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OENOBIO

Could organic viticulture Mitigate effects of climate change?

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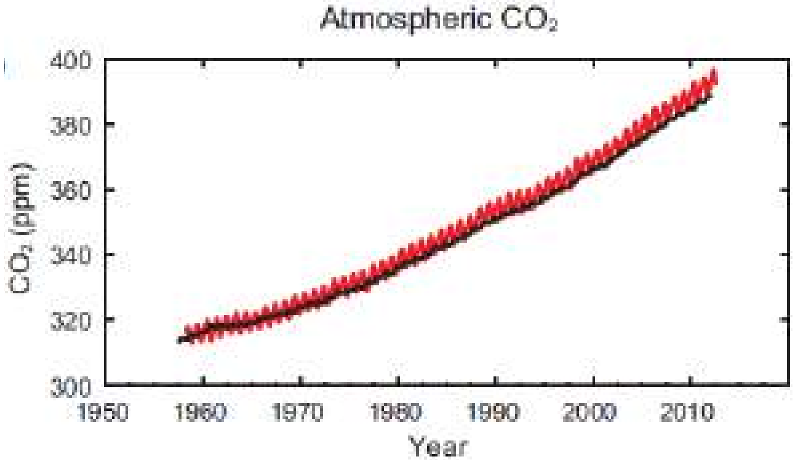
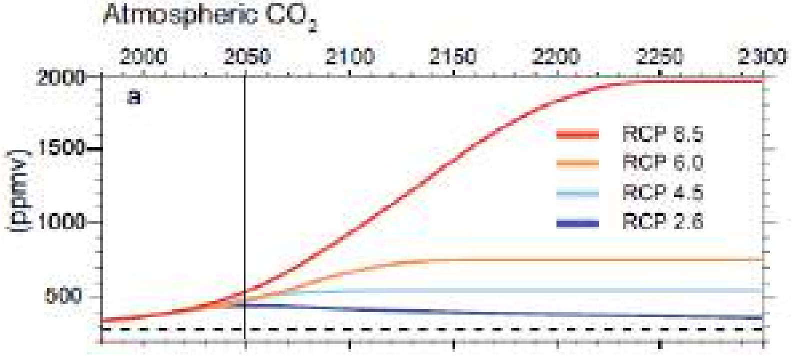
Climate change
CO_2 - concentration



Multiple observed indicators of a changing global carbon cycle: atmospheric concentrations of carbon dioxide (CO_2) from Mauna Loa (19°32´N, 155°34´W – red) and South Pole (89°59´S, 24°48´W – black) since 1958



Atmopspheric CO_2, as simulated by Earth System Models of Intermediate Complexity (EMICs) for the four Representative Concentration Pathways (RPC) up to 2300 (Zickfeld et. al 2013). The dashed line indicates the pre-industrial CO_2 concentration.

- annual atmospheric CO_2-increase of 1.5-3 ppm according to several emission-scenarios
- mid of 21st century → +20 % CO_2 (IPCC, 2013)
- studies on plant response to CO_2 enrichment are of high interest regarding future crop production

Is viticulture sensitive to elevated CO_2?

↓

VineyardFACE experiment

- started as part of the LOEWE research cluster FACE2FACE
- investigation of consequences of climate change, adaption to climate change and reduction of greenhouse gas emissions to 2050

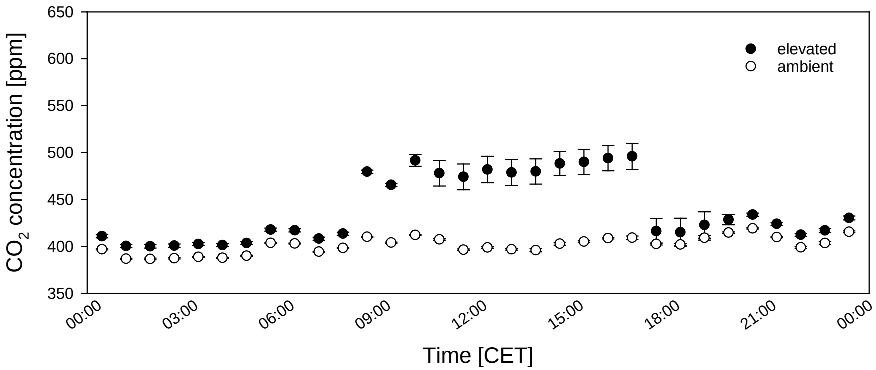
Experimental setup - VineyardFACE @ HGU

- Geisenheim, Rheingau, Germany (50°N, 8°E)
- sandy loam
- temperate oceanic climate:
  - 10.5 °C, 543 mm (Ø 1981-2010)
- ring system with two treatments:
  - aCO_2 → ambient CO_2 400 ppm
  - eCO_2 → elevated CO_2 + 20 %
- CO_2 enrichment started 2014
- 365 days from sunrise to sunset
- two varieties:
  - Riesling cl. 198-30 Gm, SO4
  - Cabernet Sauvignon cl. 190, 161-49 Couderc
- spacing: 1.8 m x 0.9 m / 1.6 m² per vine
- cane pruned 5 nodes/m²
- management following GAP and IPM

Wohlfahrt et al., 2018

Experimental setup - VineyardFACE @ HGU

- diurnal CO_2 concentration
  - 05/02/2017



- daily CO_2 concentration
  - 14-22/07/2015

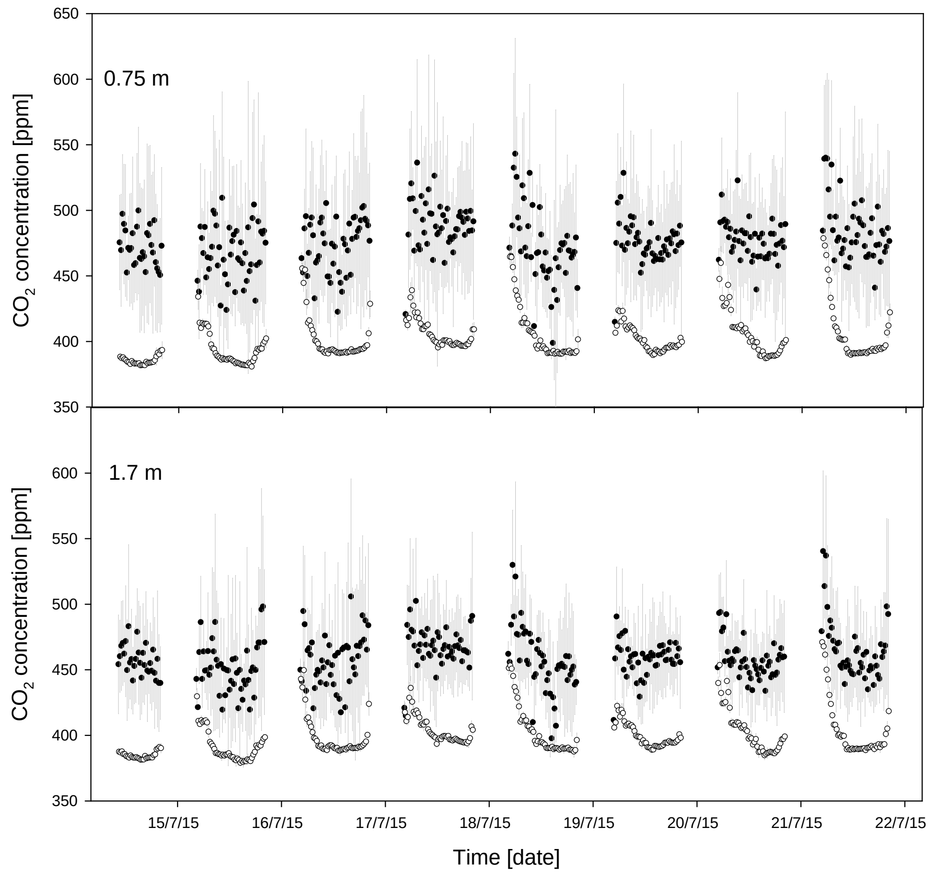


Fig.: Daily averaged carbon dioxide concentration of the soil efflux analyzer (Li-Cor LI-8100/8150 Multiplexer) from 14-22/07/2015 measured at heights of 0.75 m and 1.7 m from sunrise to sunset. Means ± sd.

