Organic carbon sequestration potential, rate and associated practices, as observed in Swiss arable land

Pascal Boivin, Xavier Dupla, Ophélie Sauzet, and Karine Gondret

University of Applied Sciences and Arts Western Switzerland
mailto: *pascal.boivin@hesge.ch*

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Content *(you can click on the text to move to…)*

Introduction

- While great expectations are placed on carbon sequestration in soils[1,2] to support climate change, a highly confusing and contradictory message on its feasibility can be found in literature. Most of this research, however, was not performed in farm fields.
- Restoring Soil Organic Carbon (SOC) or Organic Matter(OM) content is not only a matter of climate mitigation. Cultivated soils are sharply depleted in OM, which is the main factor of topsoil quality.
- **What is the current situation with respect to SOC sequestration / emission in arable land?**
- **What are the corresponding practices?**
- This study proposes some answers from large scale field observation and farmers interviews in western Switzerland.

1. https://www.4p1000.org/,
2. https://easac.eu/fileadmin/PDF_s/reports_statements/Negative_Carbon/EASAC_Report_on_Negative_Emission_Technologies.pdf

Data sets

- Since 1993, Swiss farmers must analyse each field at least every ten years to receive the environmental subsides. OM content of the 0-20 cm layer is one of these mandatory analyses.
- In this study we used the results of these analyses from cantons of Vaud (Vd) and Geneva (Ge) (> 50'000 analyses in total), for about 65'000 ha of arable land (annual crops).
- Analyses were selected according to different criteria, e.g. performed in a certified laboratory with Black&Wakley method, field limits unchanged with time etc. (> 8'000 analyses)
- The change of OM with time was calculated on ≈ 3'000 fields (2200 in Vd and 800 in Ge)

Data quality

- Composite sampling was performed by farmers according to official guidelines. An optimized protocol was determined[1]
- We sampled fields in parallel to farmers and made inquiries on the sampling protocols applied.
- Field SOC minimum detectable change was estimated to 0.1% g g-1 of soil.
  - Submitted to Frontiers in Env. Sci.
- For SOC change rate with time, we used successive analyses of the same fields after checking on aerial photographs that the field limits remained unchanged.

