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Towards climate-neutral agriculture: exploring scenarios for arable and dairy farms

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Towards climate-neutral agriculture: exploring scenarios for arable and dairy farms

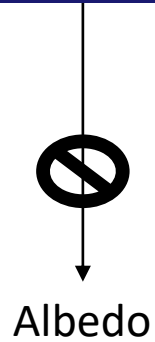
Emily Miranda Oliveira, Julie Auberger, Michael Carson and Hayo van der Werf

INRAE UMR-SAS

LCA Food - Barcelona

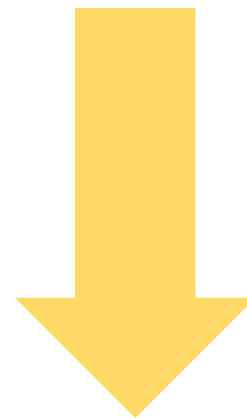
09.09.2024

Climate neutrality?



“Net greenhouse gas emissions produced are balanced by removing an equivalent amount of greenhouse gases from the atmosphere”

GHG emissions



Carbon sequestration

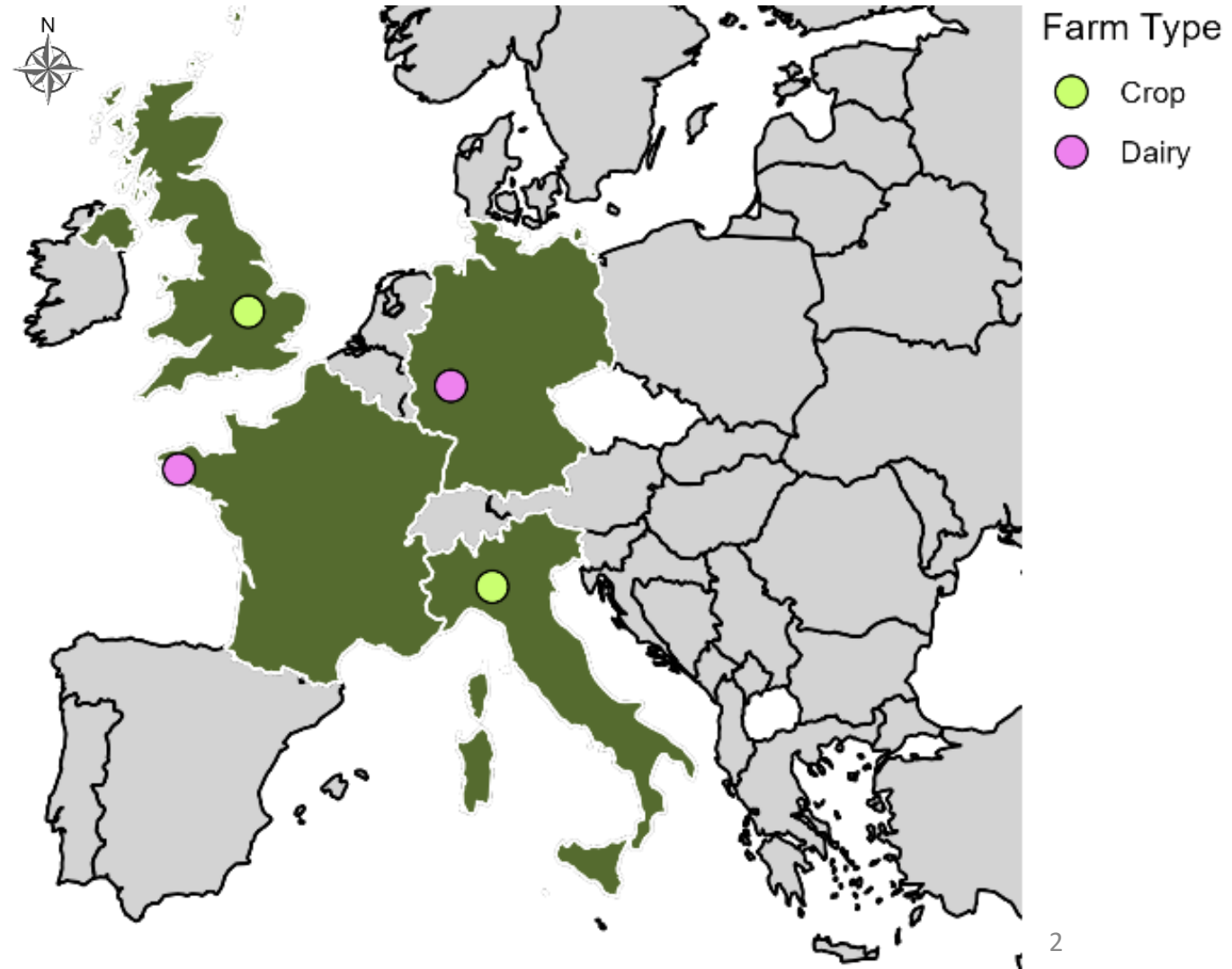


ClieNFarms INRAe

4 focus farms:

