SOIL CARBON SEQUESTRATION AND GHG EMISSION IN MEDITERRANEAN CROPLANDS

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Outline

1. **Review:** factors involved in net carbon storage and options for SOC stock enhacement
2. **Meta-analysis:** Carbon content in organic versus conventionally managed soils: preliminary results
3. **Modelling:** full GHG accounting in organic and conventional rainfed olive orchards

Review

Factors involved in net carbon storage and options for SOC stocks enhacement

In collaboration with:

Andreas Gattinger
Matthias Häni

Review: factors involved in net C storage and options for SOC stock enhacement

- Woody and herbaceous cropping systems
- Irrigation
- N fertilization
- Agroforestry
- Soil Inorganic Carbon (SIC)
- Organic matter imports
- Tillage effects
- Organic management

Woody and herbaceous cropping systems

WOODY

- Soil conservation practices can minimize erosion and enhace SOM and yields at the same time
- Most remarkable practices for C sequestration are:
  - Cover crops
  - Prunning residues
  - Agro-industrial wastes

HERBACEOUS

- Self-produced organic inputs are limited by residues availability
- Straw retention and green manures may be good practices, but they can decrease usable yields
- OM imports may be needed to achieve sequestration

Irrigation

- It can promote C sequestration by boosting primary productivity
- But it can also cause SOC decrease by enhacing soil respiration
- There is a high sequestration potential if high OM recycling rates are adopted

Nitrogen fertilization

- Effects on SOC are unclear: positive, negative and neutral effects have been found
- Positive effects are presumably linked to higher productivity
- Negative effects probably occur due to N-induced increase of SOC mineralization rate

Soil inorganic carbon

- This soil C pool is usually neglected, but it can represent a high proportion of soil mass in many Mediterranean soils

- Irrigation can promote SIC formation or loss depending on water and soil properties

- SIC depletion has been detected in soils affected by N over-fertilization and olive mill wastes evaporation ponds

Agroforestry

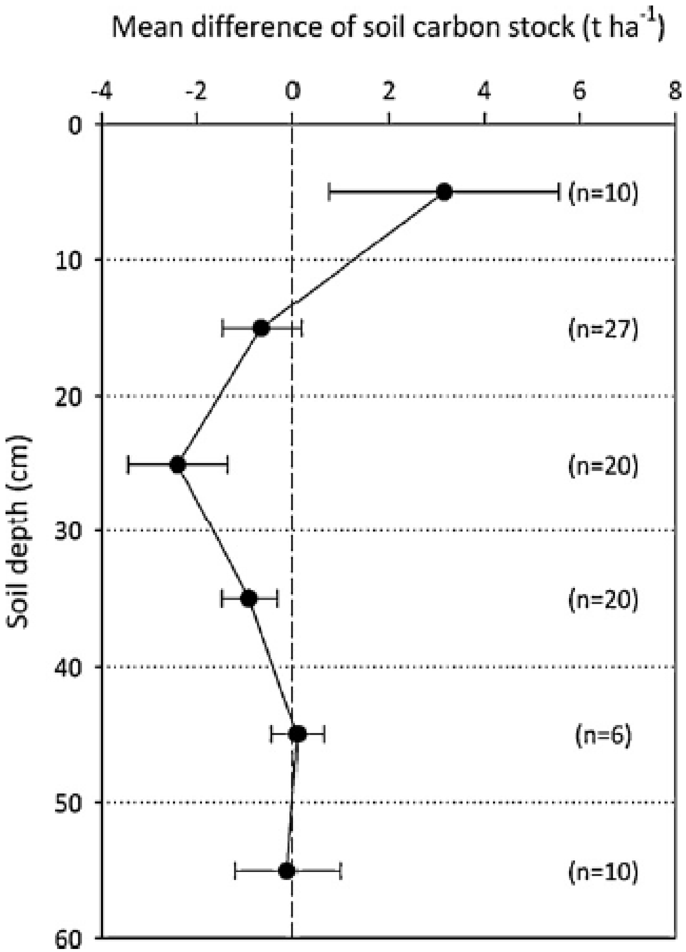
- Very few studies
- Hedgerows can enhace SOC in nearby croplands many meters away
- Effects of intercroped trees on crop yield are unclear

Organic matter imports

- **Municipal solid wastes** and **sewage sludge** are far from reaching the required standards for organic farming.
- **Manures** use is burdened by insufficient animal integration
- **Agro-industrial wastes:** many examples of successful soil performance if they are composted

Tillage

- ☐ 61 papers have been found studying tillage effects
- ☐ SOC increase related to CT has been measured in most cases, but it can be caused by shallow sampling
- ☐ A meta-analysis is being to address this question (data not shown)



