Assessing CAP impact on soil C stocks with big data

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GPW Assessment of environmental impacts of the CAP
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The study

- Framework: EJP SOIL Towards climate-smart sustainable management of agricultural soils https://ejpsoil.eu/
  - H2020 co-fund programme
  - 2020 – 2025
  - Up to 1200 researchers in 24 countries
- CARBOSEQ – EJP SOIL project
  - 1 task to evaluate the impact of CAP implementation on Soil Organic Carbon stocks:
  - Direct payments (first pillar):
    - conditionality - GAEC protection for soil
    - Eco-schemes
  - Rural Development Programs (second pillar):
    - voluntary commitments beyond GAEC
    - in Italy implemented through regional programs

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CAP implementation data

- Current CAP : too recent:
  - previous CAP 2014 -2022

- Georeferenced data, parcel level, describing area and time of implementation of CAP measures by farms
  - Case study in Sicily (around 2 mlns parcels)
  - data for whole Sicily: from 2019 until 2022 (4 different shapefiles for each RDP measure)

psr 2019 misure selezionate — PSR_2019_count — Elementi Totali: 56422, Filtrati: 56422, Selezionati: 0

	ATTO_19	CODI_B_19	CUAA_19	UFFI_19	ID_INTE_19	CODI_19	DESC_19	ID_PARC_19	SUPE_19	quotamean	Erosioneme	slope%mean
1	117569791	34240014869	CPZSLV65P53B...	CAA Confagrico...	3975717	10.1.C-02.C	10.1-C-02.C-M...	403270935	50961	450,805667371...	10,0577910040...	22,6345397765...
2	117761662	34240016559	SRAMRT73M45...	CAA CIA - TRAP...	3975718	10.1.C-02.P	10.1-C-02.P-M...	404680655	39703	249,322373647...	36,8746791223...	10,9724167566...
3	117935790	34240039759	MRTGPP65B02...	CAA CAF AGRI ...	3975717	10.1.C-02.C	10.1-C-02.C-M...	407682928	12502	153,229067847...	2,13635562149...	11,1864500499...
4	117935790	34240039759	MRTGPP65B02...	CAA CAF AGRI ...	3975717	10.1.C-02.C	10.1-C-02.C-M...	407682927	37545	173,010899510...	2,43721681777...	12,5410374937...
5	117935790	34240039759	MRTGPP65B02...	CAA CAF AGRI ...	3975717	10.1.C-02.C	10.1-C-02.C-M...	407682920	25491	188,297769818...	4,07705735648...	10,1294750372...
6	117935790	34240039759	MRTGPP65B02...	CAA CAF AGRI ...	3975717	10.1.C-02.C	10.1-C-02.C-M...	407682918	17319	245,449421635...	5,36209678649...	12,2332970301...
7	117935790	34240039759	MRTGPP65B02...	CAA CAF AGRI ...	3975717	10.1.C-02.C	10.1-C-02.C-M...	407682939	41881	145,342515563...	-1,5805486183...	4,35621189389...
8	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785941	8073	80,8408775329...	14,1366536993...	16,3170411927...
9	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785940	12640	64,3022217220...	5,19143135258...	6,49362390571...
10	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785939	11544	83,6957348094...	13,9953023811...	16,0882024204...
11	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785938	27191	63,2088662927...	5,21410729629...	8,41945553232...
12	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785936	21357	60,7501865835...	-1,1204115324...	5,70140507992...
13	117679045	34240207349	RMNSVT38L29...	CAA CAF AGRI ...	3975710	11.2.1-00M6	11.2-1-00M6-A...	407785934	6678	69,3930511474...	9,63813532330...	13,4633237600...
14	118309335	34240113299	PRFMRA70D47...	NULL	3975716	10.1.C-02.M	10.1-C-02.M-M...	416477046	151838	950,392497328...	3,11924351356...	21,2367367705...
15	118309335	34240113299	PRFMRA70D47...	NULL	3975716	10.1.C-02.M	10.1-C-02.M-M...	416477044	23153	891,056963015...	1,30047932746...	12,8868437913...
16	118309335	34240113299	PRFMRA70D47...	NULL	3975716	10.1.C-02.M	10.1-C-02.M-M...	416477043	9426	885,900199381...	1,86146635313...	19,7975896835...
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18	118131577	34240076579	CRLPQL70R01A...	CAA Confagrico...	3975675	11.1.1-00C8	11.1-1-00C8-FR...	412291661	15398	37,8985411071...	4,44037642711...	6,10060735702...