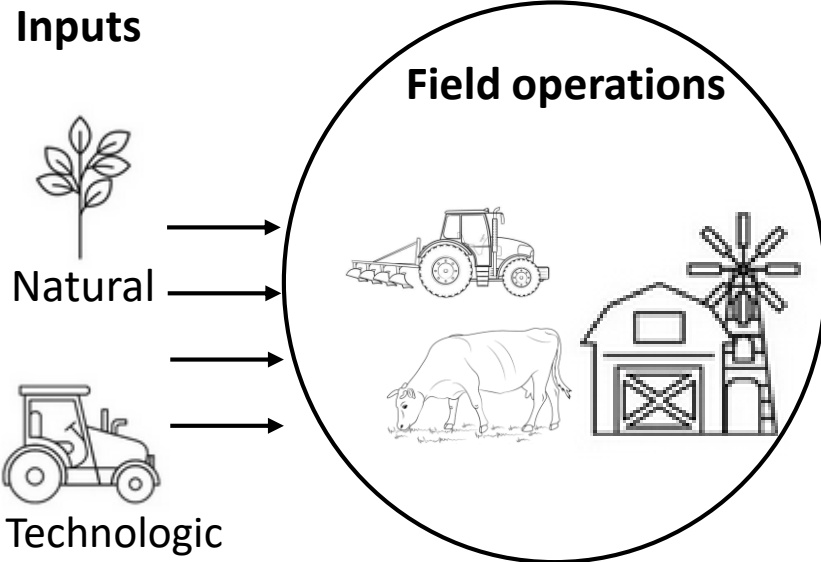
UK_arable
IT_arable **Conv.**
FR_dairy

DE_dairy **Org.**

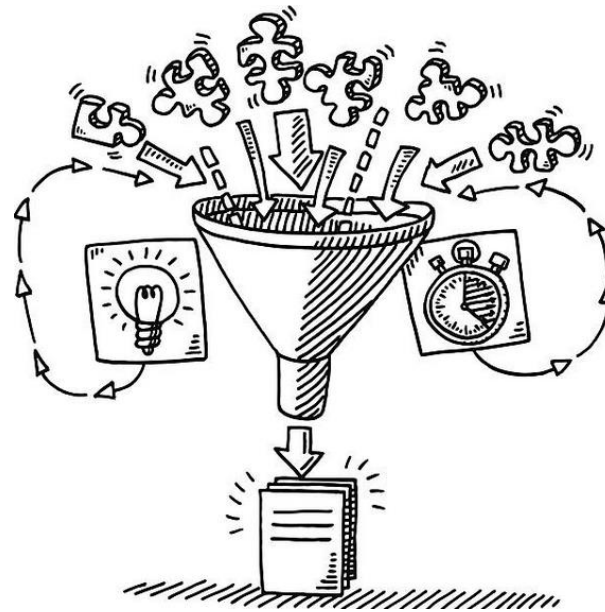


Life cycle assessment - LCA

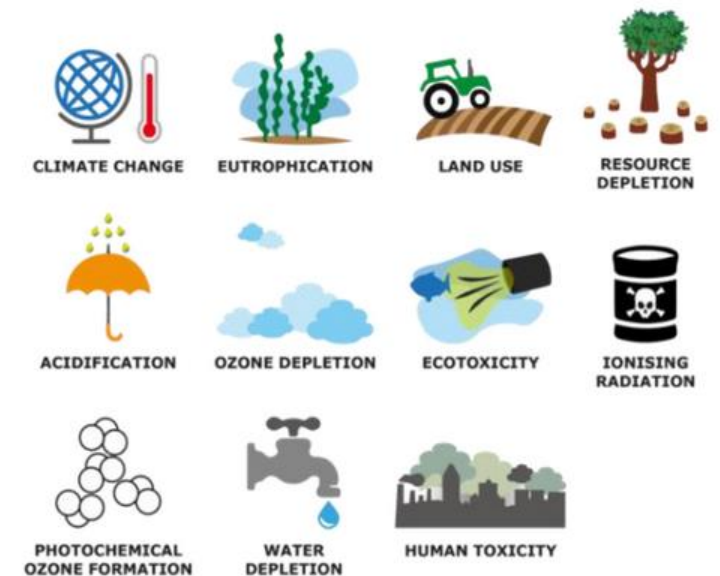
Goal and scope definition



Inventory analysis



Impact assessment



Sala et al. 2016

Life cycle assessment - LCA

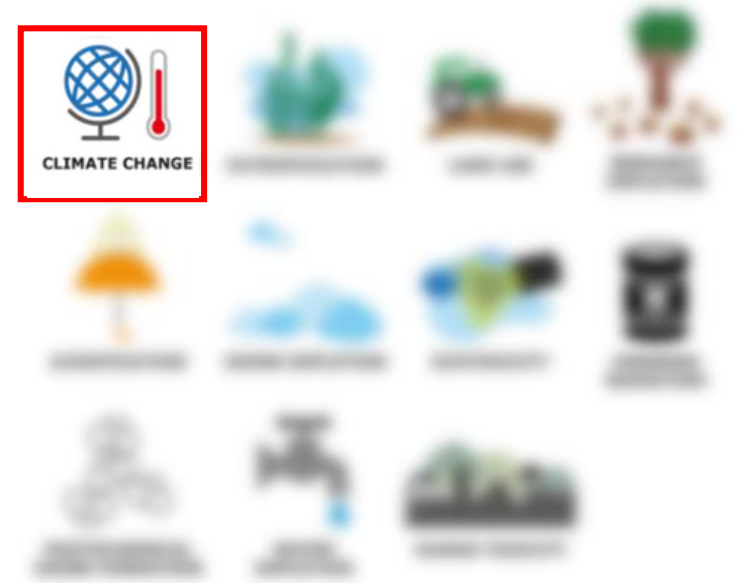
Single score: Climate change
Method: Environmental Footprint 3.1