Luo et al., 2010

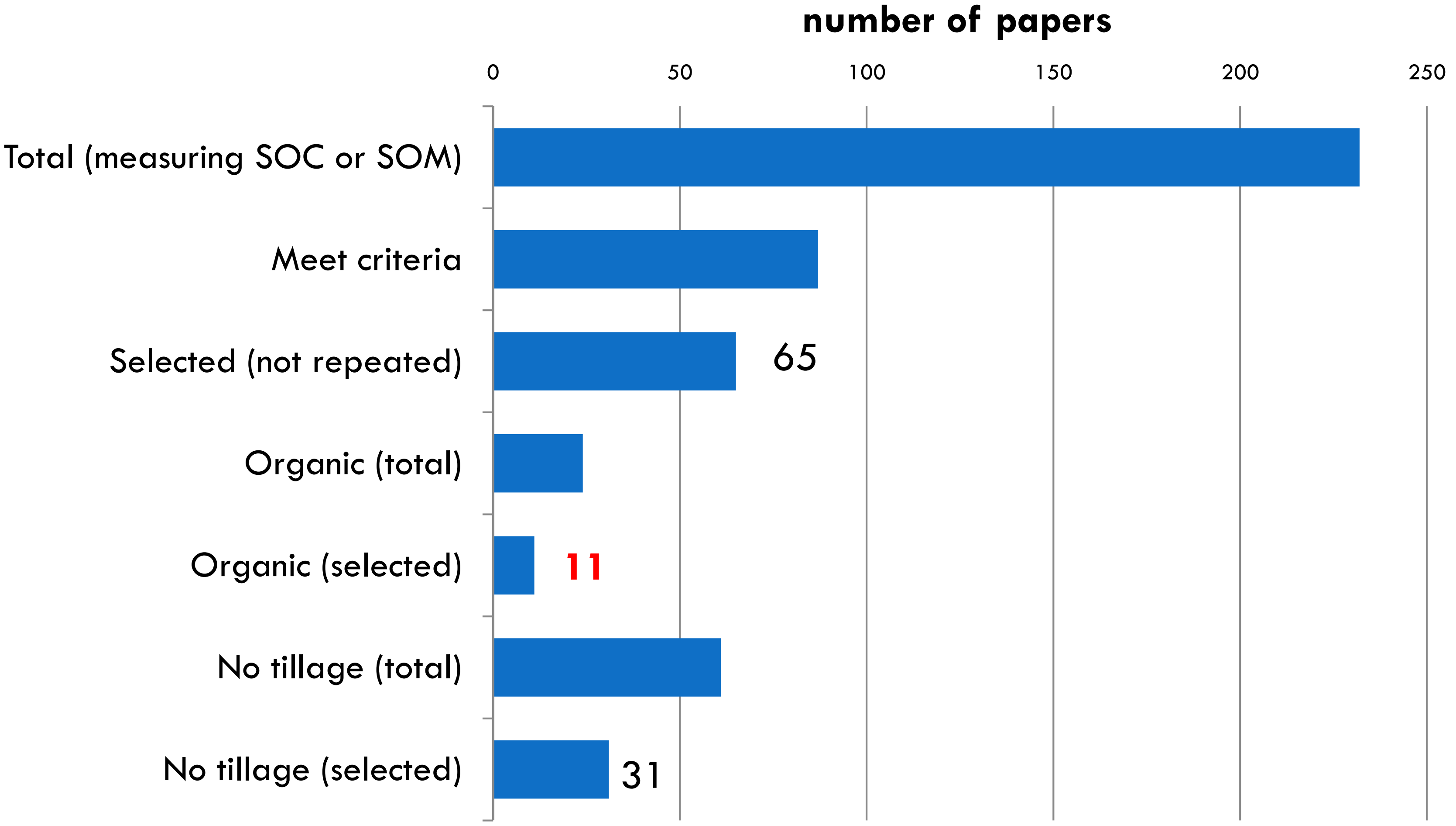
Meta-analysis

Organic management effect on soil organic carbon storage

In collaboration with:

Andreas Gattinger
Matthias Häni

Data selection for Meta-analysis



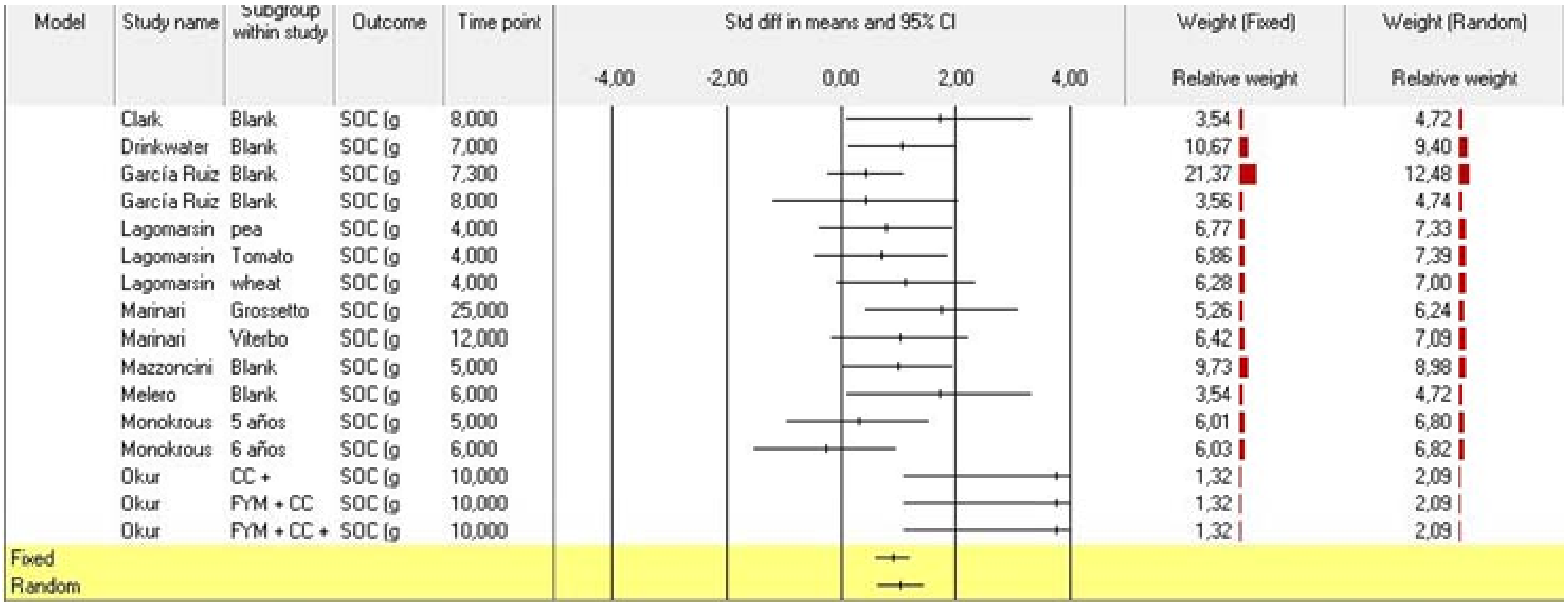
Approaches

- 3 parameters have been chosen for the comparison
  - SOC (g C kg soil^{-1})
  - C stock (Mg C ha^{-1})
  - C sequestration (Mg C ha^{-1} y^{-1})
- Analysis perfomed with Comprehensive Meta Analysis software