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CAP implementation data

Each RPD shapefile: all agricultural parcels where measure was applied.
For each record:

- a progressive number of CAP support request (ATTO)
- fiscal code of the owner/manager of the parcel (CUAA);
- RDP measure sub-code (DESC_INTE);
- Parcel ID (ID_PARC);
- Parcel surfcae (ha, SUPE_UTIL).

Feature	Value
RDP 2022	
ATTO	108611338
CUAA	MRXXXXXXXXXX2Q
DESC_INTE	11.2-1-00M3-FORAGGERE
ID_PARC	317412609
SUPE_UTIL	10918

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CAP implementation data

RPD shapefile contains a limited amount of info but georeferenced →
it can be integrated with other georeferenced data with different formats,
using geostatistical procedures in GIS environment

- Environmental databases
- Maps (vector or raster)
- Data grid

MORE COMPLETE DATASET FOR:

- statistical analyses
- simulations e.g., present study

Altitude from DEM (Raster)
Slope from DEM (Raster)

Soil typology from maps (vector)
Erosion from maps (raster)
Desertification from maps (vector)

Climate grid reference (Data grid)

FOR EACH PARCEL

Feature	Value
RDP 2022	
ATTO	108611338
CUAA	MRxxxxxxxxx2Q
DESC_INTE	11.2-1-00M3-FORAGGERE
ID_PARC	317412609
SUPE_UTIL	10918
quotamean	585.204579072840033
slope%mean	19.574951227973489
STSmajorit	63.000000000000000
Erosioneme	8.952564001083374
ESImajorit	5.000000000000000
Id	28563

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CAP implementation data - Challenges

- Collection of data from Italian coordinator of the paying agencies of the CAP:
  - Very long process:
    - different “languages”
    - no fundings
    - no Ministerial duty
- Data quality :
  - No unique ID for each parcel
  - Different georeferenced area for the same parcel over time
  - Different codes for the same measure over time
  - Fiscal code can vary on the same parcel
  - > 1 measure funded on the same parcel referring to several crops → area for each measure?

  → Very difficult to describe the evolution of land management over time

psr2019_validity [2]	
DESC_INTE	SRA29-2-0002-FORAGGERE
(Derived)	
(Actions)	
ATTO	117980028
CODI_BARR	34810008309
CUAA	MRSxxxxxxxxx2Q
UFFI	CAA Confagricoltura - CALTANISSETTA - 001
ID_INTE	3976897
CODI_INTE	SRA29.2-0002
DESC_INTE	SRA29-2-0002-FORAGGERE
ID_PARC	408724934

Feature	Value
PSR_2022_validity	
DESC_INTE	11.2-1-00M3-FORAGGERE
(Derived)	
(Actions)	
ATTO	108611338
CODI_BARR	14240709262
CUAA	MRSxxxxxxxxx2Q
UFFI	NULL
ID_INTE	3970264
CODI_INTE	11.2.1-00M3
DESC_INTE	11.2-1-00M3-FORAGGERE
ID_PARC	317412609

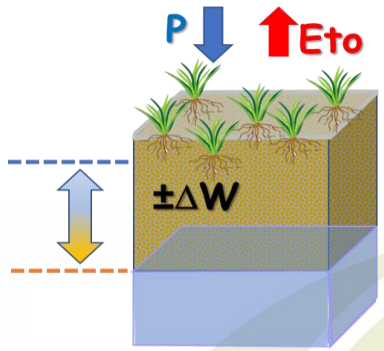
Estimation of SOC dynamics

- SOC stock change over time due to CAP measures implementation
- Biophysical model: RothC adjusted to arid environment (RothC10_N, Farina et al., 2013)