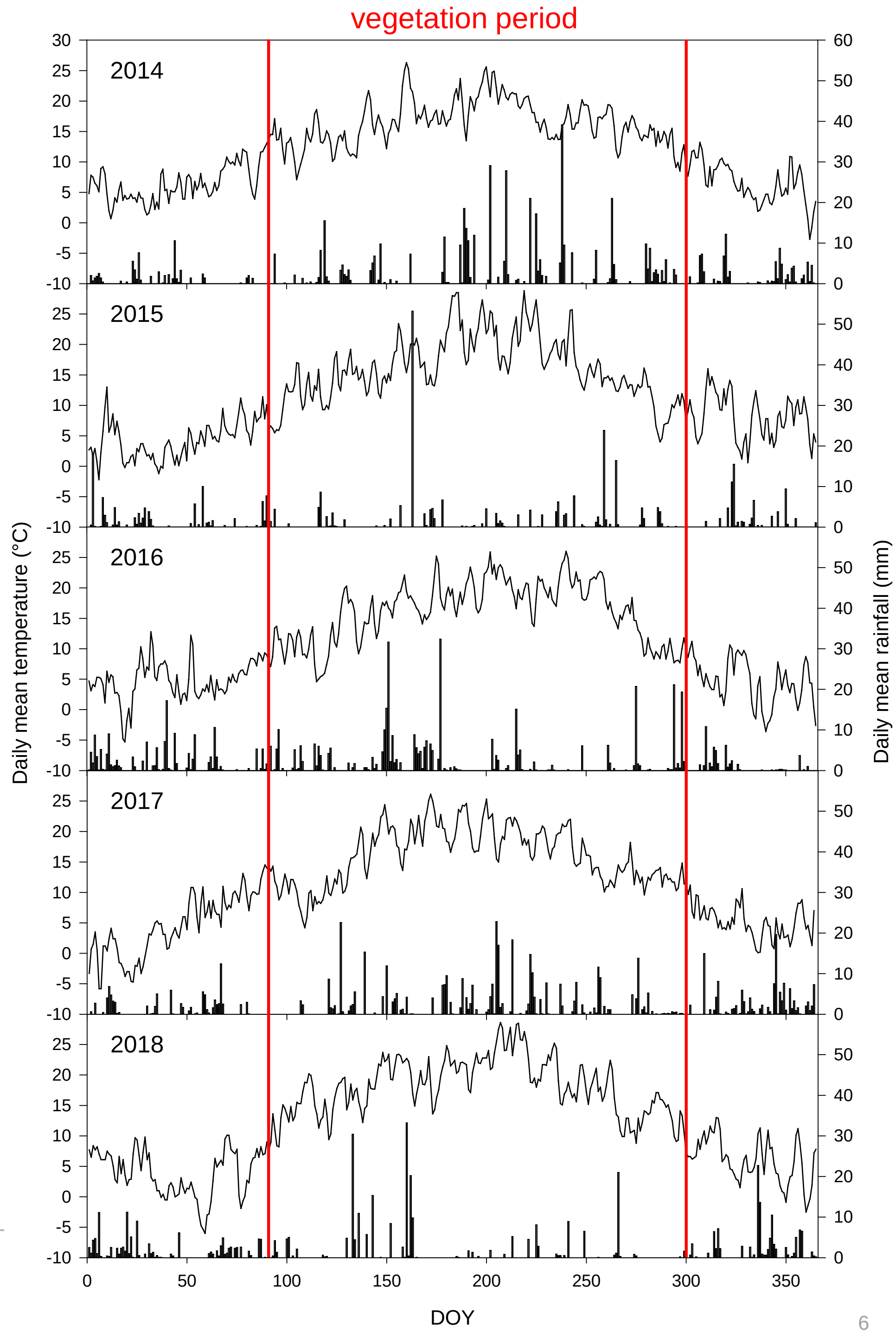
Wohlfahrt et al., 2018

Climatic conditions - VineyardFACE @ HGU

- daily mean air temperature (solid line) and rainfall (black bars) at Geisenheim in 2014, 2015, 2016 and 2017

- annual average temperature:
  - 2014: 12.2 °C
  - 2015: 11.7 °C
  - 2016: 11.2 °C
  - 2017: 11.3 °C
  - 2018: 12.3 °C

- annual rainfall:
  - 2014: 599 mm
  - 2015: 396 mm
  - 2016: 583 mm
  - 2017: 590 mm
  - 2018: 470 mm

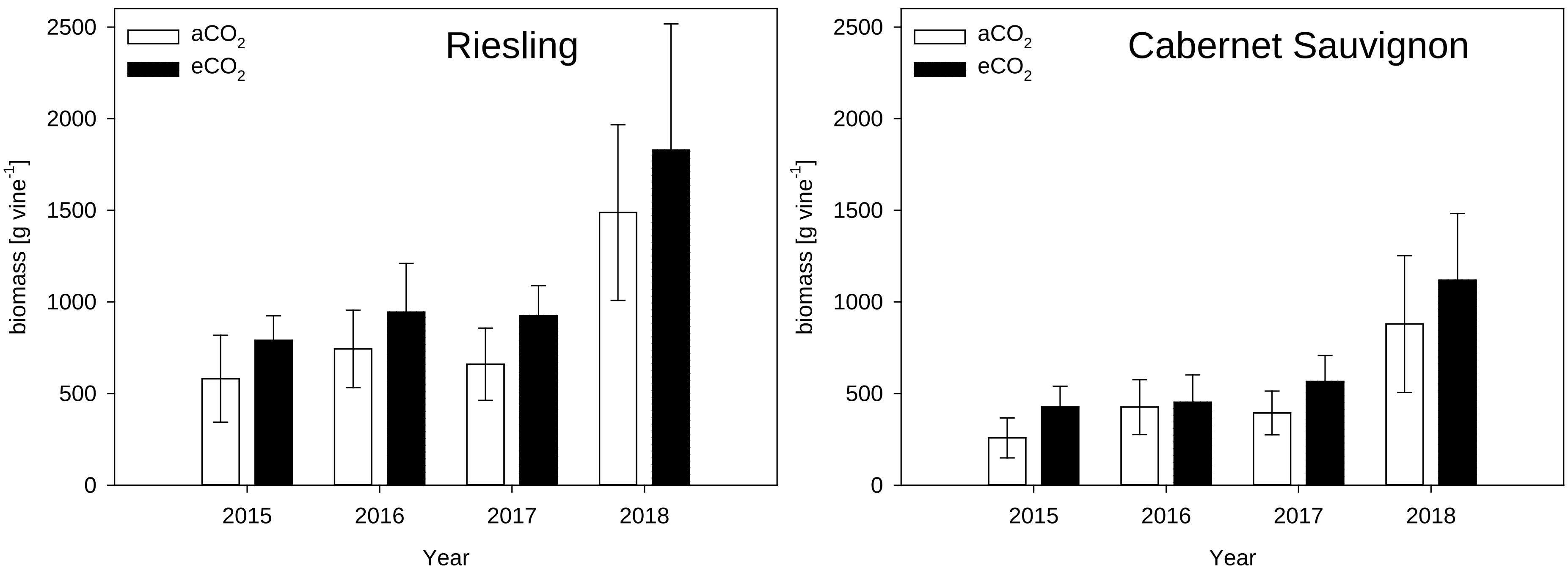


Wohlfahrt et al., unpublished

VineyardFACE
Leaf biomass

- increased leaf biomass under eCO_2
- increased lateral leaf area under eCO_2
- supported by higher photosynthesis rates under eCO_2