SOC (g C kg soil^{-1})

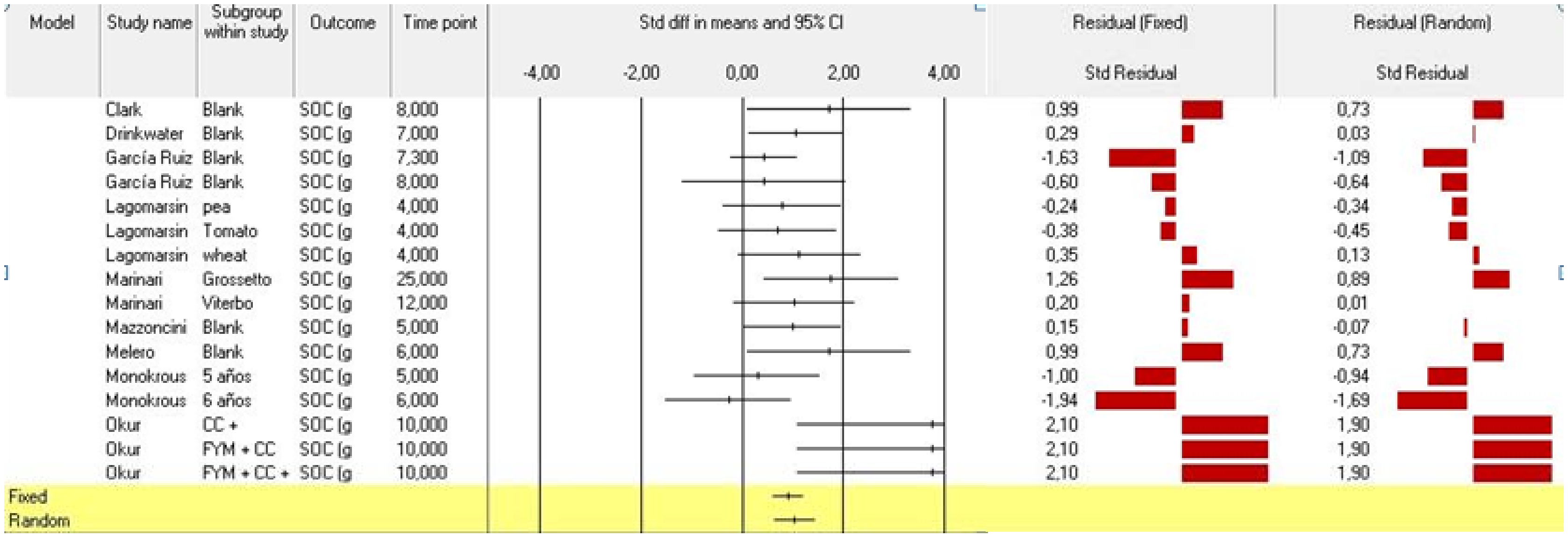
- N=10
- n=16
- Data have only been transformed from other measure if there was enough information
- Studies in California (2), Italy (3), Spain (3), Greece (1) and Turkey (1)
- Index: **Standard Differences in means**

SOC (g C/kg)



Model	Study name	Subgroup within study	Outcome	Time point	Std diff in means and 95% CI	Weight (Fixed) Relative weight	Weight (Random) Relative weight
	Clark	Blank	SOC (g	8,000		3,54	4,72
	Drinkwater	Blank	SOC (g	7,000		10,67	9,40
	García Ruiz	Blank	SOC (g	7,300		21,37	12,48
	García Ruiz	Blank	SOC (g	8,000		3,56	4,74
	Lagomarsin	pea	SOC (g	4,000		6,77	7,33
	Lagomarsin	Tomato	SOC (g	4,000		6,86	7,39
	Lagomarsin	wheat	SOC (g	4,000		6,28	7,00
	Marinari	Grossetto	SOC (g	25,000		5,26	6,24
	Marinari	Viterbo	SOC (g	12,000		6,42	7,09
	Mazzoncini	Blank	SOC (g	5,000		9,73	8,98
	Melero	Blank	SOC (g	6,000		3,54	4,72
	Monokrous	5 años	SOC (g	5,000		6,01	6,80
	Monokrous	6 años	SOC (g	6,000		6,03	6,82
	Okur	CC +	SOC (g	10,000		1,32	2,09
	Okur	FYM + CC	SOC (g	10,000		1,32	2,09
	Okur	FYM + CC +	SOC (g	10,000		1,32	2,09
Fixed							
Random							

SOC (g C/kg)