Soil properties: Texture
Rock fragments
Organic carbon

Climate: Precipitation
Temperature
Potential evapotranspiration

Monthly soil water balance



Crop sequence +
Amount of Carbon input
(plant residues) +
Quality of Carbon input
(How resistant to microbial degradation = CO_2 emission)

$$\Delta_{SOC\ stock} = \sum C_{input} - \sum C_{CO2}$$

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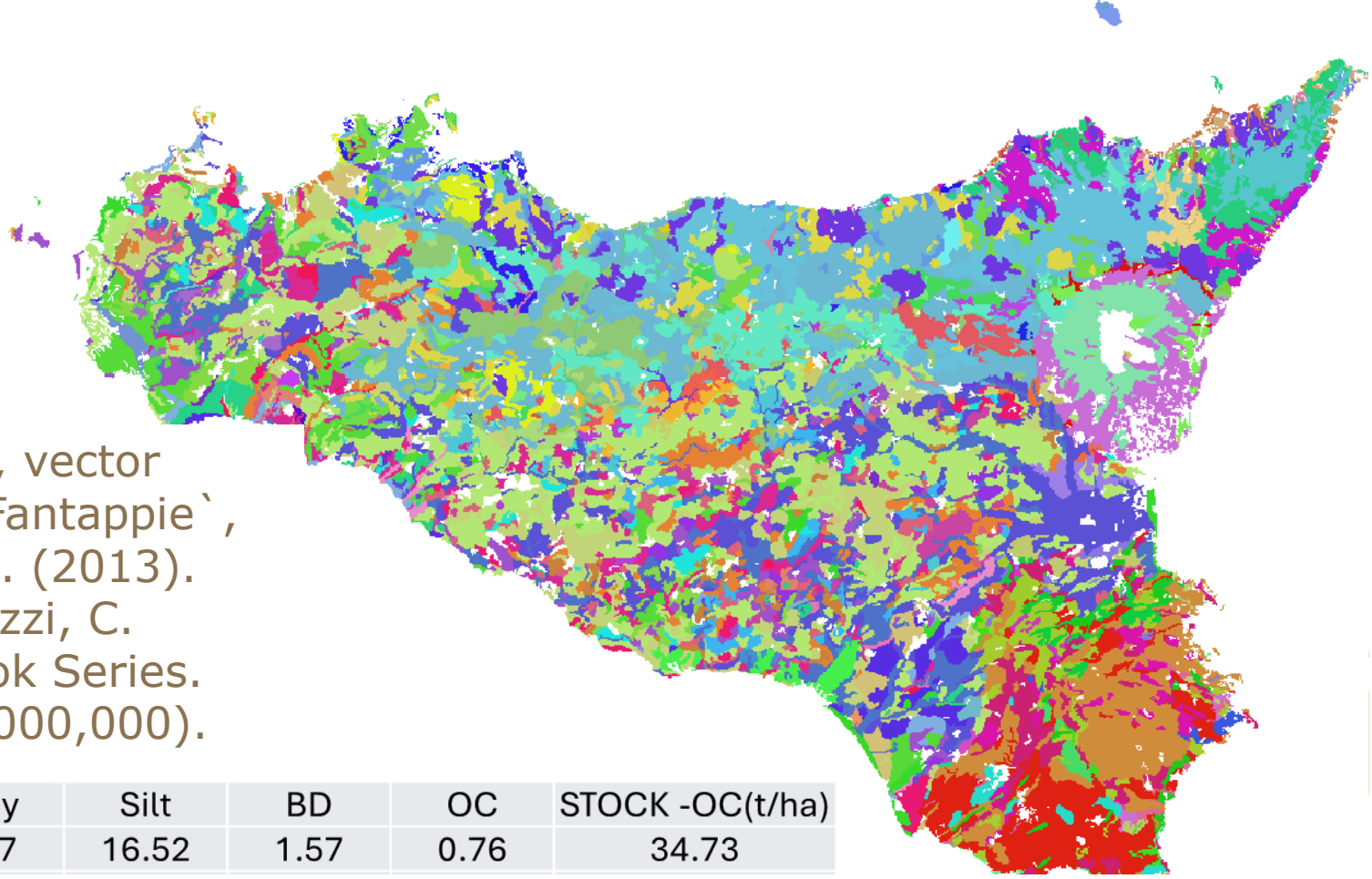
Soil data



113 SOIL TIPOLOGIES

Soil Unit map: CREA-AA, 1:250,000 scale, vector format. Costantini, E. A. C., Barbetti, R., Fantappie`, M., L'Abate, G., Lorenzetti, R., & Magini, S. (2013). Pedodiversity. In Costantini, E. A. C. & Dazzi, C. (Eds.), The Soils of Italy, World Boformatok Series. doi:10.1007/978-94-007-5642-7_6 (1:5,000,000).

SOIL UNIT	STS_N	DEPTH	SK	Sand	Clay	Silt	BD	OC	STOCK -OC(t/ha)
56.1ANvi13	1	30.00	2.93	79.71	3.77	16.52	1.57	0.76	34.73

Why this source?