Year: 2021
Cut-off: 1 %

Goal and scope definition

Inventory analysis

Impact assessment

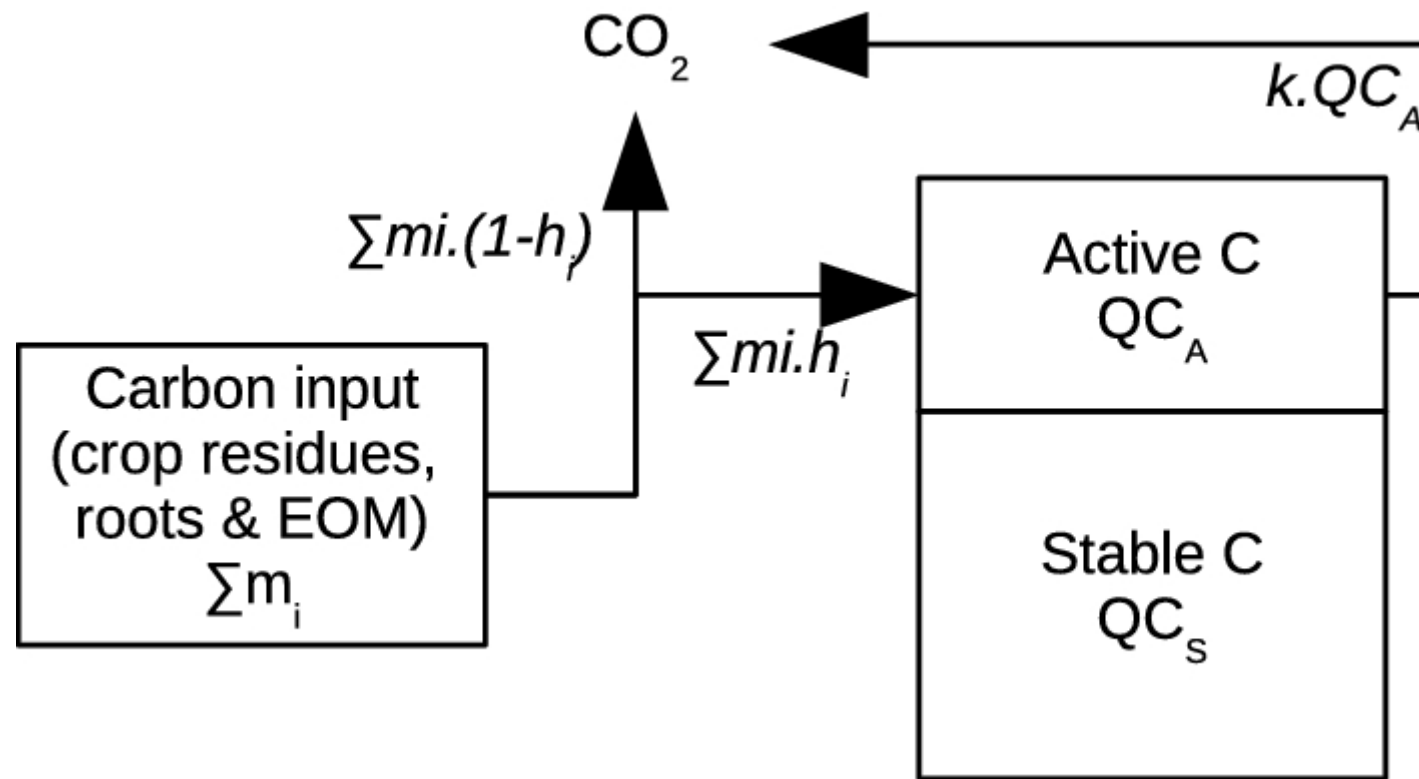


Simapro

Minimum set of input data

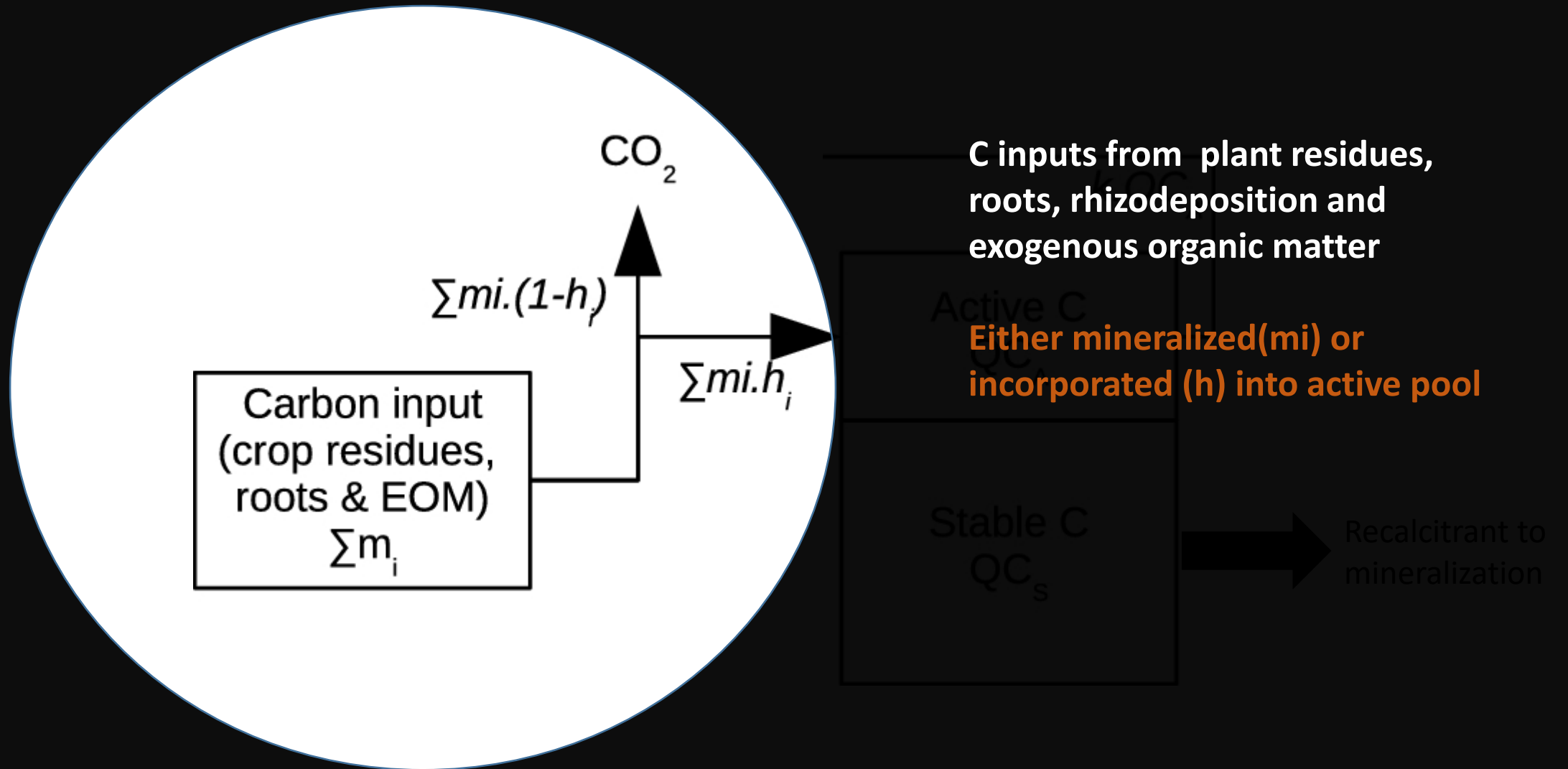
- 1. C inputs:** crop yields, crop residues management or directly measured C inputs to **compute above and belowground C inputs** from plants.
- 2. Management data**, if available:
 - Soil tillage (depth);
 - Irrigation;
 - Exogenous Organic Matter (EOM) application (type, rate and date);
- 3. Soil data** (clay and carbonate contents, pH, SOC content, C:N and bulk density of soil) and depth to compute SOC stocks;
- 4. Climatic data** (mean annual temperature, precipitation and evapotranspiration).