Model	Study name	Subgroup within study	Outcome	Time point	Std diff in means and 95% CI	Residual (Fixed) Std Residual	Residual (Random) Std Residual
	Clark	Blank	SOC (g	8,000		0,99	0,73
	Drinkwater	Blank	SOC (g	7,000		0,29	0,03
	García Ruiz	Blank	SOC (g	7,300		-1,63	-1,09
	García Ruiz	Blank	SOC (g	8,000		-0,60	-0,64
	Lagomarsin	pea	SOC (g	4,000		-0,24	-0,34
	Lagomarsin	Tomato	SOC (g	4,000		-0,38	-0,45
	Lagomarsin	wheat	SOC (g	4,000		0,35	0,13
	Marinari	Grossetto	SOC (g	25,000		1,26	0,89
	Marinari	Viterbo	SOC (g	12,000		0,20	0,01
	Mazzoncini	Blank	SOC (g	5,000		0,15	-0,07
	Melero	Blank	SOC (g	6,000		0,99	0,73
	Monokrous	5 años	SOC (g	5,000		-1,00	-0,94
	Monokrous	6 años	SOC (g	6,000		-1,94	-1,69
	Okur	CC +	SOC (g	10,000		2,10	1,90
	Okur	FYM + CC	SOC (g	10,000		2,10	1,90
	Okur	FYM + CC +	SOC (g	10,000		2,10	1,90
Fixed							
Random							

Fixed effects

Standard difference in means: 0,928
p-Value: <0,001

Random effects

Standard difference in means: 1,043
p-Value: <0,001

C Stock (Mg C ha^{-1})

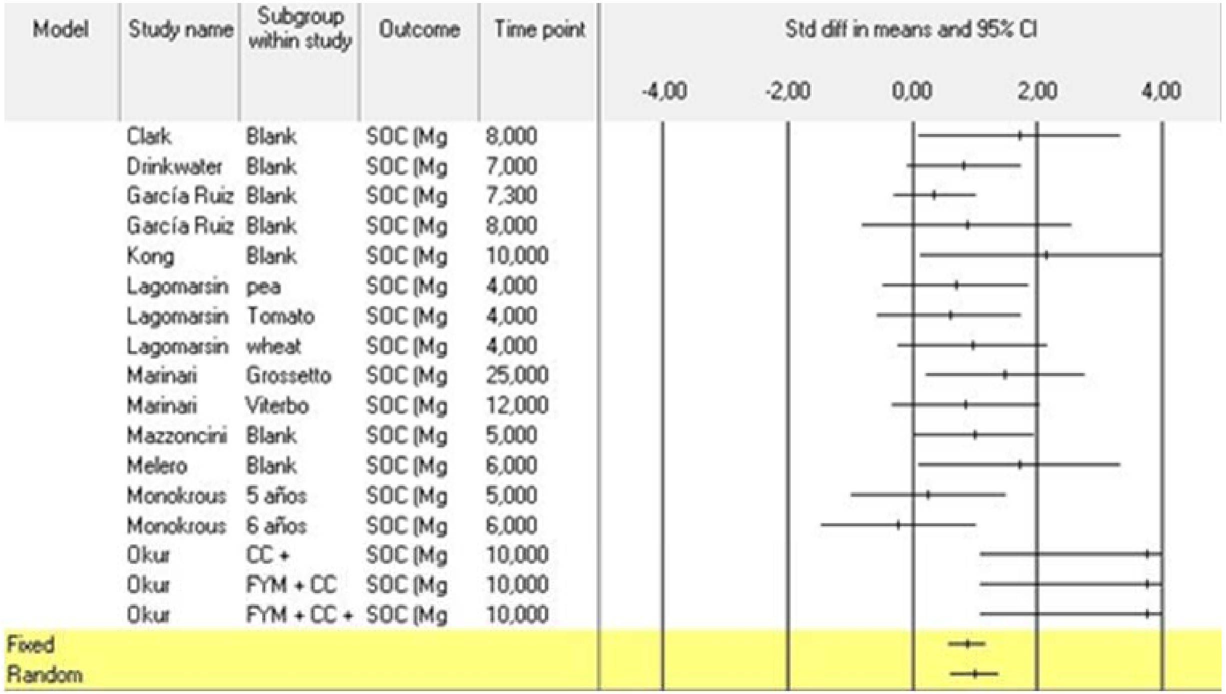
- n=17
- N=11

- Some bulk density data has been estimated with a pedotransfer function based on Mediterranean soil data

- Studies in California (3), Italy (3), Spain (3), Greece (1) and Turkey (1)

- Index: **Standard Difference in means**

C Stock (Mg C ha^{-1})



Model	Study name	Subgroup within study	Outcome	Time point
	Clark	Blank	SOC (Mg	8,000
	Drinkwater	Blank	SOC (Mg	7,000
	García Ruiz	Blank	SOC (Mg	7,300
	García Ruiz	Blank	SOC (Mg	8,000
	Kong	Blank	SOC (Mg	10,000
	Lagomarsin	pea	SOC (Mg	4,000
	Lagomarsin	Tomato	SOC (Mg	4,000
	Lagomarsin	wheat	SOC (Mg	4,000
	Marinari	Grossetto	SOC (Mg	25,000
	Marinari	Viterbo	SOC (Mg	12,000
	Mazzoncini	Blank	SOC (Mg	5,000
	Melero	Blank	SOC (Mg	6,000
	Monokrous	5 años	SOC (Mg	5,000
	Monokrous	6 años	SOC (Mg	6,000
	Okur	CC +	SOC (Mg	10,000
	Okur	FYM + CC	SOC (Mg	10,000
	Okur	FYM + CC +	SOC (Mg	10,000
Fixed				
Random				