1. https://www.youtube.com/watch?v=QtbBNbSMSuA

Sequestration potential

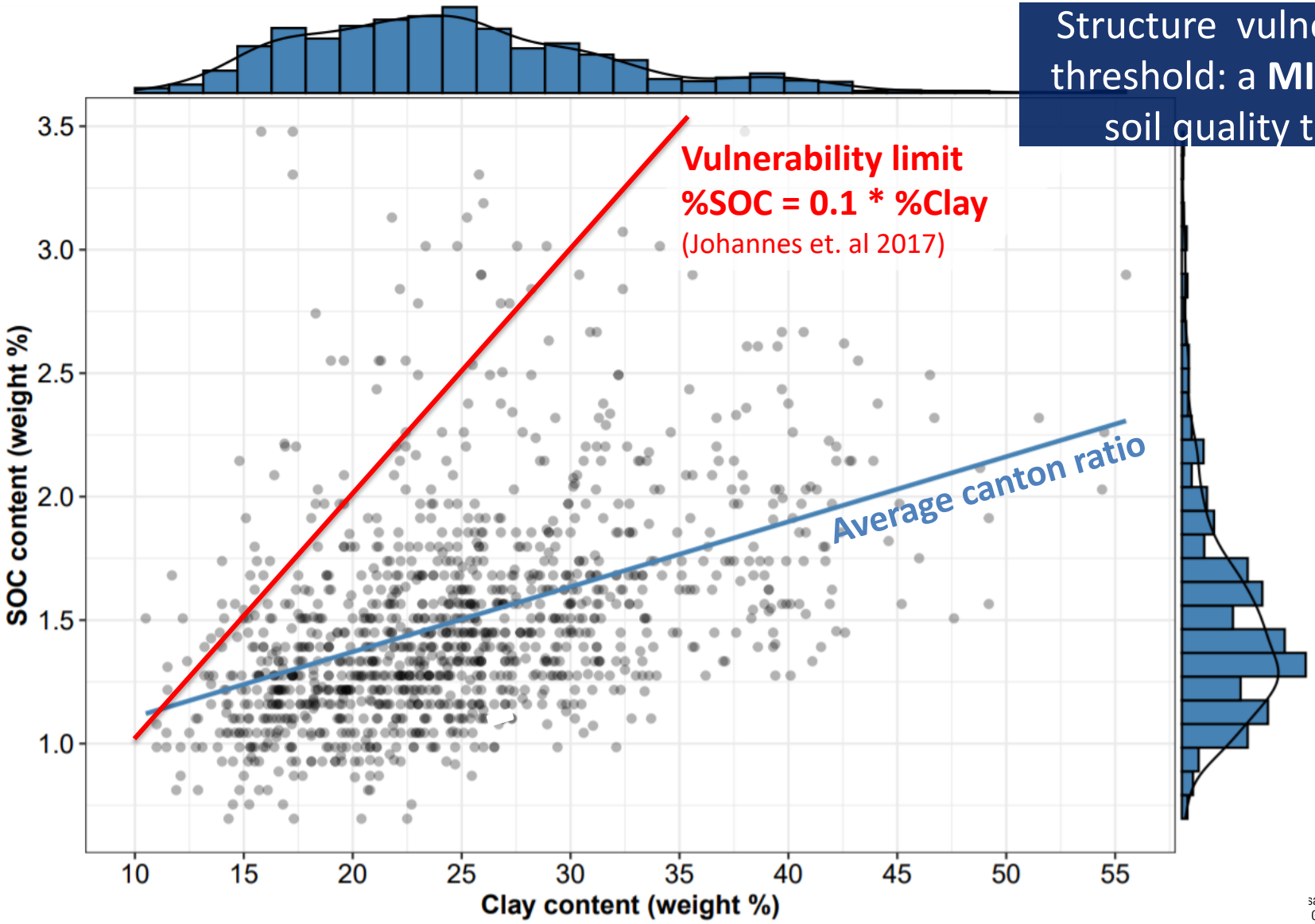
- Johannes et al. (2017)[1] have shown that the minimum SOC content for acceptable soil structure vulnerability was 10% of clay content.
- We used the difference between the observed SOC and this ratio to calculate the SOC deficit – thus representing a minimum SOC increase required for soil quality, and considered it as the sequestration potential. (next slides)
- We converted this deficit into C stocks using soil bulk density calculated from a PTF established from the regional soil database and taking into account SOC.

1. Johannes, A., Matter, A., Schulin, R., Weisskopf, P., Baveye, P. C., and Boivin, P. (2017). *Geoderma* 302, 14–21. doi:10.1016/j.geoderma.2017.04.021.