Soil organic carbon evolution - AMG model



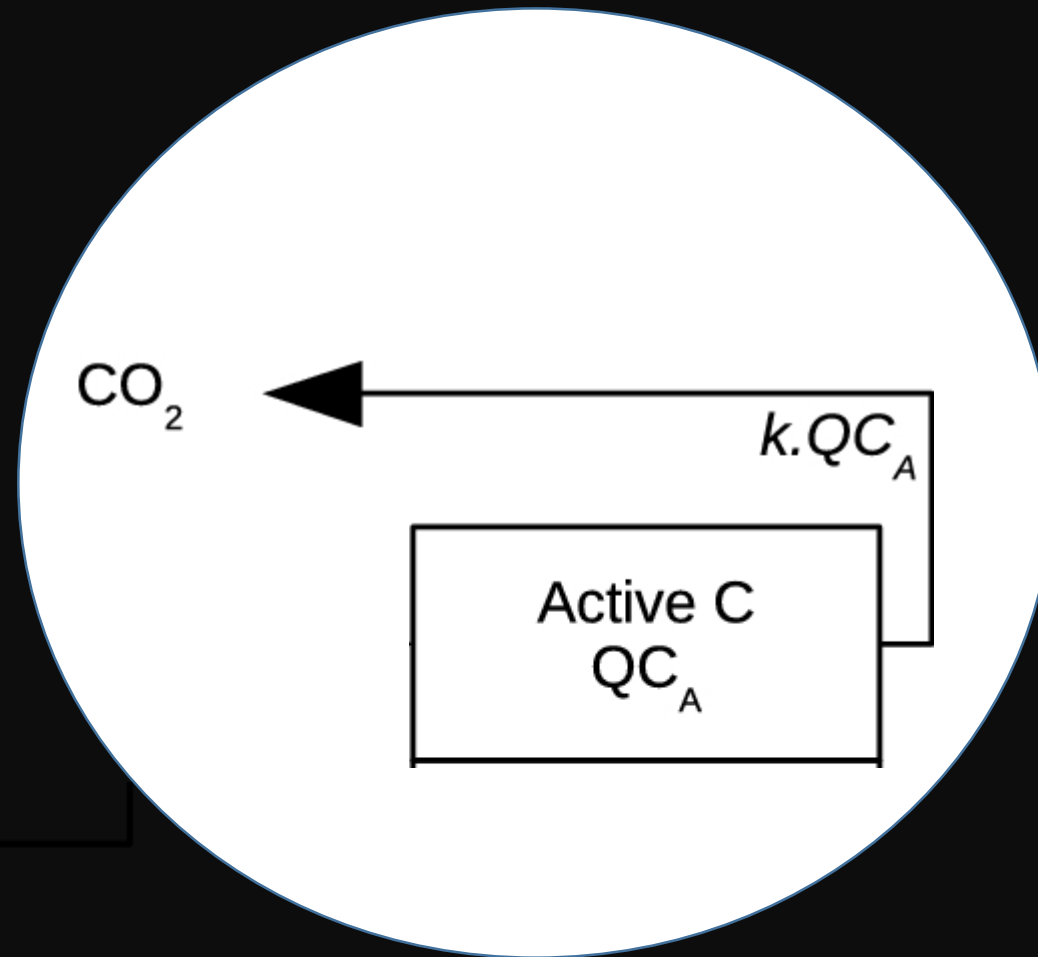
Andriulo et al. 1999, Clivot et al. 2017, Clivot et al. 2019

AMG model



The **active C pool decomposes** according to first-order kinetics with a rate constant k **affected by the climate** (mean annual water balance and air temperature) and **soil characteristics** (clay and carbonate contents, pH and C:N ratio of the total SOM) (Clivot et al. 2017)

Mean residence time (MRT) of active SOC ranging from **7 to 26 years** (Clivot et al. 2019).