→ higher water uptake (transpiration), even though WUE increased under eCO_2

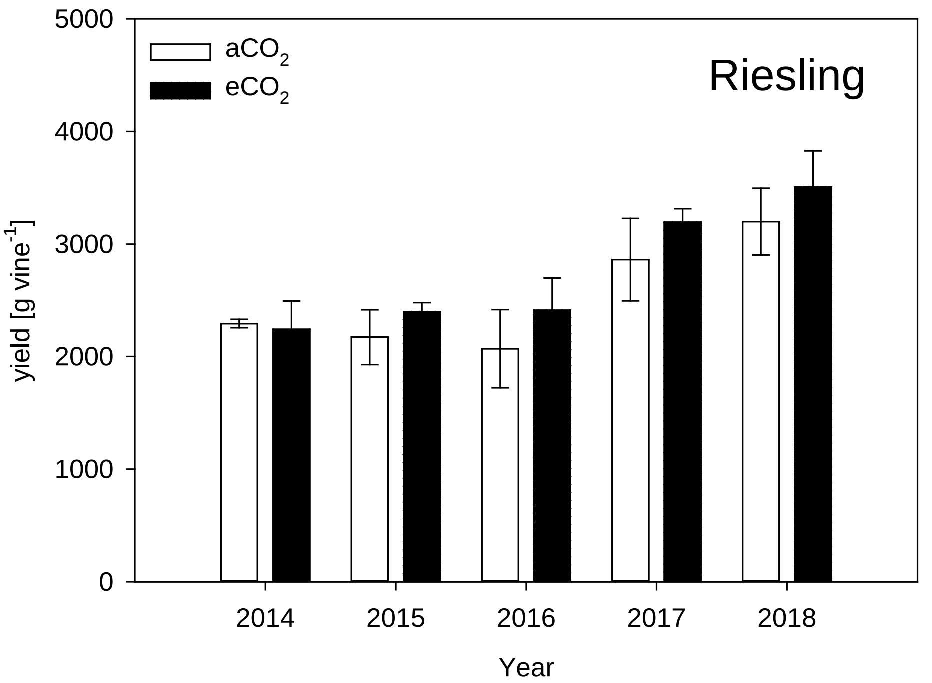


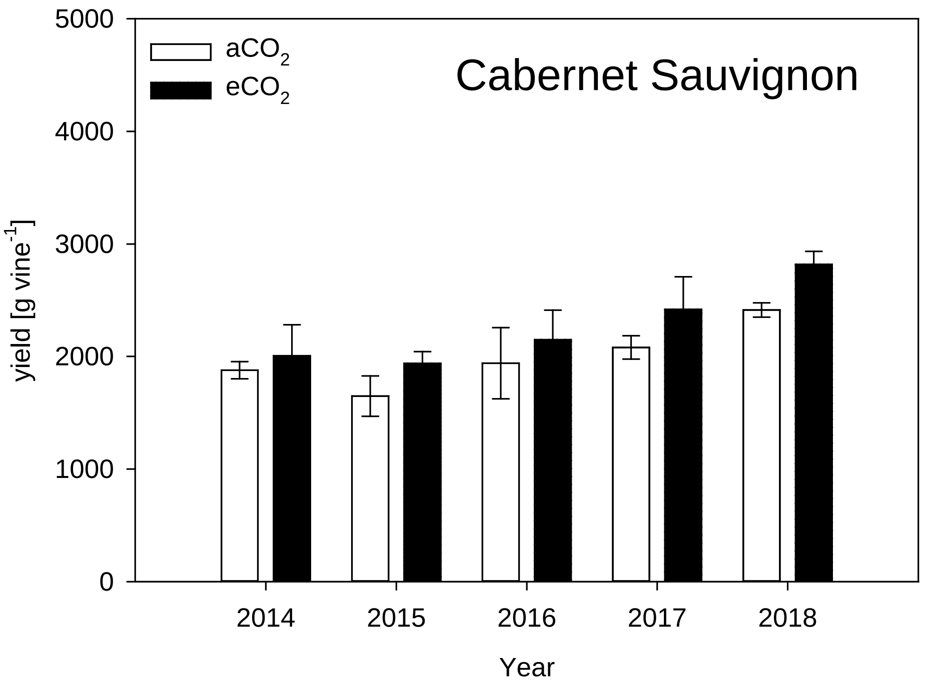
Wohlfahrt et al., unpublished

VineyardFACE
Yield

- bunch number not affected by eCO_2
- yield & bunch weight increased under eCO_2
- 2014 did not differ significantly → fruit set 2013 (no eCO_2)

	Bunch number [bunches vine^{-1}]			
Year	CS aCO_2	CS eCO_2	R aCO_2	R eCO_2
2014	14.3 ± 0.1	13.1 ± 0.9	18.5 ± 0.5	18.2 ± 0.8
2015	14.0 ± 0.2	13.7 ± 0.4	19.4 ± 0.3	19.0 ± 0.2
2016	12.2 ± 0.7	12.4 ± 0.3	17.2 ± 0.5	17.6 ± 0.6





Wohlfahrt et al., unpublished

VineyardFACE
Fruit quality

- no differences in total soluble solids under eCO_2
- higher sugar yield under CO_2 due to higher crop load
- organic acids (malic acid) mostly affected in warmer years under eCO_2

- no differences in must and wine quality

Wohlfahrt et al., 2018

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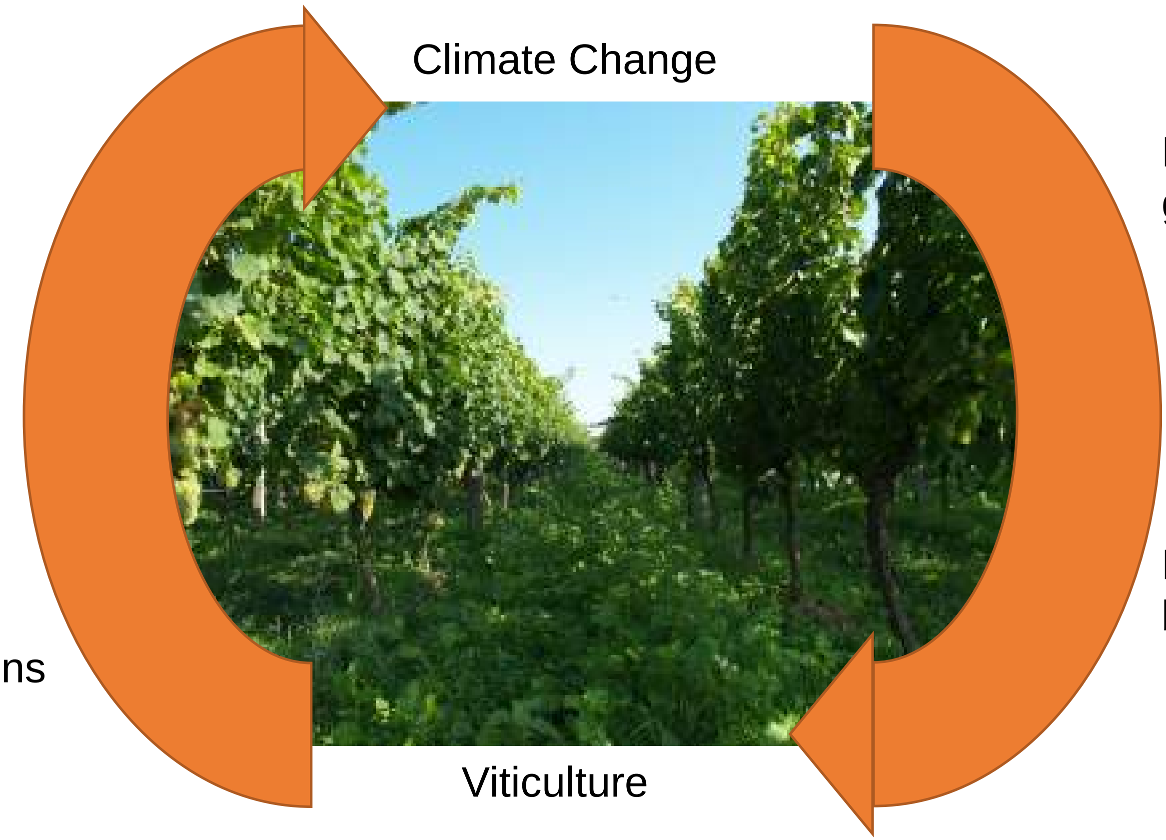
Climate Change ↔ Viticulture