SOC:Clay ratio #1 - Geneva

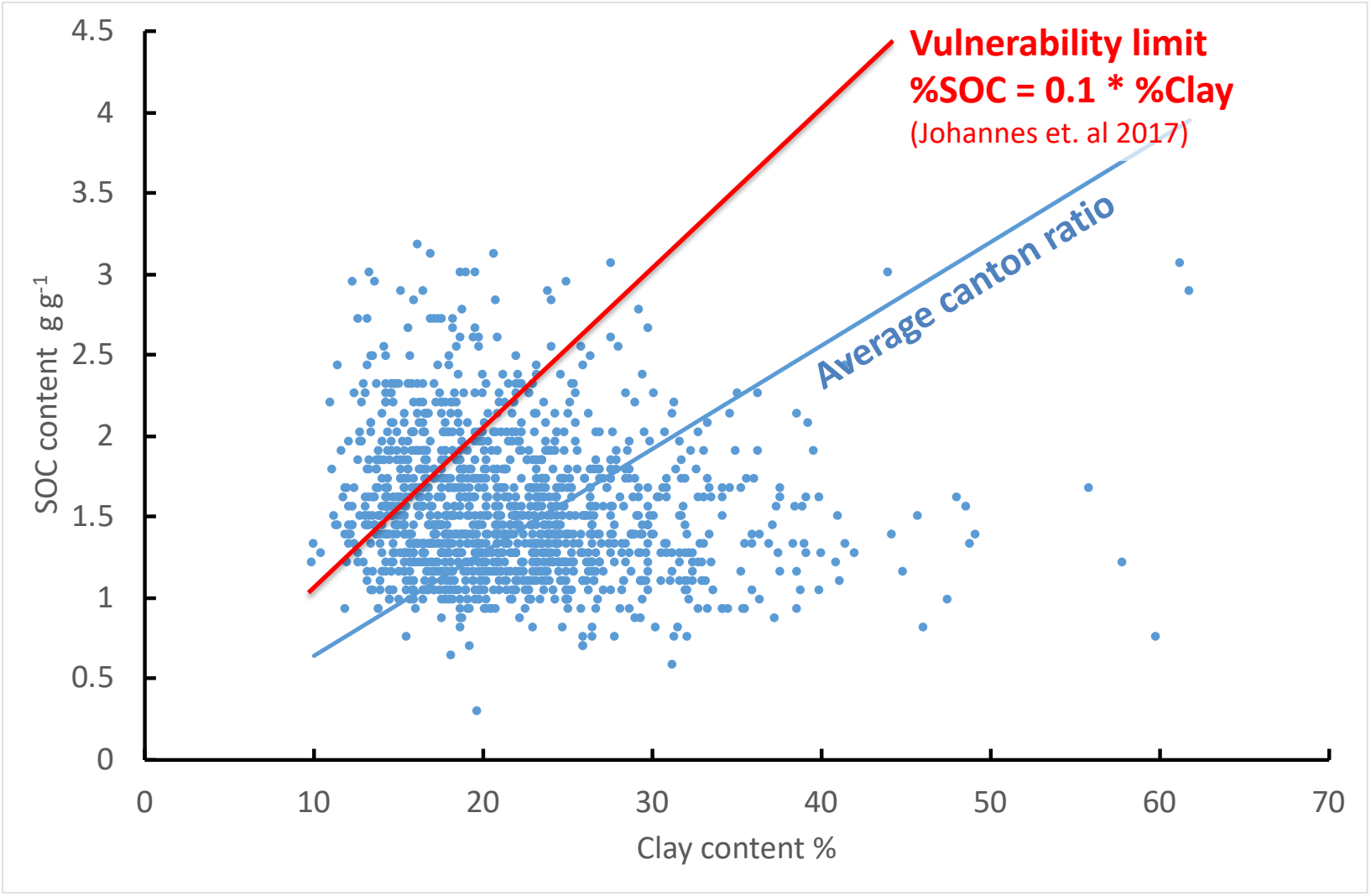
Arable land – main crops

Structure vulnerability threshold: a **MINIMUM** soil quality target



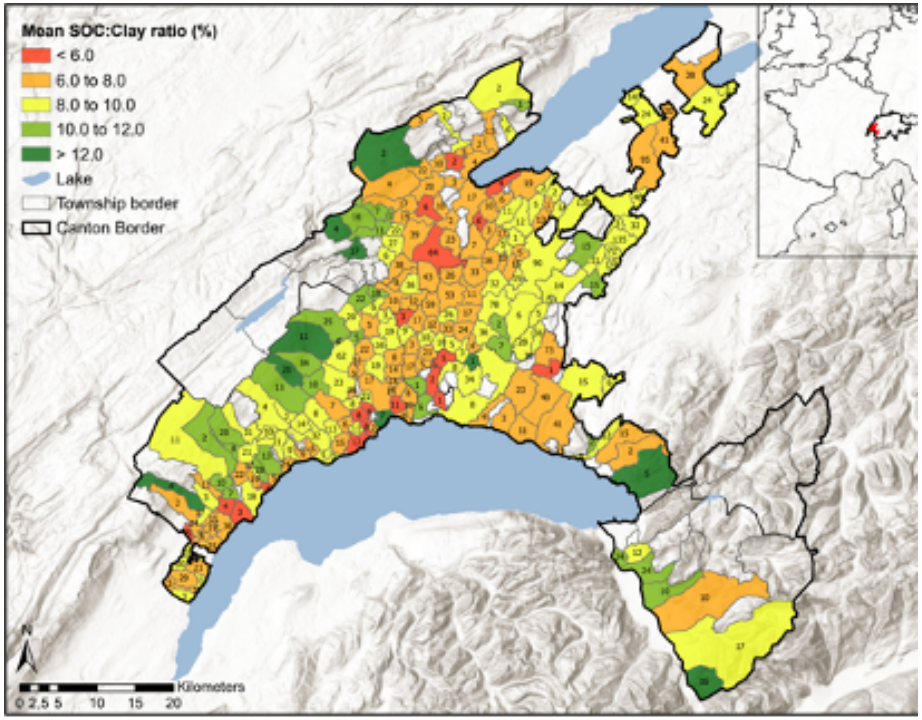
SOC:Clay ratio #2 - Vaud

Arable land – main crops



Sequestration potential

- Average SOC:Clay ratio ranged from 6% (Geneva) to 8% (Vaud) (Jura: 7%).
- With respect to the 10% minimum value this yielded *minimum estimated deficits*:
  - 700’000 t CO2 (Geneva) on 7’000 ha
  - 2’000’000 t CO2 (Vaud) on 53’000 ha
- These values were adopted as minimum objectives for the climate plans