AMG model

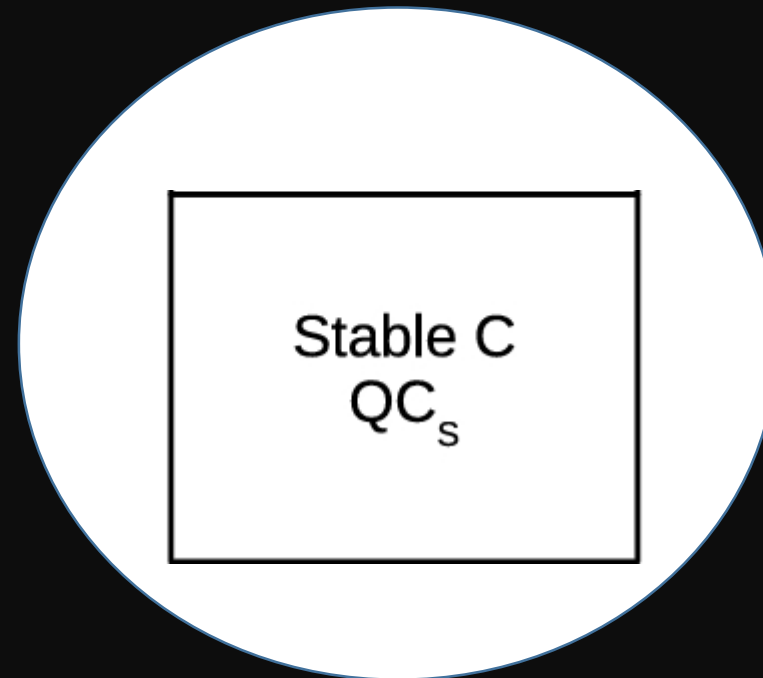
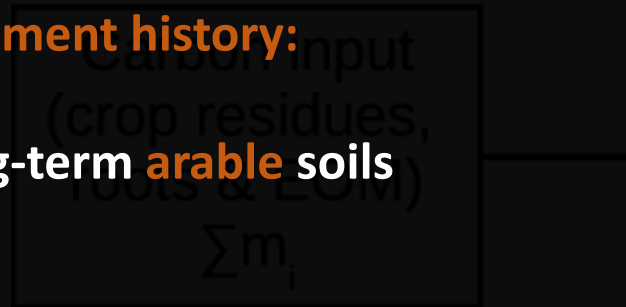
Recalcitrant to mineralization

The initial proportion of QCS in the total SOC is dependent on management history:

65% in long-term **arable** soils and

40% for long term **grassland** history

Saffih-Hdadi and Mary 2008



Project stages

1. Business as usual: Which activities are contributing the most for the farm GHG emissions?

 Contribution analysis

2. Which improvements could be made?

 Ecodesign scenarios part 1

3. What does it take for these farms to achieve climate neutrality?

 Ecodesign scenarios part 2

Project stages

1. Business as usual: Which activities are contributing the most for the farm GHG emissions?

 Contribution analysis

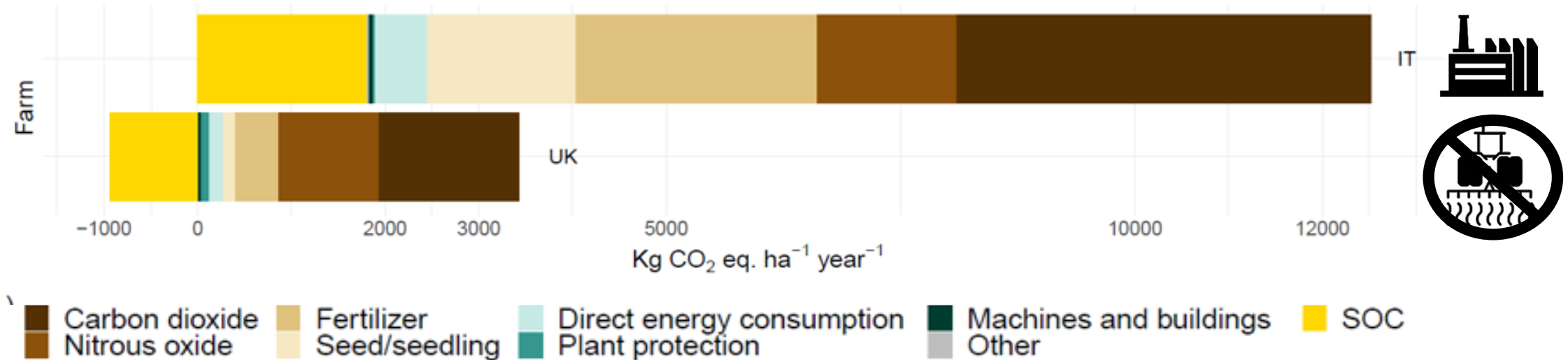
2. Which improvements could be made?