Fixed effects

Standard difference in means: 0,882
p-Value: <0,001

Random effects

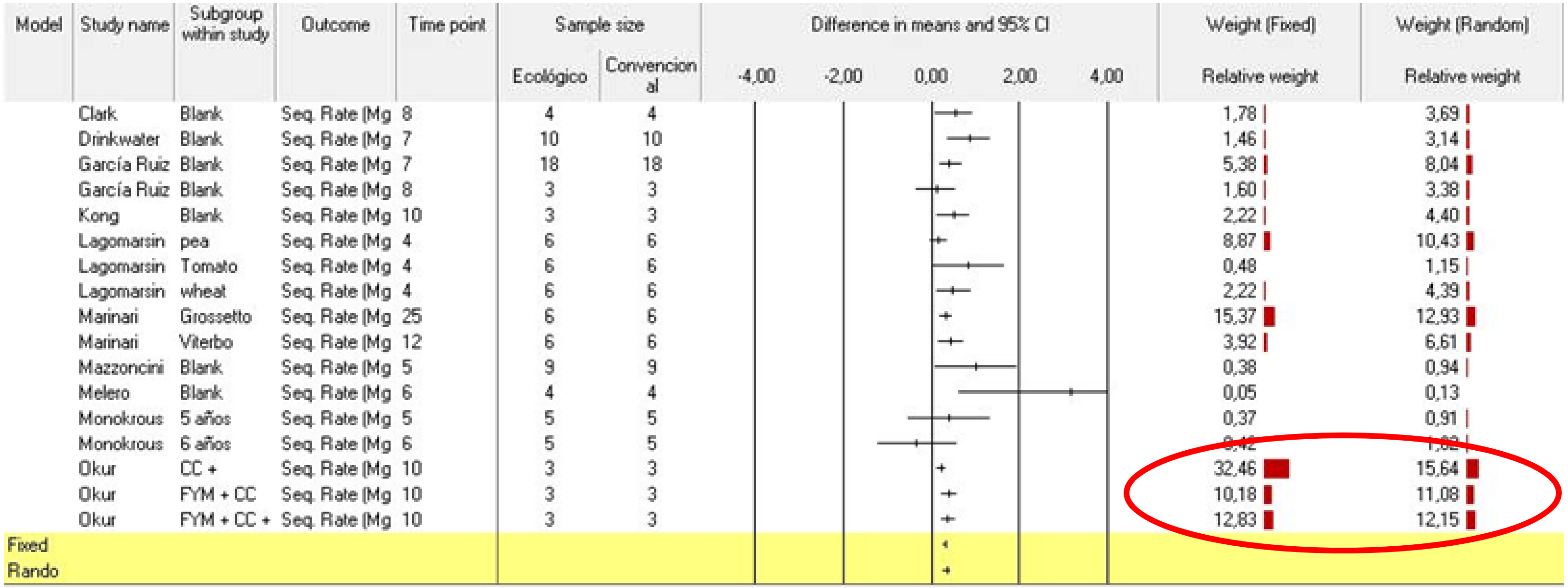
Standard difference in means: 1,01
p-Value: <0,001

C sequestration rate (Mg C ha^{-1} y^{-1})

- The data set is the same as C stock's
- But C sequestration rate integrates temporal data
- Standard Deviation has been calculated from C stock SD data
- Index: **Raw Differences in means**

C sequestration rate (Mg C ha^{-1} y^{-1})

Raw Differences in means



Model	Study name	Subgroup within study	Outcome	Time point	Sample size		Difference in means and 95% CI	Weight (Fixed)	Weight (Random)
					Ecológico	Convencional	-4,00 -2,00 0,00 2,00 4,00	Relative weight	Relative weight
	Clark	Blank	Seq. Rate (Mg	8	4	4		1,78	3,69
	Drinkwater	Blank	Seq. Rate (Mg	7	10	10		1,46	3,14
	García Ruiz	Blank	Seq. Rate (Mg	7	18	18		5,38	8,04
	García Ruiz	Blank	Seq. Rate (Mg	8	3	3		1,60	3,38
	Kong	Blank	Seq. Rate (Mg	10	3	3		2,22	4,40
	Lagomarsin	pea	Seq. Rate (Mg	4	6	6		8,87	10,43
	Lagomarsin	Tomato	Seq. Rate (Mg	4	6	6		0,48	1,15
	Lagomarsin	wheat	Seq. Rate (Mg	4	6	6		2,22	4,39
	Marinari	Grossetto	Seq. Rate (Mg	25	6	6		15,37	12,93
	Marinari	Viterbo	Seq. Rate (Mg	12	6	6		3,92	6,61
	Mazzoncini	Blank	Seq. Rate (Mg	5	9	9		0,38	0,94
	Melero	Blank	Seq. Rate (Mg	6	4	4		0,05	0,13
	Monokrous	5 años	Seq. Rate (Mg	5	5	5		0,37	0,91
	Monokrous	6 años	Seq. Rate (Mg	6	5	5		0,42	1,02
	Okur	CC +	Seq. Rate (Mg	10	3	3		32,46	15,64
	Okur	FYM + CC	Seq. Rate (Mg	10	3	3		10,18	11,08
	Okur	FYM + CC +	Seq. Rate (Mg	10	3	3		12,83	12,15
Fixed									
Rando									

Fixed effects

Difference in means: 0,335 Mg C ha^{-1} y^{-1}
p-Value: <0,001

Random effects

Difference in means: 0,377 Mg C ha^{-1} y^{-1}
p-Value: <0,001

Preliminary conclusions

- Organically managed soils in Mediterranean areas have a higher **SOC concentration** than conventional soils (p<0,001)

- Organically managed soils in Mediterranean areas contain larger **SOC stocks** than conventional soils (p<0,001)

- **C sequestration rate** under organic management is 0,38 Mg C ha-1 y-1 higher than under conventional managemenent
  - This result is preliminary
  - Weighting method will probably be changed
  - Some treatments may be withdrawn