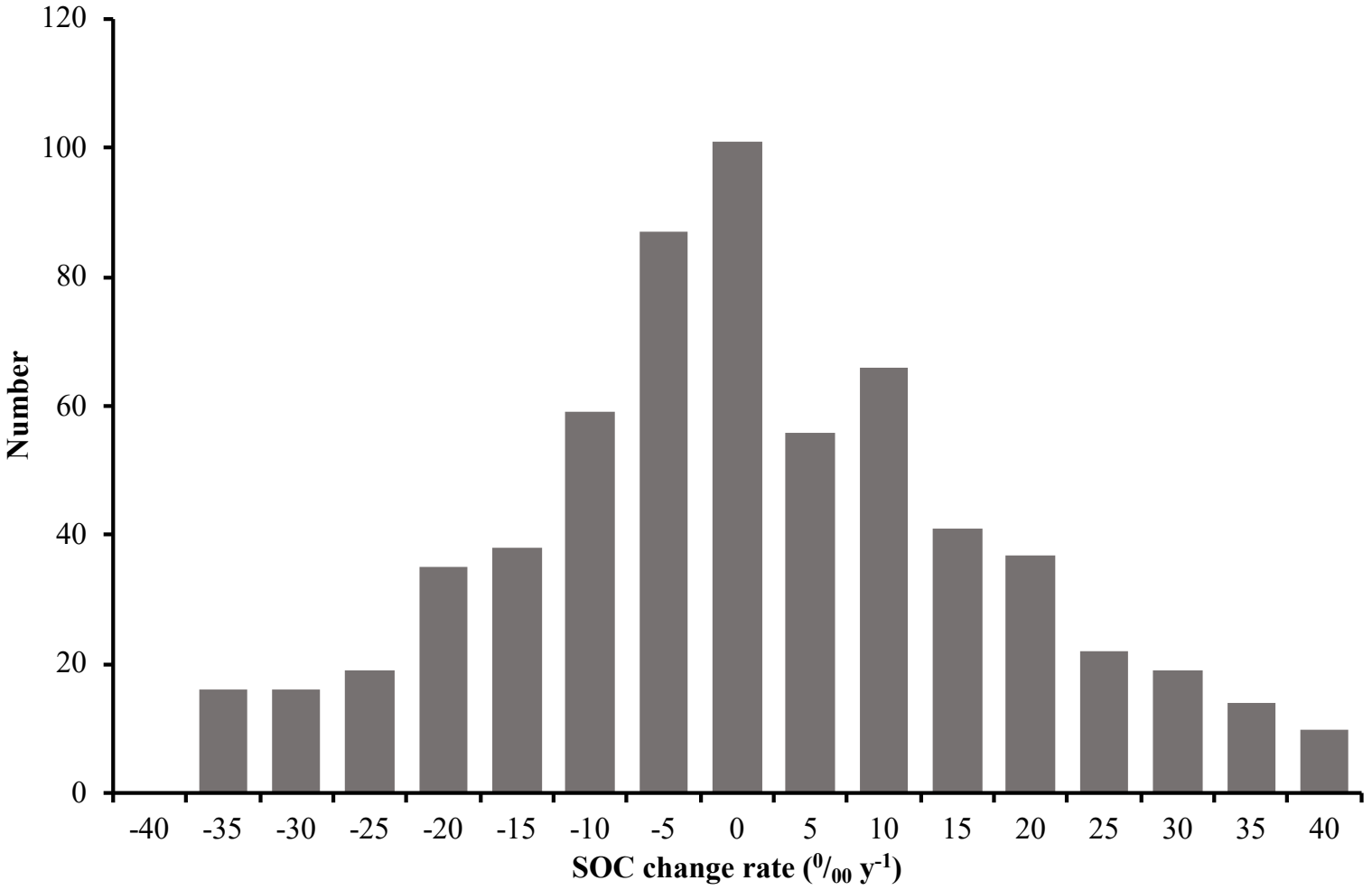


Annual SOC change rates

- Observed annual SOC change rates ranged from -50 ‰ + 50 ‰ in both cantons
  - See following slides
- The average annual change rate increased linearly from -4 ‰ to 9 ‰ from 1995 to 2019 in both cantons
  - See following slides
- This was broadly connected to:
  - Since 1998, cover crops and rotations of min 4 crops are mandatory
  - 2008 – now: fostering of reduced tillage and conservation agriculture practices