Only map available at regional level

Challenges?

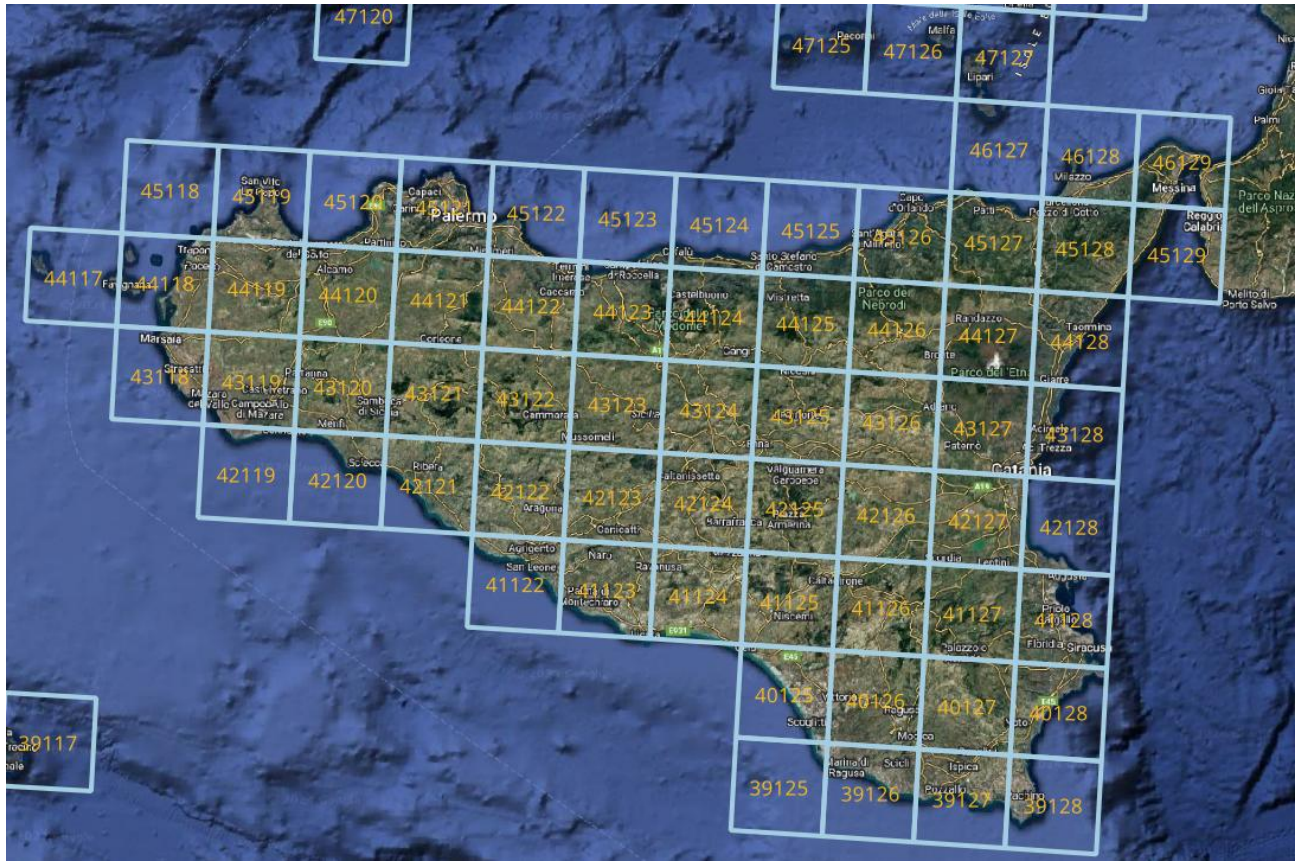
Regional map derived from national map based on soil typologies: geospatialised information derived from reference soil profiles.

How to overcome?

Soil samples at farm level where RDP measures are implemented.

Monthly climate data - time interval 2000-2023

- Precipitation (mm)
- Temperature (°C)
- Potential evapotranspiration (mm)



Why this source?
Freely available at EU level, constantly updated

Challenges?
None. Good spatial scale of information for the regional level simulation.
Long time series → needed for the initialisation of the RothC model (estimation of C input level, from which the initial SOC stock derives)

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Downloaded from the European climate database on a 25x25 km grid (https://agri4cast.jrc.ec.europa.eu/DataPortal/Index.aspx).