Direct CO_2 emissions

Indirect CO_2 emissions

Soil derived greenhouse gas emissions



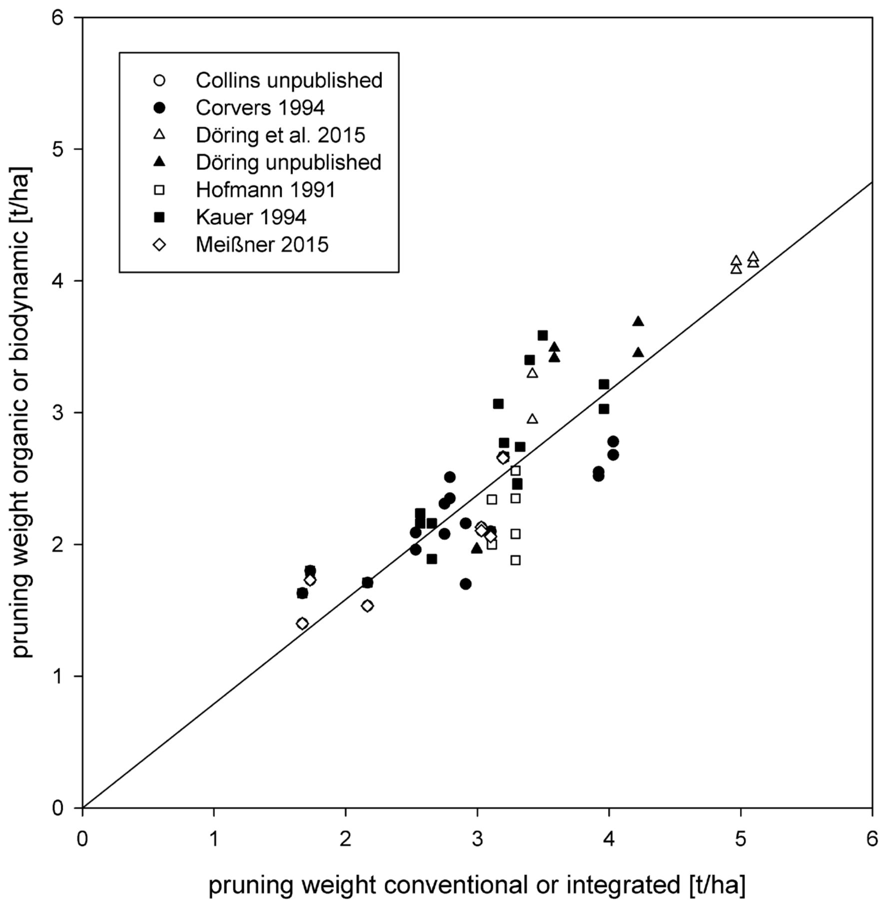
Enhanced growth

Enhanced yields

Enhanced berry weights

Organic Viticulture Affecting Growth

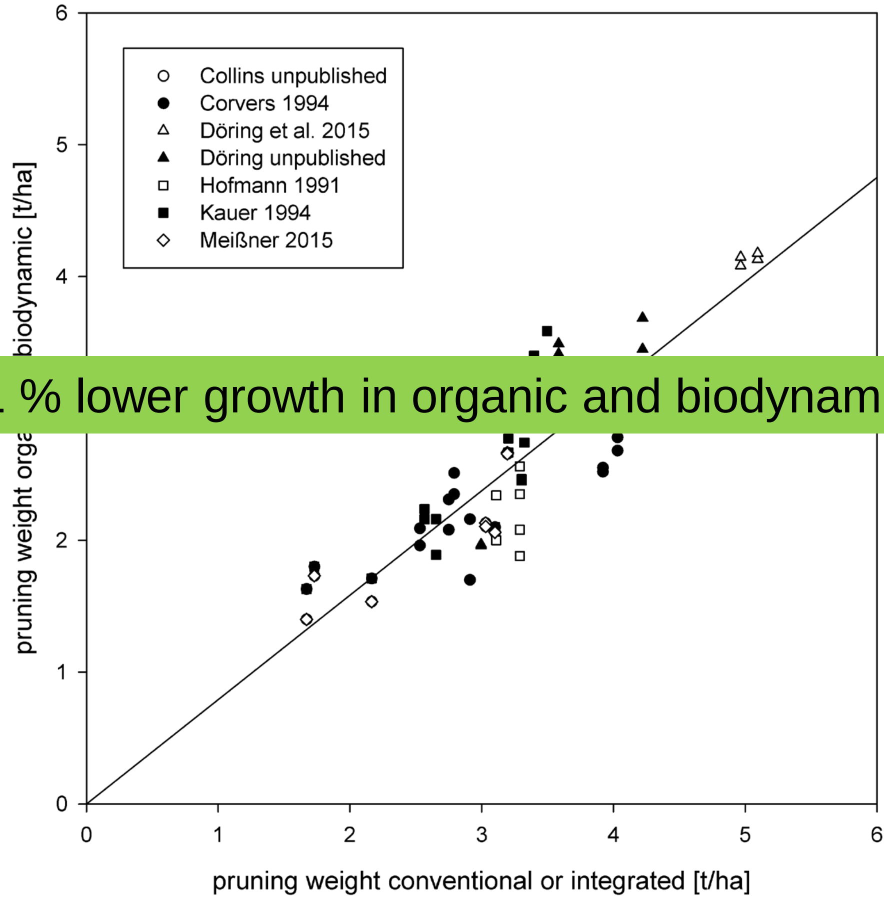
Döring et al. (2019)



- Pruning weights in organic and biodynamic viticulture compared to integrated and conventional viticulture

Organic Viticulture Affecting Growth

Döring et al. (2019)

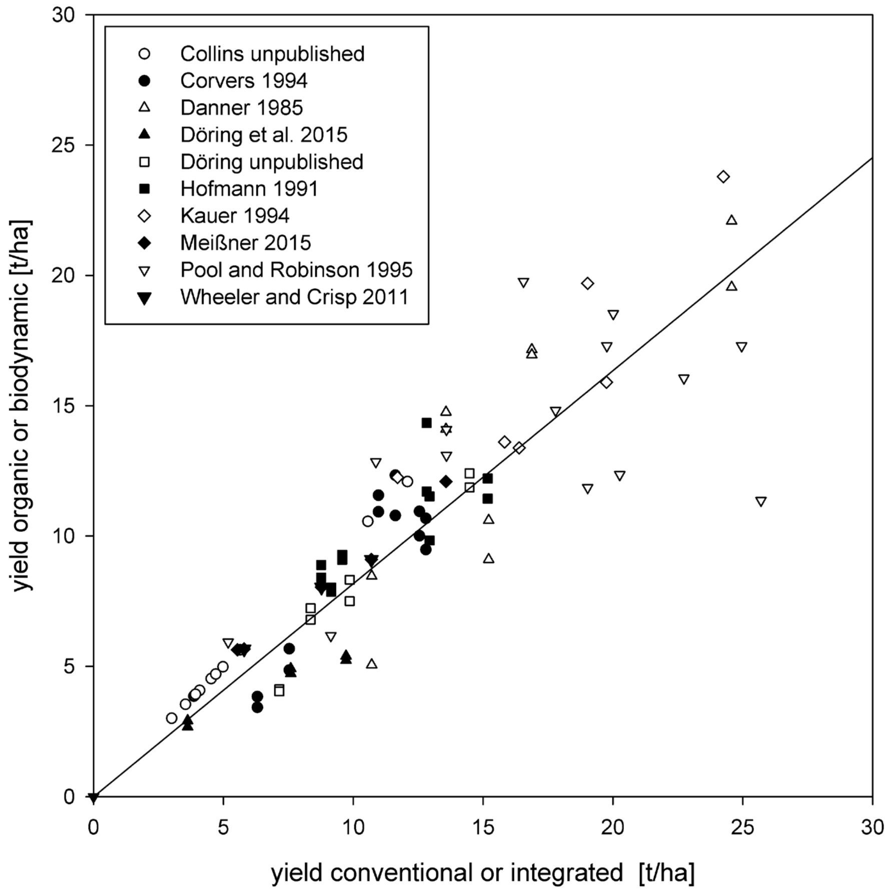


- Pruning weights in organic and biodynamic viticulture compared to integrated and conventional viticulture

21 % lower growth in organic and biodynamic systems across different environments

Organic Viticulture Affecting Yields

Döring et al. (2019)



- Yields in organic and biodynamic viticulture compared to integrated and conventional viticulture

Organic Viticulture Affecting Yields

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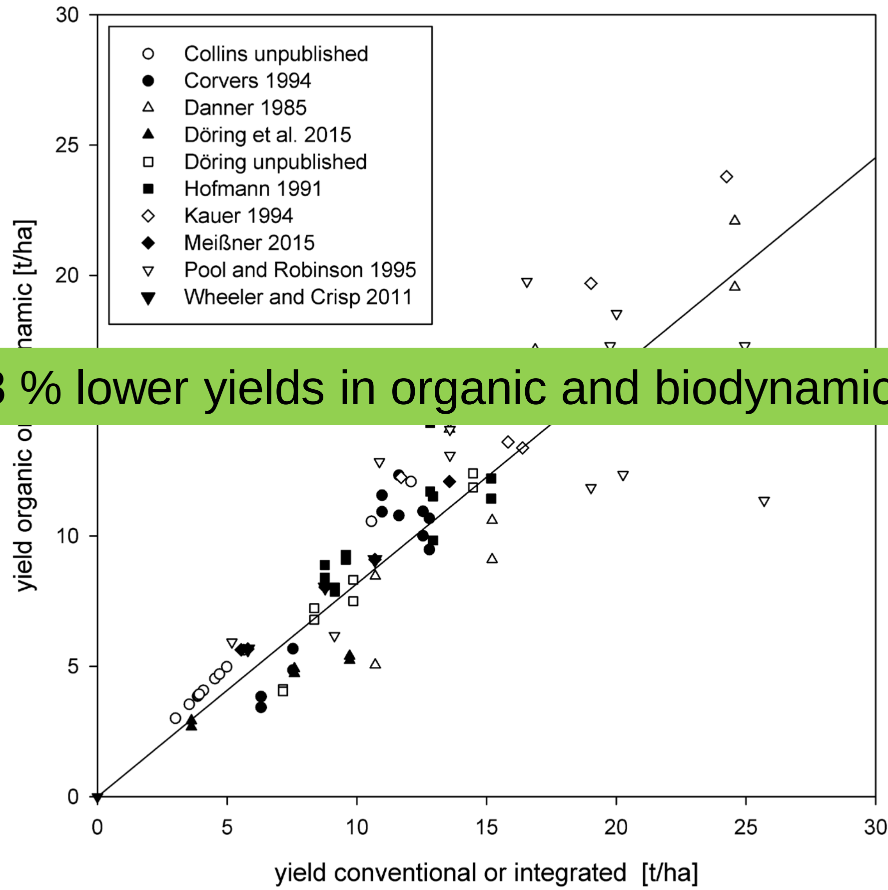
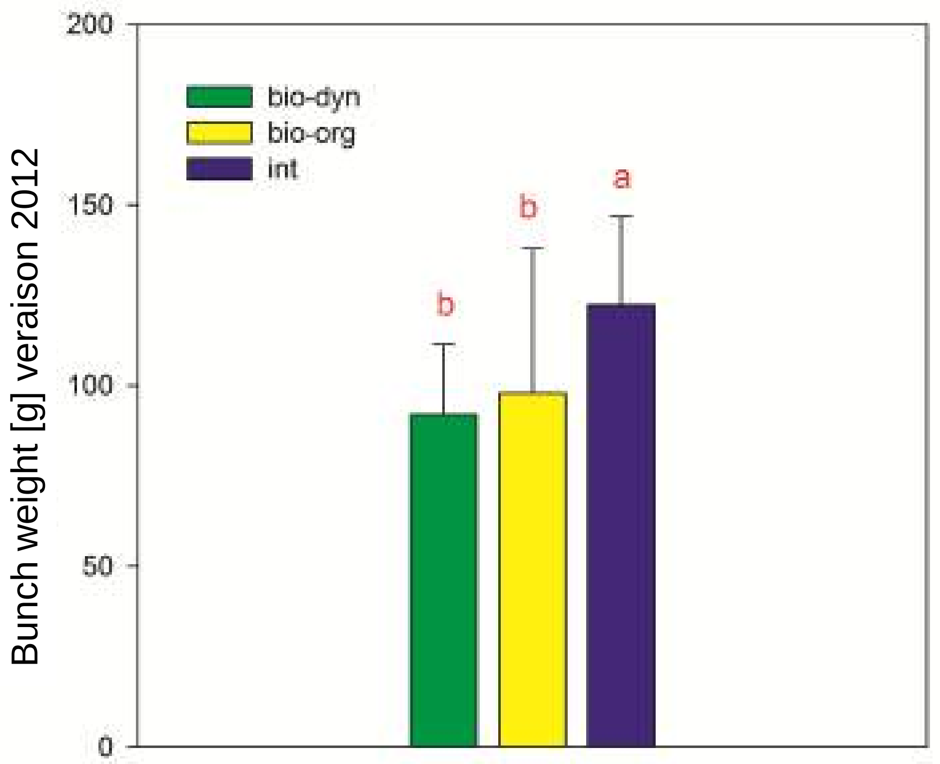