 Ecodesign scenarios part 1

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 Ecodesign scenarios part 2

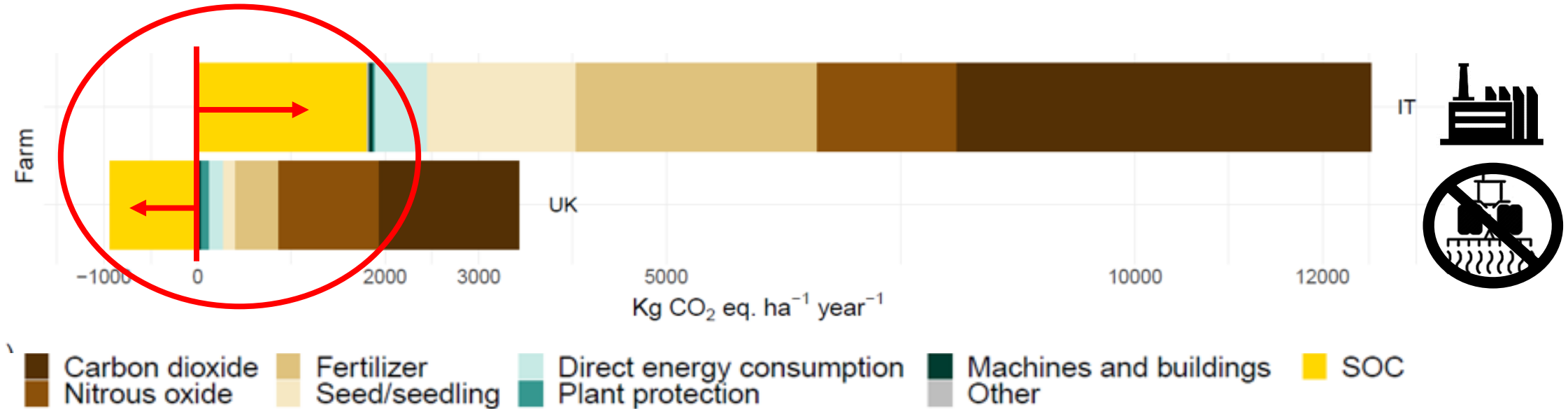
Business as usual



ITALY (IT) – Industrial tomato farm 75 ha

UNITED KINGDOM (UK) – Research and educational farm 132 ha

Business as usual



ITALY (IT) – Industrial tomato farm 75 ha

UNITED KINGDOM (UK) – Research and educational farm 132 ha

Business as usual

ITALY (IT)



Tomato



Silage maize



Wheat

UNITED KINGDOM (UK)



Rapeseed



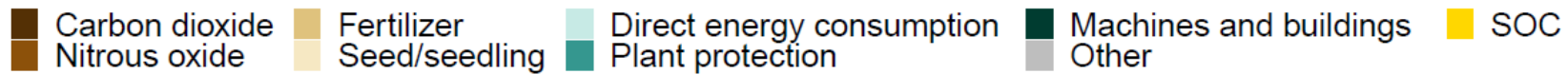
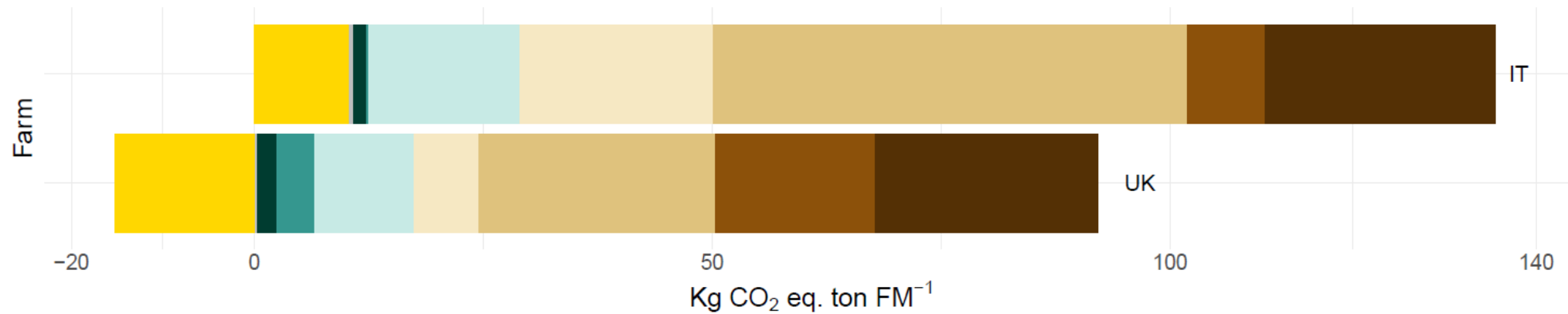
Wheat



Faba beans



Barley



Project stages

1. Business as usual: Which activities are contributing the most for the farm GHG emissions?

↳ Contribution analysis

2. Which improvements could be made?

↳ Ecodesign scenarios part 1

3. What does it take for these farms to achieve climate neutrality?

↳ Ecodesign scenarios part 2

Ecodesign actions

- Based on ClieNFarm and Nestlé's action catalogue + literature review + less complexities in the modeling process

Selection of actions

- Part 1 – **Productivity constrained (PC) scenario**: actions with potential yield impact < than 10% and potentially high GHG emission reduction

Area based calculation

- Part 2 – **Climate Neutral (CN) scenario**: actions can deviate from *status quo* if necessary