Crop yields & management data → Carbon Input

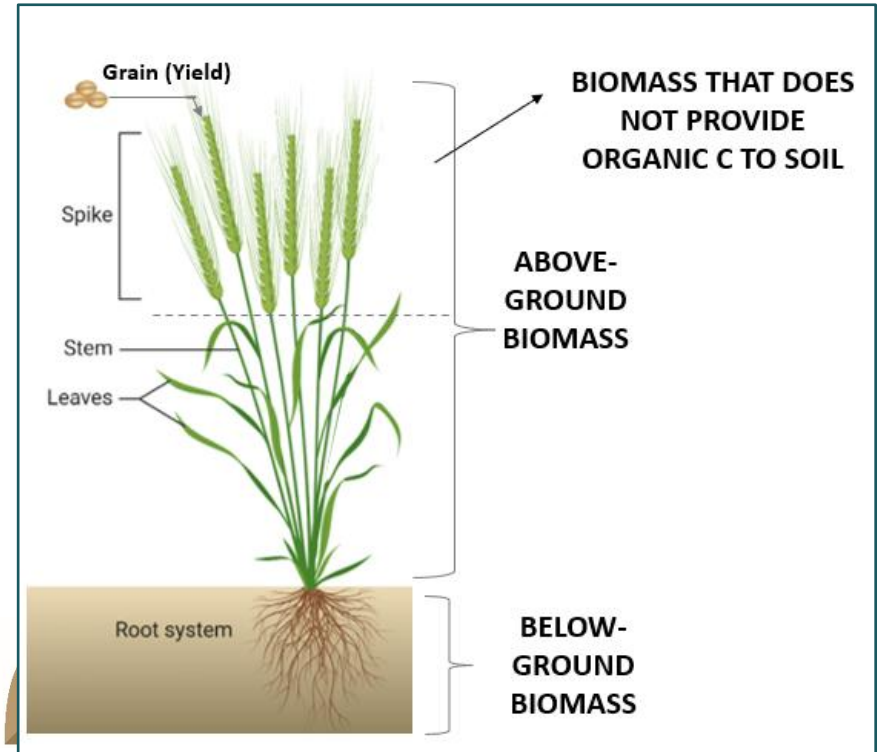
- For each Province and crops: **Yield** data from ISTAT - National Istitute of Statistics. Example:

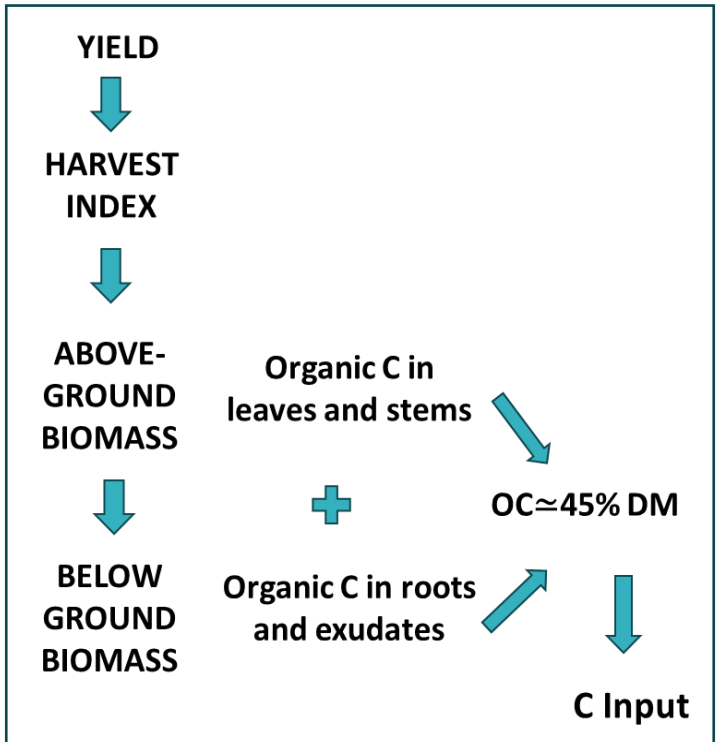
Crops	Agrigento	Caltanissetta	Catania	Enna	Messina	Palermo	Ragusa	Siracusa	Trapani
	Yield q ha^{-1}								
Winter wheat	27.6	27.5	28.6	28.8	27.3	27.2	32.3	27.2	22.9
Oat	104.4	48.5	15.0	48.5	157.5	29.4	101.6	100.2	20.5
…	…	…	…	…	…	…	…	…	…

Yearly Carbon Input

- **Crop rotation and common agricultural management**: experts' opinion
- **Scientific allometric function:** transformation of crop yields into C input

(it calculates C contribution from aboveground biomass, root and exudates)





Why ISTAT? Official data homogeneous at national level. Detailed at the Province level.