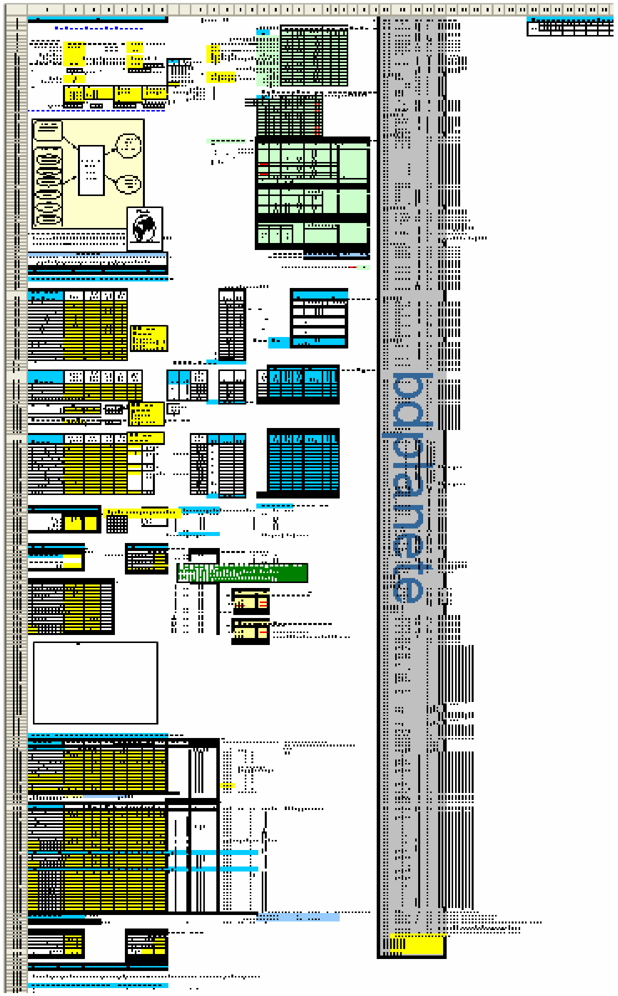
Modelling

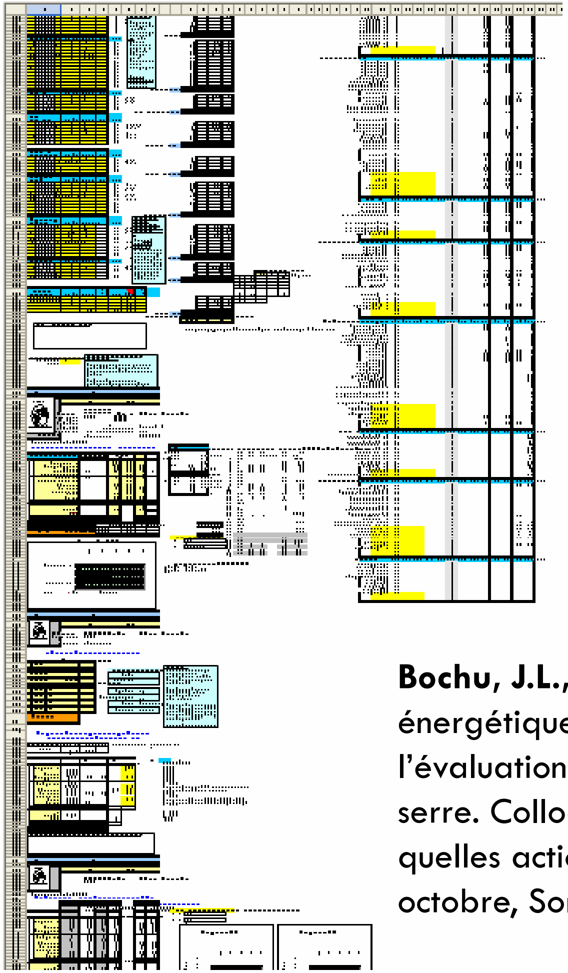
Full GHG accounting in organic and conventional rainfed olive orchards

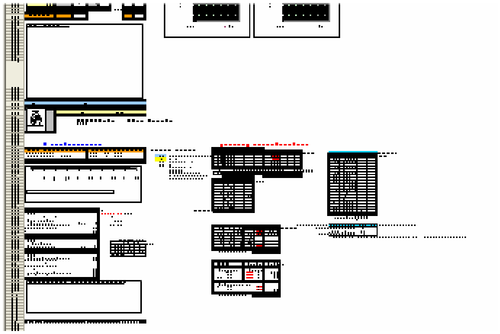
In collaboration with:

Gloria Guzmán
Antonio Alonso

PLANETE model







Bochu, J.L., 2002. PLANETE: méthode pour l'analyse énergétique des exploitations agricoles et l'évaluation des émissions de gaz à effet de serre. Colloque national: Quels diagnostics pour quelles actions agroenvironnementales? 10 et 11 octobre, Solagro, pp. 68–80.

Changes in the model

- N_2O emission factor has been changed to 1% (IPCC, 2007)
- Some missing data has been included
- A carbon sequestration module has been coupled to PLANETE

Carbon sequestration module

- Based on Henin-Dupuis (1945)
- A static organic C pool has been added
- K1 and k2 values have been obtained from recent literature