Annual SOC change rates

Geneva – 800 fields

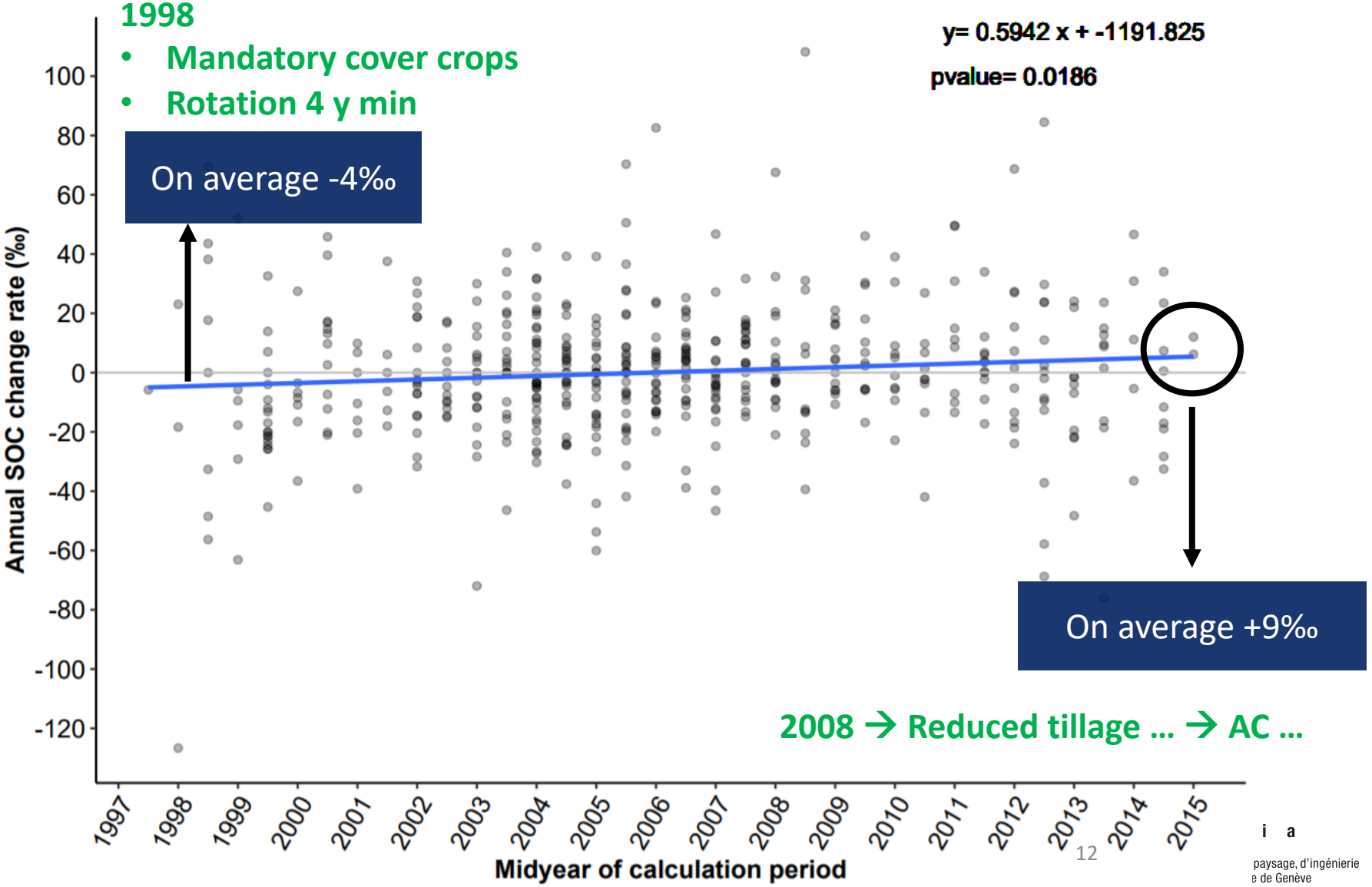


Annual SOC change rates time trend