Challenge?

Different soils, crops and yields at province level: simulations run at province level: more complex elaboration

Challenges: selection of CAP measures

RDP CAP measure possibly impacting on SOC		Inclusion or exclusion from the SOC impact analysis	Reasons for inclusion or exclusion in the SOC impact analysis
8.1.A	Planting of new forests	**Excluded**	Data available only for 2021 No Carbon input data in Roth-C 10N for tree species in managed forests
8.1.B	Maintenance of new planted forests	**Excluded**	Data available only for 2021 No Carbon input data in Roth-C 10N for tree species in managed forests
10.1.A	Integrated agricultural production	**Excluded**	No data available on this measure
10.1.B	Environmentally sustainable management methods	**Included**	
10.1.C	Conversion and maintenance of croplands into permanent grasslands	**Excluded**	No Carbon input data in Roth-C for livestock C input
10.1.F	Conservative agriculture	**Included**	
13.1	Agriculture in mountain areas	**Excluded**	Not enough details on soil management practices in RDP
13.2	Agriculture in protected areas (e.g., Natura 2000)	**Excluded**	Not enough details on soil management practices in RDP
13.3	Agriculture in areas subject to other constraints	**Excluded**	Not enough details on soil management practices in RDP
11.1	Conversion to organic agriculture	**Currently excluded**	Vast application area in terms of crop: more specific information are described in organic farming regulation for each crop
11.2	Maintenance of organic agriculture	**Currently excluded**	Vast application area in terms of crop: more specific information are described in organic farming regulation for each crop

Challenges: selection of CAP measures

Selected RDP CAP measure		Measure requirements in terms of soil management	Simulated with Roth-C 10N	Duration
10.1.B	Environmentally sustainable management methods	Improvement in the efficiency of water management through software	**NO – not enough specific info at farm level**	5 years
		Improvement in the efficiency of fertiliser management through software	**NO – not enough specific info at farm level**	
		Erosion control: **Cropland**: - Spring-Summer crops: cover crops (leguminous or mixed) during autumn-winter	**YES (soil cover during autumn and winter)**	
		- Crop rotation: 2/5 years leguminous crop	**YES**	
		- Residues incorporation into soil.	**YES (% of crop residues derived from yields and local agronomists)**	
		- Cropland with av. slope >8%: work soil along level curves;	**NO – soil work not simulated by Roth-C10_N**	
		Erosion control: **Tree crops**: Interrow grassing with leguminous or grasses in autumn; If impossible: compost (1 t/ha)	**YES (soil cover during autumn)**	

COUNTERFACTUAL SCENARIO

Compared with:

- Cropland: no crop rotation or different crop rotation, no cover crops
- Tree crops: no grassing and no compost

