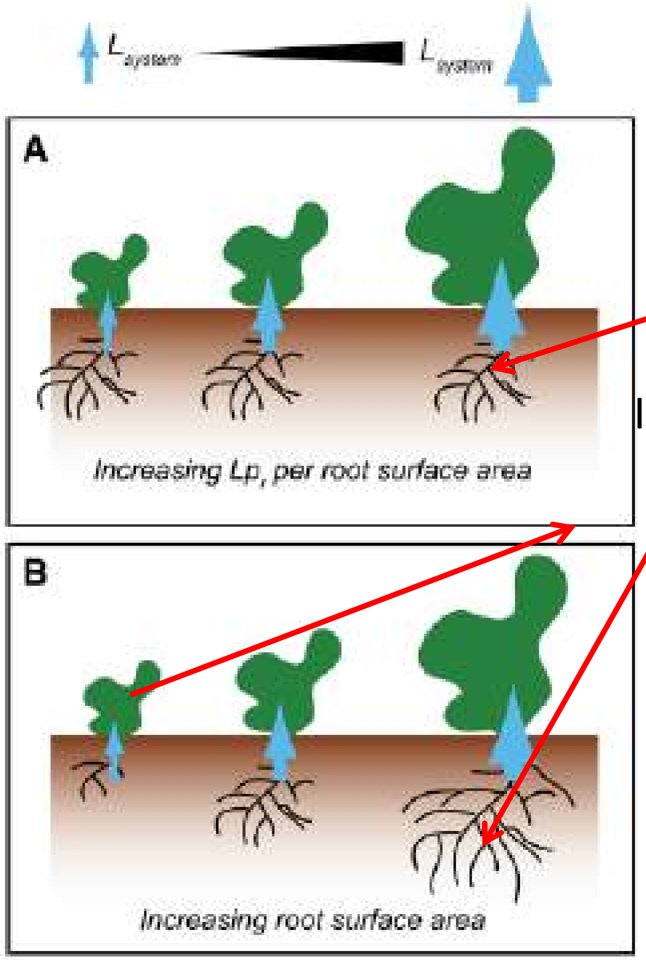
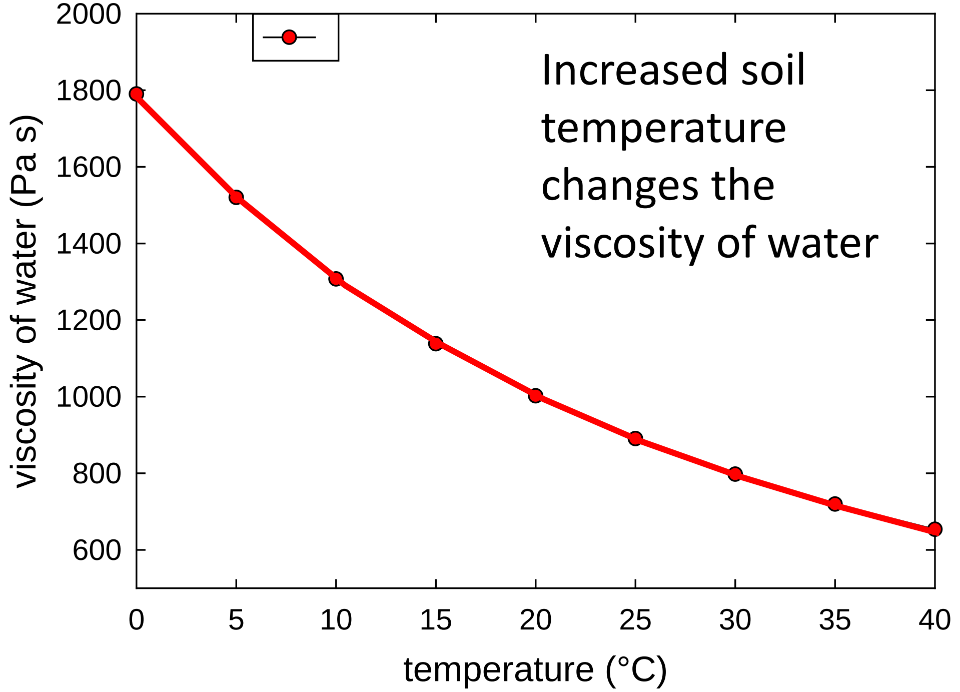


Fig. 3 It has been hypothesized that increases in scion growth can be brought about by increases in the rootstock's ability to take up water. Both of the examples above show increases in whole root system hydraulic conductance (L_{system}) from *left* to *right* (*blue arrows*). However, increases in L_{system} can result from a increases in hydraulic conductivity per unit surface area (Lp_r), b increases in whole root system surface area, or a combination of both. (Color figure online)



Zhang et al. (2016) The influence of grapevine rootstocks on scion growth and drought resistance. Theor. Exp. Plant Physiol. DOI 10.1007/s40626-ß16-0070-x

Why is this important?