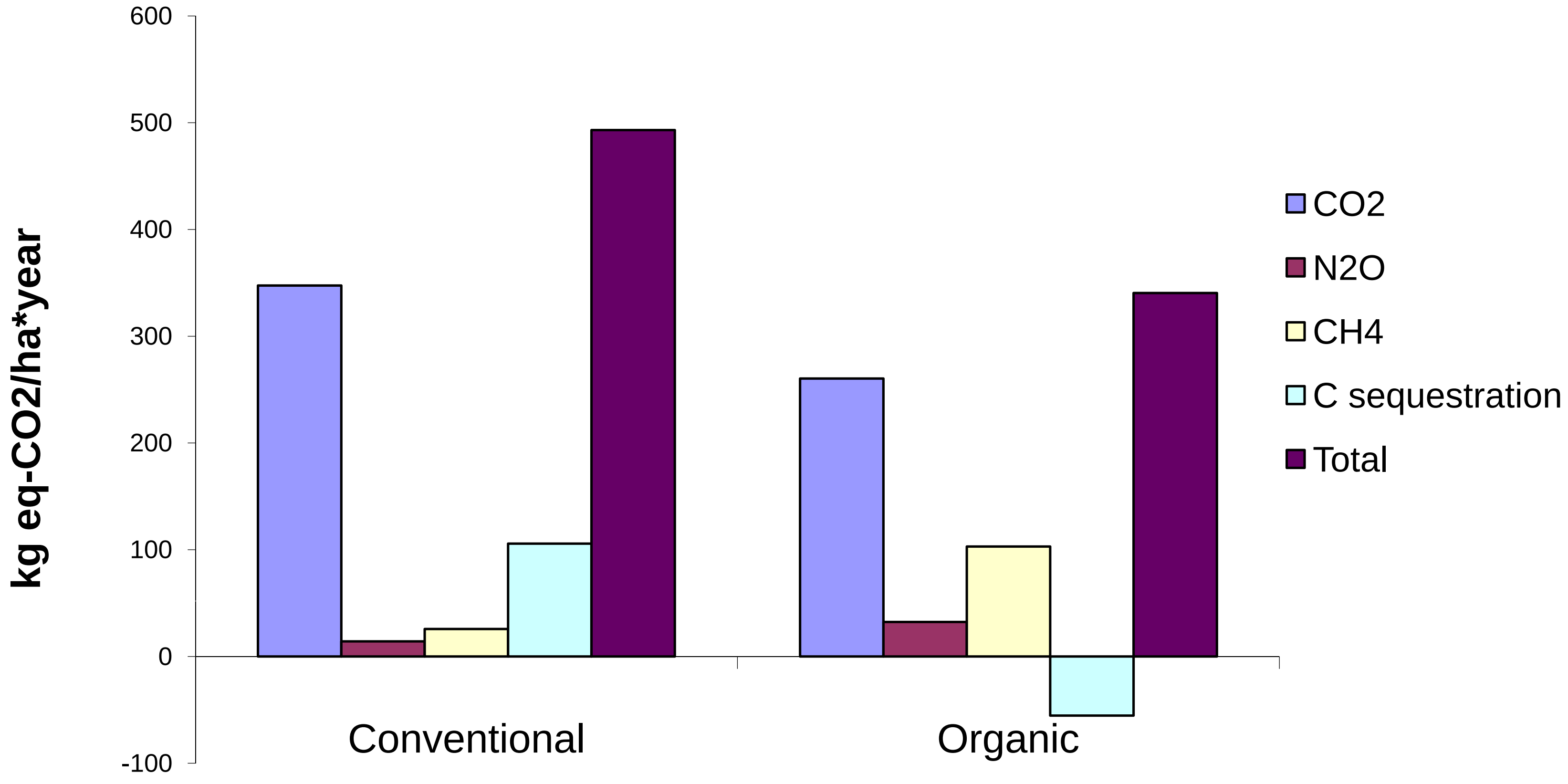
Study area

- 28 conventional and 25 organic olive growers have been interviewed
- Los Pedroches, Córdoba (South Spain)
- Subhumid Mediterraean climate
- Rainfall: 600 mm
- Stony, acid soils. Steep slopes.
- Rainfed conditions
- Very low productivity
- Very extensive managmenent
- High cattle integration