- Yields in organic and biodynamic viticulture compared to integrated and conventional viticulture

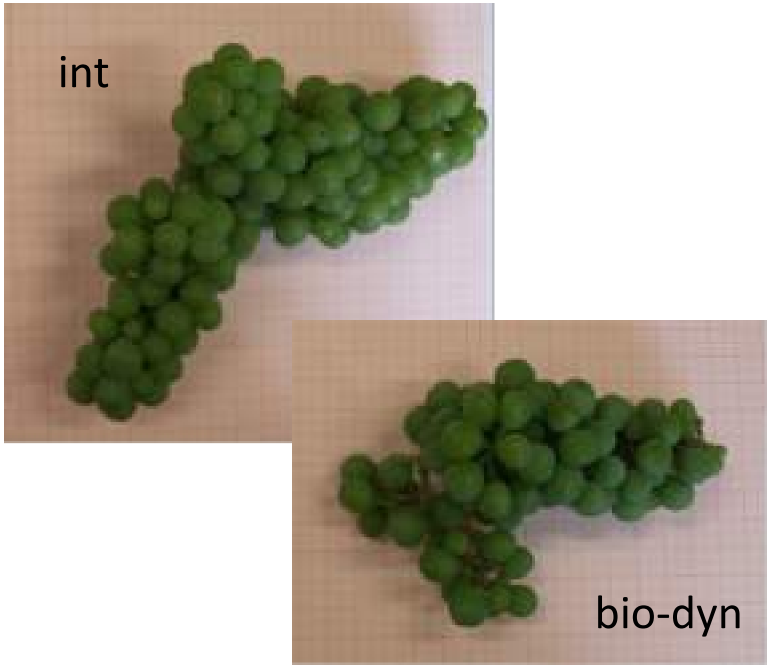
18 % lower yields in organic and biodynamic systems across different environments

Organic Viticulture Affecting Bunch Weights

Döring et al. (2015)

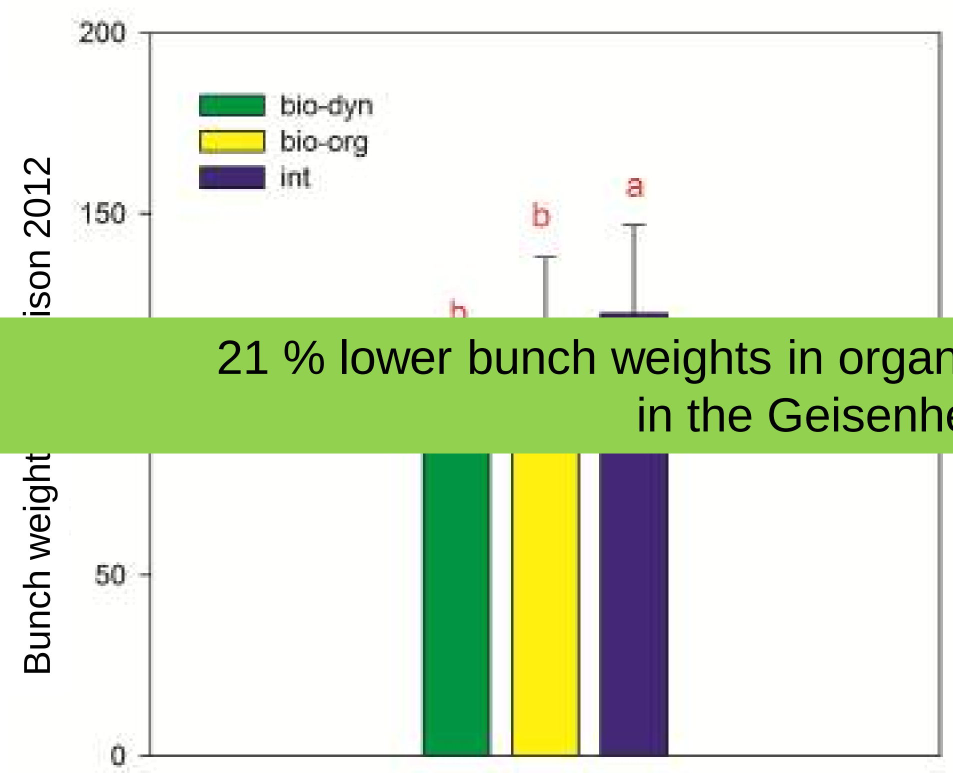


Bunch weight in organic and biodynamic plots is significantly lower compared to integrated viticulture (Geisenheim trial)



Organic Viticulture Affecting Bunch Weights

Döring et al. (2015)



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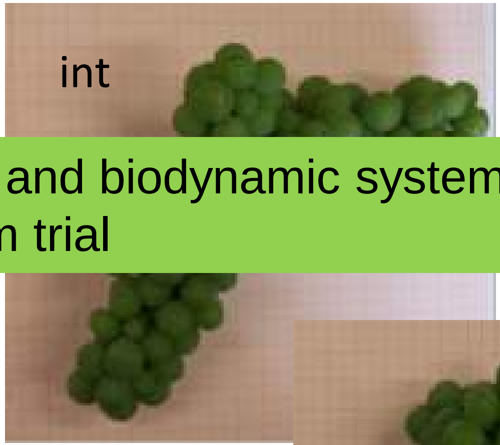
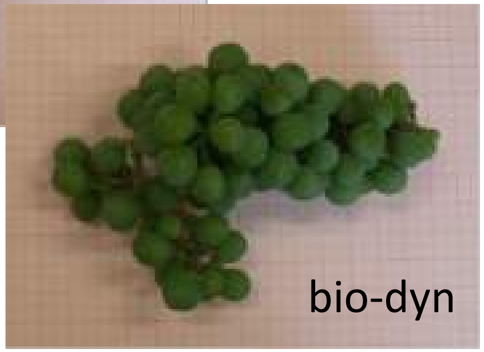
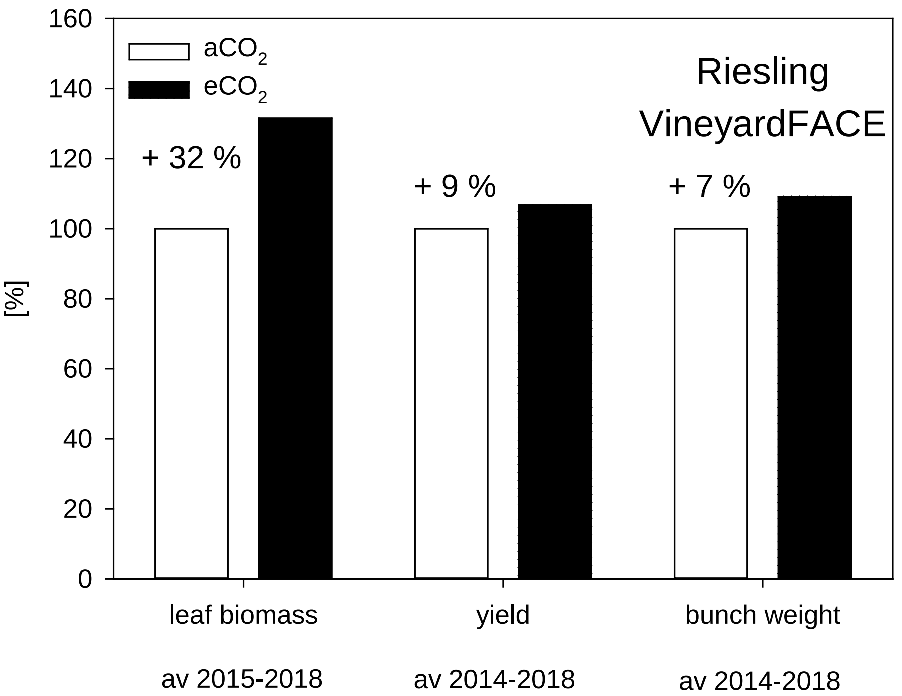
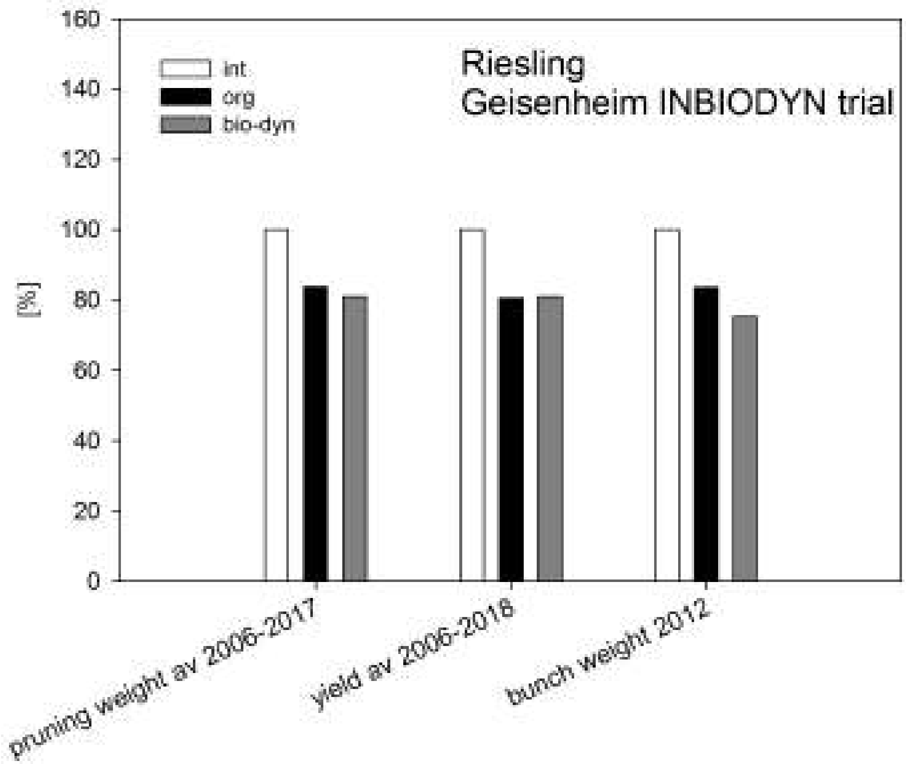