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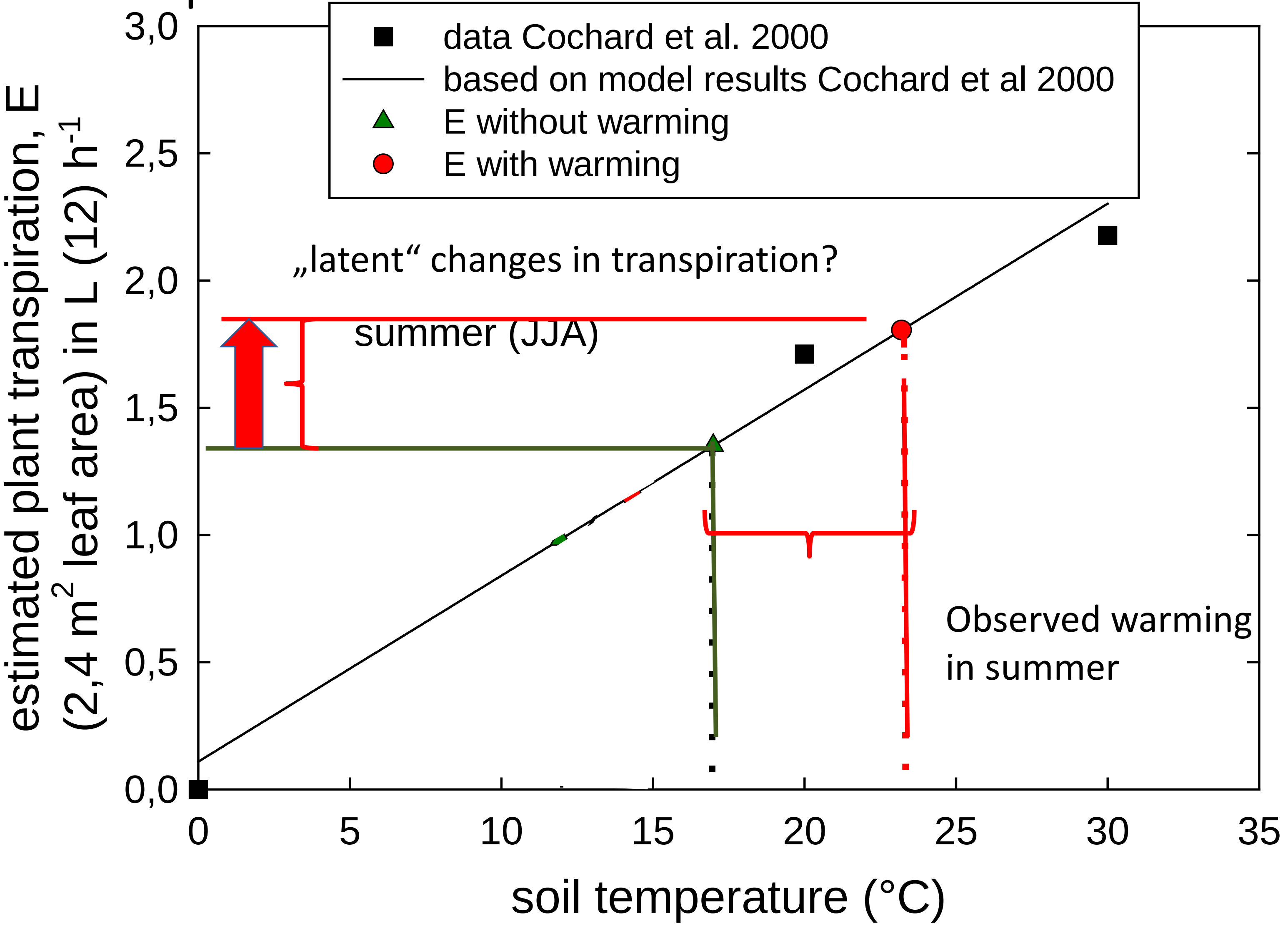
According to the Hagen-Poiseuille equation, which describes laminar flow through ideal capillaries:

$$Kh = \pi \frac{\sum_{i=0}^{n} d^4}{\mathbf{128\eta}}$$

Where is Kh is the hydraulic conductance (say in the plant root), d (m) is the diameter of the conducting vessel to the 4th power and η is the viscosity of water (MPa s)

A decrease in water viscosity due to an increase in temperature will increase conductance and thus INCREASE transpiration rate

Theoretical change in plant transpiration rate due to a change in soil – plant xylem water temperature



Analysis compared to: Cochard et al. (2000) Temperature effects on hydraulic conductance and water relations of Quercus robur L. Journal of Exp. Botany, 51: 1255-1259

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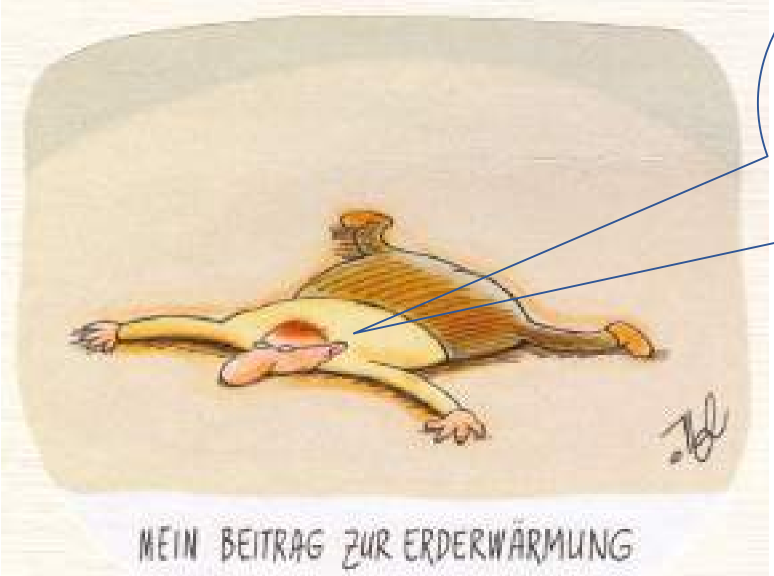
Conclusion

- just focusing on soils and the apparently occurring changes in temperature together with management systems and water availability show how complicated all these interactions act on an agricultural system
- we can only devise regional adapted strategies if we use different approaches, especially different measurement set ups

Look at it differently

1ha vineyard produces 10 Mio L of oxygen, enough for 20 people, worldwide we have 7.6 Mio ha, producing enough oxygen for 121 Mio. people

And: save the earth, it‘s the only planet with WINE!



My contribution to global warming!

Thank you for your attention