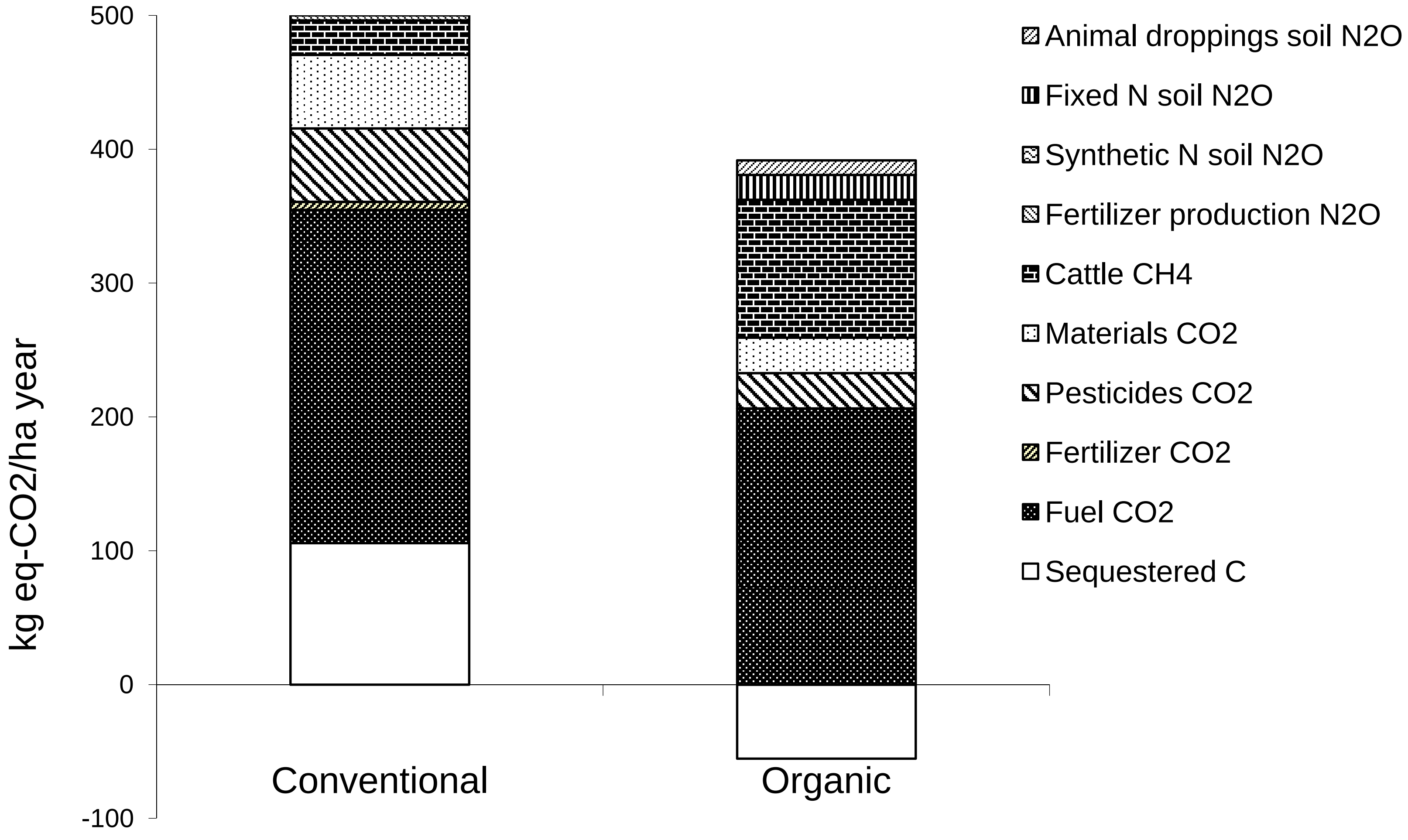
Study area

http://jfdelafuente.blogspot.com/2008/01/ruta-mtb-los-pedroches-sierra-de.html

Organic and conventional GHG budget



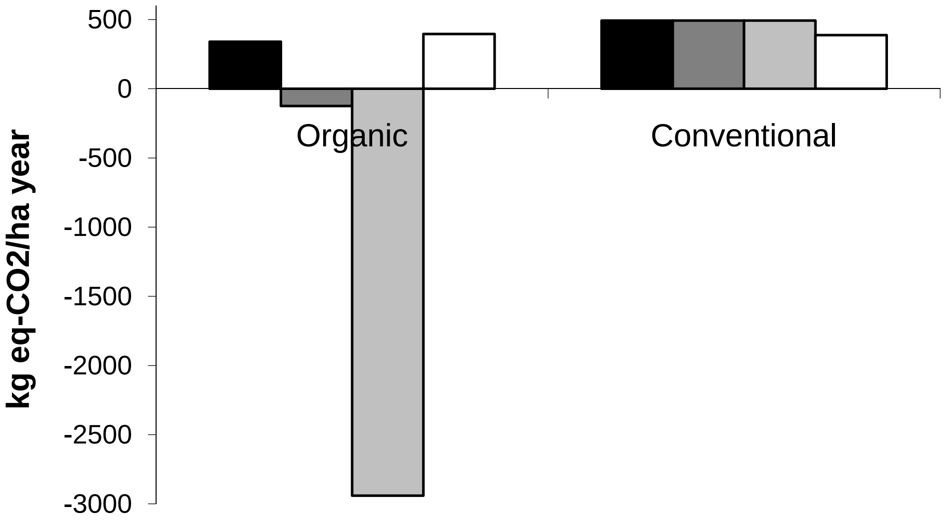
Organic and conventional GHG budget



Scenarios

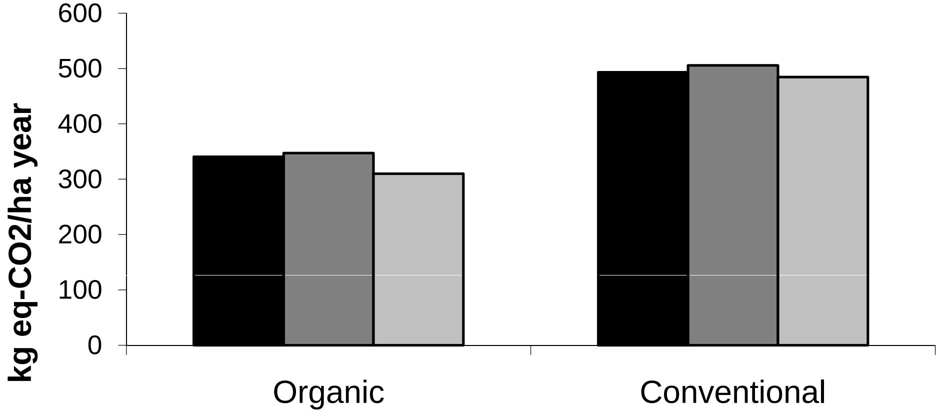
	N_2O Emission factor	C sequestration
Base scenario	1%	Henin-Dupuis
Nitrous oxide		
Mediterranean rainfed EF scenario	0,1-0,11%*	Henin-Dupuis
PLANETE EF scenario	2%	Henin-Dupuis
Carbon sequestration		
Potential C sequestration scenario	1%	H-D (full biomass recycling)
Average Mediterranean C sequestration scenario	1%	0,91 Mg ha^{-1} eco
Null C sequestration scenario	1%	0 Mg ha^{-1}

Performance of different scenarios



C sequestration rate variation

- ■ Base scenario
- ■ Potential C sequestration scenario
- ■ Average Mediterranean C seq. scenario
- □ Null C sequestration scenario



N_2O Emission factor variation

- ■ Base scenario
- ■ PLANETE EF scenario
- ■ Medit. rainfed EF scenario

Thank you very much!!!

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