Geneva – 800 fields

1998

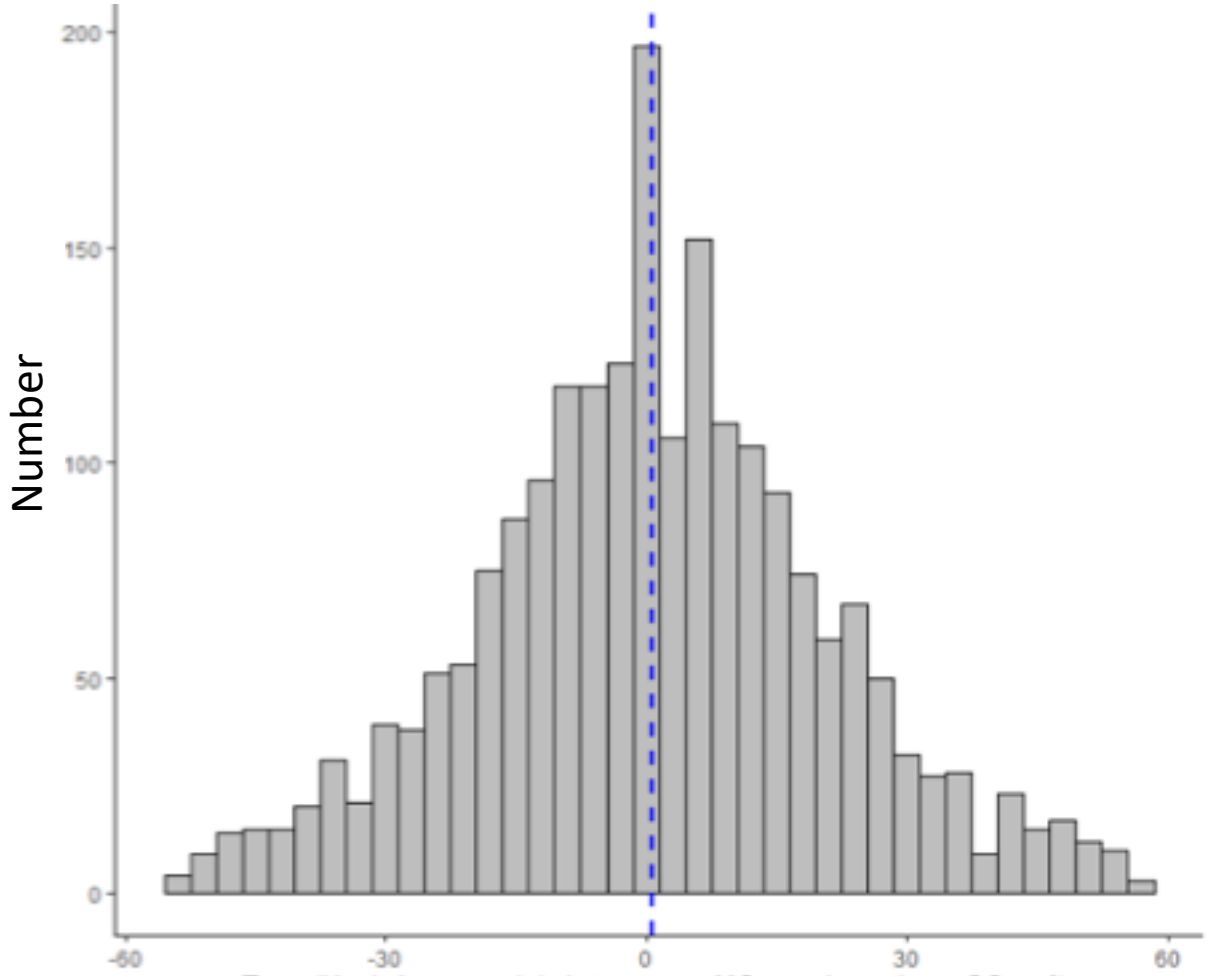
- **Mandatory cover crops**
- **Rotation 4 y min**