21 % lower bunch weights in organic and biodynamic systems in the Geisenheim trial

Hypothesis: Organic Viticulture Mitigates Effects of Climate Change on Growth, Yield, and Bunch Weight



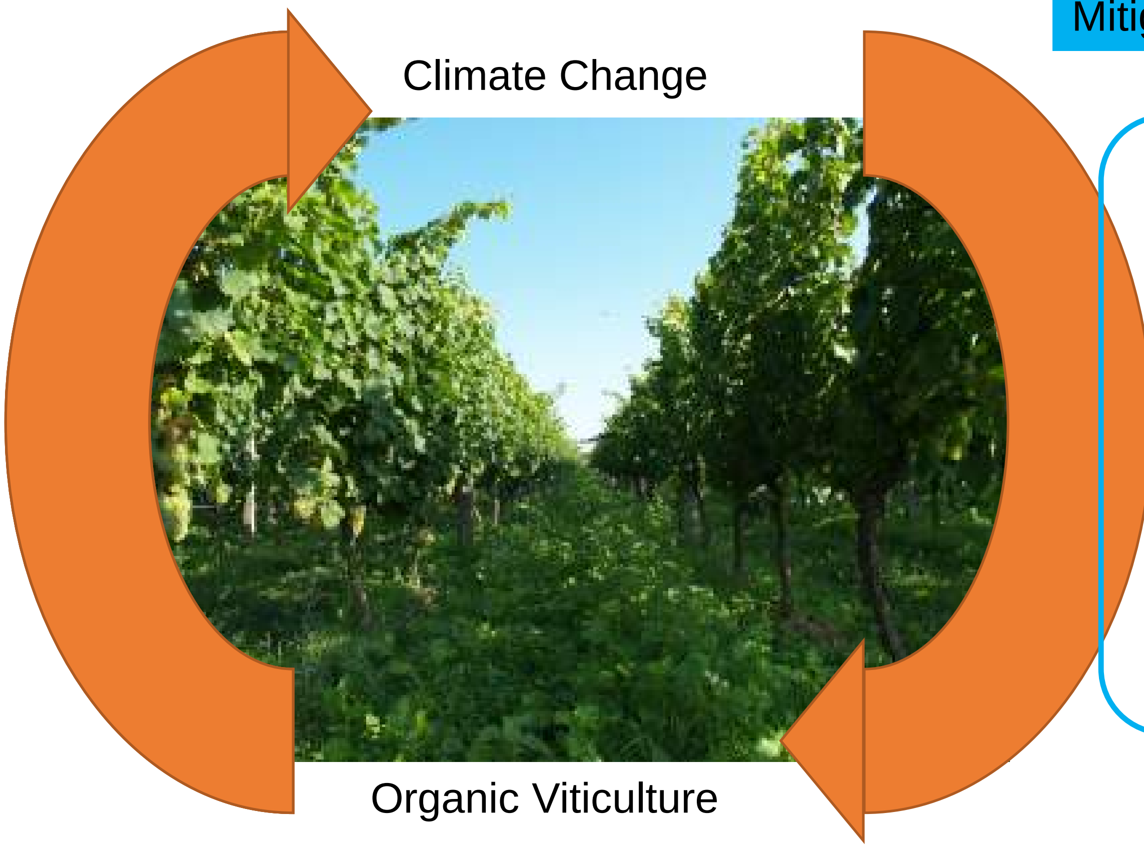


Climate Change ↔ Organic Viticulture

Direct CO_2 emissions

Indirect CO_2 emissions

Soil derived emissions

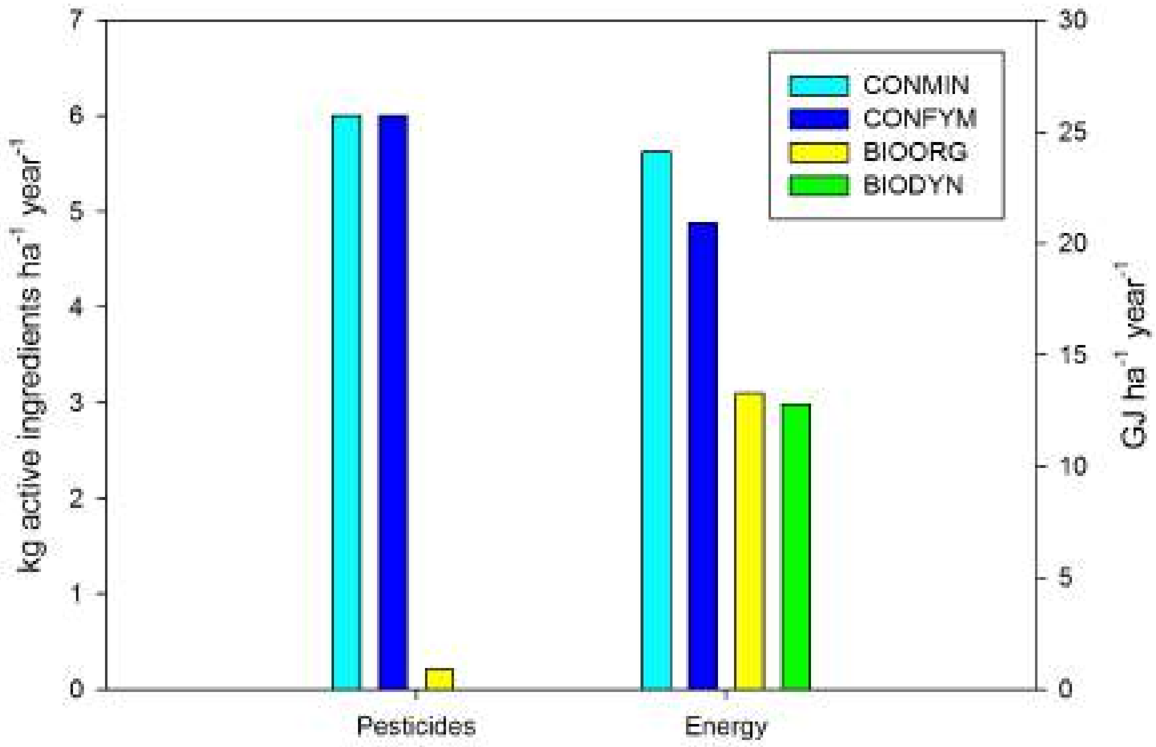


Mitigation of…

- Enhanced growth
- Enhanced yields
- Enhanced berry weights

Agriculture Affecting Climate Change (1)