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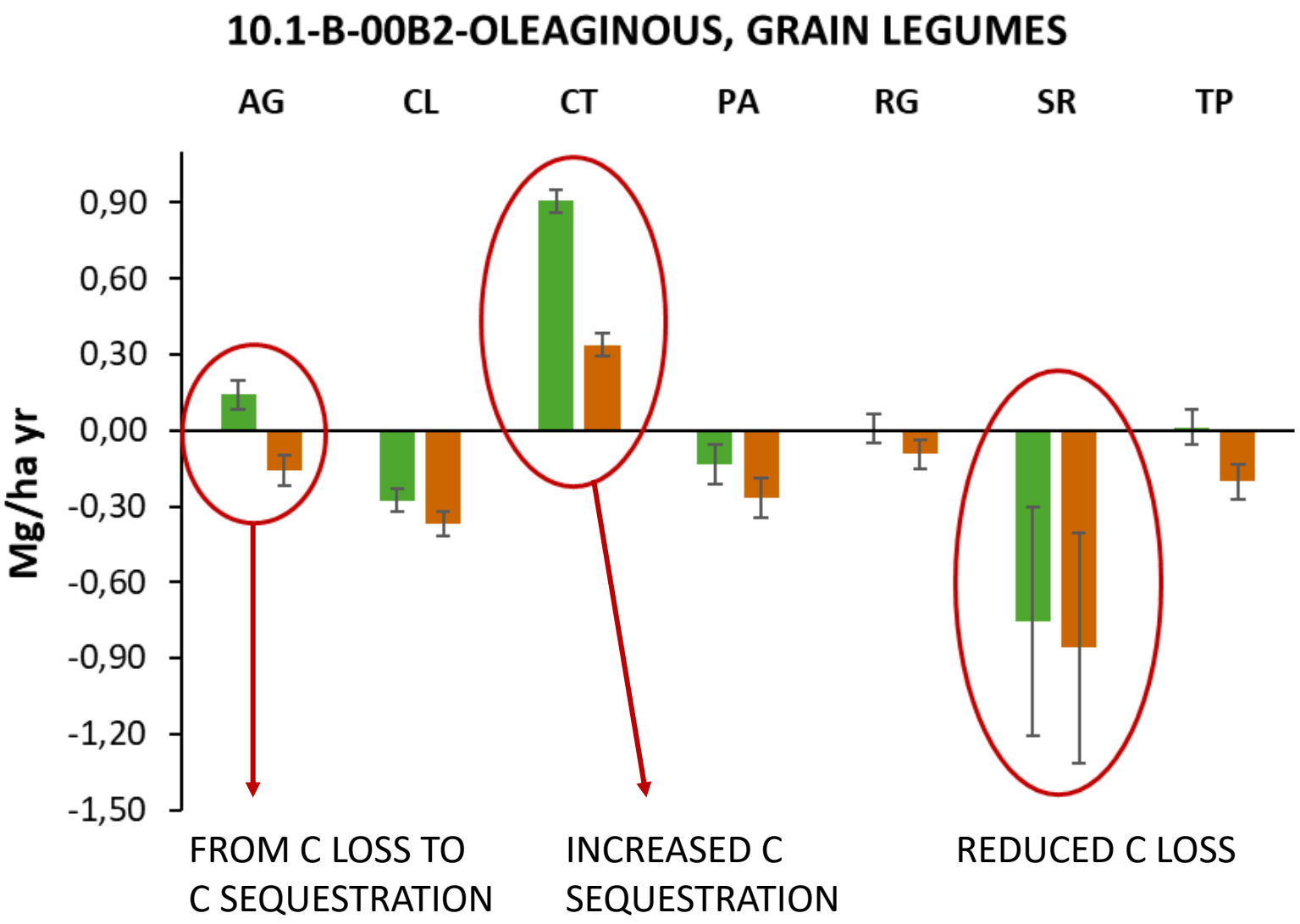
Challenges: selection of CAP measures

Selected RDP CAP measure		Measure requirements in terms of soil manageent	Simulated with Roth-C 10N	Duration
10.1. F	Conservative agriculture	Sod-seeding	**NO – soil work not simulated by current version of Roth-C**	7 years
		Mulching with agricultural residues	**NO – mulching not simulated by current version of Roth-C**	
		Crop rotation: autumn-winter grain cereals + grain leguminous or mixed fodder	**YES**	

COUNTERFACTUAL SCENARIO

Compared with no crop rotation

Results



CODES OF PROVINCES IN SICILY

RDP MEASURE IMPLEMENTATION

NO RDP MEASURE

- THIS IS ONE EXAMPLE
- OVERALL POSITIVE IMPACT OF ALL TESTED RDP MEASURES IN ALL PROVINCES AND CROPS

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Conclusions

Although challenging, using **big data** for CAP evaluation of environmental impacts is **crucial** because:

- **Homogeneity of data quality** → fundamental in large scale evaluation such as CAP impact even if data might be less accurate than local and smaller scale databases

Replicability:

- **At MS level:**
  - for Italy, the simulation can be extended at national level if data about RDP implementation are made available from the Paying Agency
  - Can be applied in other MS
  - Can be expanded to the first pillar
  - Can be extended to current CSP interventions

  } if data are available and after accurate methodological evaluation

- For homogeneous evaluation at **EU level**, for comparative analysis → favour the use of EUROSTAT instead of national institutes of statistics

We warmly encourage:

- To make data about CAP measures implementation at parcel level from Paying Agency **available to researchers** or other bodies in charge of setting up methodologies for CAP evaluation
- To foster the **interoperability** between Paying Agencies and scientific/environmental data sources

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Thank you for your attention!

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