Chosen actions – 20 years scenarios

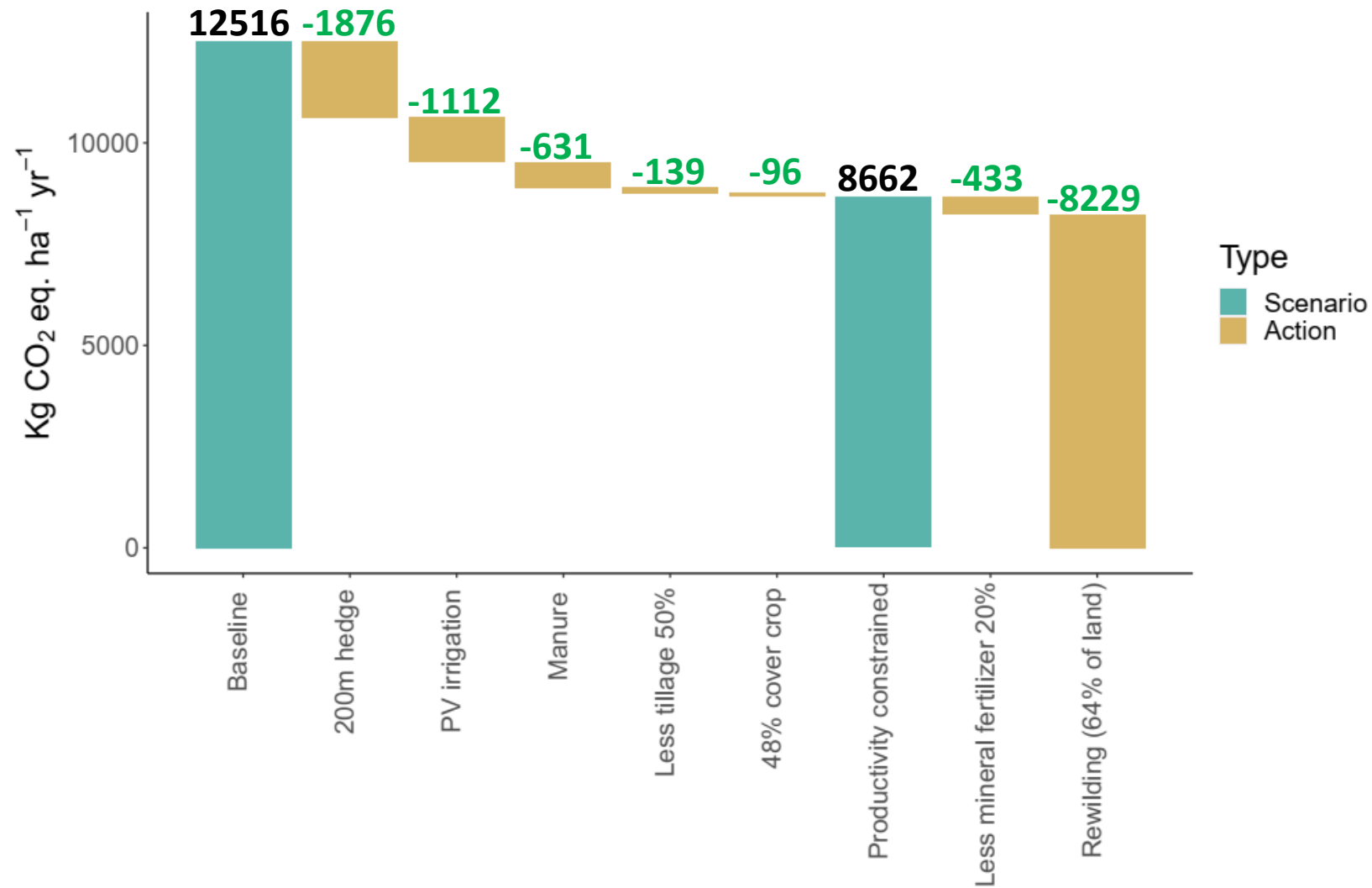
Mitigation actions	Reduce emission	Increase sequestration
1. Applying manure		
2. Cover crop (when it fits in rotation)		
3. Extend temporary grassland in rotation		
4. Extend permanent grassland area in farm		
5. Implementing hedge		
6. Rewilding (biomass storage, 20 years)		
7. Photovoltaic - water pump		
8. 50% less tillage		
9. Use of 20% less fertilizer		
10. Feed additives (Bovaer)		

Eco-design scenarios – Italy

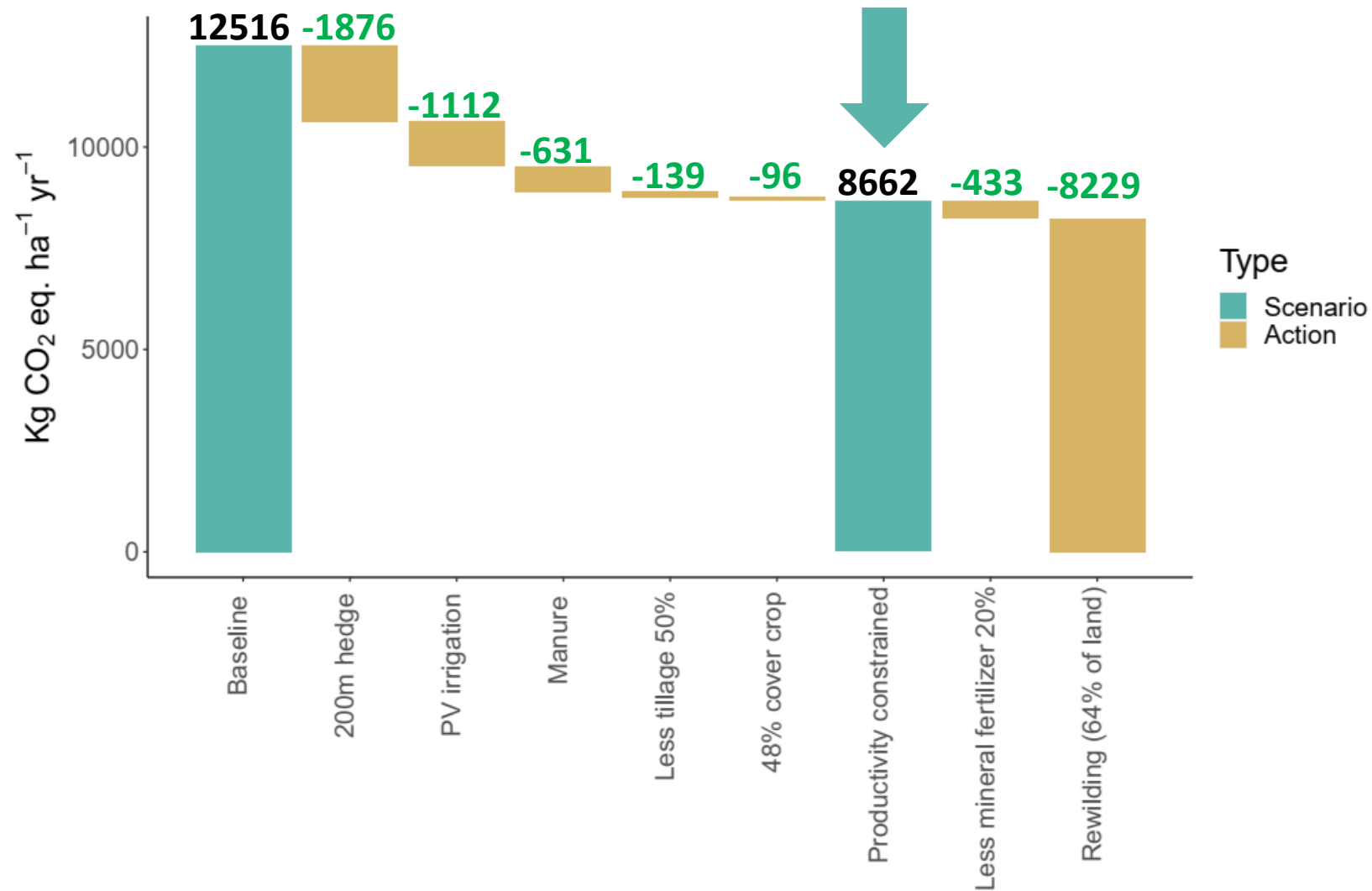
Scenario	Mitigation actions	Implementation	Mitigation potential	Contribution scenario	Reference/calculation
PC	Planting 200 m hedge ha ⁻¹	30	-1906	-1876	Drexler et al. 2020 + own calculation
PC	Establishing cover crops		-96	-96	AMG - mustard (yield: 0.5 t DM)
PC	Applying manure		-631	-631	AMG - replacing N from 20% decrease in min. fertilizer. 6 t of manure for wheat and Maize and 8 t for tomato
PC	Decreasing tillage by 50%		-139	-139	Means + simapro
PC	* Fully solar powered irrigation system	479	-1136	-1112	Todde et al. 2018 + own calculations
CN	Use 20% less mineral fertilizer		-433	-433	Means + simapro
CN	Rewild 64% of the land		-4758	-8397	Mondière et al. 2024