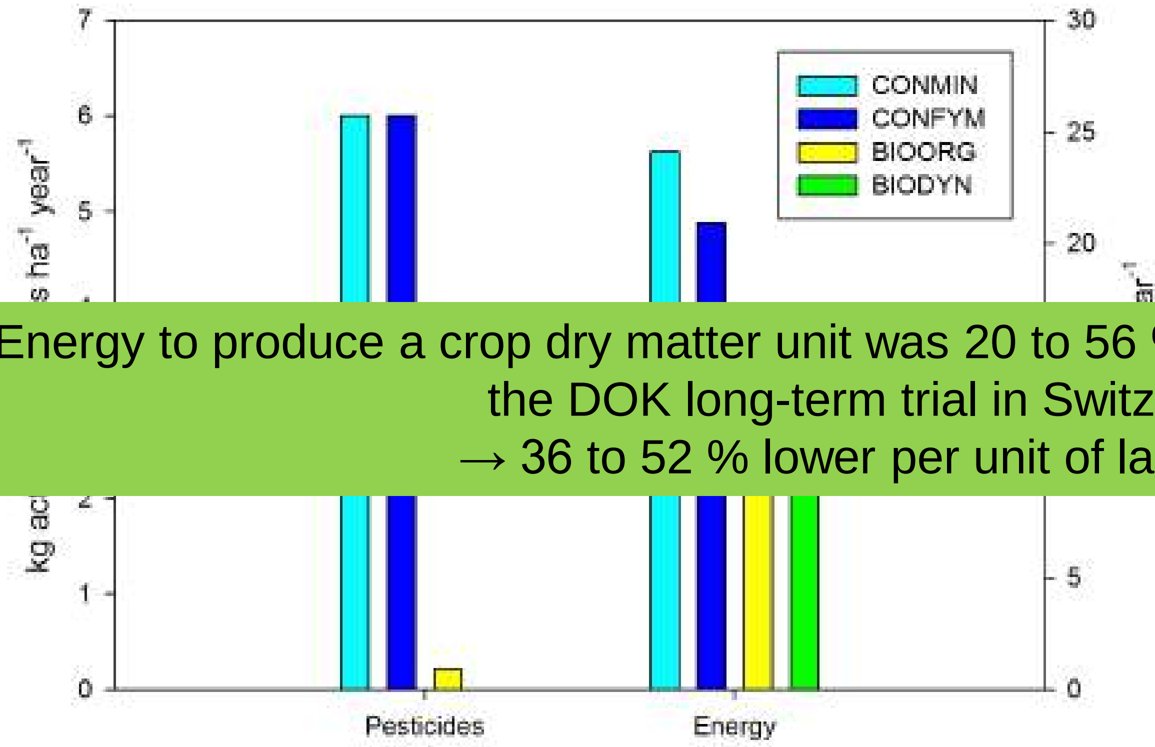
Mäder et al. 2002 – inputs of pesticides and energy



- Amount of pesticides and amount of energy used in the respective systems of the DOK long-term trial 1985-1991 (modified according to Mäder et al. 2002)

Agriculture Affecting Climate Change (1)

Mäder et al. 2002 - inputs of pesticides and energy

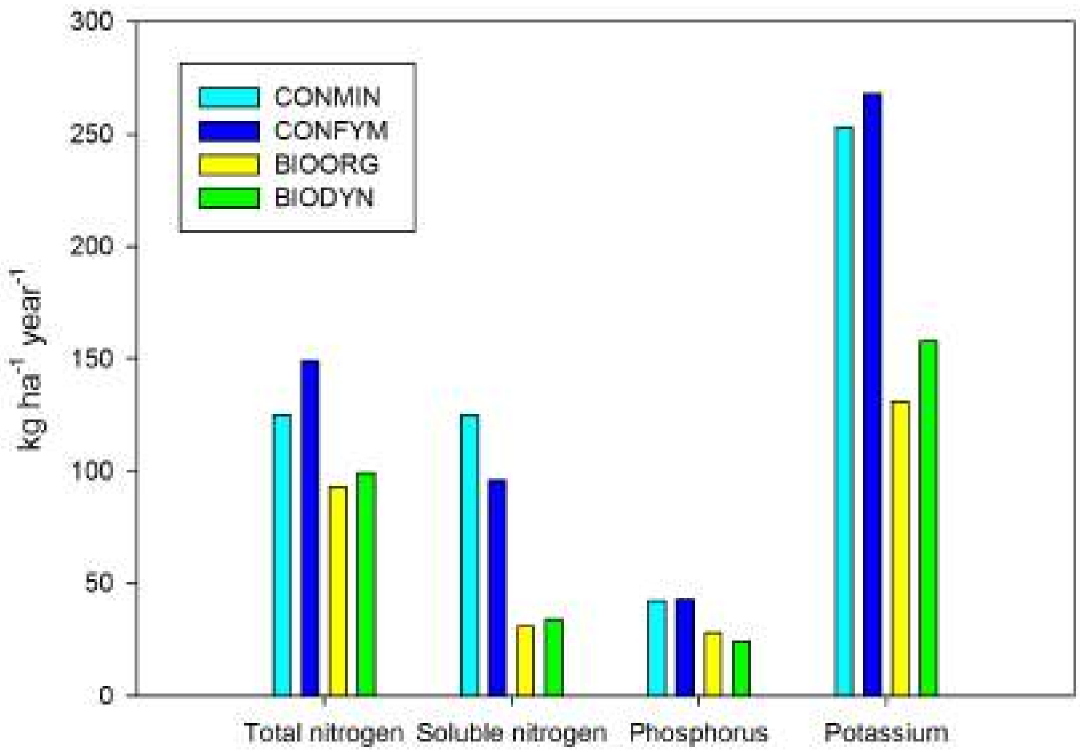


- Amount of pesticides and amount of energy used in the respective systems of the DOK long-

Energy to produce a crop dry matter unit was 20 to 56 % lower in organic systems in the DOK long-term trial in Switzerland
→ 36 to 52 % lower per unit of land area

Agriculture Affecting Climate Change (2)

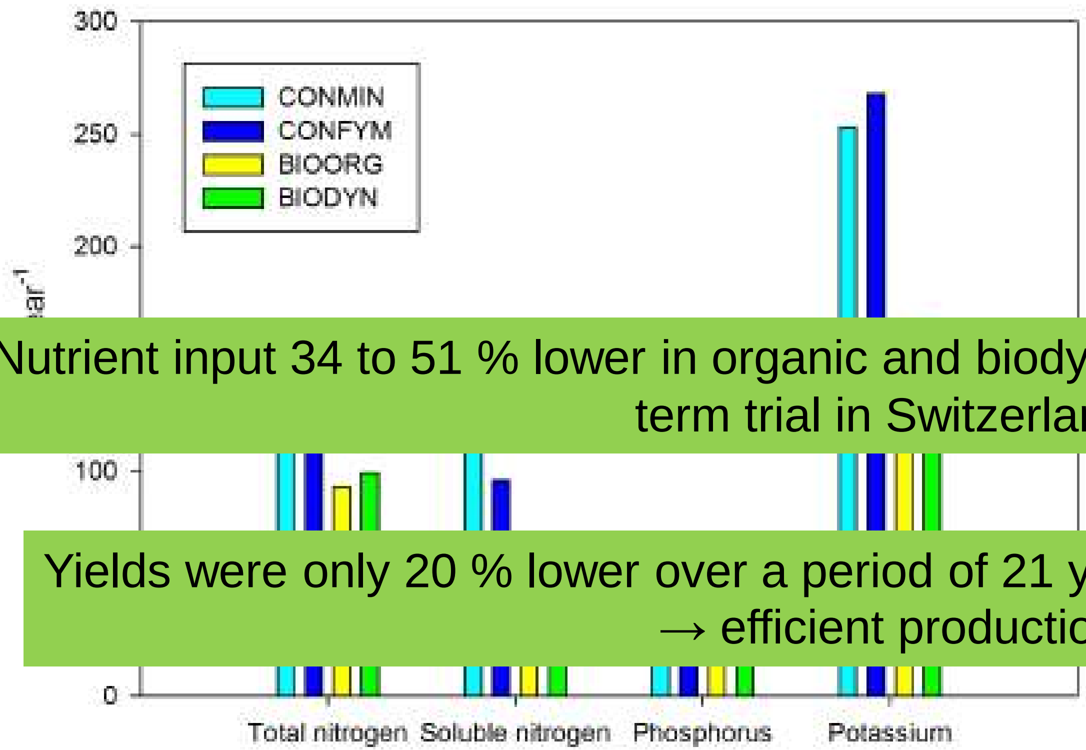
Mäder et al. 2002 – nutrient inputs



- Inputs of N, P, K used in the respective systems in the DOK long-term trial (modified according to Mäder et al. 2002)

Agriculture Affecting Climate Change (2)