2008 → Reduced tillage … → AC …

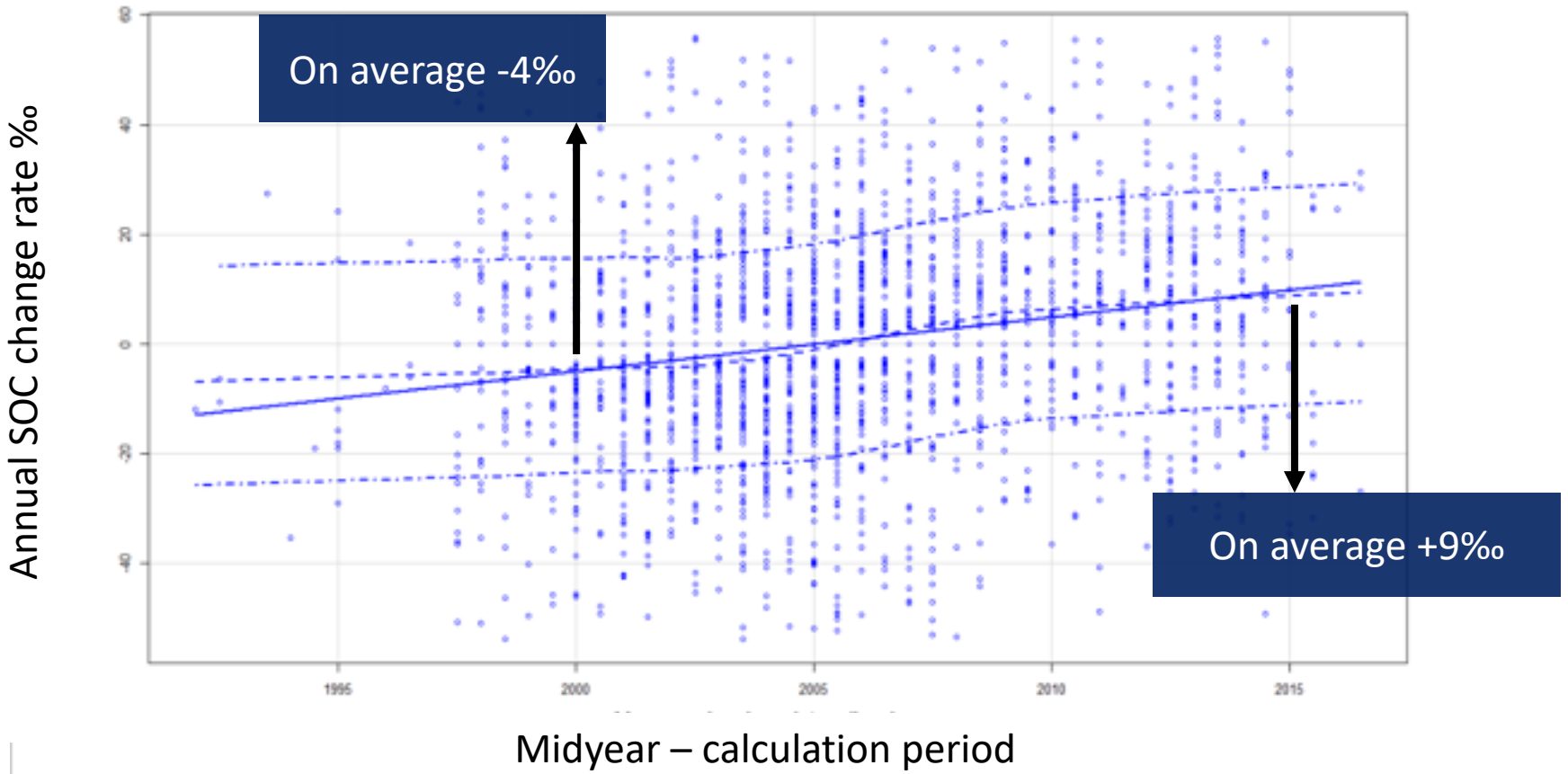
Annual SOC change rates

Vaud – 2200 fields



Annual SOC change rates time trend

Vaud –2200 fields



Associated practices

- 120 farmers were interviewed.
- Their past-ten years practices were compared to the SOC change rate of their soils (focus on 1-2 fields per farm).
- Practices were evaluated following 3 major pillars:
  - Mechanical impact (STIR index)
  - Vegetal intensity (biomass + soil cover + plant diversity)
  - Organic amendments intensity

Associated practices

Major conclusions

- Conservation Agriculture (CA) and mixed breeding – annual crop farms represent the majority of the high carbon sequestration rates.
  - However, conventional tillage systems with high vegetal intensity may also sequester carbon at high rates.
  - However, not all so-called CA systems are sequestering. Low vegetal intensity may jeopardize the efforts.
- High STIR and limited vegetal intensity account for the highest carbon emission rates.
- High application of organic amendments contribute to sequestration but this is not a requisite.
- The major factor for carbon sequestration is vegetal intensity, in particular cover crop biomass and diversity.
- Carbon sequestrating farms show equal or larger gross margin per ha than conventional ones.

Conclusions and perspectives

- The deficit in soil organic carbon was up to 70% compared to a minimum soil quality reference.
  - This requires to increase SOC at rates much larger than 4‰ to restore the soils in the coming 3 decades.
- Observed carbon sequestration rates ranged from -50‰ to + 50‰.
- The SOC change rate increased from -4‰ to +9‰ in the past 20 years at regional scale.
- Conservation Agriculture and Breeding are the major systems allowing for sequestration at high rates (e.g. 20 ‰ to 50 ‰).
  - However failures are observed with farms theoretically applying such systems, and high sequestration can be observed with conventional tillage systems
  - Therefore, any agri-environmental management scheme aiming at soil quality restoration and SOC increase should be result-based rather than action based[1].
- The major factor for high sequestration rates is vegetal intensity.

1. Burton, R. J. F., and Schwarz, G. (2013). Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change. *Land Use Policy* 30, 628–641.

Thank you for your attention