* with a **Carbon Pay Back Time** of 10.5 years, 9.5 years of the 20 year scenario would be of clean renewable energy (assuming no further use of fossil fuel pumps)

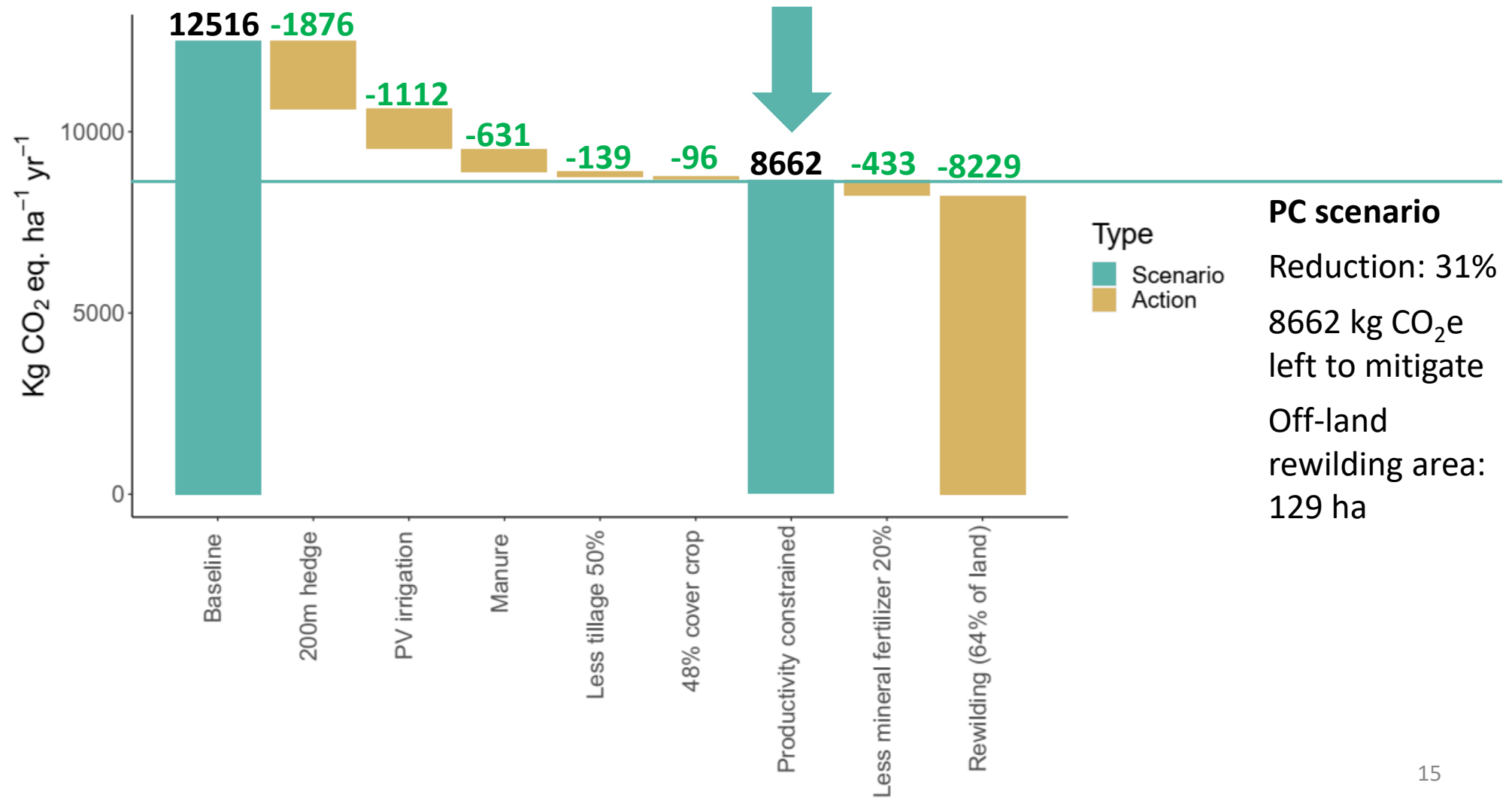
Eco-design scenarios – Italian case



Eco-design scenarios – Italian case



Eco-design scenarios – Italian case



Conclusions

- **None** of the arable farms achieved **climate-neutrality** in the Baseline scenario.
- At the industrial tomato farm (IT), **climate neutrality was not reached under the Productivity constrained** scenario.
- Achieving on-farm climate neutrality would required **additional actions** and **alleviating the productivity constraints**.

Thank you for your attention!
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Hayo van der Werf



Julie Auberger



Michael Corson