Mäder et al. 2002 – nutrient inputs



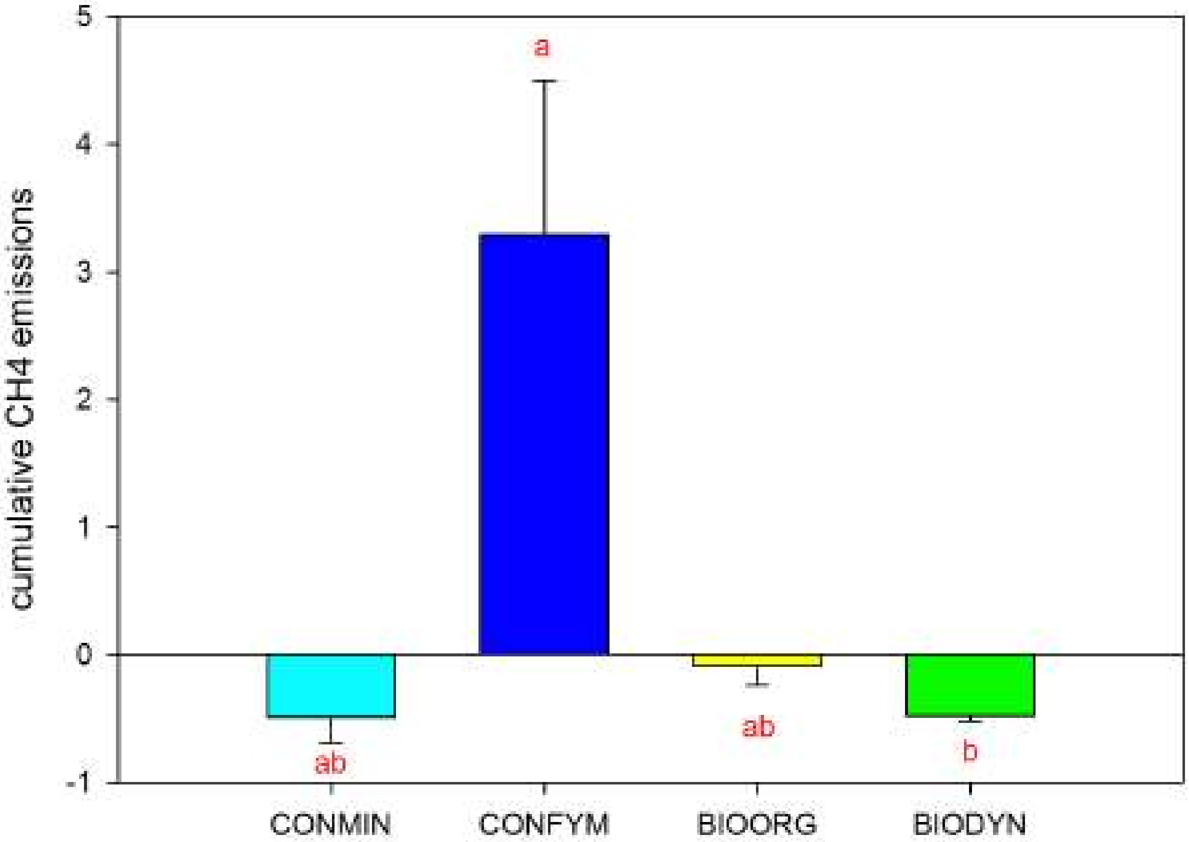
- Inputs of N, P, K used in the respective systems in the DOK long-term trial (modified

Nutrient input 34 to 51 % lower in organic and biodynamic systems in the DOK long-term trial in Switzerland

Yields were only 20 % lower over a period of 21 years (different crop rotations) → efficient production

Agriculture Affecting Climate Change (3)

Skinner et al. 2019 – soil derived greenhouse gas emissions



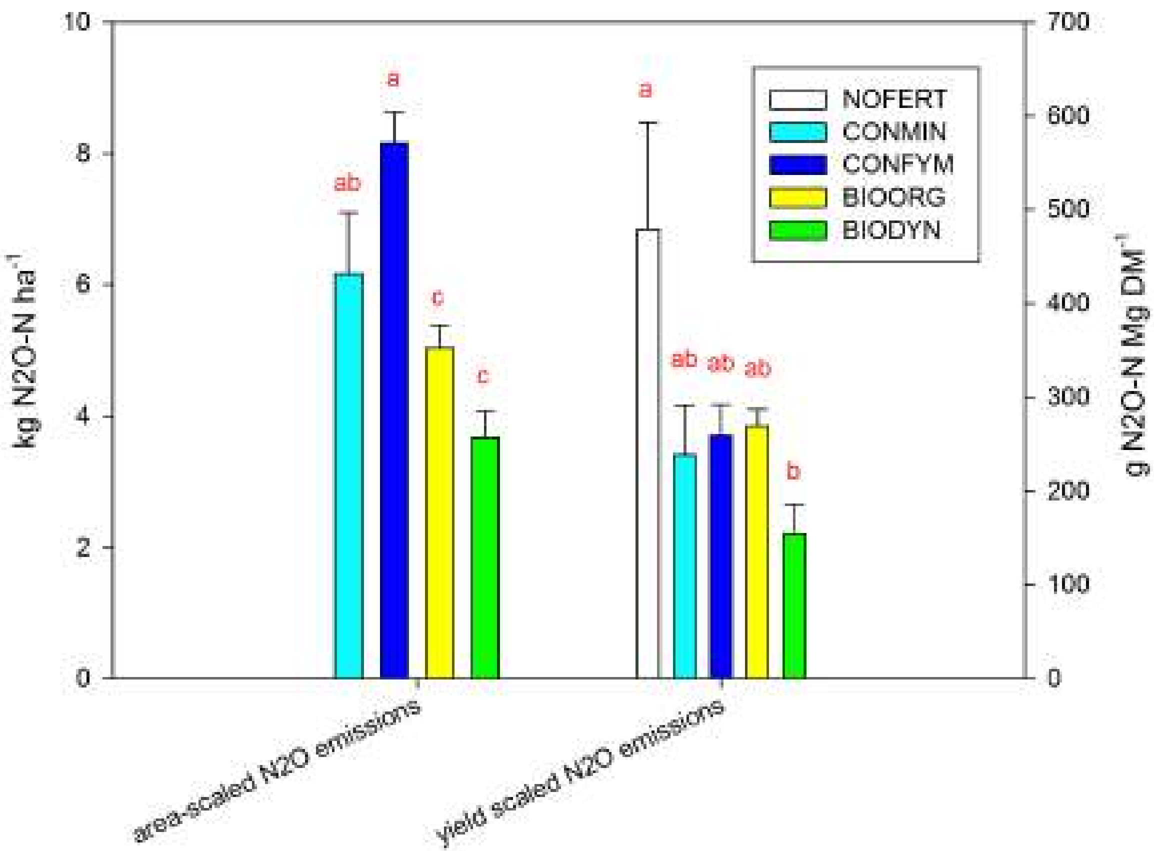
- Annual data of CH_4: grass clover, silage maize, green manure

↑ **CH4:**

- Solid manure application and ploughing + fertilization of maize (CONFYM)

Agriculture Affecting Climate Change (4)

Skinner et al. 2019 – soil derived greenhouse gas emissions



Annual data of N_2O-N: Grass-clover, silage maize, green manure

↑ **N_2O :**

- Solid manure application + ploughing (CONFYM)
- Mineral fertilization + sowing (CONMIN)
- Fertilization of silage maize (all systems)
- Dependent on soil moisture + Nmin

Hypothesis: Organic Viticulture Mitigates Climate Change

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- Organic viticulture is expected to reduce inputs due to denial of herbicides, mineral fertilizers, and synthetic spray agents (low input system; Mäder et al. 2002)
  - It exclusively relies on products of natural origin

- Organic viticulture is expected to use slightly higher amounts of fuel compared to conventional/ integrated systems

- Organic viticulture is expected to reduce gas emissions from the soil
  - No mineral N fertilizers: ↓ N_2O emissions (Skinner et al. 2019)
  - Cover crop with legumes: ↑ N_2O emissions (Muhammad et al. 2019)
  - Higher microbial activity: ↑ CO_2 emissions (Muhammad et al. 2019)
  - Higher carbon sequestration, higher SOC: ↓ CO_2 emissions (Longbottom, Petrie 2015)
  - ↓ NO emissions (preliminary results Hieber 2011)
  - NH_3, CH_4, NO_x emissions? Herbicide application under-vine area?

Climate Change ↔ Organic Viticulture

Reduction of…

Direct CO_2 emissions

Indirect CO_2 emissions

Soil derived emissions

Climate Change

Organic Viticulture

Mitigation of…

Enhanced growth

Enhanced yields

Enhanced berry weights

Literature cited

- Wohlfahrt Y., Tittmann S., Schmidt D., Rauhut D., Honermeier B., Stoll M. The effect of elevated CO_2 on berry development and bunch structure of *Vitis vinifera* L. cvs. Riesling and Cabernet Sauvignon. Appl. Sci. 2020, 10, 2486.
- Döring J, Collins C, Frisch M, Kauer R. Organic and Biodynamic Viticulture Affect Biodiversity and Properties of Vine and Wine: A Systematic Quantitative Review. Am. J. Enol. Vitic. 2019; 70(3): 221-242.
- Skinner C, Gattinger A, Krauss M, Krause H-M, Mayer J, van der Heijden MGA, Mäder P. The impact of long-term organic farming on soil-derived greenhouse gas emissions. Scientific Reports 2019; 9:1702. https://doi.org/10.1038/s41598-018-38207-w
- Wohlfahrt, Y., Collins, C., & Stoll, M. (2019). Grapevine bud fertility under conditions of elevated carbon dioxide. OENO One, 53(2).
- Wohlfahrt Y., Smith J.P., Tittmann S., Honermeier B, Stoll M. (2018). Primary productivity and physiological responses of *Vitis vinifera* L. cvs. under Free Air Carbon dioxide Enrichment (FACE). European Journal of Agronomy, 101, 149-162.
- Döring J, Frisch M, Tittmann S, Stoll M, Kauer R. Growth, Yield and Fruit Quality of Grapevines under Organic and Biodynamic Management. PLoS One 2015. https://doi.org/10.1371/journal.pone.0138445
- Mäder P, Fließbach A, Dubois D, Gunst L, Fried P, Niggli U. Soil fertility and biodiversity in organic farming. Science 2002; 296: 1694-1697.